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Pleistocene molluscs from research boreholes in the Heidelberg Basin

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Abstract: Cores cut in the research boreholes at Viernheim and Parkinsel P34 and P35 in Ludwigshafen were analysed to investigate their fossil content, and particularly the remains of molluscs. The selected material was suitable for reconstructing the palaeoclimatic conditions and simplifies the chronostratigraphic classification of individual beds. Two mollusc species and one rodent species from the Lower Pleistocene (Lower Biharium) were identified in the northern Upper Rhine Graben for the first time (in the Viernheim borehole). The fossils from the Lower Pleistocene sections of the Viernheim borehole are clearly related to the Uhlenberg fauna from Bavarian Swabia dated as Upper Villanium/Tegelen.

[Pleistozäne Mollusken aus Forschungsbohrungen im Heidelberger Becken]

Kurzfassung: Bohrkerne der Forschungsbohrungen Viernheim und Parkinsel P34 und P35 aus Ludwigshafen wurden auf ihren fossilen Inhalt, besonders auf Molluskenreste, untersucht. Das ausgelesene Material ist geeignet die paläoklimatischen Verhältnisse zu rekonstruieren und erleichtert die chronostratigraphische Einstufung einzelner Schichten. Zwei Molluskenarten und eine Nagetierart wurden erstmalig aus dem Altpleistozän (Altbiharium) der Bohrung Viernheim für den nördlichen Oberrheingraben nachgewiesen. Die aus den altpleistozänen Abschnitten der Bohrung Viernheim vorliegenden Fossilien weisen deutliche Beziehungen zu der in das Obere Villanium/Tegelen datierten Uhlenberg-Fauna aus Bayerisch-Schwaben auf.

Keywords: Upper Rhine Graben, Quaternary, Pleistocene, Arvicolidae, Mollusca, Stylommatophora, Pupilloidea, Gastrocoptinae

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1 Introduction

The mollusc fauna in the Upper Rhine Graben is very important for palaeoclimatology because most of the mollusc species are still present today in the flood plains of large valleys, and their habitats and lifestyles are known. They provide information on hydrological and climatic change, and landscape history, and can therefore provide "valuable pieces in the dating puzzle" (Engesser & Münzing 1991). Most endemic mollusc species already colonised our landscapes in the Upper Pliocene. In addition, the northern Upper Rhine Graben in the Pleistocene lay in an optimum development zone according to the description by Ložek (1969) of the climatically favourable zones of the Czech Republic and Southwest Germany. During the interglacials, the climate here meant that the mollusc fauna was much more habitat sensitive than that of northern Central Europe. During the periods of glaciation, the glacial ice did not extend into the Upper Rhine Graben area, which meant that the area had favourable conditions for the survival of animals, as well as molluscs. Loess steppes exist in the Upper Rhine area during the high glacial periods.

2 Research boreholes in the Heidelberg basin

2.1 Fossil material and depositional conditions

The thanatocoenosis of molluscs from a core only reflects a small piece of the overall landscape complex. It is therefore also important to look at the sediments in more detail. Fossils are often found in the argillaceous layers of the "Zwischenhorizonte" (intermediate horizons) as well as in the fine and medium-grained sands of the "Kieslager" (gravel beds). The grey sand horizons of the "Rhenish Facies" (Hoselmann 2008) in the Lower Quaternary may contain open steppe fauna of the glacials and interglacials. The coarser the sediment, the poorer the preservation of the mollusc shells. The coarser gravels also contain few species because they are formed during glacial conditions. An exception are the loess horizons which are, however, usually only found at the boundary to slope deposits. Loess horizons contain mollusc fauna which although species poor, contain characteristic high glacial species. These horizons are not found in the cores from the fluviatile Rhine Graben. However, molluscs do occur in some sandy beds, which indicate high glacial conditions. The work of Bartz (1959) is recommended for a short, though usually still valid subdivision of the Pleistocene in the northern Upper Rhine Graben, and for the description of the most important associated fossil localities – although the middle sandy sequence described in this paper is today classified as Middle Pleistocene (Engesser & Münzing 1991).

2.1.1 Condition of preservation of fossil molluscs

Complete gastropods and molluscs are only rarely preserved. This is possible in some of the clay lenses of the intermediate horizons as well as in a few hard "Terra Rossa beds" from Cromerian horizons. This also applies to small specimens in sand, finer gravel beds and flood sediments. In other cases, identification of species is based on the characteristic properties of the aperture armatures and the surface structures. The shells are sometimes corroded, polished or seriously fragmented by transport and the influence of water. We now know that the thickness of the shells does not provide any information on the climatic conditions: thick-shelled gastropods were also present during interglacials and are therefore not necessarily an indicator of a colder climate (Geissert 1967a).

2.1.2 The Oberer Zwischenhorizont (OZH)

The Oberer Zwischenhorizont (Upper Intermediate Horizon) is undoubtedly the most interesting level in all of the investigated boreholes because of the numerous mollusc remains and also because it contains sensitive interglacial species whose presence can be correlated with palynological analysis. Exceptions are the ar-

gillaceous peat beds from the low peat bogs of the Upper Pleistocene which mostly originated in periglacial periods. They are present in thin beds, e.g. in boreholes from around Darmstadt and Riedstadt (SCHWEISS 1988). At the west edge of the Rhine Graben, the minor thickness of the Obere Kieslager (Upper Gravel Horizon) of the OZH means that the OZH is already encountered at a depth of around 30 m. In addition, this OZH originated in the Middle Pleistocene as deduced from pollen analysis (KNIPPING 2004) and from the molluscs. The further to the east one looks at the Quaternary sequences, the thicker and more detailed they become. The Viernheim research borehole therefore includes several argillaceous intermediate horizons. The Lower Pleistocene in Viernheim is reached in the third, lower horizon. The Oberer Zwischenhorizont is characterised by beds of sandy, silty and argillaceous sediments. The thickness and nature of the OZH can fluctuate widely (ENGESSER & MÜNZING 1991).

