Excavations at the Late Miocene MN9 (10.3 Ma) Locality of Höwenegg (Hegau), Southwest-Germany, 2004-2006

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Abstract
We provide a short history of the development of the Höwenegg quarry between 1985 and 1996, the rationale for continuing the excavations in 2003, and the progress made during the 2004-2006 campaigns. In the 2004 field season we completed our excavation at the western extent of the Main Höwenegg Trench, and retrieved a disturbed *Miotragocerus* skeleton in close proximity to the other two skeletons retrieved in 2003. We also opened a 5 m thick section in a trench 50 m north of the JÖRG and TOBIEN Quarry, and established the presence of vertebrate fossils and even richer deposits of fossil plant material. The 2005 and 2006 field seasons were dedicated to establishing and opening a new quarry adjacent to, and on the immediate western border of the Main Höwenegg Trench. The establishment of this new Western Quarry required extensive support from the Town of Immendingen for cutting down trees, removing a 1 m thick soil horizon with a thick mat of roots, and undertaking trenching and bulldozing of disturbed sediments. The Western Quarry, approximately 100 m² in area, was extensively excavated by stratigraphic horizon, and initial correlations to the JÖRG and TOBIEN stratigraphic section made. We provide here statistics on the relative percentages of biotic elements collected, and their representation in our excavations. These analyses demonstrate that Unit 11, a marl where the *Miotragocerus* and *Trionyx* skeletons were excavated in 2003 and 2004, is both the richest and contains the most diverse biotic elements at the Höwenegg. These horizons were not excavated in 2004-2006 in the new Western Quarry, but will be in the 2007 field season.

Kurzfassung
Grabungen in der Spätmiozänen (MN9, 10,3 Mio. Jahre) Wirbeltierfundstelle Höwenegg (Hegau, Südwestdeutschland) in den Jahren 2004-2006
Nach einer kurzen Zusammenfassung der Aktivitäten an und um die Fossilfundstätte Höwenegg im Zeitraum von 1985 bis 1996 und der Gründe, die im Jahre 2003 zur Wiederaufnahme der Grabungen geführt haben, wird über die Grabungskampagnen 2004 bis 2006 berichtet. Während der Grabung 2004 wurden die Arbeiten am Höwenegg-Hauptprofilschurf weitergeführt, wobei ein weiteres Skelett der Antilope *Miotragocerus* in der Nähe der beiden 2003 gefundenen geborgen werden konnte. Zusätzlich wurde ein weiterer Profilschurf etwa 50 m nördlich des Grabungsareals von JÖRG und TOBIEN geöffnet, in dem sich sowohl Wirbeltierreste zeigten als auch ein Pflanzen führender Horizont freigelegt werden konnte. Die Grabungen in den Jahren 2005 und 2006 dienten zunächst dazu, eine neue Grabungsfläche direkt oberhalb (westlich) an den Hauptprofilschurf angrenzend zu erschließen. Mit schwerem Gerät wurden auf über 100 m² Bäume und eine mehr als ein Meter dicke Schicht Waldboden abgeräumt und an den nun freiliegenden Höwenegg-Schichten die Grabung in stratigrafischen Horizonten aufgenommen. Dabei wurde versucht, die Befunde mit JÖRG und TOBIEN'S Schichtbeschreibungen zu korrelieren, und nach einer geodätischen Einmessung der Schichtenfolge und der Funde zu einem räumlichen Modell der Fundstelle zu gelangen. Eine statistische Auswertung der bisher während der Ausgrabungen 2003-2006 gemachten Wirbeltierfunde zeigt, dass die Schicht 11, ein heller Mergel, in dem 2003 und 2004 die *Miotragocerus*- und *Trionyx*-Skelette gefunden worden waren, bislang sowohl am fossilreichsten war als auch die höchste Diversität aller im Augenblick erschlossenen Höwenegg-Schichten aufwies. Diese Schicht wird aber auf der neuen Grabungsfläche erst während der Grabung im Jahr 2007 erreicht werden.

