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BITHYNIA TENTACULATA (LINNAEUS, 1758) AS AN INDICATOR OF AGE AND DEPOSITION ENVIRONMENT OF QUATERNARY SEDIMENTS

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ABSTRACT: Shells and opercula of an aquatic snail *Bithynia tentaculata* (L.) occur commonly in Quaternary deposits as a substantial component of subfossil malacocenoses. They have been noted mainly in lacustrine chalk and calcareous gyttja, as well as in silts and muds accumulated in fluviatile environments. The contemporary geographical range of this taxon is very wide, comprising the whole Palaearctic except areas extending north of the Arctic Circle. In subfossil assemblages of molluscs *B. tentaculata* (L.) has been described almost exclusively from Holocene and Interglacial deposits, apart from a few localities of sediments accumulated during the cold periods of Pleistocene, particularly in Late Glacial phases. As the range of the mentioned species is limited to the zones of the temperate, boreal and Mediterranean climate, it can be pointed out as a climatic-stratigraphic indicator, useful in malacological analysis of Quaternary deposits. Only a few taxa of aquatic molluscs have such a value. The proportion of shells and opercula characterizes sedimentary environments.

KEY WORDS: Poland, Holocene, aquatic molluscs, climatostratigraphy, *Bithynia tentaculata*, shells/opercula

INTRODUCTION

Climatic changes, cyclically repeated during the Quaternary, determined the course of geological processes, distribution and transformations of biocenoses and migrations of many plant and animal species. The reconstruction of the course of these changes is based on geological and geomorphological studies as well as – to a large degree – on palynological, malacological and diatomological analyses, considering studies on plant macrofossils and vertebrate faunae. Data on the present range of taxa, their ecological and climatic tolerance, and their association with oceanic vs. continental climate are assumed as the basis for interpretation.

Changes that took place at the end of the last glaciation, and especially on the transition Vistulian/Holocene, are clearly reflected in sequences of mollusc assemblages which characterize profiles of sediments deposited in various environments (LOŽEK 1970). This pertains especially to terrestrial fauna which fairly quickly responds to changing ecological conditions and diversification of vegetation cover. The faunae of freshwaters display a greater stability, and according to some authors they provide almost no climatic-stratigraphic indicators which would be useful for divisions of profiles of Late Quaternary deposits. This view finds no confirmation in the light of malacological studies carried out both in Poland and in adjacent countries (MENZEL 1910, 1911, 1915, LOŽEK 1964, ALEXANDROWICZ 1987a, b, ALEXANDROWICZ & ALEXANDROWICZ 1995). In many profiles there occur aquatic molluscs typical of cold climate (*Pisidium stewarti* Preston, *P. obtusale lapponicum* Clessin) on one hand, and taxa of higher thermal requirements, such as *Gyraulus albus* (O. F. Müll.) or *Acroloxus lacustris* (L.) on the other. A water snail *Bithynia tentaculata* (L.) is especially noteworthy in this context, since it is commonly recorded from various kinds of deposits and its shells and opercula, easy to identify, are mentioned from many profiles and localities. They often constitute an important or

even dominant component of aquatic mollusc assemblages, especially in lacustrine carbonate deposits (DEMBIŃSKA 1924, KASPRZAK & BERGER 1978, ALEXANDROWICZ 1980a, b, 1987a, b, 1988a, b, 1989, 1995a, ALEXANDROWICZ & TCHÓRZEWSKA 1981). Preliminary data on the application of this species in palaeoclimatic and stratigraphic interpretation have been presented by the author in 1995 during a symposium in Sosnowiec which was devoted to the problems of threshold changes of natural environment on the transition of Late Glacial and Holocene (ALEXANDROWICZ 1995b). The study has been financed by Academy of Mining and Metallurgy as the scientific project 10.140.551.

DIAGNOSTIC CHARACTERS OF *BITHYNIA TENTACULATA* (L.)