2.1.3 The Pliocene clays

Because of the absence of molluscs, the Pliocene samples provided no results in the Ludwigshafen boreholes or in the Viernheim borehole. Only a few rare shell remains were found which could not be identified because of the frequent strong corrosion of the fragments. Plant residues were however frequently found. Only very rare molluscs have been found previously in boreholes within Pliocene sediments of the southern Rhine Graben. (GEISSERT 1964, 1967b, 1980; NORDSIECK 1974; SCHLICKUM & GEISSERT 1980; WEDEL unpublished).

2.2 The Ludwigshafen boreholes (Rheinland-Pfalz)

The filling of the Rhine Graben with Quaternary sediments increases considerably to the east towards the edge of the Odenwald, so that the

Fig. 1: *Perforatella bidentata* (GMELIN, 1788), Gernsheim C00-BK1 at 88.4 m.

Abb. 1: *Perforatella bidentata* (GMELIN, 1788), Gernsheim C00-BK1 bei 88,4 m.

Fig. 2: *Gastrocopta moravica oligodonta* (KROLOPP, 1979), Viernheim research borehole, 132.6-132.7 m.

Abb. 2: *Gastrocopta moravica oligodonta* (KROLOPP, 1979), Forschungsbohrung Viernheim, 132,6-132,7 m.

thickest Quaternary deposits are encountered around Heidelberg. The thickness is much thinner at the western margin of the Rhine Graben so that in borehole P35, the Tertiary boundary is already found at a depth of 183 m. The Quaternary is divided up into sequences of terraces built up by gravel horizons and intermediate horizons. Similar to palynological investigations, sampling concentrates on the dark, argillaceous intermediate horizons representing interglacial deposits.

2.2.1 Borehole P34

Borehole P34 (Ludwigshafen-Parkinsel, Tab. 1) has much less investigatable material than the other boreholes. The only malacological sample with any usable material comes from the first sample taken from the OZH at 21 m depth. The dark beds contain numerous mollusc remains. The high proportion of *Valvata cristata* (O. F. Müller, 1774) and *Gyraulus crista* (Linnaeus, 1758) indicate swampy stagnant water conditions on the flood plains. 98 per cent of the species found are water molluscs. Of the few terrestrial gastropods found, they are all of hydrophilic species with the exception of *Clausilia* fragments transported in by water, and *Aegopinella* sp.. The thanatocoenosis is very similar to that of early Holocene flood plains in which flood plain clay is formed and Tschernozems and para brown earths can develop to maturity (Ložek 1964). The terrestrial molluscs found in the samples are of climate-independent species and therefore often not very useful for determining the temperature fluctuations. *Vertigo substriata* (Jeffreys, 1833) and *Oxyloma elegans* (Risso, 1826) are typical swamp and peat bog species and not necessarily restricted to calcareous soils, although the charophytes present (calcalgae) indicate such an environment. Pollen analysis of the pollen from the Oberer

Fig. 3: *Gastrocopta n. sp.* from the Viernheim research borehole, 174.3-174.4 m.

Abb. 3: *Gastrocopta n. sp.* aus der Forschungsbohrung Viernheim, 174,3-174,4 m.

Fig. 4: *Parafossarulus crassitesta* (Brömme, 1883), Ludwigshafen Maudach A36 borehole, 27.5-28.0 m OZH.

Abb. 4: *Parafossarulus crassitesta* (Brömme, 1883), Bohrung Ludwigshafen Maudach A 36 27,5-28,0 m OZH.

Zwischenhorizont in P34 analysed by KNIPPING (2004) confirmed its attribution to the Cromerian Complex (interglacial III or IV). This also matches the results reported by RÄHLE (2005) and the author for the boreholes in Mannheim and Ludwigshafen described below.

2.2.2 Borehole P35

The Quaternary is divided up into sequences of terraces built up by gravel horizons and intermediate horizons, whereby the uppermost "Oberer Zwischenhorizont" of borehole P35 begins at 19 m and does not end until 34 m. 5 samples were taken from this zone. It is followed by an 8-metre-thick "Unteres Kieslager". This is underlain by sandy sequences containing organic material (peat) at six positions. Mollusc samples were extracted from 50-50.3 m and at 88.7 m. A "Unterer Zwischenhorizont" lies between 98 and 109 m. The "Unterer sandig-schluffigen Abfolgen" (Lower sandy-silty sequences) continue on to the Pliocene boundary. A sample from 178.9 m was selected from this zone. Another sample was collected in the Pliocene clays at 236.1 m in P35. Two additional samples from the Pliocene at 276.2 and 287.5-287.9 m were investigated from borehole P35a which was drilled directly adjacent to P35.

The most concentrated mollusc remains in borehole P35 are also found in the uppermost layer in the OZH at 21.9 m, and in the "Oberer sandige Folge" (Upper Sandy Suite) at 50 m. Both horizons contain gastropod fauna primarily belonging to interglacial species. The samples differ in the spectrum of species they contain. The sample at 21.9 m primarily contains terrestrial species pointing to the presence of a flood plain forest (*Perforatella bidentata*). The fauna from the sample at 50 m is aquatic consisting of stagnant plant-rich waters (*Gyraulus crista*, *Lymnaea stagnalis*, *Bathyom-*

Fig. 5: *Borysthenia naticina* (MENKE, 1845) from the Viernheim research borehole, 164.0-164.2 m.

Abb. 5: *Borysthenia naticina* (MENKE, 1845) Forschungsbohrung Viernheim, 164,0-164,2 m.

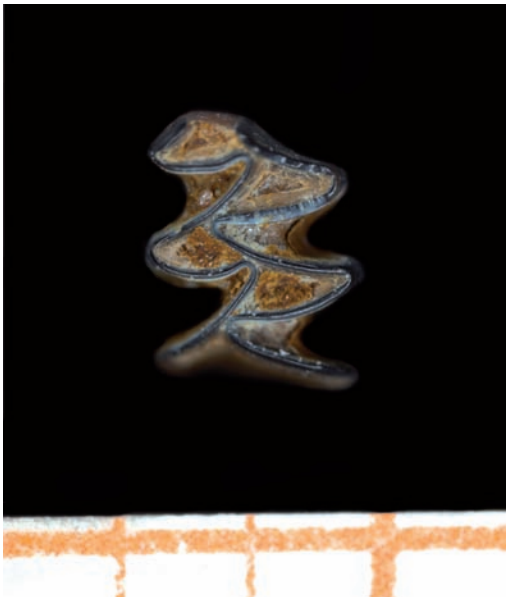

Fig. 6: Molar 2 of *Mimomys ostramosensis* (JANOSSY & VAN DER MEULEN, 1975) from the Lower Biharium in the Viernheim research borehole, 182.3-182.5 m.

