METALLURGICAL MACRO- AND MICROARTEFACTS IN FAN SEDIMENTS AS RESULT OF FLUVIAL PROCESS CHANGES – CASE STUDY FROM SIELPIA RESERVOIR (S POLAND)

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ABSTRACT

The Sielpia Reservoir is located on Czarna Konecka River in the N part of Świętorzyskie Voivodeship (Central Poland), about 30 km NW from Kielce. In the Middle Ages, there was a significant development of metallurgical industry in Old-Polish Industrial District (OPID). The Sielpia Reservoir is in place where one of historical industrial pond operated. Suddenly other reservoir drainages and disastrous flows in the middle section of the Czarna Konecka River led to intensified incision and bank erosion of the river and intensive accumulation of material in the Sielpia Reservoir. In the Czarna Konecka estuary into the Sielpia Reservoir an inland delta (high-energy subequenus fan) was deposited. These fan and inland delta were formed during many flash floods caused by failures of the dams of former industrial ponds located upstream of the reservoir.
A geological profiles in inland delta were made, and samples were taken for grain size analysis, macro-, microslags and iron spherules content by Magnetic Spherule Separation (MSS) method. The analyses have shown the occurrence of slags and iron spherules in fan sediments. Slags are mainly accumulated quite shallowly creating later characteristic aeolian pavement. Mainly delta fan is built by sandy sediments at terraces cut by the river, in which both slags and spherules do not occur. A small amount of them in the inland delta sediments confirm their redeposition from the upper section of Czarna Konecka River during flood events.

Keywords: Makro- and microslags, iron microspherules, historical metallurgy remains, redeposition, Old-Polish Industrial District

INTRODUCTION

In the Middle Ages in Holy Cross Mts. Region was a significant development of metallurgical industry in Old-Polish Industrial District (OPID) [1]. The Sielpia Reservoir is placed in one of the many old industrial ponds where historical forges were operating before. Research from other rivers in this region [2] and Europe [3],[4] indicates many traces of metallurgical activity preserved in the alluvial deposits. So far, the occurrence of microspherules in lacustrine sediments has been recognized in the Suchedniów Reservoir (Kamionka Valley)[2] and in the discussed reservoir in Sielpia Wielka (Czarna Konecka Valley), however, the spatial distribution of microartefacts in the sediments has not been studied so far. Contemporary sediments have been intensively transported and

accumulated from the upper sections of river, which in last years has formed a distinct high-energy subaquenus fan and later inland delta in the reservoir bottom [5]. Since the construction of the new reservoir at this location in 1960, it has been dredged several times due to intensive transport and accumulation of the alluvia from upstream. This led to a reduction in the reservoir capacity by up to 5 ha [6]. This reservoir is an excellent place to identify the contemporary redeposition of metallurgical microartefacts from many former forge sites located upstream in the river.

STUDY AREA

The Sielpia Reservoir is located in Holy Cross Mts. (Kielce Upland, Poland) about 30 km NW from Kielce. In many rivers of this region, like Czarna Konecka or Kamienna a former industrial ponds ware operated in the historical times [1]. On Czarna Konecka River, there were many ponds built as the part of the water wheel-powered hydrotechnical infrastructure of forges and other ironworks [1]. Sielpia Reservior is in place of one of these industrial ponds creating characteristic anthropogenic small-scale water retention system (ASWRS) on the river [1],[7]. Most of them were later destroyed or their functions were changed during economic transformations in the OPID region [1],[7]. In the river estuary into the Sielpia Reservoir an inland delta (high-energy subequenus fan) was deposited. This form located in the SE of the reservoir is the main object of the current research. The studied form was completely destroyed during the revitalization works on the reservoir finished in 2023.

