Geology, Geophysics & Environment 2021, vol. 47 (2): 109–117

A history of interdisciplinary research on Lake Wigry

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Received: 16 May 2021; accepted: 18 June 2021; first published online: 28 June 2021

Abstract: Lake Wigry is one of the best explored lakes in Poland, a feat which has been achieved thanks to the passion and efforts of numerous scientists. This tremendous endeavour was supervised and coordinated by Professor Jacek Rutkowski and January 2021 marked the fifth anniversary of the professor's death. To mark this occasion, a history of research on the lake was compiled on the basis of oral accounts and an overview of the works that have been created thanks to his ideas, supervision, and boundless empathy. It is crucial to continue the research, since it will allow for the even better protection of the environment, as well as the natural and landscape attributes of the Wigry region.

Keywords: Lake Wigry, Professor Jacek Rutkowski, aquatic environment, NE Poland

INTRODUCTION

Lake Wigry is located in north-eastern Poland within the Wigry National Park (Fig. 1). At 21.6 km^2 it is one of the largest (Górniak 2006) and deepest (max. 73 m) lakes in Poland, with a very diverse shape and bathymetry (Zdanowski 1992). It was formed during the last glaciation and has a mixed, ribbon and melting character (Ber 2009). Lake Wigry was created from a combination of six pools, different in terms of shape, depth and morphology, separated from each other by shallowing and/or narrowing (Rutkowski et al. 2009a). The predominant type of sedimentation in this lake is the carbonate variety, which is caused by the high levels of carbonates in the lake's catchment area. Clastic sedimentation is restricted solely to narrow belts along steep part of lakeshore, and organic in the closed bays of Lake Wigry. Filling the reservoir with sediments caused its slow shallowing and, consequently, the transformation of the shallows into land. Hence, the present area is different in relation to the so-called pra-Wigry and it is estimated that it could have been about 30 km^2.

Wigry is a flow-through lake fed mainly by the Czarna Hańcza and Wiatrołuża rivers. Groundwater also plays an important role in the water cycle of the lake (Bajkiewicz-Grabowska & Dąbrowski 2009). There are peat bogs and small dystrophic reservoirs in the vicinity, while on the northern shores of Lake Wigry there is a belt of kame hills, and on the peninsula, there is a Post-Camaldolese Monastery. All of this creates a beautiful picture, therefore Lake Wigry has enjoyed considerable popularity for a long time, not only because of its aesthetic appeal but also due to its recreational values. It is perhaps unsurprising that it is often called the pearl of the north.

The main purpose of the article was to review works on Lake Wigry which were created thanks to the research carried out by Professor Jacek Rutkowski and his informal interdisciplinary team.

https://doi.org/10.7494/geol.2021.47.2.109 ISSN 2299-8004 | e-ISSN 2353-0790 | Wydawnictwa AGH

Fig. 1. *Lake Wigry location (by TUBS – own work, this vector image includes elements that have been taken or adapted from files: Poland2 location map.svg (by NordNordWest) and Relief Map of Poland.png (by Викмор_B), CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=17535679, access: 5.04.2021) and Lake Wigry photomap (obtained courtesy of the Wigry National Park authorities, corrected)*

The study analyses the Polish and English-language literature that was created in connection with the scientific activity of Professor Rutkowski regarding the Wigry National Park, mainly Lake Wigry and its surroundings. Additionally, oral histories, memories, maps, notes and photos were obtained to complete this picture.

HISTORY OF RESEARCH

The first studies were conducted at the beginning of the 20th century, for example Wisłouch (1926) and Wołoszyńska (1923) studied plankton, Poliński (1922) macrofauna, Kulwieć (1904) examined the chemistry of the water and lake deposits were explored by Stangenberg (1937, 1938). The first almost complete study of Lake Wigry, which encompassed its ore, physiography and hydrography, chemistry of water and deposits as well as a biological study, was conducted by Alfred Lityński in the 1920s, and was summarized in Lityński (1926). In 1920 he established the Hydrobiological Station in Wigry which had a great influence on the development of future research. During its operation, about 300 works concerning the area of Wigry were published in print and these are largely of historical importance. The operation of the station was interrupted by the outbreak of World War II.