Abb. 6: Molar 2 von *Mimomys ostramosensis* (JANOSSY & VAN DER MEULEN, 1975) aus dem unteren Biharium der Forschungsbohrung Viernheim, 182,3 -182,5 m

phalus contortus and *Planorbarius corneus*) to slow flowing waters. Unfortunately, the material at 50 m has been compacted within a silty-sandy sediment which has become broken up as a result of elutriation. Some juvenile examples are still preserved. The composition of the thanatocoenosis at 50 m indicates the Mosbacher Sande 2 (Geissert 1970) by way of *Borysthenia naticina* (Menke, 1845) (Fig. 5), because these sands also contain this species.

The terrestrial molluscs from the sample at 21.9 m are mostly hydrophilic (e.g. *Vertigo substriata, Vallonia enniensis, Carychium minimum* as well as *Carychium tridentatum*). The sample from the OZH at approx. 21 m in borehole P34 also contains a rich mollusc fauna, although dominated in this case by freshwater species. Terrestrial snails typical of warmer conditions, as still found today under leaf mould in shady flood plain forests, are the waxy glass snails, e.g. *Aegopinella nitens* (Michaud, 1831).

The two completely preserved valves of the pea clam *Pisidium amnicum* (O. F. Müller, 1774) from 27.8 – 28.0 m are very interesting. This species occurs again at 178 m although it is primarily associated in the sample with species which tended to live in glacial, open landscapes. However, this mollusc is generally more frequent in interglacial deposits.

The molluscs in both boreholes indicate interglacial conditions. There is still some doubt, however, whether we are dealing here with the Cromerian or the Holsteinian interglacial because important type fossils are absent. The situation in the other boreholes described below is different because the molluscs in these boreholes can be confidently assigned to the Cromerian Complex.

2.3 Boreholes in Mannheim-Lindenhof (Baden-Württemberg) and Ludwigshafen – A36 Maudach (Rheinland-Pfalz)

The boreholes drilled in Mannheim-Lindenhof (Rähle 2005) and Ludwigshafen – A 36 Maudach (Wedel unpublished), are particularly interesting. They were drilled in the vicinity of the two boreholes described above and were sunk in advance of the research boreholes and investigated by LGB Rheinland-Pfalz. The boreholes contain notable fossil gastropod species from the Oberer Zwischenhorizont (Tab. 3). The first of these is *Clausilia rugosa antiquitatis* (Nordsieck, 1990). This form has been identified in the younger Tegelen up to the older Middle Pleistocene. It is replaced in the Middle Pleistocene by *Clausilia rugosa parvula* (Férrusac, 1807). The second interesting gastropod is *Parafossarulus crassitesta* (Brömme, 1885) (Fig. 4).

Two particularly well preserved examples with numerous characteristic opercula of this species were found in the Maudach borehole between 27 and 28 m depth. The genus *Parafossarulus* is no longer present in Europe (Gloer 2002). In addition, the boreholes in Mannheim and Ludwigshafen-Maudach also contained remains of *Azeca goodalli* (A. Férussac, 1821).

According to Rähle (2005), this "*crassitesta*-horizon" is not younger than Cromerian interglacial IV and not older than Cromarian interglacial III. This investigation looked at the Oberer Zwischenhorizont in eight different boreholes in Mannheim-Lindenhof, and specifically at the depth zone between 29 and 33 m. Analogous to Mannheim-Lindenhof, the Maudach borehole also contained tooth remains of early forms of the water vole *Arvicola terrestris* (Linne, 1758). The genus *Arvicola* appears in Central Europe at the earliest in Cromerian interglacial III (OIS 15) according to Koenigswald & van Kolfschoten (1996). The fauna encountered in Mannheim-Lindenhof is therefore of a very similar age to Mosbach 2 (Middle Mosbach) and Mauer, where *Arvicola* is also found (Rähle 2005). The results from other investigations of the OZH are also reported by Engesser & Münzing (1991) from boreholes that are also from the Mannheim area.

2.4 Viernheim research borehole (Hessen)

The conclusions drawn from the Viernheim borehole are that the three intermediate horizons encountered in the well reflect differentiated climatic conditions. Unlike the Ludwigs-

hafen boreholes, the Oberer Zwischenhorizont (Section Xa according to HOSELMANN 2008) is marked by climatically cooler species (Tab. 4). The second intermediate horizon from 89 m contains species preferring warmer conditions. This may possibly be the same horizon as in the Ludwigshafen-Mannheim area ("*crassitesta*" – horizon), although the type species is missing. The 5 m-thick third intermediate horizon between 164.73 and 169.9 m (Section Vb according to HOSELMANN 2008) and the underlying sandy-gravely beds, are assigned a Lower Pleistocene age. The Lower Pleistocene (Tegelen) is confirmed at 132 m be the gastropod *Gastrocopta moravica oligodonta* (KROLOPP, 1979) (Fig. 2), and at 174 m by the previously unknown *Gastrocopta n. sp*. (Fig. 3), and at 182,5 by the mollusc *Corbicula cf fluminalis* (O. F. MÜLLER, 1774) and the Arvicolidae *Mimomys ostramosensis* (JANOSSY & VAN DER MEULEN, 1975) (Fig. 8). The transition to the Pliocene contains plant remains but no molluscs, as in all of the samples looked at. The drill site was selected to penetrate the most undisturbed possible sequence of Pleistocene sediments (HOSELMANN 2008).

2.4.1 Upper Middle Pleistocene

The upper part of the borehole between 39.79 and 58.55 m depth, contains an almost 20 m thick bed of the Oberer Zwischenhorizont. Typical forest-type molluscs are not present. The molluscs are mainly climate-insensitive species of wet flood plain habitats of which *Vitrea crystallina* (O. F. MÜLLER, 1774) is the most common. This indicates that the climate was rather cool (LOŽEK 1964). The picture is dominated by species common to periglacial, open landscapes and sparse forest steppes. *Trochulus hispidus* (LINNAEUS, 1758) ("*Trichia hispida*" in older references) as well as amber snail species *Succinella oblonga* (DRAPARNAUD, 1801) and *Succinea putris* (LINNAEUS, 1758) are frequent. This thick intermediate horizon is obviously not the same as that in Ludwigshafen.

