Environmental changes of the Mazovian (Holsteinian /~MIS 11) palaeolake near Szymanowo (eastern Poland) in the light of malacological analysis

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ABSTRACT


The malacofauna of the palaeolake deposits at Szymanowo (eastern Poland) was investigated. It represents the younger part of the climatic optimum of the Mazovian (Holsteinian) Interstadial (~MIS 11) and possibly the postoptimal period. The mollusc assemblage is composed of both standing and running water species, mostly connected with temperate climate. The presence of biostratigraphical indicators of the Mazovian, Viviparus diluvianus (Kunth, 1865), Lithoglyphus jahni Urbański, 1975 and Pisidium clessini Neumayr, 1875, is noteworthy. Variability in the structure and composition of the assemblage enables palaeoecological reconstruction. Changes in the water-level, vegetation and energy conditions are inferred from the malacological succession. Three stages of the lake development were distinguished. The first one is connected with deeper conditions and predominance of V. diluvianus and L. jahni. The second one, dominated by Bithynia tentaculata (Linnaeus, 1758), records a fall of the water-level and the growth of aquatic plants, evidenced by high frequencies of Valvata cristata Müller, 1774 and Acroloxus lacustris (Linnaeus, 1758). The third stage corresponds to another rise of the water-level and an increase in V. diluvianus, L. jahni, Valvata piscinalis Müller, 1774 and Pisidium henslowanum (Sheppard, 1823), which evidence some higher energy conditions.

Key words: Molluscs; Palaeolakes; Mazovian (Holsteinian) Interstadial; Palaeoecology.

INTRODUCTION

Mollusc-bearing deposits were discovered in 1993 in the vicinity of the village of Szymanowo (eastern Poland) during fieldwork connected with the production of the Lomazy sheet of the 1:50 000 Geological Map of Poland (Albrycht 2002a). They are represented by sand, silt and mud, sometimes with organic and plant detritus (Albrycht 2002b). Mollusc shells are abundant and in good condition, but only a preliminary investigation has previously been undertaken, resulting in the analysis of barely one sample per 2.5 m interval (3.5–6 m depths) in the borehole WH-71 (Text-fig. 1). This enabled the general stratigraphy as well as the ecological and climatic conditions to be defined (Albrycht et al. 1995). According to the geological situation of the shell-bearing deposits and the composition of the malacocoenosis from Szymanowo Albrycht
et al. (1995) inferred a lake with possible overflow belonging to the Mazovian (Holsteinian) Interglacial which corresponds to Marine Isotope Stage 11 (MIS 11; Nitychoruk et al. 2005, 2006). A predominance of temperate climate with a slight cooling phase was concluded from the faunal record (Albrycht et al. 1995). The problem is that without any distinguishing beds or mollusc assemblages, virtually no changes in the succession could be inferred.

The next malacological studies at Szymanowo were connected with a biometrical investigation of V. diluvianus shells (Szymanek 2007, 2008, 2011), when nine samples were collected from excavations located at the margin of the Holsteinian deposits, ca. 1.2 km north of the WH-71 profile (Text-fig. 1). A detailed analysis of the mollusc assemblage was therefore not the main focus of that study, which merely provided some environmental background for the morphometric changes shown by V. diluvianus. Pollen analysis suggested that the deposits accumulated during the final part of the climatic optimum of the Mazovian Interglacial (Szymanek and Bińka 2006; Szymanek 2007, 2008, 2011). According to K. Bińka, the optimum itself was restricted to the Carpinus-Abies pollen Zone (Bińka 1994; Bińka and Nitychoruk 1995, 1996; Bińka et al. 1997). The end of the climatic optimum and its immediate aftermath witnessed an expansion of the thermophilous water-fern Salvinia natans (Linnaeus) and a contraction of forest communities, accompanied by a distinct increase in hazel (cf. Bińka and Nitychoruk 1996; Bińka et al. 1997).

The present paper provides a definitive study of the molluscan assemblages from Szymanowo. It presents quantitative analyses of the molluscan assemblages throughout the succession, which enable more detailed palaeoenvironmental reconstructions of the lake and its surroundings at Szymanowo.