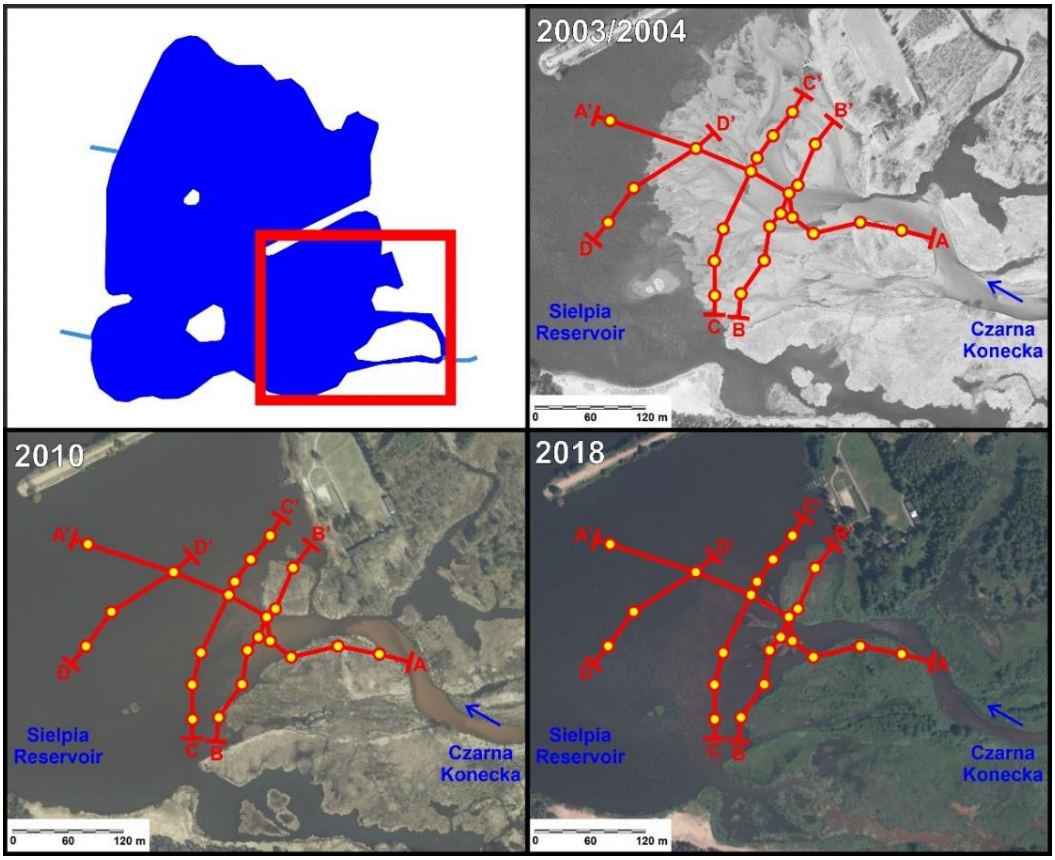

Figure 1. Location of profiles/drillings (yellow points) and cross-sections (red lines) in western part of Sielpia Reservoir in archival photos 2003/2004, 2010 and 2018 [8]

METHODOLOGY

Aim of the study is to recognize microartefacts of historical metallurgical activity on the river in the redeposited alluvia of inland delta. For this purpose, the types of macro-, microslags and microspherules were differentiated in selected grain fractions including the processes leading to their accumulation from upper section of the river.
Geological profiles and drilling were made in 2019-2020 during the hydrotechnical works on the Sielpia Reservoir that was carried out. Fieldwork was mainly concentrated in the SE part of the reservoir in the inland delta (subaqueous fan) area. Drillings and profiles were made throughout the entire form area to identify spatial lithological and sedimentological changes of the delta. The samples collected from it were subjected to grain size analyzing, macro- and microslags distribution measurement (quantitative method given in percentage) and the Magnetic Spherule Separation (microspherules per 10 grams of material) laboratory methods [9]. Also field inspection with photographic documentation of the study site was made. The research materials were supplemented with archival documentation and previous results of research conducted at this study site [2],[5],[6],[7]. Detailed analyses were carried out again for 22 geological profiles (215 samples), which will enable precise spatial recognition of the lithological structure of the studied form and the distribution of microartefacts of historical metallurgy at Czarna Konecka River.

RESULTS

Grain size analyses showed that delta (high-energy subaqueous fan) is built mainly of sand and gravel sediments with a darker layer of finer deposits admixture with visible detritus inserts. Grain size analysis amble to make a lithological reconstruction of the delta. Earlier, preliminary analyses allowed for the preparation of a less detailed longitude section considering the distribution of slags and microspherules in the sediments [2].