These may be the pre-Eemian or Early Holsteinian interbeds described by SCHWEISS (1988) from the Gernsheim and Groß-Rohrheim area. The chronostratigraphic interpretation is based on pollen analysis which indicates the pre-sence of shallow peat bogs and sparse birch and spruce growth.

The "*crassitesta*- intermediate horizon" must therefore lie much deeper because of the much thicker deposition in the eastern part of the Upper Rhine Graben. ENGESSER & MÜNZING (1991) also subdivide the OZH into three horizons with different climatic conditions. Investigations in the Karlsruhe and Mannheim areas led to a subdivision into a lower zone of interglacial Cromerian Complex sediments, followed by a middle and upper zone both marked by glacial environments, of which the upper is classified as Rissian.

2.4.2 Lower Middle Pleistocene

The species diversity in the Kieslager increases beneath the Oberer Zwischenhorizont. A mixed fauna is present at 70 m consisting of a *Fruticicola fruticum* fauna, indicating a forest steppe environment, as well as a *Succinella oblonga* fauna with a high proportion of *Pupilla muscorum* (LINNAEUS, 1758), which indicates cooler steppe conditions. In addition, there is also the pea clam (*Pisidium casertanum ponderosum* STELFOX, 1918) which is adapted to cold and extreme environmental conditions.

The *fruticum* fauna which had its optimum at 89 m because it is joined by climatically more sensitive species such as *Pomatias elegans* (O. F. MÜLLER, 1774), *Ena montana* (DRAPARNAUD, 1801), *Discus perspectives* (MEGERLE VON MÜHLFELD, 1816), *Vertigo pygmaea* (DRAPARNAUD, 1801) and *Monachoides incarnatus* (O. F. MÜLLER, 1774). These species here indicate a much warmer period. This is the "*crassitesta* intermediate horizon" in the Maudach and Lindenhof boreholes. Seven metres deeper at 97 m, cooler steppe conditions dominate again and the molluscs are largely dominated by *Pupilla muscorum*, *Succinella oblonga elongata* SANDBERGER and *Trochulus hispidus* (cf. Chap. 2.3). There are also frequent *Clausilia* remains. Particularly interesting are five well preserved

apertures of *Neostyriaca corynodes.* This is the subspecies *ornatula* (Andreae 1884), which has been identified in the Lower Pleistocene to the Lower Middle Pleistocene in Central Europe (Nordsieck 2007). It is characteristic of the "Upper Biharium" (Late Biharium, cf. Koenigswald 2007) in Cromer. Associated species are *Clausilia cruciata* (Studer, 1820) and *Clausilia dubia* (Draparnaud, 1805). This species seems to be indifferent to the climate, analogous to its associated species (Nordsieck 2006).

2.4.3 The Lower Pleistocene

The Kieslager is underlain between 131.23 and 133.18 m (Section VIIb after Hoselmann 2008) by another thin intermediate horizon with calcareous loam sand. A small snail belonging to the genus *Gastrocopta,* now extinct in Central Europe, clearly indicates a Lower Pleistocene assemblage from 132.5 m. The specimen is a well preserved shell of *Gastrocopta moravica oligodonta* (Krolopp 1979) (Fig. 2). Whilst the sediment one metre higher contains a mixed fauna indicative of a cooler "*Chondrula tridens* –steppe fauna" and a cold-moist flood plain forest fauna with a high proportion of *Perforatella bidentata* (Fig. 1) typical of open, glacial conditions, this intermediate horizon contains more thermophilic species representative of a flood plain forest. Some of the freshwater molluscs and a large number of amber snails indicate the existence of stagnant to slowly flowing waters with highly vegetated banks.

A strong increase in steppe elements, particularly *Granaria frumentum* (Draparnaud, 1801), is found in an approximately 5 m thick intermediate horizon between 164.7 and 169.9 m (Section IVb after Hoselmann 2008). This is the zone in which the bi-toothed snail *Perforatella bidentata* (Gmelin, 1791) which lives in flood plains reaches its greatest concentration in the Viernheim research boreholes. Two fragments may come from the larger, related species *Perforatella dibothrion* (M. v. Kimakowicz, 1884). There are also remains of *Clausilia rugosa antiquitatis* (Nordsieck, 1990) and the forest species *Azeca goodalli* (A. Férussac, 1821). Kieslager with sandy horizons and silty clays form alternating interbeds below the intermediate horizon and are part of an alternating sequence of interglacial and glacial sediments found in the section down to 182 m. This is indicated by the different mollusc fauna which suggest a landscape consisting of sparsely wooded forests and open steppe (*fruticum* and *tridens* fauna).

More evidence for the Lower Pleistocene is found at 174 m in the form of a previously unknown species of the genus *Gastrocopta* (Wollaston, 1878). The special feature of the shell is the absent basal tooth in the aperture armature. This *Gastrocopta* may be linked to that described from the Lower Pleistocene by Kielniki (Poland). This is found in a fauna with *G. serotina* (Ložek, 1964) and is related by Stworzewicz (1981) to *Gastrocopta theeli* (Westerlund, 1877). However, the basal tooth found in *Gastrocopta theeli* is absent in the figure on Table 1 (Fig. 3). The first classification as *Gastrocopta turgida quadriplicata* Sandberger was not confirmed.

An approx. 2.60 m thick gravel-bearing fluviatile sand horizon starts at 182.5 m and is followed by an approx. 2 m thick intermediate horizon (Section IVb after Hoselmann 2008). The shell remains of molluscs in the gravel-bearing horizon are strongly corroded or polished which indicates strong transport of the sand and gravel. Half of the aquatic species found consist of small molluscs such as *Sphaerium corneum* (Linnaeus, 1758), *Musculium lacustre* (O. F. Müller, 1774) and *Corbicula fluminalis* (O. F. Müller, 1774).