The first accurate exploration of the water-soil environment of Lake Wigry was initiated by Professor Jacek Rutkowski, who spent the last dozen or so years of researching lake sediments in the Wigry National Park. January 2021 marked the

fifth anniversary of his death, so it is worth recalling the most important events in the history of the lake's research, which could be safely ascribed to him. Detailed information on the professor's life and scientific career can be found in the works of Krzysztofiak (2015) and Król (2017), as well as on the internet (Wikipedia, n.d.).

The professor was fascinated by Lake Wigry following a canoe trip in 1969 (Krzysztofiak 2015). In 1995 he became a reviewer of a work on the geology of these areas and wanted to clarify some doubts in the field with its author, Robert Popielski (Białystok University of Technology). He became fascinated with the lake and its surroundings and noticed its considerable research potential. However, it was only after 25 years that he initiated cooperation between the AGH University of Science and Technology and the Wigry National Park, as well as regular studies of the lake's sediments. The use of geological and geophysical methods in lake research was promoted by the professor among Polish limnologists through his work with the Polish Limnological Society, of which he was a founding member. Initially, a very small group of people participated in the work and research, but with time it grew to several dozen people, a body which included both noted scientists and students (Krzysztofiak 2015). The main meeting place for those involved in research on Lake Wigry was the Environmental Education Center of the Wigry National Park on Słupiańska Bay.

Initially, very basic research was carried out using fairly simple equipment. Due to the lack of appropriate samplers, they were limited to the coastal zone. However, from year to year, the scope of research was extended and the equipment used was improved. This was connected with the need to establish cooperation with various specialists from different research centres and universities from all over Poland.

The professor had a habit that when he encountered an interesting natural phenomenon beyond his interests and competences of trying to find suitable researchers and interesting them in the problem, proposing cooperation and co-authorship of a publication. This was also the case with his research on Lake Wigry – using his extensive contacts in the community of Quaternary researchers and geographers, he encouraged many scientists to undertake interdisciplinary research on Lake Wigry. Some of them were invited by the professor to cooperate, and some expressed their willingness to cooperate themselves. It was remarkable that no one sought financial gain, and on the contrary, some of them sacrificed their holiday time and funds themselves. An interdisciplinary team led by J. Rutkowski was created and, apart from the different publications mentioned above, the results of this cooperation were numerous doctoral and MA theses. The summary of the works was the publication of the monograph entitled *Lake Wigry. The history of the lake in the light of geological and paleoecological research* (Rutkowski & Krzysztofiak 2009).

The professor always questioned why one should buy something if you can do it yourself (this partly also stemmed from the limited funds at his disposal), therefore he constructed his own gravity sampler for sediment collection, similar to the Kajak-type gravity core sampler (Kajak et al. 1965) and the Więckowski sampler (Więckowski 1961). Of course, it was created by trial and error and improved after each research season. Originally it was a plexiglass pipe with a head mounted on a steel cord – which of course did not work out. The pipe did not want to dig vertically into the sediment, and the steel cord twisted and slipped (it was difficult to pull the pipe with it). Later, the steel rope was changed into a climbing rope, as a result of which the main activity each evening was to untangle and wind the rope. It was only after a few seasons that a frame with a spool, crank and disc system was created, and the sampler itself took its final shape and turned out to be very effective – it allowed samples to be taken with an intact structure, up to 1 m long, from a depth of up to several dozen meters (Fig. 2). The analysed lake is probably the most densely tested lake in Poland – over 1,400 samples of bottom sediments have been collected there (Rutkowski 2007).

It became apparent that the gravity sampler allowed the collection of several dozen cm of sediment core, i.e. sediments spanning several hundred years to over 1,000. To study the history of the lake's development, it is necessary to obtain a core covering the full profile of lake sediments, i.e. drillings. The professor attempted to perform such drillings from ice, but for the next several years the ice sheet in Wigry was too thin.