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1. Introduction

Fossil vertebrates were first discovered at Höwenegg at the beginning of the 20th century, and the main site itself was discovered in 1936. It is renowned for its preservation of complete mammalian skeletons, including a number of females with fetuses lying in situ utero. The tridactyl horse *Hippotherium primigenium,* the archaic bosela-

phine antelope *Miotragocerus pannoniae,* and the rhinoceros *Aceratherium incisivum* are all known from multiple skeletons, and a dicerorhine deer and a tragulid species are represented by partial skeletons. Small mammals are also represented by complete skeletons (*Prolagus oeningensis*; Tobien 1986) and with the successes of our project, by teeth. A comprehensive history of the site was given by Tobien (1986). The importance of the locality has been demonstrated to the public in several popular reports (Rietschel et al., 1985, Hünermann, 1995) and recent scientific meetings (Bechly et al.,2005; Bernor & Heizmann, 2006).

Until June, 2003 there had been no quarry-level fossil excavations undertaken at Höwenegg since 1965. Several groups of mammals have been studied since 1965: carnivores (de Beaumont, 1986), rhinoceroses (Hünermann, 1982); chalicotheres (Zapfe, 1989); hipparionine horses (Bernor et al., 1997). Yet, there were many outstanding, unresolved issues about the Höwenegg site, including further refinement of its actual chronometric age, the sedimentologic and taphonomic regimes under which the vertebrate skeletons were accumulated, the actual diversity of biotic elements at Höwenegg and their distribution throughout the stratigraphic section. Ultimately, we wish to achieve an integrated reconstruction of Höwenegg's taphonomic and paleoenvironmental contexts. So reconstructed, Höwenegg will become an even more important reference locality for Central Europe, and facilitate European chronologic correlations, biogeographic and paleoenvironmental reconstructions.

In 1985 Tobien invited Bernor to undertake collaborative studies of the Höwenegg hipparion, *Hippotherium primigenium* (Bernor et al., 1997). With funding awarded by NATO (to Bernor) and DFG (to Tobien) work on the hipparions took place. In order to better understand the geological context of the Höwenegg assemblage, Professor Dr. Siegfried Rietschel, director of the Staatliches Museum für Naturkunde, Karlsruhe, organized a three week excavation of a 10 m long, East-West trending geological trench hereafter referred to as the Main Höwenegg Trench (MHT). Bernor and Munk were members of this field party.

In 1991, we opened the MHT again in order to sample fresh volcanic material for Dr. Carl Swisher (Berkeley Geochronology Lab) to date. During this excavation we also discovered a complete skull and some foot bones of *Miotragocerus,* now on display at the paleontological museum of the Town of Immendingen (Hegau). The discovery of this skull represented important new evidence that complete, museum quality specimens still existed within the Höwenegg deposits. Also in 1991 Mittmann was charged with databasing all of Tobien's original data on the original Höwenegg excavations. This included 3-dimensional coordinates from a fixed point, still clearly identifiable within the original quarry. This data will form the basis of a stratigraphic and spatial comparison of Jörg and Tobien's collections to ours.

The MHT was opened again in 1992 in preparation for an on-site field excursion by 25 scientists attending the Immendingen-Schloss Reisensberg symposium on the *Evolution of Western Eurasian Neogene Mammal Faunas* (Bernor, Fahlbusch & Mittmann, 1996). A review of the geological context of the site and its importance for reinterpreting the chronology of the "Hipparion Datum" was provided by Woodburne et al. (1996). A single crystal $^{40}Ar/^{39}Ar$ date of 10.3 +/- 0.19 Ma was published by Swisher (1996) based on his 1991 sampling at the site. At this juncture it was apparent that initiating new investigations at Höwenegg had the potential to yield important new data on the site.

Field research was finally reinitiated at Höwenegg in the summer of 2003. Professor Dr. Volkmar Wirth, director of the Staatliches Museum für Naturkunde, Karlsruhe (SMNK) authorized a new, extensive field campaign at Höwenegg. The campaign was organized in cooperation with the Stuttgart Natural History Museum (SMNS). During the first week of the 2003 excavation we discovered the distal limb elements of a *Miotragocerus* skeleton in the trench. In the second week we uncovered this specimen and found that it was a complete skeleton (female with two full term fetuses in situs utero). In addition to these individuals, we found abundant in situ remains of molluscs, leaves, fruits and a new species of fossil cervid. These results were amplified upon in an excavation report published in 2003 (Heizmann et al., 2003).

