

Hydrological and climatic conditions of development of alkaline spring-fed fens in Poland and their significance for palaeoenvironmental reconstructions



Radosław Dobrowolski¹⁾, Małgorzata Mazurek²⁾, Zbigniew Osadowski³⁾

¹⁾Faculty of Earth Sciences and Spatial Managements, Maria Curie-Skłodowska University, Kraśnicka Str. 2CD, Lublin, Poland

²⁾Institute of Geoecology and Geoinformation, Adam Mickiewicz University, Dzięgiełowa 27, Poznań, Poland

³⁾Department of Botany and Genetics, Pomeranian University in Słupsk, Arciszewskiego Str. 22B, Słupsk, Poland



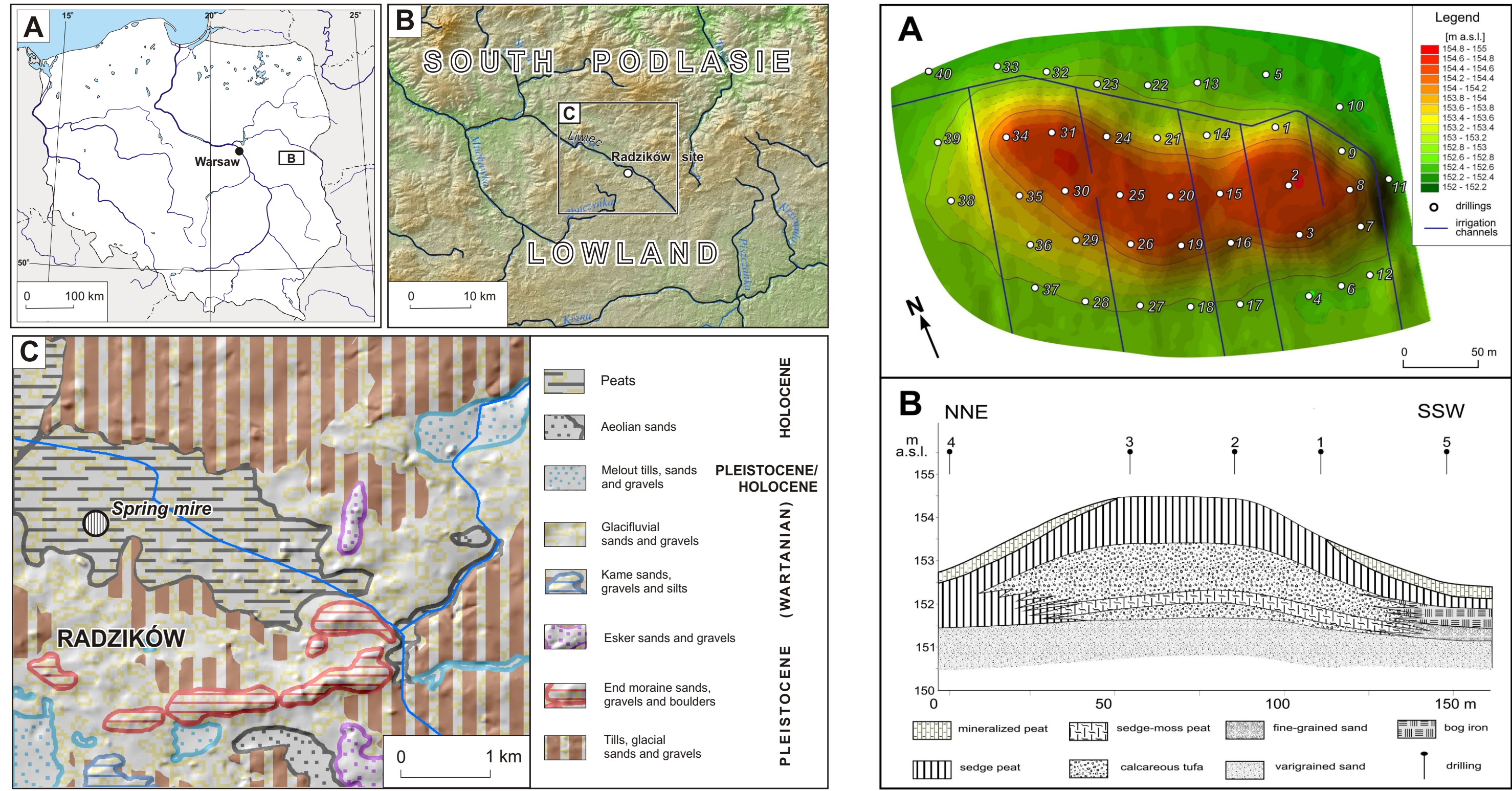
INTRODUCTION

Spring-fed fens belong to the rare group of alkaline fens supplied by groundwater of concentrated flow. Groundwater controls peatland hydrology, ecology and morphology, and the geochemical properties of its sediments. Apart from a characteristic botanical composition (=spring hygrophytic species), alkaline soligenous peatlands are also distinguished by their pattern of lithological deposits featuring interbedded peat and calcareous tufa (Dobrowolski, 2011). Their biogenic-carbonate sequences are an excellent analytical material for the Late Glacial-Holocene palaeoenvironmental reconstructions (Dobrowolski et al. 1999,2005,2010; Pazdur et al. 2002). Despite their morphological similarity and small size (usually <1 ha), spring-fed fens are found in very different conditions. In Central Europe they occur in different landscape types, geological-morphological and climate conditions. They are known from mountains (Hajek et al. 2002, 2006, Hajkova&Hajek 2003), uplands (Kovanda 1971, Dobrowolski 1998, 2000, Dobrowolski et al. 2005), and glacially modified plateaux (Wołejko et al. 1994, Grootjans et al. 2006, Osadowski et al. 2009, Dobrowolski et al. 2010, Mazurek et al. 2014).