Fig. 2. *Sediments cores from Lake Wigry – examples of lake deposits: 1 and 2 – organic sediment, 3 and 6 – calcareous (carbonate) gytja in the upper part and lacustrine chalk in the bottom part, 4 and 5 – lacustrine chalk*

In the summer of 2003, thanks to cooperation with employees from the University of Gdańsk, drilling was performed from a platform (Fig. 3). In the core from Słupiańska Bay, it was possible to reach the bottom of the lake sediments after drilling through 5.4 m of sediment – this drilling was later thoroughly tested and the results were published (Rutkowski et al. 2007a).

A separate problem was how to move around the lake and the location of the sampling site. Initially, the samples were taken from a kayak or pedalo. The kayak was not particularly comfortable due to the lack of space for all of the requisite equipment and its inherent instability. The park paddle boat, on the other hand, was very slow, and it took some time to master navigation. Motorboats only started to be used after the cooperation with the Wigry National Park was formalized (Fig. 4).

The beginning of research on Wigry preceded the development of satellite navigation to the degree to which it became popular, and therefore localization was carried out using field methods, i.e. setting azimuths on three characteristic points with a compass, which, with difficulties in staying on the point, gave an accuracy which ranged from several dozen to a hundred meters. It was only since year 2000 that the location was carried out using a GPS coupled with a computer, and it was possible to plan the sampling sites in advance to an accuracy of 5 m.

Fig. 3. *The core of sediment sampling from Słupiańska Bay (photo L. Krzysztofiak)*

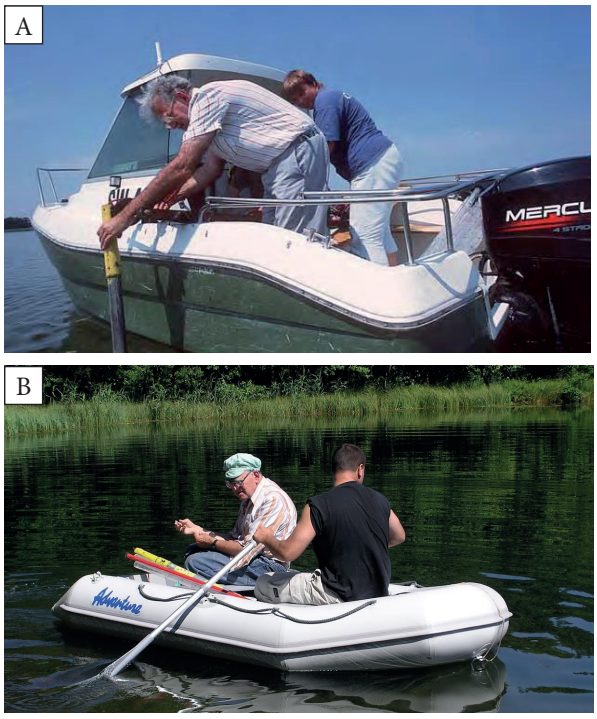

Fig. 4. *Prof. J. Rutkowski with Dr K. Król on the motorboat (A, photo L. Krzysztofiak) and on a pontoon with an employee from the Wigry National Park (B, photo K. Król)*

MAIN RESEARCH RESULTS

The first studies concerned the lithology of glacial gravel lying on the bottom of the lake (Popielski & Rutkowski 1998, Rutkowski 2001). It resulted from the professor's interest in this type of sediment, as he had developed a commonly used method of examining quaternary gravel. He conducted an analysis of the gravel beds at the foot of the cliffs and the segregation of pebbles in the beach environment. He drew attention to their petrographic composition due to the great importance of pebbles made of limestones or dolomites, which are the source of calcium in lake waters. Subsequently, all lithological types of sediments were investigated – including their occurrence and sedimentation environment. Facial variability was analysed using cartographic methods. Four main facies were distinguished: clastic formations (sand and gravel), lacustrine chalk (over 80% calcium carbonate), carbonate gyttjas and organic gyttjas. In the vicinity of the mouth of the Czarna Hańcza River, there is specific facies of river and lake sediments (Rutkowski et al. 2009c) (Fig. 5). From the lithology of sediments, the field of study interest was extended to more and more new research directions as geology, hydrochemistry, hydrobiology, paleoecology, etc.