Beyond the brief overview given above, this report will give a concise accounting of our progress excavating at Höwenegg during the 2004, 2005 and 2006 summer field seasons. We report herein both the principal technical and scientific results of these last three field campaigns. A more detailed systematic and paleoecologic treatment of the paleobotanical, invertebrate and vertebrate studies will follow separately. The analyses we include here on proportions of Höwenegg biotic content,

overall and by stratigraphic unit, is inclusive of the 2003 field season.

2. The 2004-2006 Excavations

In 2004, with funding provided by the LSB Leakey Foundation, we continued working in the northwest corner of the JÖRG and TOBIEN quarry, at the western limit of the Höwenegg excavation trench. This area was on the northwestern extent of the MHT excavated in 1985, 1991 and 1992 (WOODBURNE et al., 1996; HEIZMANN et al. 2003: Plate 2). In this area we excavated a third partial and disturbed *Miotragocerus* skeleton in the immediate vicinity of the other two skeletons. We illustrate here the second well preseved *Miotragocerus* skeleton found in 2003, which included a carapace of a *Trionyx* within it (Plate 2 a) & b). Also in 2004 Professor WIRTH initiated a broader cooperation between the SMNK and the Staatliches Museum für Naturkunde Stuttgart (SMNS). As part of this cooperation, three formal working groups were organized to assist in the retrieval, curation and eventual publication of all biotic elements from Höwenegg. These include: Plants (EDER, Project Leader), Invertebrates (RASSER, Project Leader), Vertebrates (BERNOR and HEIZMANN, Project Co-Leaders) and an Analytical Working Group (MITTMANN, Project Leader).

In the summer of 2005, the SMNK and SMNS undertook another four weeks of excavation at Höwenegg**.** Our principal work was to establish a new, approximately 100 m² quarry on the west side of JÖRG and TOBIEN'S quarry. This involved the use of heavy machinery on the steep slope for cutting down trees, removal of large roots and a thick soil horizon (Figure 1 & 2). After removing the forest and approximately 1 m of overburden, we excavated a further 8 cubic meters of Höwenegg sediment. Given that the excavation occurred only in the higher part of the section (about 1.5 m above the vertebrate skeleton layer and in sediments heavily affected by solifluction), no complete skeletons were found during this campaign, but about 130 isolated specimens of a diverse vertebrate fauna (equids, bovids, cervids, rhinos, proboscideans, turtles, fish) were recovered. Of major importance was the first in situ discovery of micromammal (lagomorph material) and several fish skeletons. The washing and screening of about 200 kg of sediment provided the first fossil remains of rodents (a cricetid molar; Plate 3 a) & Figure 3).

In 2005, we excavated an exploratory trench 50 m to the north of our new excavation quarry (hereafter, The Northern Trench; Figure 4). This was done to establish whether or not fossil-bearing sediments could be documented outside the classical quarry area. This section, 5 m in thickness, established the occurrence of principally marl sediments with rich fossil plant and some vertebrate material, including postcranial elements of a rhinoceros. Also during the 2005 sum-

Figure 1. 2005 excavation showing machinery used in preparation of the Western Quarry. – Photographs: by the authors, if not noted differently.

Figurge 2. Excavation progress in Western Quarry July 3, 2006.

mer field season, technicians from the SMNK and SMNS undertook a latex peel (a "Lackprofil") of the 6.5 m section that constitues the western wall of the Jörg and Tobien excavations (figure 6). After the 2005 summer field season, a 23.5 m deep core was drilled on the northern edge of the new excavation, and in close juxtaposition to the local basaltic intrusion. This core transected the complete Höwenegg section as well as the contact between the Höwenegg beds and the

Figure 3. Professor Oldrich Fejfar sorting matrix for small mammals.

Figure 4. Northern Trench profile with WOLFGANG MUNK working with Wackerhammer.

underlying Tertiary sediments. A detailed study of this core is planned by the Geochronologic Institute, Heidelberg, but the initial results reveal three sedimentary facies, from lowest to highest: a marine layer (? OMM), believed to be Lower Miocene, a lower tuffite level presumed to represent Höwenegg volcanics, and Höwenegg Schichten (or informally Höwenegg Formation) which is estimated to constitute no more than 4 m of section in a stratigraphic position below the JÖRG and TOBIEN excavations. This core, and possibly an additional core, could provide us with new insights into Höwenegg's paleoenvironmental setting.

