ESM 1 Materials and methods, extended

Lithology and geochemistry

For lithological analyses, the samples were prepared by drying at room temperature until dry, grinding, and sifting through a 2-mm sieve to separate the skeleton and earth particles. Soil texture analysis of particles with a diameter below 2 mm was performed by applying the laser diffraction method using a Mastersizer 2000 (Malvern Instruments, Inc., Southborough, MA, USA) with a wet dispersion accessory (Bartmiński et al 2011). Statistical and graphic analyses of data, considering sieve and laser analysis results, were conducted using the Gradistat 5.11 software (Blott and Pye 2001, as modified by Juśkiewicz 2006). Further analyses relied on essential granulometric parameters such as average grain diameter, standard deviation, skewness, and kurtosis calculated using the Folk and Ward (1957) method on a phi scale. They served to assess the sedimentation environment and processes responsible for the accumulation of sediments (Racinowski et al. 2001).

In the case of geochemical analyses, trace elements were extracted in *aqua regia* according to ISO 11466 (1995) and then filtered into 100 ml volumetric flasks. The elements such as Cu, Zn, Mn, Fe, Pb, Ni, and Cr are determined by atomic absorption spectrometry (ASA) in an acetylene flame, Na and K using atomic emission spectroscopy (ESA) in an acetylene-air flame, and calcium in an acetylene-nitrous oxide flame. Phosphorus was determined colorimetrically with ammonium molybdate (PN-EN 15487 standard). The total organic carbon (TOC), total sulphur (TS) and total nitrogen (TN) were analyzed using a VarioMax elemental analyzer (Elementar). For TOC analyses, the samples were decarbonated with 0.1 M HCl. Additionally, a samples were subjected to a loss on ignition test to determine an approximate organic matter content, whereby a 1-gram sediment sample was heated to a temperature of 560°C for 4 h (Dean 1974; Heiri et al. 2001). The calcium carbonate content was determined by the Scheibler method (Myślińska 2001).

Palaeobotanical analyses

Samples for palynological analysis were digested in hot 10% potassium hydroxide (to remove humic compounds) and soaked in 40% hydrofluoric acid for 24 h (to remove the mineral fraction). Next, to remove the carbonates, samples were treated with 10% hydrochloric acid. Then, the acetolysis was carried out. One *Lycopodium* tablet (Batch 050220211, containing 18,407 spores per tablet; produced by Lund University) was

added to each sample during the laboratory procedures for the calculation of microfossil concentration and further pollen accumulation rate (Stockmarr 1971). The acetolysed samples were washed in distilled water and mounted in glycerine. Pollen, spores, selected non-pollen palynomorphs (NPPs) and microcharcoal particles (size fraction: 10–100 μm) were counted under an upright microscope (Zeiss Axio SCOPE A1) until the number of total terrestrial pollen (TTP) grains in each sample reached at least 500. Sporomorphs were identified with the assistance of atlases, keys (Moore et al. 1991; Beug 2004), various publications, and also the image database in the case of NPPs (Miola 2012; Shumilovskikh and van Geel 2020; Shumilovskikh et al. 2022). Identification of Cereal-type grains was based on a diameter size of pollen grain and its annulus (equal or greater than 40 μm and 8 μm, respectively). The results of the palynological analysis were expressed as percentages, calculations based on the ratio of an individual taxon to the TPS, i.e., the sum of AP (arboreal pollen) and NAP (non-arboreal pollen), excluding aquatic and wetland plants, cryptogams, and NPPs. Accumulation rates (unit: sporomorphs/particles cm^{-2} yr^{-1}) of selected sporomorphs and microcharcoal particles ($CHAR_{micro}$) were calculated by multiplying sporomorph taxon or microcharcoal particle concentrations (unit: sporomorphs/particles cm^{-3}) by deposit accumulation rate (unit: cm yr^{-1}).

Plant macrofossils were sieved under the stream of water. They were identified using a Delta Optical SZ-450 stereoscopic microscope, at a magnification of 8 and 45×, and a transmitted light microscope. Species determination of individual plant macrofossils was done based on Velichkevich and Zastawniak (2006, 2008) and a private carpological collection belonging to M. Gałka. The results are summarised in the diagram in absolute numbers, while the vegetative parts of vascular plants (wood and rootlets) are given in percentages of the total volume of the sediment samples. Plant nomenclature follows Mirek et al. (2002).

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