Two members of the genus *Bithynia* occur in Poland: *B. tentaculata* (L.) and *B. leachi* (Sheppard). The former has a conical shell of poorly convex whorls and aperture outline tapered in its upper part. The latter has strongly convex whorls and rounded aperture (URBAŃSKI 1957a, LOŽEK 1964, PIECHOCKI 1979, FALNIOWSKI 1989, FECHTER & FALKNER 1990, GLÖER & MEIER-BROOK 1994). Shells of *B. tentaculata* (L.) reach usually the height of 9–12 mm (sporadically up to 16 mm), and those of *B. leachi* (Sheppard) are smaller (5–7 mm high). The variability of the shell shape is mainly expressed as varied degree of elongation and varied size of the body whorl (Fig. 1). The variation was the basis for distinguishing varieties of unclear taxonomic status, such as *B. tentaculata producta* Menke, *B. tentaculata codia* Bourguignat, *B. tentaculata albida* Rimmer, *B. tentaculata matritensis* Graells, *B. tentaculata ventricosa* Menke, *B. tentaculata crassitesta* Brömme, *B. tentaculata gardnensia* Dyduch et Falniowski (GEYER 1927, GERMAIN 1931, EHRMANN 1937, SIVICKIS 1960, DYDUCH & FALNIOWSKI 1979, PIECHOCKI 1979).

The operculum of *B. tentaculata* (L.) has, in its apical part, an angular termination with an angle close to right, and its outline is flattened or even concave on the left. These diagnostic characters are clearly marked in mature specimens in their final phase of growth, and less so in juvenile shells. The operculum in *B. leachi* (Sheppard) is oval and rounded on all sides (Fig. 1).

DISTRIBUTION RANGE OF *BITHYNIA TENTACULATA* (L.)

Information on the present distribution of *B. tentaculata* (L.) is contained in papers of GEYER (1927), EHRMANN (1937), LOŽEK (1956, 1964), JAECKEL (1960), GROSSU (1986) and FECHTER & FALKNER (1990). These are general data, usually with no source of information indicated. In some cases they are not identical or even contain contradictory elements and should be verified based on detailed faunistic publications. *B. tentaculata* (L.) is a Palaearctic species inhabiting Europe and western Asia, including Mediterranean zone and North Africa. Its presence in North America is a result of introduction. The richest and most abundant populations are found in Central Europe where *B. tentaculata* (L.) is one of the most often recorded water snails, and an important component of aquatic malacocenoses. It plays such a role, among others, in the Danube River basin, on the whole length of the river valley (FRANK et al. 1990).

The northern part of the range includes Scotland, southern and central Scandinavia, shores of the Gulf of Bothnia, Finland and Karelia, and the area located between St. Petersburgh and Archangelsk. The data on its presence on Iceland and Greenland are ambiguous. It was also recorded from the mountains, among others Alps, where it reaches the altitude of 1600 m a.s.l. Especially noteworthy are original data on the composition of malacofauna of the Swedish part of Lappland, in an area of varied topography and occupied partly by tundra and partly by pine-birch forests, of a mean annual temperature of -0.8 – -2.5°C. The aquatic malacocenosis includes 23 species of snails and bivalves, among others *Lymnaea peregra* (O. F. Müll.), *L. ovata* (Drap.), *L. truncatula* (O. F. Müll.), *Anisus contortus* (L.), *Gyraulus rossmaessleri* (Auerswald), *Sphaerium corneum* (L.), *Pisidium obtusale lapponicum* Clessin and *P. milium* Held (JAECKEL 1961). However, *B. tentaculata* (L.) has not been recorded.

A detailed analysis of distribution of particular mollusc species in northern Europe was presented by JOHANSEN (1904). It follows from his results that in Scandinavia and northern Russia no specimens of *B. tentaculata* (L.) have been found in the zone of birch forests, of mean temperature in July of 8–12°C, while the species has been found within the range of forests with admixture of hazel (*Corylus*), of July isotherm 14–16°C.