We present the results of palaeoenvironmental studies of the alkaline spring-fed fens from several dozen of sites from Poland. Our investigations in all sites were similar and included: (1) land survey with the use of GPS (Global Positioning System) receivers, (2) detailed geological-sedimentological investigations of the bed, and specialist analyses (=multi-proxy data), i.e. (3) geochemical, (4) palynological, (5) malacological, (6) of plant macrofossil remains, (7) of carbon and oxygen stable isotopes, (8) radiocarbon dating.

This work was carried out as a part of the project No NN306 279 035 financed by the Polish Ministry of Science and Higher Education.

Radzików site (RAD-2) - South Podlasie Lowland (Eastern Poland)



Geological situation in the surrounding of the Radzików site.

Geology and morphology of the Radzików spring-fed fen.

Lithology of spring-fed fens

Biogenic sediments in the spring-fed fens are represented mainly by peat of the following type: a/ moss and sedge-moss, mainly in bottom part of profiles, b/ sedge (*Carex*) and sedge-reed commonly; c/ sawgrass (*Cladium*) - very seldom, d/ alder swamp forest (*Alnus*) quite often, e/ willow peat (*Salix*) collateral, f/ reed (*Phragmites*) usually in top part of profiles.

Carbonate sediments occur commonly in the deposits of spring-fed fens and at the same time constitute one of the lithological characteristics of their soligenous character. In the conditions of the functioning spring-fed fens, with ascension supply, they are deposited as calcareous tufa. Calcareous tufa occur in the deposits of spring-fed fens as strongly diversified in terms of their structure (sensu Miall 1978) and fraction (sensu Rutkowski 1991). They may form homogenous, massive series of coarse-grained tufa (0,6-2 cm) and very coarse-grained ones (>2 cm), or occur as relatively thin mid-peat interbeddings of fine-grained tufa (0,006-0,2 cm) and silt (<0,006 cm).