Text-fig. 1. Location of the Szymanowo site
LOCATION AND GEOLOGICAL SETTING

The Szymanowo site is located in eastern Poland, about 18 km southeast of Biała Podlaska and 2 km east of the village of Łomazy (Text-fig. 1). It is in a marginal part of the Łomaska Depression. In the vicinity of the site there is a flat, mostly agricultural area underlain by Holocene fluvial deposits, Vistulian lacustrine sands and silts, fluvioglacial sands of the Krznanian/Odranian? (Saalian) Glacial Stage, and tills of Sanian 2 (Elsterian) age. Near the surface, Mazovian deposits with abundant mollusc shells occur (Text-fig. 2). Their age was established on the basis of the pollen analysis (Albrycht 2002b; Szymanek and Bińka 2006; Szymanek 2007, 2008, 2011), as well as the molluscan fauna, which included two species characteristic of the Mazovian, Viviparus diluvianus (Kunth, 1865) and Lithoglyphus jahni Urbaniśki, 1975 (Albrycht et al. 1995; Szymanek 2011). In Britain V. diluvianus is also regarded as an indicator of the Hoxnian stage = early part of MIS 11 (Kerney 1971; Meijer and Preece 1995; Keen 2001; Roe 2001; White et al. 2013), whereas in the Netherlands it appears in both the Holsteinian and Tiglian (Meijer 1989; Gittenberger et al. 2004). L. jahni is unknown from the late Middle Pleistocene in NW Europe but is known from the Augustovian (Bavelian) of Poland (Skompski 2009) and the Netherlands, where it also occurs in the Tiglian (Meijer 1989; Gittenberger et al. 2004).

In the vicinity of the studied section the fossiliferous interglacial lake sediments are limited to a belt 1.3 km long and up to 600 m wide, extending from north to south (Text-fig. 1). They lie on sandy silts without mollusc remains, accumulated in the late phase of the Sanian 2 Glaciation (Szymanek and Bińka 2006; Szymanek 2011), or directly overlie the Sanian 2 till. They are covered by lacustrine sands and silts of the Vistulian Glaciation (Albrycht 2002a, b) (Text-fig. 2). In the northern part of their occurrence, at the excavated profile, they are covered only by topsoil and 0.2 m of colluvial silts. The mollusc-bearing deposits reach a thickness of 1.3 m and are represented by three layers: dark grey (N2 in the Munsell colour system) sandy silt (1.8–1.1 m), yellowish brown (5Y 4/6) fine-grained clayey sand (1.1–0.75 m) and light grey (N6) sandy silt (0.75–0.5 m). The mollusc accumulation is extremely rich, reaching about 90% of the deposit volume in the lower part of the profile and ca. 60% in the uppermost samples. These deposits, especially the dark grey silts, may correspond to the middle part of an interglacial series, which divides two complexes of organic lake and backwater sediments described in this area by Albrycht (2002b).

MATERIAL AND METHODS

At Szymanowo the same nine samples used in the biometric study of V. diluvianus were analysed for molluscs (Szymanek 2007, 2008, 2011). They were each 10 cm thick and were collected from an excavation ca. 0.9 m wide, 2.4 m long and 1.8 m deep, from depths of 1.6–0.55 m. About 3 litres of sediment per sample (weight 3–6 kg) were taken from the three mollusc-bearing horizons. Samples 9 to 6 (1.6–1.15 m) were taken from the lowest layer of sandy silt, samples 5 to 3 (1.1–0.8 m) and samples 2 to 1 (0.75–0.55 m) represented the sand and the uppermost sandy silt respectively.

Mollusc analysis comprised quantitative methods. Samples were dried in the air and then wet-sieved using a 0.5 mm mesh, according to procedures described by Ložek (1964, 1986, 2000), Alexandrowicz (1987) and Alexandrowicz and Alexandrowicz (2011). All identi-
fiable shells and mollusc remains were collected from the dried residue. They were determined under a stereo-
scopic microscope at magnifications up to 64x and counted following Ložek’s (1964) method for broken in-
dividuals. The number of bivalves was halved in the cal-
culation (1 individual = 2 valves). Some shell frag-