The sample contained two shell remains of *C. fluminalis* with the characteristic hinge. *C. fluminalis* is only known in Germany from the Holsteinian and the Tegelen. This species appears in Europe in the Late Pliocene and has its widest distribution during the Tegelen (Meijer & Preece 2000).

Another important stratigraphic discovery is the well preserved molar (M2) of a water vole (Arvicolidae), found in the sample from a depth of 182.4 m. Dr. Lutz Christian Maul (Senckenberg Institute, Weimar) identified the

specimen as a molar from *Mimomys ostramosensis* (JANOSSY & VAN DER MEULEN, 1975) (Fig. 9). Although not unusual, it is fairly rare to find identifiable remains of small rodent fossils in material collected from boreholes (WEDEL 1999). The distribution of Arvicolidae species is now very well known in Europe and tied to chronostratigraphic tables. Analogous to *Corbicula fluminalis,* this water vole lived in the "Lower Biharium" (*Mimomys pusillus – Mimomys savini*- zone, KOENIGSWALD 2007), and the "Villanyium" approx. 1.6 to 2.0 million years ago. This species has previously only been found at a few locations in Europe (MAUL 2002). This is only the second identification of this species in the Upper Rhine area in addition to Neuleinigen near Grünstadt (MALEC & TOBIEN 1976). HEIDTKE (1979) dated the Neuleinigen fauna, also on the basis of large mammal fossils, as Lower Pleistocene with a dry-warm to subtropical climate. The fossils were found in the material filling a fissure (Neuleinigen 11) in a limestone quarry. HEIDTKE climatically compared Neuleinigen with the fauna from Hohensülzen (STORCH et al. 1973) reporting that the older Hohensülzen fauna represented the moist-warm river valleys, and Neuleinigen the topographically higher dry steppe.

The smaller two-metre-thick intermediate horizon in the Viernheim research borehole is underlain by an approx. 3.80 m thick, carbonate-rich, gravely sand bed which gradually grades into the sandy-silty series of the Lowest Quaternary. This sequence of interbedded rocks extends down to 224 m where they are underlain by limnic-fluviatile Pliocene sediments (HOSELMANN 2008). This sandy-silty suite again documents fluctuating climatic conditions where the climate optimum at 196.5 m is indicated by fewer forest-living molluscs (*Fruticicola fruticum, Vitrinobrachium breve, Discus rotundatus*). Forest species are absent at 194 m. Open landscape species such as *Pupilla muscorum* are dominant. These molluscs may indicate the earliest glacial period of the Pre-Tegelen in the Lower Quaternary. There is now a significant general decline downwards in the number of species and individuals. The last mollusc remains are found at 223 m comprising only three freshwater species and one terrestrial species. In contrast, the samples now contain large quantities of plant remains.

3 Comments on biostratigraphically important species

Perforatella bidentata (GMELIN, 1791) and *Perforatella dibothrion* (*M. v. KIMAKOWICZ, 1884*)

P. bidentata (fig. 1) is often found in the Pleistocene sands and fine-clastic intermediate horizons of the Upper Rhine Graben. It is particularly common in the Lower Pleistocene deposits in the Viernheim research borehole. Occurrence are known into the Late Eemian (MÜNZING 1999). The species can be easily identified on the basis of the two teeth (basal and palatal) in the lower aperture area. This is a pure flood plain snail (alder marsh) which requires a wet habitat. It is found in both interglacial as well as glacial contexts. It still lives in eastern Central Europe (Thuringia, Bavaria, Saxony, Austria, Czech Republic, Slovakia, Poland and Hungary) and at scattered localities in south-eastern Scandinavia. The species was found far to the west in the Pleistocene. This is confirmed by specimens collected near Paris by GEISSERT (pers. comm.)

The related species *Perforatella dibothrion* is a type fossil for the interglacial habitats of the Rhine valley in the Lower Pleistocene and Lower Middle Pleistocene. GEISSERT (1970) found a complete example in the Mosbacher Sande 2 and reports several discoveries in gravel pits in the Upper Rhine (GEISSERT 1969). Two fragments were found in the sample from 167.35 – 167.45 m in the Viernheim borehole, which may belong to this species. RÄHLE (2005) also mentions *Perforatella* remains which he assigns to this species, from the Oberer Zwischenhorizont in borehole P18 Mannheim-Lindenhof. The main differences to *P. bidentata* are a much higher aperture and two stronger teeth, although the space between the two teeth is narrower than in *P. bidentata*. The shell has clear ribs, and the first whorls have a surface structure with small

scales. This species is only found alive today in eastern Slovakia and in the Carpathians where it lives in the sub-mountainous zone in moderately wet deciduous forests (Kerney et al. 1979). Its distribution in the Late Pleistocene in Europe was continental-Atlantic, i.e. much broader than today.

Gastrocopta (Vertigopsis) moravica oligodonta (*Krolopp 1979*) (Fig. 2)

This is the first confirmation of this species in the Upper Rhine Graben, and comes from the Viernheim research borehole. The shell is less conical than the nominate form *G. moravica* (Petrbok, 1959). The intraparietal tooth of the aperture is reduced to a thickening at one point. Krolopp (1979) found it together with *Gastrocopta serotina* (Ložek, 1964) in Hungary near Szabádhidvég (comm. Feyér). Both these species had previously only been identified in the Lower Pleistocene (Upper Villanyum – Lower Biharium). These two species are therefore very chronostratigraphically significant as type fossils for the Late Tegelen (Krolopp 1986). The *Gastrocopta* genus is extinct in Europe. The youngest representative of the genus in the Pleistocene is the species *Gastrocopta theeli* (Westerlund, 1877).

Rähle (1995) found *G. moravica oligodonta* in argillaceous high flood deposits in Uhlenberg (Iller-Lech Plate, Bavarian Swabia). The Uhlenberg fauna contains molluscs which were also encountered in Viernheim in samples from 131 m and 182 m, and are characteristic species for the Lower Pleistocene. In addition to *G. m. oligodonta*, another interesting find was a fragment possibly belonging to *Cochlostoma salomoni* (Geyer, 1914). Geissert (1983) mentions this species from Rhine sediments at Gambsheim and La Wanzenau, which are classified as Tegelen. Further interesting species are *Clausilia rugosa antiquitatis, Azeca godalli* and *Ena montana*. All of these species are assigned to the interglacial fauna elements, whereby the two *Gastrocopta* species were already part of Pliocene faunas and are unknown beyond the Lower Pleistocene.