Professor Rutkowski, in cooperation with Kaja Pietsch (AGH UST Krakow), Andrzej Osadczuk (University of Szczecin) and Lech Krzysztofiak (Wigry National Park), was the first to use high-resolution seismic equipment to study the bottom of the lake (Król 2017). Seismic-acoustic profiles made it possible to recognize the thickness of the sediments and the conditions of their deposition. It was also the sedimentation rate assessed on the basis of drilling in profundal sediments, and it varies from 0.08 to 1.12 mm/year, averaging 0.45 mm/year (Piotrowska 2009).

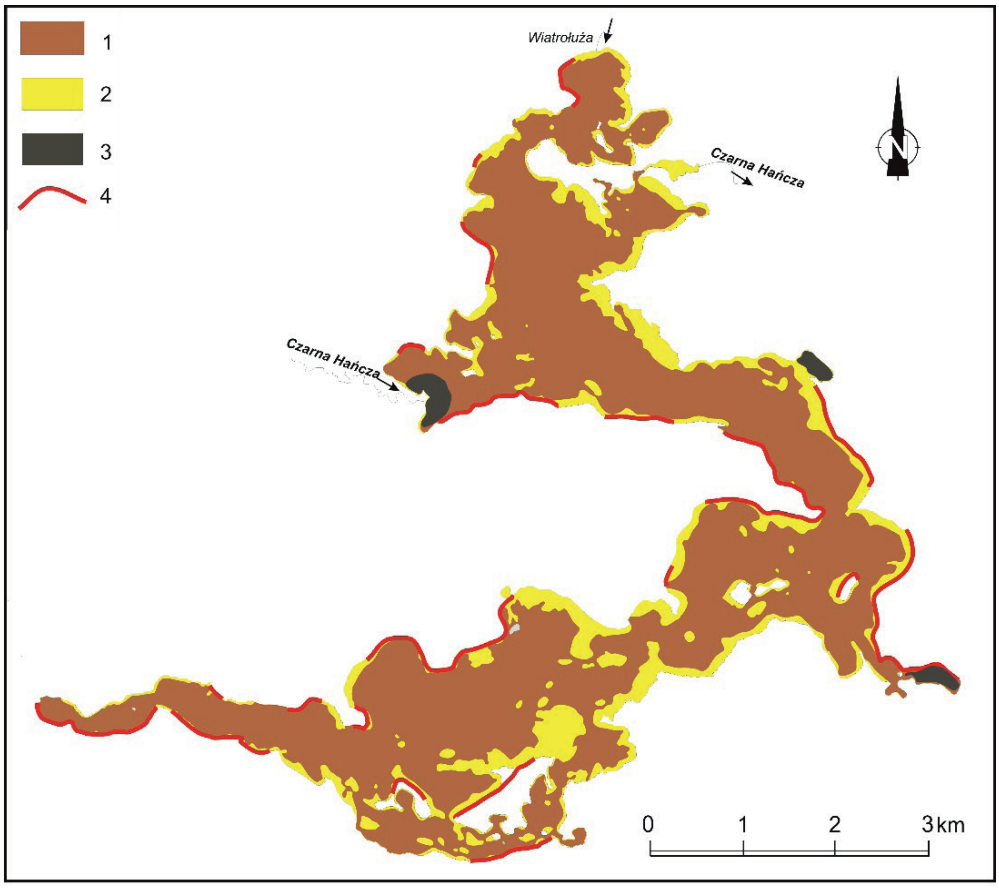

Fig. 5. *Facial variability in Lake Wigry: 1 – carbonate gyttjas, 2 – lacustrine chalk, 3 – organic sediment, 4 – clastic sediment (Rutkowski & Król 2005)*