PALAEOENVIRONMENTAL RECONSTRUCTIONS BASED ON PEAT-TUFA DEPOSITS

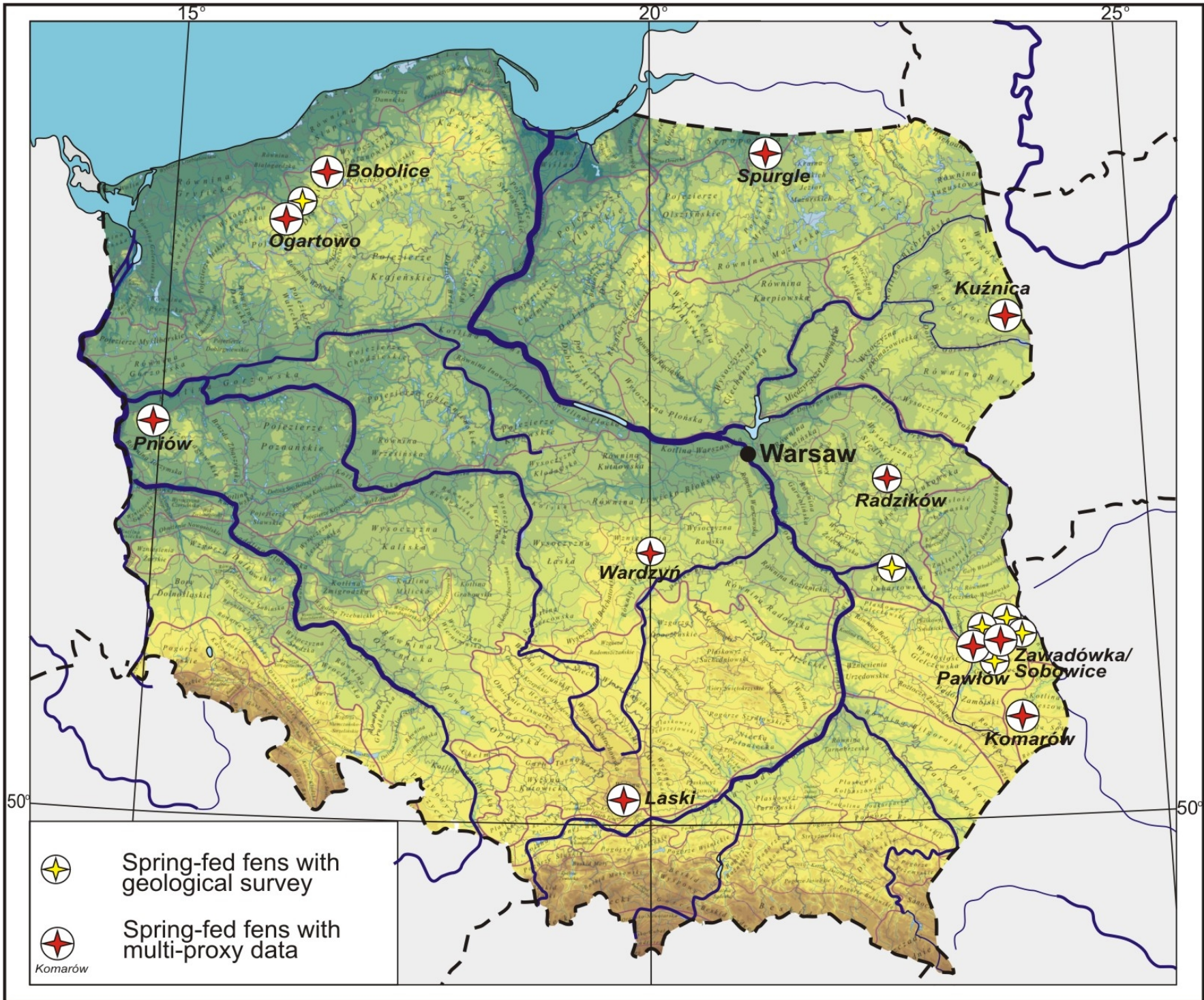
Multi-proxy data of peat-tufa deposits from spring-fed fens (=sedimentological, macrofossil, malacological, pollen and stable isotopic analysis), together with radiocarbon age determinations document diversity of environments of biogenic carbonate sedimentation resulting from: (1) the conditions of groundwater circulation and their physico-chemical properties, and (2) changes in climatic conditions (humidity and temperature).

The obtained results enable to:

- (1) determine the time of the Weichselian permafrostdegradation in diversified locations in terms of space (along the meridional and latitudinal transects),
- (2) determine the genetic type of depositional environment of carbonate deposits,
- (3) reconstruct main evolution phases of individual spring-fed fens, together with determination of auto- and allochthonous factors that influence their development,
- (4) reconstruction of main Holocene climatic events in regional and global scales.