In the profiles of Late Quaternary deposits of northern Germany described by MENZEL (1910, 1911, 1915), few specimens of *B. tentaculata* (L.) appear at the zone characterized by the presence of *Gyraulus*

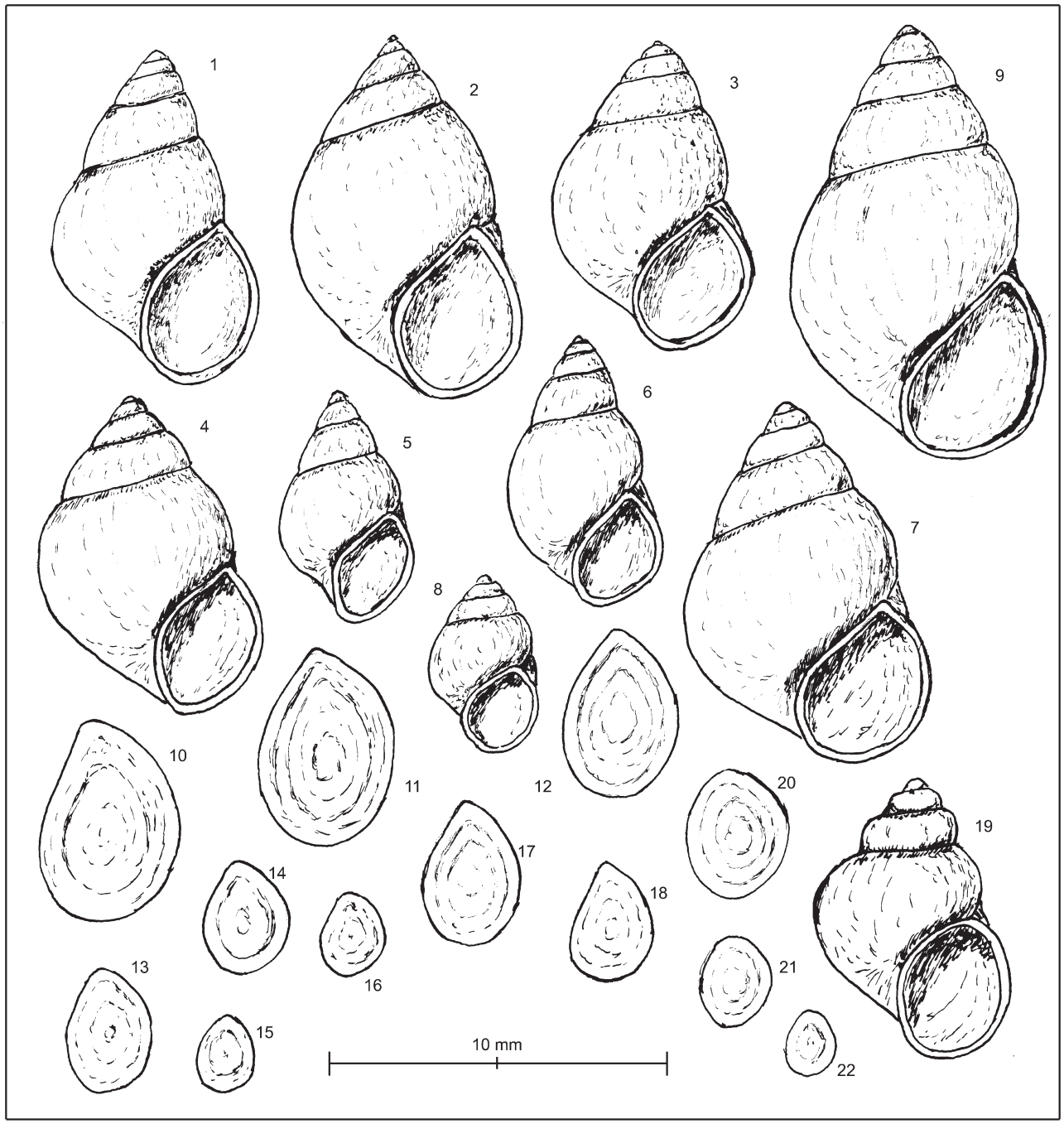

Fig. 1. Shells and opercula of species of *Bithynia* occurring in Poland. *B. tentaculata* (L.): 1–9 shells, 10–18 opercula; *B. leachi* (Sheppard): 19 – shell, 20–22 – opercula