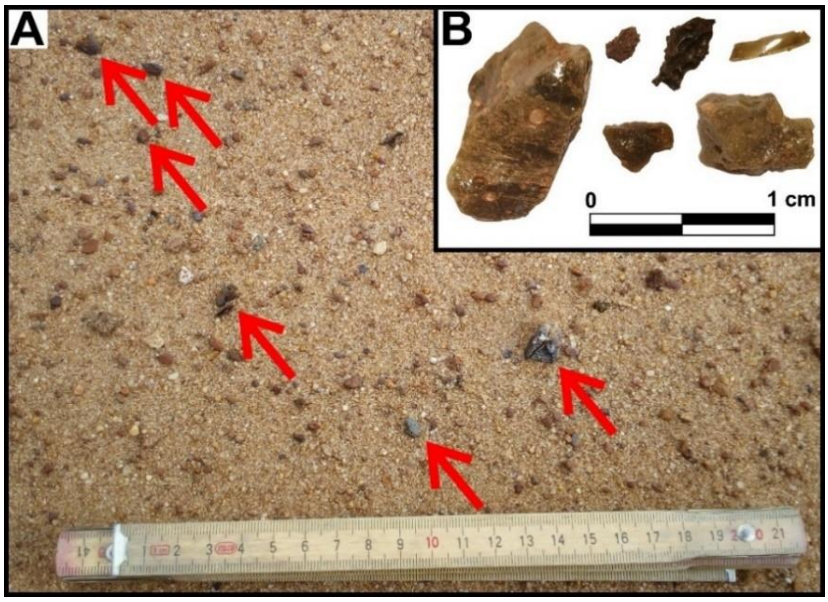

Figure 2. A – Aeolian (deflation) pavement made of slag formed on the surface of Sielpia inland delta (Photo P. Przepióra 2019),
B – Macro- and microslags separated from sediments (Photo P. Przepióra 2024)