FINAL REMARKS

- (1) Deposits of alkaline spring-fed fens are suitable source of information about palaeoenvironmental conditions.
- (2) Multi-proxy data obtained from peat-tufa deposits (from all analysed sites) are generally compatible (especially for the LG/H boundary and main Holocene climatic events).
- (3) Beginning of formation of spring-fed fens deposits in Poland are dated to:
 - **Allerød** - in extreme southern locations (Silesian Upland),
 - **Young Dryas/Preboreal transition** - in central and eastern locations (Lublin Upland, Podlasie Lowland)
 - **Preobreal/Boreal** - in northern locations (South Pomerania Lakeland)
 - **Boreal/Atlanticum** - in extreme north-eastern locations (Masurian Lakeland)
- (4) Main phases of carbonates accumulation in the spring-fed fens deposits (corresponding with warm and humid climatic episodes) are dated to the Atlanticum climatic optimum (period between 6600 and 6000 years BP) and Subatlanticum phase of the Holocene (between 800 and 700 years BP).



Locations of study sites in Poland.



Examples of studied spring-fed fens.

GEOLOGY AND HYDROGEOLOGY OF ALKALINE SPRING-FED FENS IN POLAND

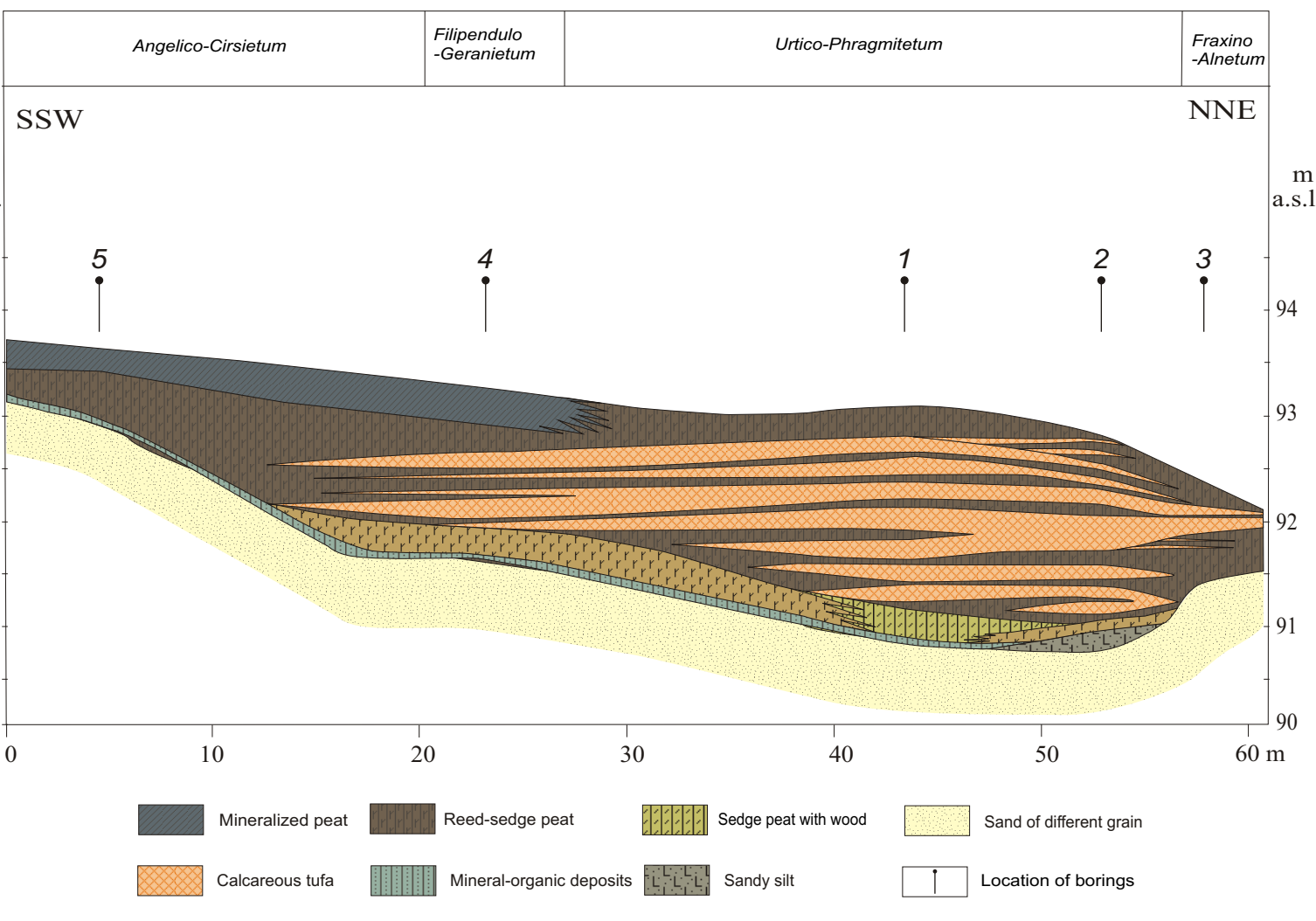
Sites of alkaline spring-fed fens in Poland are located both, in carbonate uplands (=karst regions) and glaciogenic lowlands (=old- and young-glacial regions). An important component that connects all sites is similarity of natural supply (=artesian type), associated with unlocking the vertical circulation of groundwater as a result of degradation of Weichselian permafrost (Late Glacial/Holocene transition). The thickness and lithologic sequence of sediments that build peat deposits is derived from many factors. Among them hypsometric position, the depth of the form, the local supply system and groundwater circulation should be considered decisive.