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**TOTAL OF TAXA**

26 27 28 32 30 19 27 22 22

**TOTAL OF SPECIMENS**

2007 2282 2116 3247 5029 3537 3481 4879 1970
ments were classified only to the rank of genus. The molluscs were then grouped in accordance with their ecological preferences (Text-fig. 3). The latter attributions were based on Ložek (1964), Alexandrowicz (1987), Alexandrowicz and Alexandrowicz (2011) and supplemented after Ložek (1976, 1982), Körmig (1966), Piechocki (1979), Skompski and Makowska (1989), Piechocki and Dyduch-Falniowska (1993), Glöer (2002) and Welter-Schultes (2012). The structure of mollusc assemblages was shown by spectra of species and specimens (Text-fig. 4). Changes in the associations in the vertical succession were illustrated on the percentage malacological diagram (Text-fig. 5). The Bithynia-index (BIN), representing the proportion of opercula and shells of *Bithynia tentaculata* according to the formula $\text{BIN} = (\text{opercul}a - \text{shells})/(\text{opercul}a + \text{shells})$ (Steenberg 1917; Alexandrowicz 1999), was calculated in order to characterise the sedimentary environment.

**RESULTS**

The mollusc assemblage from Szymanowo comprises 21 snail taxa and 20 bivalve taxa, represented altogether by 28,548 individuals (Text-fig. 3). The numbers of both taxa and specimens fluctuate in the profile, ranging from 19 to 32 and from 1970 to 5029 respectively (Text-figs 3, 4). In the lower part of the section (samples 9 to 5; 1.6–1.0 m), single valves of ostracods assigned to four taxa were also found: *Scottia browniania* (Jones, 1850), *Scottia tumida* (Jones, 1850), *Darwinula stevensoni* (Brady and Robertson, 1870) and *Candona* sp. In most samples occasional remains of fishes, rodents, and amphibia also occurred, including Pike, *Esox lucius* Linnaeus, 1758 (sample 9), and Water vole *Arvicola terrestris* (Linnaeus, 1758) (sample 1).

**Palaeoecology**

Except for one land snail *Succinea putris* (Linnaeus, 1758), usually connected with moist habitats and shores of water bodies (Kerney et al. 1983; Wiktor 2004; Welter-Schultes 2012), all the species represent freshwater conditions. They were classified as species of temporary water bodies (ecological group 10), species of permanent water bodies of stagnant waters (group 11) and species of flowing waters (group 12) (Text-fig. 3). The samples are dominated by group 11, which represents between 45 and 69% of all species and between 96 and 100% of all specimens (Text-fig. 4). Most species in this group, including the most frequent *Bithynia tentaculata*, *Lithoglyphus jahni* and *Viviparus diluvianus*, are common in both standing and running waters. However, amongst molluscs typical of lakes *Pisidium lilljeborgii* Clessin, 1886 and...
Acroloxus lacustris (Linnaeus, 1758) should be mentioned. The latter inhabits zones of rich immersed vegetation, often accompanied by Gyraulus albus (Müller, 1774). The euryoecious Pisidium henslowanum (Sheppard, 1823) is also common in lakes (Alexandrowicz 1987; Alexandrowicz and Alexandrowicz 2011), but it almost never inhabits closed water bodies, indicating overflow through the lake (Piechocki and Dyduch-Falniowska 1993; Welter-Schultes 2012).

Rheophile species (group 12) are also numerous with a frequency of 19 to 41%, but the number of individuals in this group is distinctly lower and does not exceed 3% (Text-fig. 4). Fluvial conditions are preferred with a frequency of 19 to 41%, but the number of individuals is almost never found in temporary water bodies, but these are usually represented by single specimens. Only Valvata cristata Müller, 1774 and Segmentina nitida (Müller, 1774), regarded as plant-associated taxa (Piechocki 1979; Piechocki and Dyduch-Falniowska 1993; Welter-Schultes 2012). They are rather an accessory element of the fauna, which becomes slightly more common in the upper part of the section (samples 1 to 5; Text-figs 3, 5). The mollusc assemblage also contains a few taxa of temporary water bodies, but these are usually represented by single specimens. Only Valvata cristata Müller, 1774 and Segmentina nitida (Müller, 1774), regarded as plant-associated taxa (Piechocki 1979; Piechocki and Dyduch-Falniowska 1993; Welter-Schultes 2012), reach somewhat greater abundances. The amphibious form Galba truncatula (Müller, 1774) is also a noteworthy element of this group.

Many species from Szymanowo prefer well-oxygenated waters, for example Valvata cristata, Bithynia tentaculata, V. piscinalis, Acroloxus lacustris, Sphaerium rivicolus (Lamarck, 1818), Pisidium nitidum and P. supinum. In addition V. cristata, V. piscinalis and Pisidium henslowanum favour eutrophic conditions (Welter-Schultes 2012).