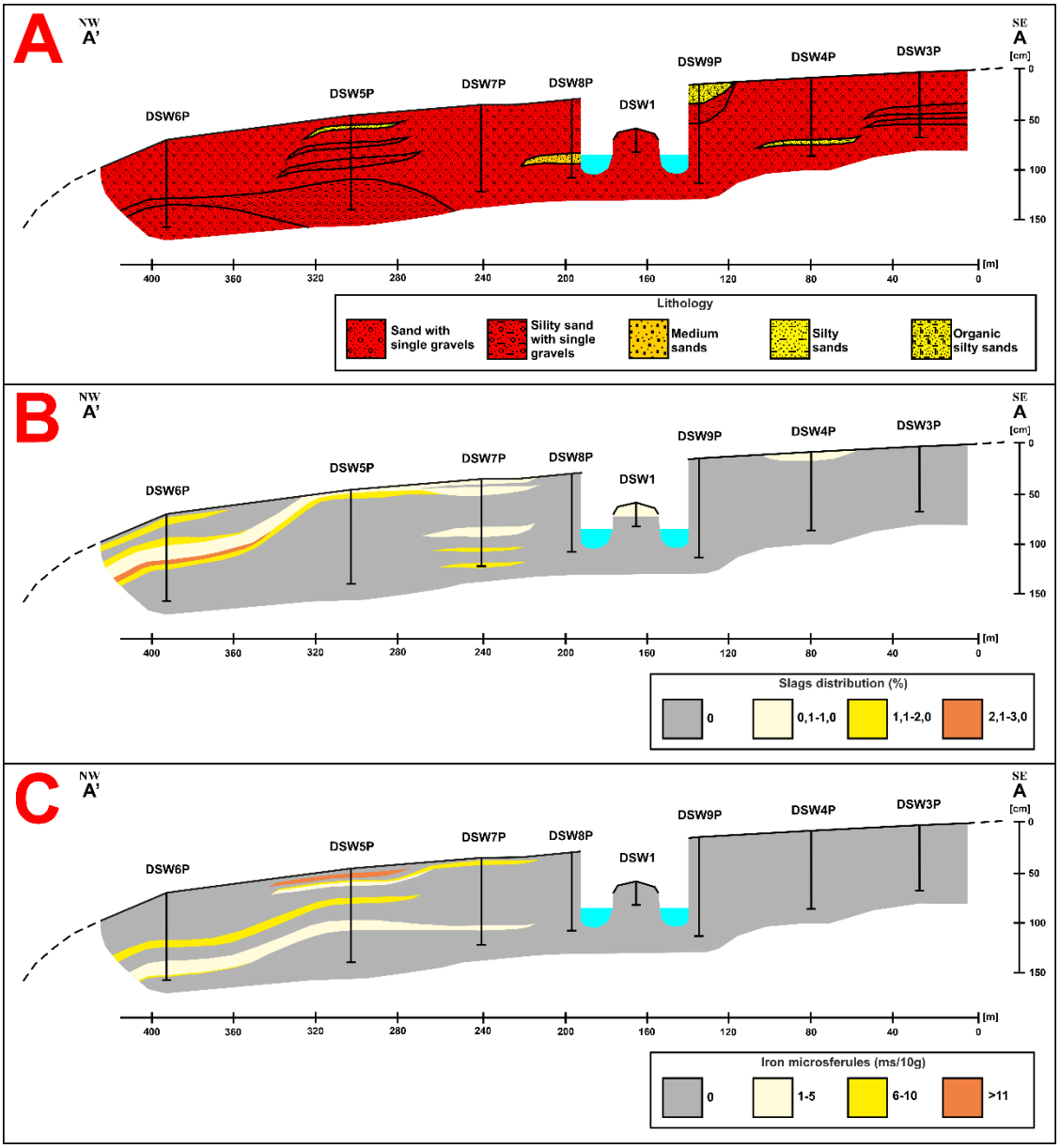

Figure 3. Selected A-A' cross-section of Sielpia inland delta [2], [6] (supplemented and changed): A – lithological data; B – distribution of macro- and microslags in fan sediments; C – distribution of iron microsferules in fan sediments.

These results confirmed the possibility of measuring not only macro- and microslags, but also iron microspherules redeposited from the upper section of the river. Cross-sections made based on geological profiles indicated the distribution of individual metallurgical artefacts in the delta sediments. Macro- and microslags are mostly found in the surface and mostly shallow sediments at the head of the delta. They occur mainly in sandy and gravelly material that create visible aeolian (deflation) pavement on the surface after drying of the reservoir in 2019 (Fig. 2). Iron microspherules, however, usually occur only in the finer fraction of sediments, often where no macro- or microslags have been detected. The artefacts detected in the sediments form distinct layers in the frontal part of the studied form (Fig. 3). The percentage of macro- and microslags does not exceed 10% in the analyzed samples, but most often their number is trace, as reflected by values below

1%. In the case of iron microspherules, the situation is analogous to slags, and their number is relatively small (from a few to a dozen pieces per 10 grams of sieved sample), however, possible measurement errors caused by the small weight of the available samples should be considered.

DISCUSSION

In the Middle Ages, there was a significant development of metallurgical industry in OPID. Many ironworks and forges were built along most of the rivers of the area [1]. This led to the construction of ASWRS with small industrial ponds [1],[7]. At the beginning of the 20th c. many of those ponds were drained with the collapse of the metallurgical and water mills activity. Later, the abandoned dams of former industrial ponds were destroyed and led to a flash floods in the river [10]. In the Czarna Konecka River this flash flood led to intensified incision and bank erosion and intensive accumulation of material in the Sielpia Reservoir forming a high-energy subequenus fan [5]. A macro-, microslags, and microspherules have been detected in the delta sediments of the Sierpia Reservoir, which are traces of historical metallurgical activity in the river. These occur in relatively young subequenus fan and later delta sediments that existed in the reservoir until 2019, confirming long-term intensive redeposition processes on the river. Small number of these artefacts in the sediments is probably caused by its redeposition (flushed out), but also by the fact that during the flash flood the river cut the Pleistocene sandy terraces [7], in which these artefacts did not occur. New analyses have shown the occurrence of slags and iron spherules mainly at the delta front. Slags are mainly accumulated quite shallowly, and their greatest concentration occurs directly at the head of the analyzed form. The constantly supply of more slags by the river is confirmed by occurring of them in the bar in the channel cutting the delta (Fig. 3). The occurrence of iron spherules occurs only at the delta front, and they are found deeper at the head of the delta. A small amount of both slags and spherules in the sediments of the inland delta confirms their redeposition from the upper section of Czarna Konecka River during floods [7]. However, there is a clear fundamental difference in the sediments in which macro- and microslags and microspherules are accumulated. Slags are predominantly found in coarse sediments carried by stronger water currents, for example during flash floods, forming distinct sand-gravel layers. Microspherules, on the other hand, occur mostly in a sediment with finer fraction admixture, indicating that they accumulate mostly under low-energy flow conditions. These results show a relationship between types of redeposited sediments with metallurgical artefacts that occur in them.

CONCLUSIONS

Iron spherules detected in the delta sediments of Sielpia Reservoir can relate to mainly their redeposition from upstream of the river. The macro- and microslags preserved in the delta's sediments were flushed out from the upper section of Czarna Konecka, where many forges operated with similar industrial ponds (ASWRS) These reservoirs were abandoned and destroyed led to create flash floods. The formed layer of iron spherules may indicate the accumulation of these sediments during one of such catastrophic events on the river during 21st c. The results of MSS and slags separation show a relationship between the types of redeposited sediments in which metallurgical artefacts occur. Most of the slags are accumulated in coarse alluvium when microspherules only in sediments

with admixture of finer fraction. This is caused, i.a., by the size of the particles carried in different water flow strengths.

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