Glacial landscapes. Spring-fed fens in such type of landscapes are concentrated mainly in the contact zones of geomorphological units of different geological structure and in the areas of considerable hypsometric gradients, such as:

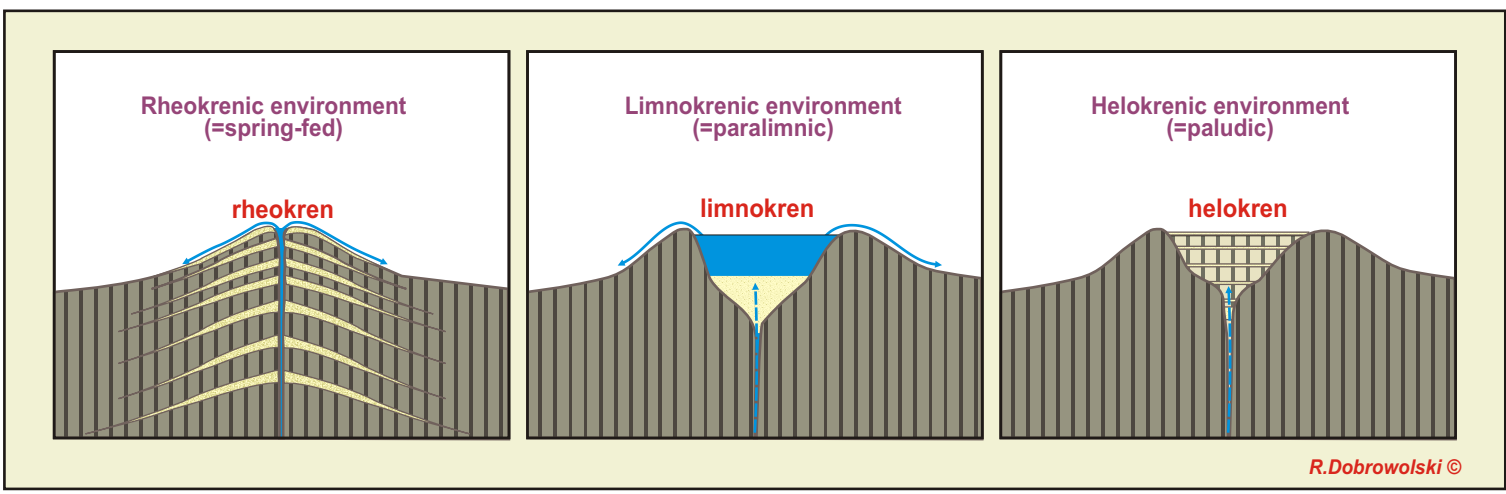
- (1) morainic plateau scarps,
- (2) fluvioglacial outflow valleys on outwash plains,
- (3) valleys of subglacial origin, and
- (4) slopes of melt-out depressions on morainic plateaux.