Also worth noting is the presence of the plant-associated ostracods Scottia browniana (Roe 2001) and the ostracod Darwinula stevensoni (Sywula 1974; Skompski 1991), indicative of rather shallow zones of water-bodies.

**Stratigraphy**

Three mollusc species from Szymanowo have stratigraphical significance. Apart from Viviparus diluvianus and Lithoglyphus jahni, Pisidium clessini (described by Albrycht et al. (1995) as Pisidium sulcatum (S.V. Wood, 1851)) is also quite abundant. In western Europe Meijer (1989), Keen (2001), and Gittenberger et al. (2004) link the last appearance of this species with the Holsteinian Interglacial, but in Britain it also occurred in sequences assigned to both MIS 9 and MIS 7 (Roe et al. 2009). It was also common in the Early Pleistocene, but in Poland it has only been found in the Mazovian. However, Skompski (1996) mentioned its occurrence in the Eemian Interglacial of Ukraine and Belarus.

The ostracods Scottia browniana and S. tumida used to be considered typical of the Holsteinian Interglacial (Kempf 1971; Robinson 1979; Skompski 1991) until both were found in younger deposits in Germany (Pietrzeniuk 1987). In addition, S. tumida occurs in the Eemian Interglacial at Ruszkówek in central Poland (Kozydra and Skompski 1995).

**Palaeoclimate**

Most of the identified species have wide climatic amplitude. Interglacial conditions are indicated by warm-demanding species e.g. Viviparus diluvianus, Borysthenia naticina, Sphaerium rivicolus and Pisidium moitessierianum Paladilhe, 1866. The thermophilous Bithynia tentaculata indicates a somewhat warmer phase of lake development. Some species reach the Arctic Circle, but they are also frequent in temperate climates e.g. Valvata piscinalis, Pisidium henslowanum or even the cold-tolerant Porcellio lilljeborgii.

**DISCUSSION**

The molluscan assemblages from Szymanowo represent the Mazovian (Holsteinian) Interglacial (~MIS 11). The correlation with MIS 11 in the study area is certain, based on detailed isotopic and palynological investigations of a 55 m thick core of lake deposits of the nearby Ossówka site, and has already been widely discussed (Nitychoruk et al. 2005, 2006). An assignment to the Mazovian is also documented in the stratigraphic papers of Gozhik et al. (2012) and Lindner et al. (2013) and is obligatory for eastern Poland at the moment.

The pollen analysis of the deposits from Szymanowo suggests that they represent the final part of the climatic optimum and its transition to the post-optimal period (Szymanek 2011). The composition of the mollusc assemblage, with the dominant species and great abundance of specimens reflecting stagnant water, points to a lacustrine environment. The considerable amount of river species, despite the low number of individuals, suggests some higher energy conditions. Periods of possible water movements as well as ecological changes in the water body can be derived from the variability of the malacological succession.
The mollusc assemblage at Szymanowo is dominated by Lithoglyphus jahni, Bithynia tentaculata and Viviparus diluvianus, which constitute ca. 5–62%, 2–76% and 8–46% of the community respectively (Text-fig. 5). The frequency of the dominant species is very unstable and the associated species such as Valvata piscinalis, Pisidium henslowanum, and Acroloxus lacustris do not exceed 10%. The lowermost part of the succession (samples 9 to 6) is dominated by L. jahni and V. diluvianus. B. tentaculata, which prefers well-oxygenated waters with rich vegetation, expands distinctly between samples 7 and 5, accounting for over 70% of the assemblage (Text-fig. 5). This is a warm-loving species and it occurs only occasionally during cooler periods (cf. Alexandrowicz 1999; Jaeckel 1960; Dzieržek and Szymanek 2013). Such conditions are also supported by the expansion of V. cristata and A. lacustris, which attain the highest abundance in samples 6 to 4 and 6 respectively (Text-fig. 5). At this time, the water body was densely overgrown by the water fern Salvinia natans (Szymanek 2008, 2011). It is reasonable to assume that the water level in the lake was low, as S. natans, V. cristata and B. tentaculata prefer relatively shallow water, typically 0.7–1.8 m (Piechocki 1979; Alexandrowicz 1987, 1999; Alexandrowicz 2008). Also noteworthy are the almost equal numbers of shells and opercula of B. tentaculata indicated by Bithynia-index (BIN) values close to 0 (Text-fig. 4). It suggests that the lake, despite supporting a rich vegetation, was generally devoid of rush and reed beds which often favour the separation of shells and opercula. Such separation may be also influenced by currents (e.g. Sanko et al. 2011), which were clearly minimal. Also noteworthy is the fact that the maximum of B. tentaculata corresponds to the lowest values of V. diluvianus and L. jahni. Usually such disproportion is explained by changes in water chemistry (Skompski 1980, 1989, 1996; Lindner et al. 1991). Increase in acidification connected with an increase in humidity and supply of humic acids affects the disappearance of B. tentaculata, as noted at Bocziów in Western Poland (Skompski 1980, 1989), while its decrease may cause a rise in populations of B. tentaculata. The latter was observed in the neighbouring Hrud I site (Lindner et al. 1991; Skompski 1996; Szymanek 2012). According to Piechocki (1979) B. tentaculata finds optimal conditions in a pH range of 6.4 to 8.55.