The 2006 field season, funded by the National Science Foundation through the Revealing Human Origins Initative (award to BERNOR through the SMNK), was dedicated to excavating the new western quarry. In 2006 we employed a professional survey team, Dipl.-Ing. KARSTEN MALIGE, Muggensturm, to tie our collection of biotic elements into the German grid system, and relate our finds both stratigraphically and spatially, to JÖRG and TOBIEN's collection. There was an extensive upper solifluction level that was mostly excavated during the field season (Plate 1). Approximately 100 m³ of sediment were excavated in 2006, yielding a diverse assemblage of plants, invertebrates and vertebrates. Amongst the vertebrate remains were a lower jaw fragment and complete metapodial of a large cat, attributed to *Machairodus aphanistus* (Plate 3 b), known also from Eppelsheim, Rhenanian Palatinate, Western Germany.

3. Scientific Results

We present here a brief overview of our scientific results from 2004-2006. In some cases we include data from our 2003 field season. A number of publications integrating our scientific results with those of JÖRG and TOBIEN's results (TOBIEN, 1986) are in preparation and will be published separately.

Plants

During JÖRG and TOBIEN's 1950 - 1954 excavations, few plant remains were observed in the

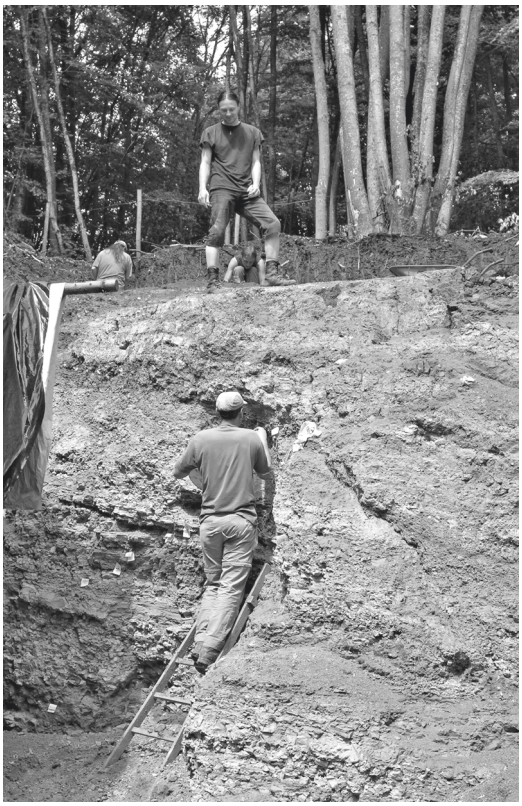

Figure 5. Michael Rasser sampling western wall of Jörg and Tobien's quarry.

Höwenegg deposits. Jörg et al. (1955) stated that plant remains were rare and poorly preserved, except for *Celtis* stonefruits. Further plant material was collected during the excavations 2003 and 2004. In 2005, a palaeobotanical working group was formed by Prof. Dr. J. Eder, which included S. Giersch, Drs. M. Slamkova, V. Wähnert and C. Strömberg. The main quarry yielded plant remains through the section, but the Northern Trench was particularly productive in yielding whole leaves, fruits and seeds. Also, eight pollen samples, separated from sediments by Dr. Adam Hölzer have been analyzed (3 from the exposure, location not exactly known, 5 from the drill core). A total of 155 specimens, mostly impressions of diaspores, and about 200 specimens of leaves have been retrieved. Of 23.5 m of drill core sample 9.75 m were relatively rich in pollen. Samples at the 10.75 m and 15.75 m intervals yielded only few taxa and the samples at 20.7 m and 21.5 m were lacking pollen. The sample taken at 9.75 m yielded herb and shrub species. These samples indicated the presence of a mesophytic forest. The material from the samples 1-3 taken from the exposed section (but without exact location in the profile) is well preserved. Eder et al. also identified a rich assemblage of fossil fruits from our sample profiles:

1. In profile Höw 03/I layers 9, 12-14 and 17 yield plant material
2. In profile Höw 04/II layers 5-7 yield plant material

These plant materials represent woody plants and reed plants from the lake surroundings, and aquatic taxa preferring shallow water. In general, the material is not very well preserved but represented by colourless impressions lacking cuticles. However, there are some remarkable exceptions to this (Plate 3 d), e) & f).