stroemi (Wstld) (= *Gyraulus gredleri* (Gredl.) = *Gyraulus acronicus* (Fér.)), while its numerous shells occur at the zone with *Planorbis umbilicatus* O. F. Müll. (= *Planorbis planorbis* (L.)). Both these zones have been assigned to Holocene. No *B. tentaculata* (L.) was found at the zone with *Planorbis arcticus* Beck (= *Planorbis sibiricus* Dunker) and *Columella columella* (Martens), corresponding to Late Glacial (MENZEL 1910, 1911, 1915). A similar stratigraphic range is displayed by this species in the Russian lowland (DANILOVSKIY 1955), and in Slovakia and Czech Republic, where besides numerous Holocene localities (also Interglacial) the taxon has been cited from one profile of Late Glacial deposits (LOŽEK 1964). Its presence in Alleröd deposits of central Germany was recorded also by JAECKEL (1960).

The other species, *B. leachi* (Sheppard), has a wide distribution range which is associated with its considerable climatic tolerance. Accordingly, it was cited from an array of localities of Vistulian deposits in such countries as Germany, Czech Republic,

Slovakia and Hungary (EHRMANN 1937, JAECKEL 1960, LOŽEK 1964, GROSSU 1986).

BITHYNIA TENTACULATA (L.) IN HOLOCENE DEPOSITS OF POLAND

B. tentaculata (L.) is one of the most common components of Holocene aquatic mollusc assemblages in Poland; it is found in both carbonate and terrigene deposits. In many sites the age of such deposits is documented by radiocarbon dating or palynological and malacological analyses.

Mollusc assemblages with *B. tentaculata* (L.) are known from several localities of Holocene carbonate deposits in western Poland, near Zielona Góra and Gorzów Wielkopolski. They were recorded from deposits of lacustrine chalk: Pomorsko, Zabór, Szumiąca and Osiek (ALEXANDROWICZ 1980a). In the first of the mentioned localities there are radiocarbon-dated deposits. In chalk assigned to Late Vistulian, deposited mainly during Alleröd, aquatic fauna was found with *Gyraulus acronicus* (Fér.), *G. laevis* (Alder) and *Pisidium lilljeborgi* Cles., but with no *Bithynia*. A younger lacustrine chalk representing Mesoholocene (time interval 7,095±50 – 4,110±60 years BP) abounds in opercula of *B. tentaculata* (L.) which, in the upper part of the profile, constitute the main component of the association. There are also shells of this species, though less numerous (ALEXANDROWICZ & NOWACZYK 1982). A considerable proportion of specimens of *B. tentaculata* (L.) was found in sandy Holocene lacustrine deposits, underlying peat-bogs in the vicinity of Wolsztyn (ALEXANDROWICZ & ŻUREK 1991).

In Szczecin Pomerania the taxon was noted from outcrops of lacustrine chalk in Lubiatów and on the lake Płoń. Both species of *Bithynia* are abundantly represented in the profile of Holocene mineral-organic deposits and in peat slime in Brzesk on the lowland Nizina Pyrzycka (KOWALKOWSKI & BERGER 1966). Lacustrine deposits of Late Glacial and Lower Holocene, exposed in the coastal cliff in Niechorze, contain mollusc assemblages with *B. tentaculata* (L.). However, the taxon was found in the upper part of the profile, corresponding to the Preboreal phase of Eoholocene, but single specimens appear also in deposits assigned to Late Alleröd (KOPCZYŃSKA-LAMPARSKA et al. 1984).