Apart from employees from the AGH University of Science and Technology in Krakow, the research involved, among others, scientists from: the Silesian University of Technology in Gliwice, the Institute of Geological Sciences of the Polish Academy of Sciences in Warsaw, the Institute of Botany of Polish Academy of Sciences in Krakow, University of Bialystok, University of Gdańsk, Adam Mickiewicz University in Poznań, Jan Kochanowski University of Kielce, University of Szczecin, Maria Curie-Skłodowska University in Lublin, the Nicolaus Copernicus University in Toruń and Bialystok University of Technology as well as the State Geological Institute in Warsaw, the Institute of Meteorology and Water Management in Białystok and the Maritime Institute in Gdańsk. The research results have been published in various scientific journals. Over one hundred and several dozen scientific articles and communications have been published. They formed the basis of many diploma theses, including four doctoral dissertations and dozens of MA theses, mainly at the AGH University of Science and Technology in Krakow and the Jan Kochanowski University of Kielce. A significant part of the results of the research conducted on Wigry was presented in the form of papers given at various national and international conferences. Among others, at the conference devoted to Wigry – the scientific and educational conference "Jezioro Wigry" (Stary Folwark 2009). Since 2003, annual Wigry Sessions have been organized by the Quaternary Palaeogeography Commission of the Polish Academy of Arts and Sciences in Krakow, the Faculty of Geology, Geophysics and Environmental Protection of AGH and the Wigry National Park.

Work on the lake can be divided into several basic categories (Tab. 1) paying attention to both general recognition as well as detailed research. The most important publications that were created in a given topic are listed below, where more detailed data can be found.

Table 1
Publishing activity on Lake Wigry, considering various research directions

Subject	Research team (Institution)	Examples of publications
Geological structure and geomorphology	DRILLING AND GEOLOGICAL MAPPING A. Ber (Polish Geological Institute in Warsaw)	Ber (2009a, 2009b)
	SEISMIC PROFILES J. Rutkowski, K. Pietsch, K. Król (AGH UST Krakow); A. Osadczuk (University of Szczecin); L. Krzysztofiak (Wigry National Park); S. Rudowski (Maritime Institute in Gdańsk)	Rutkowski et al. (2002, 2005, 2009b)
Origin and evolution of the lake	J. Rutkowski, K. Król, D. Prosowicz, U. Aleksander-Kwaterczak, J. Szczepańska, A. Kostka (AGH UST Krakow); L. Krzysztofiak (Wigry National Park); A. Osadczuk (University of Szczecin); N. Piotrowska (Silesian University of Technology in Gliwice); S. Hałas (Maria Curie-Skłodowska University in Lublin), S. Żurek, M. Kupryjanowicz (University of Bialystok); E. Zawisza, K. Szeroczyńska (Polish Academy of Sciences in Warsaw)	Kupryjanowicz (2007), Zawisza & Szeroczyńska (2007), Aleksander-Kwaterczak (2009)
Bathymetry and shaping of the shoreline	J. Rutkowski (AGH UST Krakow); A. Osadczuk (University of Szczecin); L. Krzysztofiak (Wigry National Park); A. Choiński (Adam Mickiewicz University in Poznań); R. Skowron (Nicolaus Copernicus University in Toruń)	Choiński & Skowron (1998), Rutkowski et al. (2009a)
Sediments research	LITHOLOGY J. Rutkowski, D. Prosowicz, K. Król, U. Aleksander-Kwaterczak (AGH UST Krakow); L. Krzysztofiak (Wigry National Park); R. Popielski (Bialystok University of Technology)	Popielski & Rutkowski (1998), Rutkowski (2001), Rutkowski et al. (2007a, 2009c)
	AGE AND RATE OF SEDIMENTATION N. Piotrowska, A. Pazdur, J. Pawłyta, G. Poręba, J. Sikorski, M. Szczepanek (Silesian University of Technology in Gliwice); S. Hałas (Maria Curie-Skłodowska University in Lublin)	Pawłyta et al. (2004), Piotrowska (2009)