Chondrula tridens (O. F. Müller, 1774) and *Granaria frumentum* (Draparnaud, 1801) are possible indicators of steppe landscapes at the edge of the flood plain forests. Both species have recently become much rarer in Europe because their habitats are virtually no longer existent.

Gastrocopta (Vertigopsis) sp. (Fig. 3)

The small conical shell is 1.9 mm high and 1.0 mm wide. The five arched whorls increase uniformly in size up to the penultimate whorl – the last whorl becomes smaller towards the aperture. The apertural border with the lip is well formed and slightly folded over towards the spindle. The shell is shiny, slightly stripy and has a weakly developed palatine torus. It has three strong teeth, one columellar, one palatal and one parietal, although the adjacent palatine wall of the specimen is damaged and partially missing. The teeth are almost the same distance apart and their tips almost point towards one another. A characteristic feature is the complete absence of a basal tooth. This form has not previously been identified in the Pleistocene.

4 Conclusions

Fossil molluscs were investigated from three research boreholes drilled in the Heidelberg Basin. Special attention was given to the Oberer Zwischenhorizont (OZH) because, particularly at the western margin of the Upper Rhine Graben, it stands for the Middle Pleistocene interglacials which are assigned to the Cromerian Complex. Whilst the OZH is relatively thick at Ludwigshafen and already encountered at a depth of around 21 m, the similar or slightly thinner horizon is first encountered in Viernheim at a depth of around 39 m. A lower horizon in the Viernheim borehole lying at around 50 m depth contains a mollusc fauna probably derived from the earlier Holsteinian period. A much thicker intermediate horizon is found as the deepest horizon between 195 and 223 m at the boundary to the Tertiary. It is divided up by several small

Kieslager (gravel horizons). Evidence of Lower Pleistocene mollusc assemblages have already been found above this horizon from 132 m. The findings support the assumption proposed by ENGESSER & MÜNZING (1991), that the Oberer Zwischenhorizont covers two to three climatically different epochs, whereby the deepest horizon in the Rhine Graben can be assigned to the Lower Pleistocene on the basis of its fossils, whilst the upper horizons have Pre-Eemian or Holsteinian character.

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Table 1: Research borehole Ludwigshafen Parkinsel P34.

Tab. 1: Forschungsbohrung Ludwigshafen Parkinsel P34.

Classification	qp(a)				tpl			
Parkinsel P34	OZH	OZH	UZH	UZH	Reuver?			
Art:	20.50-21.00	36.8-37.5	147.8-148.0	160.3-160.4	176.0-176.5	207.8-208	232.2-232.4	290.7-290.8
Aegopinella sp.	1							
Clausiliidae indet.	1							
Trochulus sp.	1							
Vertigo sp.	3							
Vertigo substriata	3							
Oxyloma elegans	1							
Succinea putris	1							
Pisidium amnicum	1							
Musculium lacustre	2							
Valvata cristata	125							
Planorbis planorbis	5							
Lymnaeidae indet.	200							
Stagnicola aff. palustris	2							
Valvata macrostoma	1							
Acroloxus lacustris	2							
Gyraulus crista	30							
Hippeutis complanatus	3							
Planorbarius corneus	6							
Sphaeriidae indet.	90	2						
Galba truncatula	6							
Bithynia tentaculata (Opercula)	85					1		
Bithynia tentaculata	4							
Valvata piscinalis	6							
Viviparus sp. (Opercula)	1							
Pisidium pulchellum	10							
undetermined fragments of molluscs	2			1				1
Number:	592							
Piece of plants	x	x	x	x	x	x	x	
Charophyts	x							
Small mammals	x							

OZH = Oberer Zwischenhorizont; UZH = Unterer Zwischenhorizont; qp(a) = Older Pleistocene; tpl = Pliocene

Table 2: Research borehole of Ludwigshafen Parkinsel P35/P35a (first part).

Tab. 2: Forschungsbohrung Ludwigshafen Parkinsel P35/35a (erster Teil).

Classification:	qp								tpl		
Parkinsel P35 / P35a	OZH					OSF		USF	(P35a)		
Species:	21.90	26.33-26.37	27.2-27.24	27.8-28.0	30.26-30.3	50.0-50.3	88.70	178.00	236.10	276.20	287.5-287.9
Clausiliidae indet.	6							1	n. F.	n. F.	n. F.
Vitrinobrachium breve	1										
Aegopinella sp.				1							
Aegopinella nitens				1							
Monachoides incarnatus				1							
Arianta arbustorum	4					1					
Vitrea crystallina	1							2			
Perforatella bidentata	8			1							
Vallonia excentrica	3										
Vallonia pulchella	1										
Vertigo pygmaea	2					2					
Pupilla muscorum	2							1			
Vertigo sp.	2					3					
Trochulus sp.	2	1				4		1			
Cochlicopa lubrica Komplex	3										
Punctum pygmaeum	4										
Deroceras laeve	1										
Vertigo angustior	3										
Succinella oblonga						4		1			
Vertigo substriata	1										
Carychium tridentatum	4										
Carychium minimum	2										
Oxyloma elegans	3										
Succinea sp.	2										
Vallonia enniensis	1										
Succinea putris								1			
Unioniidae indet.								4			
Pisidium amnicum				2				5			
Borysthenia naticina						2					

Table 2: Research borehole of Ludwigshafen Parkinsel P35/P35a (second part).

Tab. 2: Forschungsbohrung Ludwigshafen Parkinsel P35/35a (zweiter Teil).