Rich malacological materials were collected in central Pomerania. In lacustrine chalk deposits: Marcelin, Prostynia, Borzytuchom and Łubiana there occur three types of mollusc assemblages, the association with Bithynia-operculum being the most numerously represented (ALEXANDROWICZ & TCHÓRZEWSKA 1981). In carbonate and organic-carbonate deposits described from the Grabowa river valley near Darłowo (RYBICKI & ŻUREK-PYSZ 1989) there is a characteristic sequence of mollusc assemblages. In the lowest part it is an assemblage with *Vertigo genesii* (Gredl.) and *V. geyeri* Lindh., higher there appear rich faunae with *B. tentaculata* (L.), including consecutively such species as *Discus ruderatus* (Fér.), *Planorbis planorbis* (L.), *Discus rotundatus* (O. F. Müll.), *Vertigo antivertigo* (Drap.) and *V. moulinsiana* (Dupuy). The age of the deposits containing numerous specimens of *Bithynia*, representing Eo- and Mesoholocene, was determined based on radiocarbon dating and malacological data (ALEXANDROWICZ 1987a, FILONOWICZ & KRZYMIŃSKA 1989). In the Słupia river valley lacustrine chalk and calcareous gyttja contain mollusc assemblages in which *B. tentaculata* (L.) is present or absent. In the profiles located SE of Słupsk (Gałęźnia Mała, Stożek Glaźny), Early Holocene deposits with opercula and shells of *B. tentaculata* (L.) were distinguished, and in boreholes in the town gyttja was found which corresponded to Late Vistulian and contained a fauna with characteristic species: *Vertigo genesii* (Gredl.), *V. geyeri* Lindh., *Pisidium stewarti* Preston and *P. obtusale lapponicum* Cles., but completely devoid of *Bithynia* (ALEXANDROWICZ et al. 1989, 1990). A similar type of Late Glacial fauna was described by BRODNIEWICZ (1979) from carbonate deposits exposed in the Baltic cliff near Ustka.

Profiles of lacustrine chalk in Orle near Wejcherowo (ALEXANDROWICZ 1988a) are especially noteworthy. Few opercula of *Bithynia* were found in profile A, in deposits which, based on palynological analysis, were classified in the zone called „Orle 2b", with *Betula-Pinus-Salix-Populus*, together with appearance of pollen of *Ulmus* and *Corylus* (LATAŁOWA 1988). Numerous shells, and especially opercula, of these snails are present in profiles B and C, in the palynological zone „Orle 3" with *Corylus-Pinus* (LATAŁOWA 1988). Both these zones were assigned to Holocene, Preboreal and Boreal, respectively. Holocene lacustrine chalk and calcareous gyttja with *B. tentaculata* (L.) are known from several other exposures in Gdańsk Pomerania (Siwiałka, Nowe Polaszki, Skowarcz).

In north-eastern Poland profiles of Holocene lacustrine deposits containing malacofauna are known, among others, from the deposit of lacustrine chalk in Sołdany on the lake Kruklin (STASIAK 1963). The mollusc assemblages, besides dominant members of the genus *Valvata*, contain numerous shells and opercula of *B. tentaculata* (L.) (CZEPIEC 1997). Similar assemblages were noted by the author from several other carbonate deposits (Malinowo, Rutkowo, Lęguty), and also from deposits underlying the Biebrza

peat-bog (ŻUREK & DZIĘCZKOWSKI 1979). In precisely dated profiles of calcareous and detritus gyttja in Woryty near Gietrzwałd, malacological analyses carried out by SKOMPSKI and ALEXANDROWICZ revealed that Late Glacial deposits containing malacofauna, dominated by members of the genus *Valvata* and family Planorbidae, were completely devoid of *Bithynia* which appear only in gyttja younger than these sediments (STUPNICKA 1981, PAWLIKOWSKI et al. 1982). They occur also in carbonate and organogenic Holocene deposits in the Vistula river valley between Warsaw and Dobrzyń (BRYKCZYŃSKI & SKOMPSKI 1979, ALEXANDROWICZ 1983).

In Central and Southern Poland, in the mountains, uplands and foothills, Holocene deposits containing specimens of *B. tentaculata* (L.) were described from many localities. Especially noteworthy are profiles of lacustrine carbonate deposits from the region of Roztoki near Jasło (ALEXANDROWICZ 1987b, WÓJCIK 1987). Single specimens of *Bithynia* are found in the assemblage with *Lymnaea peregra* (O. F. Müll.), while very numerous shells characterize the association termed „tentaculata-fauna". The presence of *B. tentaculata* (L.) coincides with the beginning of Holocene and corresponds to the appearance of pollen of *Ulmus* and *Corylus* in the palynological zone dominated by *Pinus* and *Betula* (HARMATA 1987).