***Table 1** cont.*

	CHEMICAL COMPOSITION D. Prosowicz, U. Aleksander-Kwaterczak, A. Kostka, E. Helios-Rybicka, M. Kotarba, J. Szczepańska (AGH UST Krakow); A. Gałuszka, Z.M. Migaszewski, P. Pasławski (Jan Kochanowski University of Kielce); A. Paprocka (Polish Academy of Sciences in Warsaw)	Kotarba (2003), Migaszewski et al. (2003), Aleksander-Kwaterczak & Prosowicz (2007), Paprocka (2007), Prosowicz (2007), Aleksander-Kwaterczak et al. (2009), Prosowicz et al. (2009), Aleksander-Kwaterczak & Kostka (2011)
Peat bogs, the edge and sub-peat sediments of the lake	S. Żurek, D. Drzymulska (Jan Kochanowski University of Kielce); J. Rutkowski, U. Aleksander-Kwaterczak, D. Prosowicz (AGH UST Krakow); L. Krzysztofiak (Wigry National Park)	Rutkowski et al. (2008), Żurek & Drzymulska (2009)
Water research	CHEMICAL COMPOSITION OF SURFACE WATER K. Stawecki, B. Zdanowski (Stanisław Sakowicz Inland Fisheries Institute in Olsztyn); U. Aleksander-Kwaterczak, R. Zdechlik (AGH UST Krakow)	Stawecki et al. (2003), Zdanowski (2003), Aleksander-Kwaterczak & Zdechlik (2016)
	CHEMICAL COMPOSITION OF PORE WATER J. Rutkowski, J. Szczepańska, U. Aleksander-Kwaterczak, K. Król, R. Zdechlik (AGH UST Krakow); L. Krzysztofiak (Wigry National Park)	Rutkowski et al. (2007b), Aleksander-Kwaterczak & Zdechlik (2016)
Water circulation in the lake	E. Bajkiewicz-Grabowska (University of Gdańsk); M. Dąbrowski (Institute of Meteorology and Water Management in Białystok)	Bajkiewicz-Grabowska (2009), Bajkiewicz-Grabowska & Dąbrowski (2009)
Climatic conditions	A. Górniak (University of Bialystok)	Górniak (2009)
Thermal structure of the lake	W. Marszelewski (Nicolaus Copernicus University in Toruń)	Marszelewski (2009)
Paleobiological research	K. Szeroczyńska, E. Zawisza (Polish Academy of Sciences in Warsaw); M. Kupryjanowicz (University of Bialystok); W.P. Alexandrowicz, M. Bąk (AGH UST Krakow); A. Jurochnik (Polish Academy of Sciences in Krakow); T. Namiotko, W. Staniszewska (University of Gdańsk); A. Kierzek, A. Witkowski (University of Szczecin); M. Pełechaty (Adam Mickiewicz University in Poznań)	Alexandrowicz (2000), Kupryjanowicz (2007), Zawisza & Szeroczyńska (2007), Witkowski et al. (2009), Pełechaty et al. (2013)

The fact that "the history of the Lake Wigry still hides many secrets and causes discussions among scientists" is of crucial importance (Krzysztofiak 2010). A dozen or so scientific papers (e.g., Alexandrowicz & Żurek 2018, Eliasz-Kowalska & Wojtal 2020, Kostka & Leśniak 2020, Aleksander-Kwaterczak et. al. 2021) have also been created after the death of Professor Rutkowski, proving that the memory of the professor and the passion for Lake Wigry is still alive and well.

SUMMARY

Thanks to his tremendous dedication, commitment and effort, Professor Rutkowski created a valuable scientific study about Lake Wigry with the help of an interdisciplinary team of specialists and enthusiasts which he was instrumental in creating. There have been numerous scientific works produced, ranging from those that used the simplest tools to papers utilizing increasingly advanced methods. The lake still hides many unresolved issues and secrets, a fact which is attracting new groups and generations of researchers.

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Funding: *The study was financially supported by the Faculty of Geology, Geophysics and Environmental Protection at the AGH University of Science and Technology in Krakow, Poland (no. 16.16.140.315).*