Karst landscapes. Spring-fed fens in such type of landscapes are connected with the:

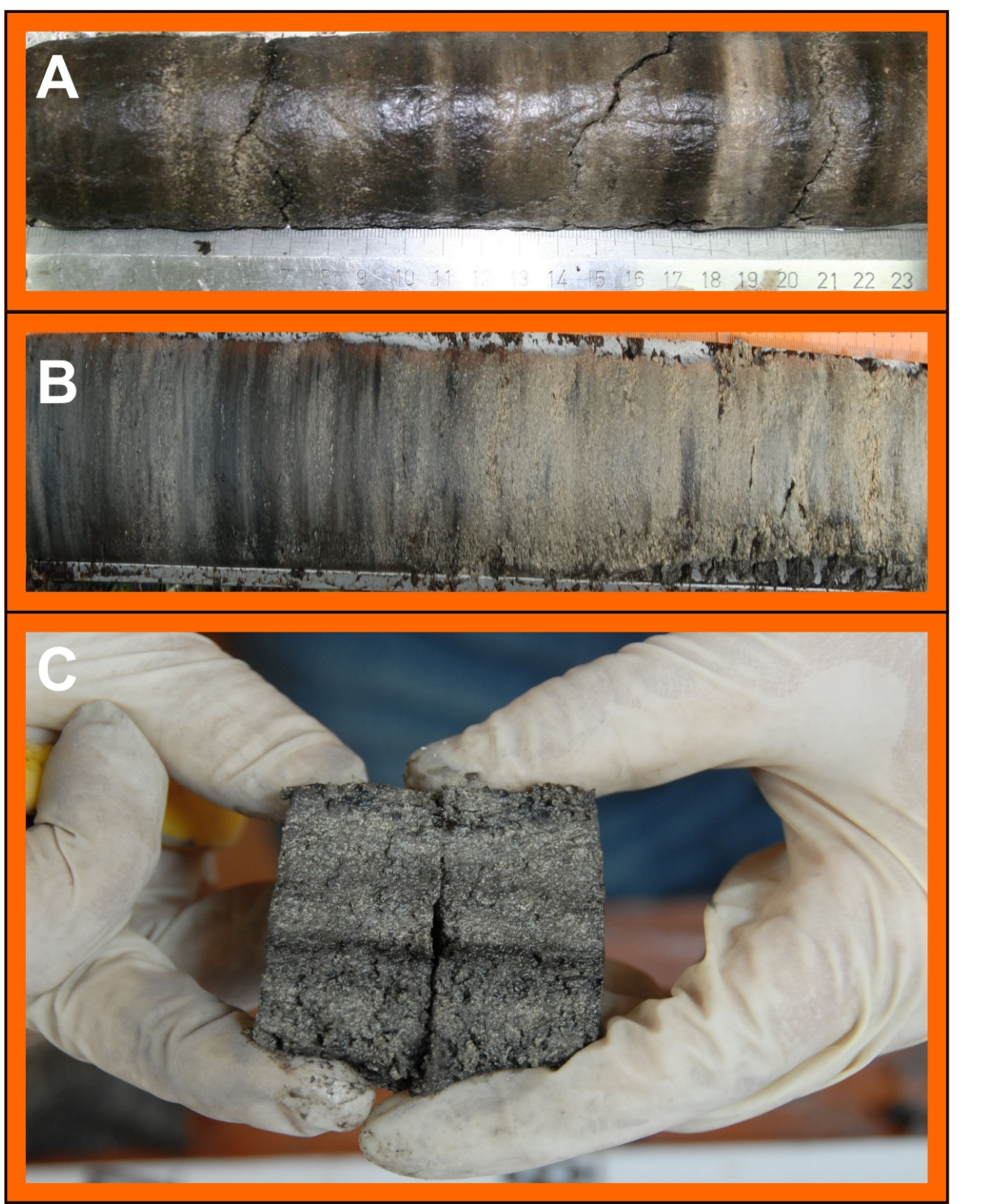
- (1) zones of the hydrogeological windows, where they are located within impervious deposits that cover the complex of carbonate rocks constituting the artesian basin,
- (2) single mesofault or mesofault zones in the carbonate complex of bedrock (=Cretaceous massif). The tension layer of the underground water table is usually weathered cortex of carbonate rocks.