In sediments deposited in river valleys, and especially those filling oxbows, shells and opercula of *B. tentaculata* (L.) are often an important component of mollusc assemblages. They were described among others from Polesie (ALEXANDROWICZ & ŻUREK 1996, ALEXANDROWICZ & SAŃKO 1997), the Bug river valley (ALEXANDROWICZ & DOLECKI 1991), the Sancygniówka river valley near Działoszyce (ALEXANDROWICZ et al. 1984, ALEXANDROWICZ 1987c), the Wisłoka river valley near Dębica (ALEXANDROWICZ 1980b), the Vistula river valley and its tributaries in the region of Cracow (ALEXANDROWICZ & CHMIELOWIEC 1992, ALEXANDROWICZ 1997) and also from the Sudete Foothills (ALEXANDROWICZ & TEISSEYRE 1997). The assemblages are characterized by the presence of species of limited thermal tolerance, including shade-loving snails. *B. tentaculata* (L.) is absent from mollusc assemblages found in the Late Vistulian deposits, containing such characteristic taxa as *Vertigo genesii* (Gredl.) and *V. geyeri* Lindh. It should be stressed, however, that few opercula indicating the presence of this species were found in silts and carbonate deposits whose age was estimated as older than 10,000 years BP, based on various evidence. It can be supposed that, like in Pomerania and in the Czech Republic, in the area discussed single specimens could have appeared in Alleröd, while their common and abundant occurrence is associated with Postglacial Period.

Shells and opercula of *B. tentaculata* (L.) were noted from various Interglacial deposits. They occur in all profiles of Eemian Interglacial in Pomerania, Wielkopolska and Sudete Foothills (LUBICZ-NIEZABITOWSKI 1929, BRODNIEWICZ 1969, MAKOWSKA 1979, SKOMPSKI 1980, 1983, 1991, CISZEWSKA 1988, 1996, MAMAKOWA 1989, ALEXANDROWICZ 1994); they were also noted from the upland Wyżyna Łódzka and from the vicinity of Warsaw (POLAŃSKI 1927, GOŁĄB & URBAŃSKI 1938, URBAŃSKI 1954, 1957b, SKOMPSKI & SŁOWAŃSKI 1961, MAKOWSKA 1971, KLAJNERT & PIECHOCKI 1972, ALEXANDROWICZ 1988b). In the lower part of the profile of carbonate deposits in Kochanów near Łódź a mollusc assemblage with *Gyraulus laevis* (Alder) and *Pisidium obtusale lapponicum* Cles. was distinguished, and above it – an assemblage with *Gyraulus albus* (O. F. Müll.) and *B. tentaculata* (L.). The sequence corresponds to the sequence of faunae observed in profiles of Late Vistulian and Lower Holocene deposits (ALEXANDROWICZ 1997). *B. tentaculata* (L.) is present also in deposits of Eemian Interglacial in other countries of Europe. It was recorded among others from several sites of travertines and calcareous tufas in Thuringia where it is a component of faunae typical for temperate climate and the zone of mixed deciduous forests (ZEISSLER 1975, 1977, MANIA 1978).

Especially noteworthy is the presence of opercula of *B. tentaculata* (L.) in Podgłębokie in the region of Lublin (SE Poland), in an assemblage including among others *Valvata piscinalis* (O. F. Müll.) and *Planorbis planorbis* (L.) (MAKOWSKA 1969). The fauna occurs in deposits that, based on palynological analysis, are included in Brörup Interstadial, and especially its phases with *Pinus-Picea* association, characterized by the presence of pollen of deciduous trees – *Quercus*, *Ulmus* and *Corylus* (JANCZYK-KOPIKOWA 1969).

The species was also found in deposits of older interglacials. Its presence was noted by the author in lacustrine chalk in Losy near Lubawa, in a profile typical of Lubawa Interglacial (KRUPIŃSKI & MARKS 1986), in gyttja assigned to Mazovian Interglacial (SKOMPSKI 1980, 1991) and in lacustrine deposits of Ferdynandów Interglacial in Bełchatów (ALEXANDROWICZ 1991a). Analogous data were reported from Germany, Czech Republic, Slovakia and Belorussia (LOŽEK 1964, MOTUZ 1975).

