Doctoral School of Geosciences

The late Quaternary sedimentological-geochemical-based enviromental history of a peat sequence of Kerek-tó from Transylvania

Theses of the doctoral dissertation

Author

Tapody Réka Orsolya

Supervisor

Prof. Dr. Sümegi Pál DSc.

Prof. Dr. Demény Attila DSc.

Department of Geology and Palaeontology

Faculty of Science and Informatics

University of Szeged

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Szeged

1. Introduction and aims

Holocene is the youngest period in Earth's history and the first epoch in which human civilisation appeared. Today, we are facing the consequences of global climate change, triggered by humans themselves (Lynas et al. 2021). Mountain ecosystems are highly sensitive to climate variability, and the Carpathian Mountains have been the study area for many climate reconstruction studies (Beniston 1994; Sonesson and Messerli 2002, Magyari et al 2012, 2018; Micu et al, 2015, Longman 2017). The Carpathian region was already inhabited during the Neolithic, and human impact, such as deforestation, grazing and animal husbandry, the creation of ploughed lands and the biodiversity loss associated with these activities can be traced back to this time (Feurdean et al. 2009, Longman et al. 2018). Understanding the relationship between human impact and climate change requires a continuous undisturbed sediment sequence and a multidisciplinary, complementary analysis, called a multi-proxy study.

Peatland is a wetland habitat in which biomass production exceeds decomposition rates, so peat formation occurs below the water table, sealed from oxygen. The bog/mire is capable of preserving the imprint of its environment in situ, within itself, and is therefore well suited as a model site for environmental reconstruction.

The first description of Holocene climate stratigraphy was based on the characterisation of Scandinavian peat sections known as the Blytt-Sernander classification (Blytt 1876, Sernander 1908). The main objective of the study is to examine the development and transformation of the peatland and peat layers under the natural or human-influenced environment in the late Quaternary.

In my thesis, I use a multi-proxy study of a continuously developed 7500-year mixed-layered peatland to reveal the changes in the relationship between climate and human communities.

In my dissertation, I was looking for answers to the following main questions:

1) Was the impact of global climate events detectable in the study area, or were there any divergences from regional climate models?

2) How did human communities change the environment of Kerek-tó, and what was its imprint on the results?

3) What kind of new information does geochemical analysis add to the results in the case of a multi-proxy study of a peat bog?

2. Applied methods

In my dissertation, sampling and processing were based on Birks' international Quaternary palaeoecological method (Birks and Birks 1980, Gaillard and Birks 2007). The sampling was carried out with a Russian peat borer in the middle of a former lake, that resulted a 560 cm long undisturbed core. The Troels-Smith (1955) system, developed for unconsolidated sediments, was used to describe the lithological stratigraphy. The principle of the system was to consider Quaternary lake, marsh and bog sediments as a mixture of a specified number of components and group them into 6 categories according to their genetics. The sediment core was analysed for sedimentological (MS, grain size, LOI), geochemical (AAS, Hand-held XRF), pollen and radiocarbon dating. The borehole was sliced at 2 cm sample intervals. The grain size was determined using an OMEC Easysizer type laser and magnetic susceptibility was determined using an MS2 Bartington type instrument (Dearing, 1994; Oldfield et al. 1978).

Drying was performed using an annealing furnace, samples were measured with an analytical weigh scale to an accuracy of four-tenths, and powdering was performed using a ceramic mortar. The determination of the organic matter and carbonate content was based on Dean's method (1974).

For the water-soluble geochemical analysis, samples were taken at 4 cm intervals. The method we used is the first step of the five-step extraction-digestion method of Péter Dániel (2004). The advantage of the water extraction is that sediment is not degraded during the analysis, thus revealing neither mineral particles nor plant remains, but information about water-soluble elements colloidally adhered to their surface is obtained (Dániel, 2004). Concentrations were measured using a Perkin-Elmer 100 atomic absorption spectrophotometer. The element composition analysis of samples was performed with Spectro xSort COMBI HH03 handheld X-ray fluorescence spectrometer (pXRF), equipped with an Rh tube and SSD detector. Pollen analysis was carried out on samples at 4 cm intervals, using standard HF methods (Wood et al. 1996, Bennett and Willis, 2001). Twelve samples were selected for radiocarbon analysis. by Accelerator Mass Spectrometry (AMS). The-depth model was generated using Bacon (Blaaw and Christen 2011; Blaauw et al. 2018) and Bayesian analysis. Conventional radiocarbon ages were converted to calendar ages using IntCal20 calibration curve (Reimer et al., 2020). Statistical analysis was performed using SPSS 25.0 statistical software package and PAST 3X Paleontological Data Analysis (Hammer et al. 2001) to identify the main factors that control elemental distribution in the core section.

3. New scientific results

The research has provided the following new scientific results:

1. Based on a core sample taken in the middle of Kerek-tó, we obtained information on a 7500-year-old undisturbed sequence with 12 radiocarbon dates. Based on the sedimentological analysis, the grain size composition of the peat sample was homogeneous. The botanical content indicates a lake phase and a peat phase. The peat phase had been gradually developed from a Sphagnum bog with dense vegetation under a wet, cooler climate into a mire with sedge-reed vegetation. The surrounding area has gradually changed from a forested environment to steppe vegetation (7th century AD (1300 cal BP years).