Classification:	qp								tpl		
Parkinsel P35 / P35a	OZH					OSF		USF	(P35a)		
Species:	21.90	26.33-26.37	27.2-27.24	27.8-28.0	30.26-30.3	50.0-50.3	88.70	178.00	236.10	276.20	287.5-287.9
Musculium lacustre						8					
Segmentina nitida	1										
Valvata cristata	3					8					
Planorbis planorbis	7					9		1			
Lymnaeidae indet.	4					5		4			
Anisus spirorbis	4					5					
Gyraulus albus			1					1			
Gyraulus crista	3					17					
Lymnaea stagnalis						1					
Pisidium sp.					1						
Planorbarius corneus	2					3		1			
Sphaeriidae indet.	2					4					
Galba truncatula	4					5					
Bithynia tentaculata (Opercula)	4				12	16					
Bithynia tentaculata						2					
Valvata piscinalis						1					
Bathyomphalus contortus						2					
Number:	90	1	1	6	13	102	0	23	0	0	0
Piece of plants	x	x	x	x	x		x		x	x	x
Ostracods	x					x					
Piece of fishs									x		x
Small mammals			x				x				
Piece of insects		x									

n. F. = no Fauna; OZH = Oberer Zwischenhorizont; OSF= Obere sandige Folge; USF= Untere sandig-schluffige Folge
pl = Pleistocene; tpl = Pliocene (only borehole P35a)

Table 3: Borehole Ludwigshafen-Maudach A-36.

Tab. 3: Bohrung Ludwigshafen-Maudach A-36.

Classification:	Middle-Pleistocene			
Lu-Maudach A 36	OZH			
Art:	23.10 - 23.40	26.40- 26.80	27.50- 28.00	**number:**
Clausiliidae indet.	7	1	7	15
Clausilia bidentata	2	1	2	5
Discus ratus rude			1	1
Vitrinobrachium breve			5	5
Aegopinella la nitidu			1	1
Ena na monta			3	3
Helicodonta obvoluta		2	2	4
Macrogastra lineolata		2	1	3
Monachoides incarnatus		1	1	2
Azeca lli gooda			2	2
Arianta arbustorum	2	1		3
Vitrea crystallina	3	3	4	10
Discus rotundatus	1	2		3
Limax inereoniger c		1		1
Cepaea hortensis	2	1	1	4
Clausilia pumila	3	5	6	14
Perforatella bidentata	7	8	29	44
Chondrula ns tride			3	3
Pupilla terri s			1	1
Pupilla nsegyrata de		2		2
Vallonia excentrica		3	1	4
Vallonia pulchella	6	2	9	17
Vallonia declivis			1	1
Vallonia costata	5		5	10
Pupilla muscorum		3	17	20
Columella olumella c		1		1
Vallonia tenuilabris			1	1
Cochlicopa ella lubric			1	1
Trochulus sp.	2	1	1	4
Vertigo sp.	8	3		11
Clausilia rugosa antiquitatis			2	2
Cochlicopa lubrica Komplex	2	3	4	9
Euconullus fulvus	1		1	2
Nesovitrea hammonis		2	11	13
Trochulus hispidus	1		3	4
Clausilia dubia		1	3	4
Helicigona lapicida	2	1	1	4
Columella dentula e			3	3
Deroceras leave	2		1	3

Vertigo substriata	3			3
Succinella oblonga	21	26	290	337
Succinella elongata		1	3	4
Carychium um minim	1			1
Oxyloma legans e			3	3
Vallonia enniensis	1	1	3	5
Vertigo genesii	1	6	44	51
Vertigo geyeri			1	1
Pseudotrichia ginosa rubi	1			1
Zonitoides nitidus			2	2
Ancylus fluviatilis	3	2	3	8
Borysthenia naticina		3	1	4
Valvata cristata			8	8
Valvata macrostoma		1	10	11
Valvata piscinalis	9	2	21	32
Bithynia sp.	26	100		126
Parafossarulus crassitesta	6	5	20	31
Bithynia tentaculata	1	1	4	6
Bithynia leachii		3	2	5
Planorbis planorbis	5	4	9	18
Planorbarius corneus	2	1	2	5
Planorbis arinatus c	1			1
Anisus leucostoma	1	3	9	13
Bathyomphalus contortus	1		2	3
Hippeutis complanatus			3	3
Segmentina nitida			2	2
Gyraulus albus	1		4	5
Gyraulus laevis		1	1	2
Lymnaeidae indet.	2		2	4
Stagnicola agg. palustris			2	2
Radix balthica		1	12	13
Radix balthica aff. ampla			5	5
Lymnaea stagnalis			4	4
Galba truncatula	6	8	5	19
Sphaeriidae t. inde		1		1
Sphaerium orneum c	2			2
Pisidium sp.		1		1
Pisidium amnicum	4	4	30	38
Pisidium upinum s			4	4
Pisidium obtusale lapponicum			9	9
Pisidium ssierianummoite		2		2
gesamt:	154	227	654	1035
Charophyts-Oogonie	x	x	x	
Piece of fishs	x	x	x	
Small mammals	x	x	x	

OZH = Oberer Zwischenhorizont

Table 4: Research borehole of Viernheim (first part).

Tab. 4: Forschungsbohrung Viernheim (erster Teil).

Classification:	Pleistocene																												Tertiär	
Viernheim FB 1	qp (j)					qp (m)											qp (a)												tpl	
Species:	12.00-13.00	18.00-18.50	35.85-36.00	46.43-46.56	49.60-49.70	50.10-50.30	51.70-51.80	53.90-54.00	59.70-59.80	66.30-66.45	70.00-70.30	89.40-89.70	96.90-97.00	104.10-104.20	108.00-108.20	115.90-116.00	131.25-131.45	132.60-132.70	155.20-155.40	164.00-164.20	167.35-167.45	174.30-174.40	182.30-182.50	194.50-194.60	196.45-196.60	204.75-204.80	214.00-214.20	223.00-223.15	228.75-228.85	239.08-310.70
Clausiliidae indet.	3	4	3		5			1		6	9	4	**20**	**10**			1	2		7	**14**	1	7		7		3			k.F.
Clausilia cruciata													2																	
Vitrinobrachium breve					1						3														2					
Aegopinella sp.												3		1			1			2	2					1				
Ena montana												2		1				1		2										
Helicodonta obvoluta														1																
Monachoides incarnatus					1							1	1	1				2		1	1				4		1			
Perforatella dibothrion																					2									
Aegopis sp.																							1							
Azeca goodalli																				1			4							
Discus perspectivus												1																		
Arianta arbustorum		4			**9**							1		2					5	7	4			1	5	1		1		
Fruticicola fruticum			1	1	5		1	1	1	2	**12**		5	1			3			1	4									
Vitrea crystallina	1	1	1		7	3		1		2	**20**	4	1	5						1				2	1	1				
Discus rotundatus																									4					
Pomatias elegans					1							1		4																
Neostyriaca corynodes ornatula											1		5																	
Monachoides cf. vicinus																								1						
Perforatella bidentata			1		7			1		1	1	4	2	7			**16**	8		7	**20**	5	2	5	**10**					
Cepaea sp.																					2									
Chondrula tridens																	3			1										

Table 4: Research borehole of Viernheim (second part).