It follows from this review that *B. tentaculata* (L.), because of its limited climatic tolerance, can be regarded as an element characteristic of Holocene and Interglacial Periods, though it is sporadically noted in a warm interphase of Late Vistulian (Alleröd) and an Early Vistulian Interstadial (Brörup). It is thus a climatic-stratigraphic indicator especially useful in the estimate of age of deposits from early phases of warm periods.

BIOMETRICAL CHARACTERS

Shells and opercula of *B. tentaculata* (L.) display a considerable variation, with respect to both their size and shape. The variation reflects mainly the effect of ecological and climatic conditions, and thus can serve as an indirect and supplementary indicator of the deposition environment of sediments in which they are contained. Application of this indicator requires systematic biometrical studies on the species, based on samples of both recent and subfossil faunae. The existing data indicate that such studies are purposeful. This is illustrated among others by the information given by LOŽEK (1964), that in calcitrophic water bodies there occur numerous but small specimens of *B. tentaculata* (L.), like those found in Holocene lacustrine chalk. A biometrical analysis of rich and properly selected material may also contribute to the explanation of morphological diversity of shells of *B. tentaculata* (L.) which was the base for distinguishing its forms, varieties or subspecies.

Preliminary studies on subfossil materials from western Poland indicate that the population from Late Holocene silts near Świnoujście is characterized by the following shell height: modal value m_d = 9–10 mm, arithmetic mean X = 8.73±0.20 mm, standard deviation SD = 1.83 mm, while in the population from Holocene lacustrine chalk of the deposit Szumiąca near Zielona Góra the respective values are: m_d = 8–9 mm, X = 7.52±0.21 mm, SD = 1.51 mm (Fig. 2). The difference is statistically significant at the level of 0.001 which means that it can be a base for interpretation. A similar diversity involves opercula, and their mean size in the materials from Świnoujście and Szumiąca is 4.29 and 3.82 mm, respectively. Even smaller opercula of *Bithynia* occur in Holocene lacustrine sands from Kiełkowo near Zielona Góra and in Early Holocene lacustrine chalk from Orle near Wejcherowo (3.16 and 2.98 mm, respectively). The results of measurements indicate that the examined populations are within the lower range of shell size reported by many authors who described the species. The character, however, is only of limited value because of the scarcity of analysed data.

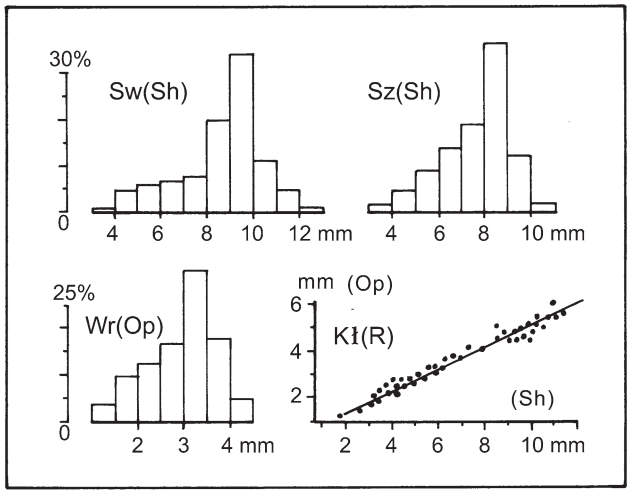

Fig. 2. Size of shells and opercula of selected subfossil populations of *B. tentaculata* (L.). (Sh) – shells, (Op) – opecula, R – relation between shell and operculum size, Sw – Świnoujście, Sz – Szumiąca near Zielona Góra, Wr – Orle near Wejcherowo, Kł – Kiełkowo near Zielona Góra

The dependence between the shell height (Sh) and operculum size (Op) analysed in the material from Kiełkowo is nearly functional, with the linear correlation coefficient r = 0.98, which for the number of specimens n = 72 is statistically significant at the level 0.001 (99.9% probability). The dependence is described by the regression equation Op = 0.40 + 0.46 Sh (Fig. 2). It makes it possible to compare sets characterized by statistical analysis of results of shell and opercula measurements, and especially to determine characters of shell populations based on measurements of opercula which in Holocene and Interglacial deposits are usually much better represented. Systematic application of results of biometrical studies on subfossil populations of *B. tentaculata* (L.) to interpretation of ecological conditions of deposition environment should be preceded by a detailed analysis of correlation and regression of specially selected sets, representing deposits of various origin.