2. Based on sedimentation rates, I identified 3 accumulation zones. The first two were established in a biogenic composition-rich vegetation environment (peat development), followed by a short period of anthropogenic influence that resulted high mineral deposition (recharged pond phase), which can be traced in the LOI and pollen data. Climatic conditions, as determined by pollen, strongly influenced peat formation. It is in accordance with regional paleoclimatological studies in Transylvania and other Central European regions (Schnitchen et al. 2006; Feurdean et al. 2013; Tóth et al. 2015; Diaconu et al. 2017), however, the gradual appearance of human cultures was increasingly transformed natural vegetation, with deforestation and cultivation, which is reflected in the appearance of erosion levels.

3. Water-soluble geochemical analysis indicates a definable boundary between peat and lake sediments for each element (Fe, Mn, Ca, Mg, Na, K). Fe and Mn were detectable from the mineral grains, but due to their water solubility, they were only detectable at the oxidative level above groundwater. The K and Na content showed the highest concentration in the lake phase, K correlated with Fe and Mn peaks, which could be related to mineral weathering, since in previous studies (Mackereth 1966; Engström and Whright, 1984; Dániel 2004) it was explained that Na, K, and Mg contents can be indicative of both chemical and physical weathering of the soil. The highest values of Na were detected in pure sedge-reed peat, which was hypothesized to be influenced by the Na-binding capacity of certain reed species (Kustár et al. 2016; Braun et al. 1993; Beeton, 1965). The highest concentration of Ca was detected in the peat layer, furthermore, it was correlated with LOI550, P and S and with arbor pollen. Since the mineral content leached from the upper soil-forming rocks did not show high Ca concentrations, I hypothesized that Ca from the deeper layers (marl), was taken up by the root zone of deciduous

trees and accumulated in leaves, thus it dissolved indirectly into the marsh accumulation basin and incorporated by vegetation as a biophilic element, this was also observed in other studies (Gorham et al. 2005, Batty and Younger, 2004).

4. I have attempted to use indicators from other literature. The Ca/Na ratio for weathering/erosion events and the Ca/Mg ratio for trophicity, i.e. the ombrotrophic/minerotrophic boundary, were used as sub-indicators (Shotyk 1988). According to these studies, if the peat Ca/Mg ratio exceeds the precipitation Ca/Mg ratio, the peat must have an additional source of Ca, that is considered to be a minerotrophic, otherwise ombrotrophic, peatland (Weiss et al. 1997, 2002; Shotyk, 1988, 1996, 2002; Muller et al. 2006; Lähteenoja et al. 2009). Based on my analysis of the water-soluble element ratio, the bog was a minerotrophic bog regardless of vegetation, while the lake shows ombrotrophic, which should be treated with certain requirements, as the uncertainty in the result is likely to be due to water solubility. The same applies to the feasibility of using the Ca/Na erosion indicator.

5. Based on the elements detected by hand-held XRF, an organic element group (P, S, Ca) and a mineralogical element group can be identified, taking into account the concentration of the elements. Among the minerogens, there are elements transported by plant vegetation (K, Cr, Rb) and elements transported by groundwater (Fe, Mn). This test result confirmed the origin of the Fe, Mn, and Ca element contents inferred from the water-soluble element analysis.

6. Principal Component Analysis (PCA) also confirmed these two groups of elements, with the PC1 and PC2 components combined into a biplot diagram that clearly distinguished the different sediment types, which, based on the Troels-Smith system, reduced the 6 sediment types identified to 4 groups (laminated lake sediment, transitional pelitic peat between lake and marsh, mixed reed peat, and moss peat). PCA did not distinguish between Lc1Th1As2 and Th2Lc1As1 and between Th3As1 and Th3Lc1 sediment types determined based on the Troels-Smith system.

7. I have investigated the possibility of productive and environmental restructuring activities of the former communities based on geochemical and pollen analytical results. Previous studies (Engström and Wright, 1984; Heathwaite and Burt, 1992; Willis et al. 1997; Braun et al. 2005) have indicated that increases in the abundance of elements such as Si, Al, K, Rb, Cr, Sr and inorganic material are indicative of both physical and chemical weathering associated with soil

erosion, since these elements originate from the surrounding soils and rocks. Therefore, it can be used as an indicator of local soil degradation and erosion processes (Willis et al. 1998). The S, P, Fe, Mn elements and the organic matter content (LOI550) show a maximum in the bog regeneration phase of the peat levels, so erosion levels and regeneration phases can be distinguished based on the abundance of the two groups of elements. In this way, I was able to define 20 erosion and peat regeneration phases at 12 cultural levels identified on a regional scale.

4. References

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5. List of publication related tot he PhD thesis

5.1. Articles used for the PhD Thesis

Tapody, R.O.; Sümegi, P.; Molnár, D.; Karlik, M.; Törőcsik, T.; Cseh, P.; Makó, L. (2021) Sedimentological-Geochemical Data Based Reconstruction of Climate Changes and Human Impacts from the Peat Sequence of Round Lake in the Western Foothill Area of the Eastern Carpathians, Romania. *Quaternary 4*, 18.

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5.2. Book, part of a book

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5.3. Conferences

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