The mollusc assemblage from the upper part of the profile (samples 3 to 1, 0.9–0.55 m) is dominated by L. jahni and V. diluvianus but again depleted in B. tentaculata. This time they are associated with Valvata pisci-
nalis and Pisidium henslowanum (Text-fig. 5). The former may point to deeper conditions since it prefers a water depth of 3–10 m (Welter-Schultes 2012) or even of 8–10 m (Alexandrowicz 1987). The decline of *V. cristata* and *A. lacustris* is probably connected with a rise of the water level and limited growth of aquatic plants. Significant representation of *P. henslowanum* suggests overflow through the lake. The general rise in rheophile species is gradual, but segregation of *Bithynia* opercula and shells in sample 1, with predominance of the latter, may also imply increasing water energy (cf. Sanko et al. 2011). The occurrence of *P. supinum*, which is usually restricted to rivers, seems to support this interpretation. However, sometimes this species can also be found in lake margins, where water movements are caused by wave action (Piechocki and Dyduch-Falniowska 1993). The oxygen content in the lake water was probably still high. Considerable frequencies of *V. piscinalis* and *P. henslowanum* may indicate amelioration of trophic conditions but could be inconsistent with good oxygenation. A notable decrease in number of specimens may be indicative of some deterioration of climatic conditions (Text-fig. 4).

Based on the malacological succession, three phases of lake development can be distinguished at Szymanowo. Two periods of somewhat deeper conditions are separated by a phase of shallowing accompanied by the development of aquatic plants. The pollen record (Szymanek 2008, 2011) is rather poor but the higher representation of the water fern *Salvinia natans* in the nearby Wilczyn and Kalilów profiles coincides with lower precipitation and a fall of the water level at the end of the climatic optimum of the Holsteinian Interglacial and in the post-optimal period (Bińka and Nitychoruk 1996; Bińka et al. 1997). Distinct continental influences at this time are also documented by the pollen and isotopic record of the Ossówka profile (Krupiński 1995, 2000; Nitychoruk 2000; Nitychoruk et al. 2005). The following deepening of the lake could be linked with the post-optimum, but there is no clear evidence for such an interpretation.

The fluctuating frequencies of *Viviparus diluvianus* and *Lithoglyphus jahni* might be also linked to taphonomic differences relating to variable hydrological conditions, without any direct climatic cause. In Britain *V. diluvianus* is a key element of the fluviial ‘Rhenish’ fauna (e.g. Roe 2001; White et al. 2013) while in Germany both Schmierer (1923) and Heck (1930) also regard this as a fluval species, albeit Hannemann (1964) postulated a lacustrine origin for deposits containing *V. diluvianus*. At many sites in Poland, especially at Ossówka, shells of this species occur in calcareous gyttja, which undoubtedly accumulated in lakes (Nitychoruk 2000). *Lithoglyphus jahni* is likewise also known from both lakes and rivers (Urbasinski 1975; Gittenberger et al. 2004; Kondrashov 2007). It is possible that their occurrence was connected with depth (cf. Szymanek 2012, 2013) and the water chemistry. The results from Szymanowo imply somewhat deeper zones of lakes occupied by *V. diluvianus* and *L. jahni*.