CONDITIONS OF DEPOSITION OF SHELL MATERIAL

In Holocene and Interglacial deposits shells and opercula of *B. tentaculata* (L.) occur jointly or separately. In many profiles of lacustrine carbonate deposits abundant accumulations of opercula (Bithynia-operculum) were observed, at an absence or only sporadic presence of shells. In other profiles, among others in sediments deposited in fluviatile environments, shells are fairly numerous or numerous and may outnumber opercula. An interpretation of this difference requires a reference to actualistic data and to observations on accumulation of shell material in recent water bodies, described among others by STEENBERG (1917) and WASMUND (1926, 1929). They indicate that after death of the animal its shell may for a long time float close to the water surface, whereas the

operculum soon falls of, sinks and becomes a part of the deposit.

Specimens transported by water currents are deposited as a whole and thus in bays of slowly flowing rivers the proportion of deposited shells and opercula is roughly equal. Often shells are more numerous than opercula, since they are much easier transported by flowing water. A similar composition of thanatocenoses characterizes deposits of all kinds of water bodies located on flood plains and influenced by episodic floods (PIECHOCKI 1969, ALEXANDROWICZ 1987a).

In the littoral of lakes, with abundant rooted vegetation, in rush and reed beds, shells stay on the surface for a long time, slowly transported towards the shore by wind and waves. At the same time, detached opercula accumulate on the bottom as the only sign of the presence of snails. In such a situation both parts are sorted and secondarily accumulated on the bottom (opercula) and shore (shells). In small water bodies with sparse vegetation such a separation takes place only to a limited extent, since specimens are rather quickly transported. Shore thanatocenoses often contain shells closed with opercula, or both components in various proportions, like thanatocenoses accumulated on the bottom, but characterized by more numerous opercula (ALEXANDROWICZ 1987a).

It follows from these data that determination of the proportion of shells and opercula of *B. tentaculata* (L.) in Quaternary deposits may be of importance for the estimate of deposition environment and conditions of accumulation. This way of interpretation was applied in the analysis of several profiles of Eemian and Holocene deposits, among others in Kochanów near Łódź, Kiełkowo near Wolsztyn and a lacustrine chalk deposit in Sołdany in the Mazurian Lakeland (ALEXANDROWICZ & ŻUREK 1991, ALEXANDROWICZ 1997, CZEPIEC 1997). Data on the archaeological site on the fossil lake in Dąbki near Łeba are especially interesting: the differences in the proportion of shells and opercula made it possible to determine the ranges of reed beds and their location in relation to the prehistorical settlement (ALEXANDROWICZ 1991b).

Systematic application of these relationships in the analysis of subfossil mollusc assemblages is rendered considerably easier due to an adequate index which may well be compared with various quantitative parameters of particular associations (number of taxa, number of specimens, diversity indices) and may be used in graphs illustrating malacological succession (ALEXANDROWICZ 1987a). The index, termed Bithynia-index, BIN, is an adapted form of differentiating formula: **BIN = (O - S)/(O + S)**, where O – number of opercula, S – number of shells. It is a normalised index which assumes value of +1 when only opercula are present in the association, -1 when there are only shells, and 0 when the proportion of both components is equal. All the intermediate values characterize the discussed proportion well and unequivocally.

CONCLUDING REMARKS

An aquatic snail *B. tentaculata* (L.) is an important and commonly found component of subfossil mollusc assemblages, described from Quaternary deposits. The limited range of its thermal tolerance justifies the statement that it bears traits of a climatic-stratigraphic indicator, characteristic of Interglacial and Postglacial Periods. The presence of numerous specimens of the snail in profiles is especially useful for defining the lower limit of Holocene, though single opercula of *B. tentaculata* (L.) are sporadically found as early as Alleröd deposits. The variation of biometrical characters of shells and opercula of *B. tentaculata* (L.) may be used for estimation of ecological conditions, and the proportion of shells and opercula, expressed by the specially defined index BIN, characterizes sedimentary environment.

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