Invertebrates

During the 2004-2006 field seasons, Dr. M. Rasser undertook a detailed collection of invertebrate fossil materials from the exposed wall on the western flank of the Jörg and Tobien quarry (figure 5). The stratigraphic section was sampled by lithologic units in order to document time-space relationships of fossil material. About 30 isolated specimens were collected, as well as about 100 hand specimens. There were 70 samples collected for washing. These samples will be sieved for invertebrates, plant remains and microvertebrates. These samples are currently under study, but include the identification of abundant limnic and terrestrial gastropods, while bivalves are absent. Large terrestrial gastropods are generally rare, but occur most abundantly within the debris flows together with wood-remains, while small gastropods are also abundant within the autochthonous lake sediments. Also discovered in the 2004-2006 field seasons were the first reported occurrences of beetles (Bechly et al., 2005).

Until now, only species lists of invertebrates were known from this locality, while paleobiological and modern taxonomic studies have not been undertaken to date. Our studies on taxonomy, paleoecology, and taphonomy will allow the reconstruction of the lake and hinterland environments. In the Molasse Zone, gastropods have frequently been used for biostratigraphic correlations. For the first time, however, the gastropod biostratigraphy of the Höwenegg area can be correlated with both geochronological data and mammal biozones.

Vertebrates

Remains of fish are not common at Höwenegg, but when they occur then they can be well preserved. The current collection, as well as JÖRG and TOBIEN'S collection of fish, are currently under study by Dr. R. BÖTTCHER.

Amongst the Tetrapoda, the Höwenegg locality yielded a large quantity of chelonian fragments and osteoderms of anguimorph lizards. Chelonian material was initially discovered in the 1950's (JÖRG et al., 1955, TOBIEN, 1997, TOBIEN & JÖRG, 1959) and was briefly evaluated by SCHLEICH (1986). The field campaigns in the years 2004 through 2006 have yielded abundant chelonian remains. Besides fragments of carapace and plastron, postcranial elements were also discovered. The material confirms the existence of a possible *Testudo* or a taxonomically similar tortoise, and *Cheirogaster*, which are referable to Testudinidae. The remains of these animals mainly occur in the slump deposits, themselves derived from steep shore deposits, where the tortoises most likely initially had been deposited. The fact that they rarely occur in the marls indicates that the Höwenegg tortoises avoided open water bodies as do extant representatives. The fossil record of *Trionyx* collected at Höwenegg during this interval of field work is excellent and occurs mainly in the marls. The anguimorph osteoderms have been preliminarily referred to *Ophisaurus*. The only remnant of Amphibia is a tibia of an undetermined anuran (HÖW 05,37/ 03/I/13-15), which was discovered during the preparation of the peel profile and represents the first evidence of this group in Höwenegg. The turtles and amphibians are important for our eventual paleotemperature and paleoecologic interpretations. This fauna is under study by FREY and others. No avian remains have been discovered from our excavations so far.

We have collected numerous remains of fossil mammals in the 2004-2006 field seasons. Most spectacular thusfar are the skeletons of *Miotragocerus* (HEIZMANN et al., 2003). However, there are additional new taxonomic records at Höwenegg, including micromammals, a new species of cervid (Plate 3 c) and evidence of *Micromeryx*.

Plate 4 a) is a pie diagram showing the percentage of different biotic elements collected and inventoried in the SMNK field catalogue. Fossil mammals constitute over 60% of the biotic elements collected by our research group between 2003 and 2006. It should be noted that fragmentary gastropods occur throughout the section, and that we only collected complete, or nearly complete gastropods, making them underrepresented in this plot. Altogether, our project retrieved three fossil mammal species previously unknown from Höwenegg: *Micromeryx* sp., Cervidae gen. and sp. to be identified, and Cricetidae, gen. and sp. to be identified. In contrast to previous excavations, very little material of the 3-toed horse, *Hippotherium* was found during the 2004-2006 field seasons.