Tab. 4: Forschungsbohrung Viernheim (zweiter Teil).

Classification:	Pleistocene																												Tertiär	
Viernheim FB 1	qp (j)					qp (m)											qp (a)												tpl	
Species:	12.00-13.00	18.00-18.50	35.85-36.00	46.43-46.56	49.60-49.70	50.10-50.30	51.70-51.80	53.90-54.00	59.70-59.80	66.30-66.45	70.00-70.30	89.40-89.70	96.90-97.00	104.10-104.20	108.00-108.20	115,90-116,00	131.25-131.45	132.60-132.70	155.20-155.40	164.00-164.20	167.35-167.45	174.30-174.40	182.30-182.50	194.50-194.60	196.45-196.60	204,75-204,80	214.00-214.20	223.00-223.15	228.75-228.85	239.08-310.70
Granaria frumentum												1					1			**11**	**30**		2				3			
Vallonia excentrica																								2						
Vallonia pulchella			1									3	2							3										
Vallonia costata					3									1																
Pupilla muscorum	3	5	3		5			1		3	**21**	7	**29**	7			1			2	6	5		**12**						
Columella columella										1																				
Vallonia tenuilabris										1	1																			
Cochlostoma sp. (cf. salomoni)																						1								
Cochlicopa lubricella		1																												
Gastrocopta sp.																						1								
Gastrocopta moravica oligodonta																		1												
Vertigo sp.											2		3								5	1								
Trichia sp.			3	1	5		1	7	2	**12**	**13**	8	**44**	**10**	1		9	1	4	2	4	2		5	6					
Cochlicopa lubrica Komplex		2			1			1		2	1		3	1	2		1	2		4	1			1	2					
Clausilia rugosa antiquitatis																				2	1									
Nesovitrea hammonis													1																	
Triochulus hispidus	3	7			2					4	**12**		**26**					1				1								
Limacidae / Agriolimacidae Komplex		1			4			2						1											1		1			
Oxychilus sp.								2																						
Oxychilus cellarius													2																	

Clausilia rugosa parvula													1																	
Clausilia dubia	1												2																	
Helicigona lapicida					1				1								1		1	2	4		1		3		2			
Succinea sp.							3	1												1	**11**		5							
Columella edentula											5		1																	
Vallonia declivis													1																	
Succinella oblonga	4	9	4						2	**17**	**25**	2	4	6			1			2		1								
Succinella oblonga elongata													**16**																	
Carychium minimum																					1									
Oxyloma elegans											6		4									2								
Vallonia enniensis					2															1										
Succinea putris					**10**	**25**					3		2					4		1						1				
Unioniidae indet.																			1											
Lithoglyphus naticoides							1																							
Pisidium supinum																				1										
Theodoxus fluviatilis														1																
Ancylus fluviatilis														2																
Borysthenia naticina																				1										
Corbicula fluminalis																							2							
Musculium lacustre																	2									1				
Valvata cristata																					1		1					3		
Planorbis planorbis	1	1	1		1	**14**	2	1	1	1	**11**	1	3	1			2	2		3	2		1			5				
Lymnaeidae Komplex	1	1			2	5				1	5		5	2										1		7				
Stagnicola agg. palustris	1										3			2			1	1		1										
Pisidium obtusale																									8					
Pisidium casertanum ponderosum											1	1		1																
Anisus spiorbis														1									1		1					
Anisus leucostoma			1			6					2	1					1	1			1									
Aplexa hypnorum					1	3																								
Valvata macrostoma	2					9	1	2			2																			

Classification:	Pleistocene																											Tertiär	
Viernheim FB 1	qp (j)					qp (m)											qp (a)												tpl	
Species:	12.00-13.00	18.00-18.50	35.85-36.00	46.43-46.56	49.60-49.70	50.10-50.30	51.70-51.80	53.90-54.00	59.70-59.80	66.30-66.45	70.00-70.30	89.40-89.70	96.90-97.00	104.10-104.20	108.00-108.20	115.90-116.00	131.25-131.45	132.60-132.70	155.20-155.40	164.00-164.20	167.35-167.45	174.30-174.40	182.30-182.50	194.50-194.60	196.45-196.60	204.75-204.80	214,00-214,20	223.00-223.15	228.75-228.85	239.08-310.70
Anisus vorticulus												1																	
Gyraulus sp.																											2		
Gyraulus albus									1	1					1			1											
Gyraulus crista						8														1			1						
Hippeutis complanatus								1																					
Physa fontinalis						5																							
Pisidium sp.								1			1	2	2	2													2		
Planorbarius corneus											2	1		2			2	5	2	7	3								
Planorbis carinatus																						1							
Radix labiata																	1												
Sphaeriidae indet.		1	1								1			1	2					1									
Sphaerium corneum					5	4																	2						
Galba truncatula					6	**25**	9	4	2	2	**11**	1	6	**11**			**10**	4	1	1	**16**		2						
Bithynia sp.								1	9					2															
Bithynia tentaculata							7		2		6			3	1		**11**		2	4			3						
Pisidium subtruncatum		1												1															
Valvata sp.									1				3												1				
Valvata piscinalis alpestris														3															
Valvata piscinalis					2			2																					
undetermined fragments of molluscs																8													
number	20	38	20	2	86	**107**	25	30	22	56	**180**	50	**196**	94	7	8	68	37	16	81	**135**	22	35	30	55	17	10	8		
small mammals				x										x			x	x					**X***					x		
charophyts																			x	x									
Piece of plants			x	x			x	x		x		x			x				x	x			x					x	x	

X* = *Mimomys ostramosensis* n.F.*= no fauna