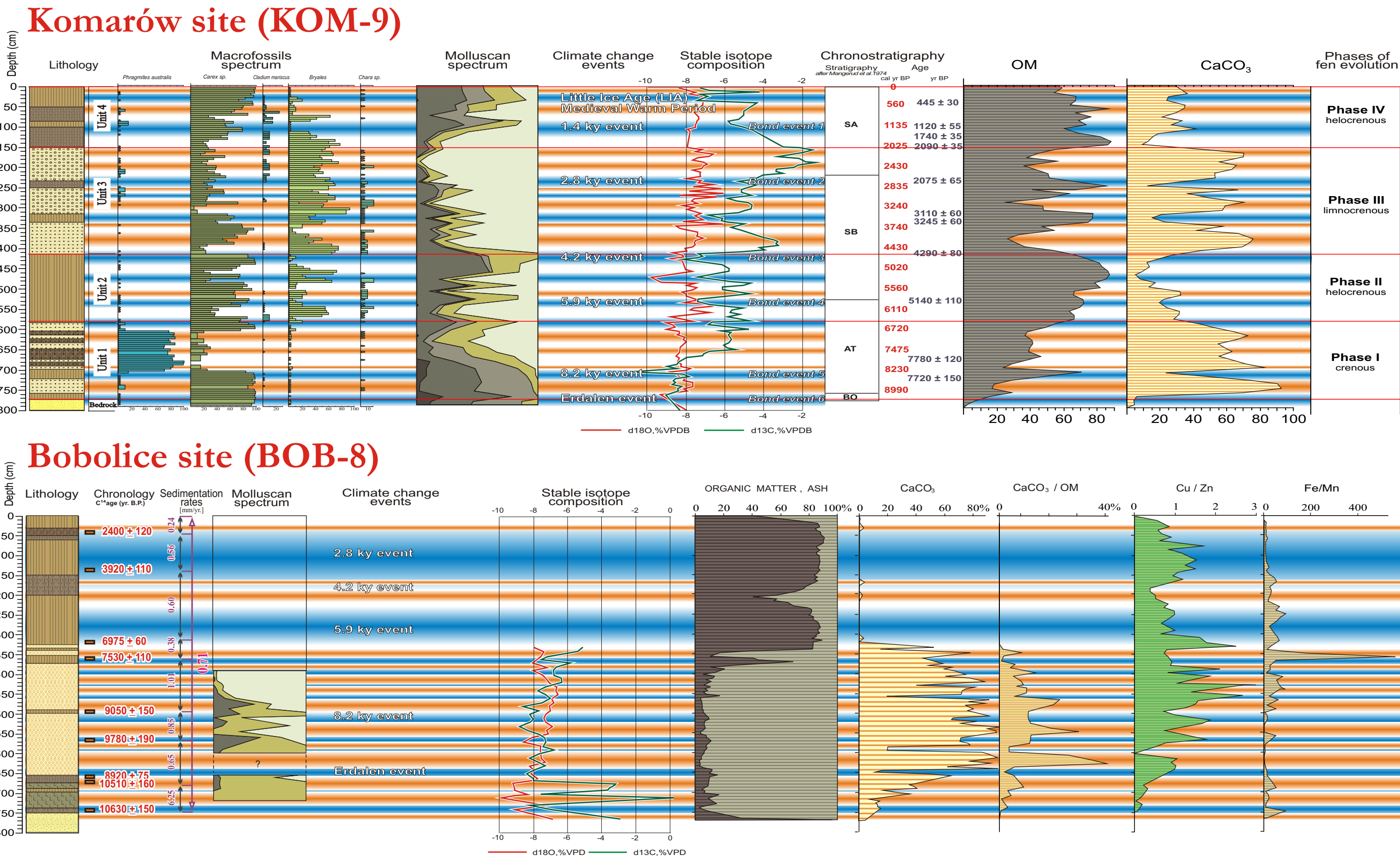
Geological cross-section through the Ogartowo spring-fed fen.



Accumulation environments in spring-fed fens (cupola ones).



Peat-tufa rhythmite from spring-fed fens: A – Kuźnica (North Podlasie Lowland), B – Ogartowo (West Pomerania Lakeland), C – Bobolice (West Pomerania Lakeland).



Comparison of multi-proxy records from Komarów and Bobolice spring-fed fens.