Plate 4 b) provides data on the proportion of biotic elements, per stratigraphic horizon, collected in the 2003-2006 field seasons. Our stratigraphic level 11 is where the three *Miotragocerus* and *Trionyx* skeletons were discovered in 2003-2004 at the northwestern edge of the geological trench. It is interesting to note that this stratigraphic level also contains the greatest diversity of biotic elements, including rare crustacean and insect remains. The 2007 field season excavated this rich fossil-bearing horizon with results that will be reported elsewhere.

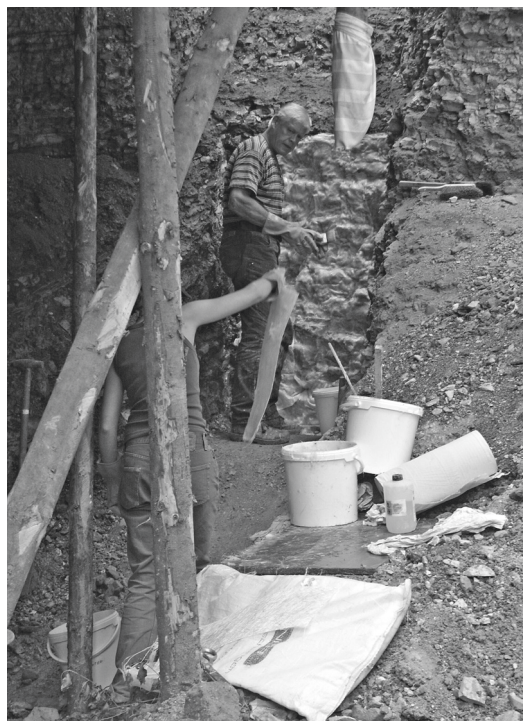

Figure 6. HARM-UWE FLÜGGE collects the "Lackprofile" on western Wall of JÖRG and TOBIEN'S quarry.

4. Conclusions

The 2003 field season provided conclusive evidence that more complete, well preserved skeletons of fossil vertebrates occur at Höwenegg. The 2004 field season reinforced this conclusion by further collection of complete skeletons. The 2005 and 2006 field seasons opened the new western quarry and established fossil bearing horizons 50 m to the north of this new quarry. The 2004-2006 field seasons documented a diverse array of biotic elements, including plant, invertebrate and vertebrate species within a secure stratigraphic and sedimentologic framework. This research will lead to a more highly resolved record of the life, ecology and paleoclimate that existed at Höwenegg 10 million years ago, and further augment its status as an important reference section for the Early Vallesian, MN 9 of Europe.

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We wish to dedicate this report to the memory of Professor Dr. F. Clark Howell who was an enormous supporter of the Multidisciplinary Project at Höwenegg, and an inspiring leader of Neogene multidisciplinary research in his own right.

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Appendix I – List of Participants 2004-2006 Field Seasons

AHMEDI, A. (SMNK) , BATTENSTEIN, M. (SMNS), BERNOR, R. L. (Howard University, Washington D.C.), BOEING, S. (SMNK), BURKHARDT, C. (SMNK), CERMAK, A. (Karls-Universtät, Prag), CLAUS, S. (Universität Heidelberg), ERKUT, B. (Karls-Universtät, Prag), FAHLKE, J. (Universtät Bonn), FEJFAR, O. (Karls-Universtät, Prag), FLÜGGE, H. (SMNS), GIERSCH, S. (SMNK), HEIZMANN, E. P. J. (SMNS), HÖRTH, M. (Bühl, ehrenamtlich), JAHNKE, S. (SMNK), KAISER, S. (SMNS), KAMENZ, M. (SMNS), KASTNER, R. (SMNK), KÖNIG, H. (Ehrenkirchen, ehrenamtlich), LEHMKUHL, A. (SMNS), LILLICH, R. (SMNS), MEISNER, A. (SMNS), MITTMANN, H. - W. (SMNK), MÖSCHEID, P. (SMNK), MUNK, W. (SMNK), RABA, W. (Universität Wien), RASSER, Dr. M.(SMNS), ROSIN, I. (SMNS), SCHNEIDER, C. (SMNS), STUKOWSKI, F. (Leonberg, ehrenamtlich), WÄHNERT, V. (SMNS), WOLF, D. (Universität Bonn), ZIEGLER, Dr. R. (SMNS), ZIEMS, A. (SMNK).