The palaeolake in the vicinity of Szymanowo contributes to the list of Holsteinian water bodies documented malacologically in the region of Biała Podlaska (cf. Lindner et al. 1991; Nitychoruk 1994; Albrycht et al. 1995; Krupiński and Skompski 1995; Szymanek et al. 2005; Szymanek 2011, 2012, 2013). Out of the few sites in the area, only the profiles from Hrud, Roskosz and Wilczyn yielded fully comparable material (cf. Szymanek 2012, 2013). The malacological records from the well known sites at Ortel Królewski and Ossówka (e.g. Nitychoruk 1994, 2000; Albrycht et al. 1995; Szymanek et al. 2005; Szymanek 2011) lack good quantitative data, precluding detailed comparison with the succession of Szymanowo. The composition of the mollusc assemblages from Hrud, Roskosz, Wilczyn and Szymanowo is similar and is characterised by the same group of taxa but some substantial differences exist. Usually three or four taxa predominate, *Lithoglyphus jahni*, *Bithynia tentaculata*, *Valvata piscinalis* and *Viviparus diluvianus*, but the dominant species varies, as do the occurrences of associated species. The most notable features at Szymanowo are the absence of *Valvata piscinalis* f. antiqua and the occurrence of *Sphaerium rivicola*, *S. solidum* and *Pisidium clessini*. The representation of species of running waters is highest in this region, but this group is still just an accessory element of the fauna, suggesting rather restricted water movements. Nevertheless, some overflow and higher energy conditions cannot be excluded. Such situations are typical of all of the water-bodies under investigation, but at Szymanowo the situation seems to be a little bit clearer. Another significant difference is the scarcity of rich bulrush zones shown by low values of the Bithynia-index. At Hrud, Roskosz and Wilczyn, expansion of reeds and bulrush is well documented by the changes of the Bithynia-index throughout the sections (Szymanek 2012, 2013).

The exact age of the mollusc associations from the palaeolakes of Biała Podlaska region is still disputed. It is certain that they represent the Mazovian Interglacial but they may not be synchronous. It is difficult to draw a picture of the mollusc assemblages typical of the different periods of the Holsteinian because they could have been strongly influenced by local conditions. The oldest, pre-optimum fauna was described from the Hrud I site. The molluscan assemblages from
Hrud II, Roskosz and Szymanowo seem to have accumulated during the climatic optimum but at Szymanowo they seem to date from the final part of the optimum and possibly the period immediately following. The molluscs from Wilczyn, with the restricted occurrence of Viviparus diluvianus and Lithoglyphus jahni and some cold-loving taxa, suggest cooler conditions of the final part of the Mazovian, supported by the occurrence of Pisidium obtusale lapponicum (Clessin) Favre and Jayet, 1938 (Szymanek 2013). In all periods changes of the water level and aquatic vegetation were noted. The palaeolake from Szymanowo appears to have been the shallowest because of the highest contribution of species of permanent water bodies. A shallow bay can also be inferred here.

CONCLUSIONS

The malacological changes through the Holsteinian palaeolake sequence in the vicinity of Szymanowo indicate a quite shallow, well-vegetated and well-oxygenated flow-through water body. Three phases in lake evolution were distinguished from initial deeper conditions, followed by a fall of the water level and an expansion of aquatic plants, to a late phase of deepening, with little water movement and a marked reduction in aquatic vegetation. The first stage of lake existence is characterised by high content of Viviparus diluvianus and Lithoglyphus jahni. The shallowing of the lake is probably connected with the development of a more continental climate in the final stage of the interglacial climatic optimum, which is evidenced by many pollen successions in the surrounding area (e.g. Bińka and Nitychoruk 1996; Krupiński 2000; Nitychoruk 2000). A fall of the water level and growth of aquatic plants are evidenced by considerable amounts of Valvata cristata and Acroloxus lacustris, with Bithynia tentaculata being dominant in the assemblage. Another rise of the water-level and some movement of the water in the third stage of lake development is recorded by an increase in Viviparus diluvianus, Lithoglyphus jahni, Valvata piscinalis and Pisidium henslowanum. The palaeoecological changes derived from the malacological succession enrich knowledge of this water body, especially in relation to the preliminary investigations previously conducted in the area (cf. Albricht et al. 1995; Szymanek 2011).

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