Plate 1. Profile of the Solifluction layer, western wall of the Western Quarry, July 6, 2006.

Plate 2 a) Second well preserved *Miotragocerus* skeleton found in 2003. – Photograph: SMNS (R. HARLING).

Plate 2 b) *Trionyx* carapace found in the abdomen of same *Miotragocerus* skeleton. – Photograph: SMNS (R. HARLING).

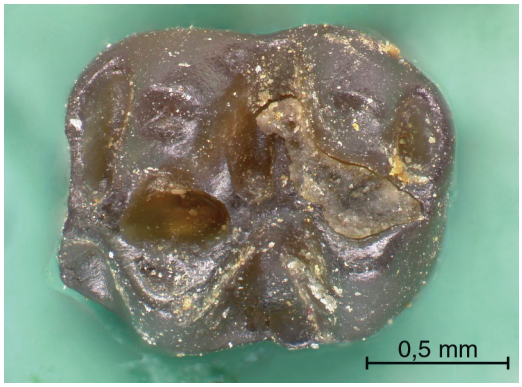

Plate 3 a) Cricetid tooth.

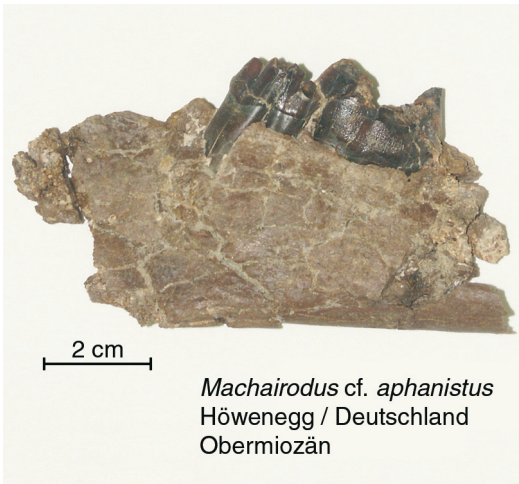

Plate 3 b) *Machairodus aphanistus* left mandibular fragment.

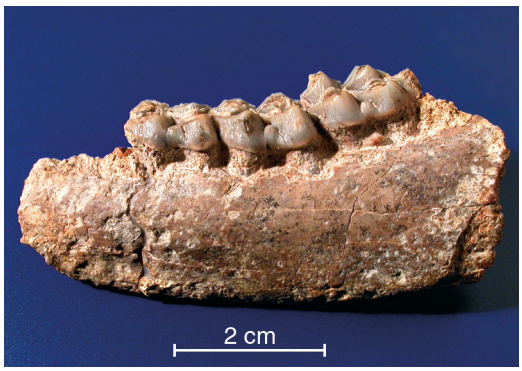

Plate 3 c) partial mandible of a new cervid species found at Höwenegg in 2003 (E. HEIZMANN, in preparation).

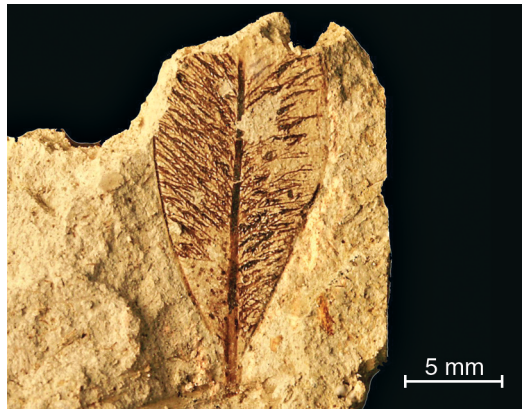

Plate 3 d), e) & f) Fossil plant material from the 2004-2006 excavations. d) *Buxus* fossil leaf from the Northern Trench.

Plate 3 e) *Populus* fossil leaf from the Northern Trench.

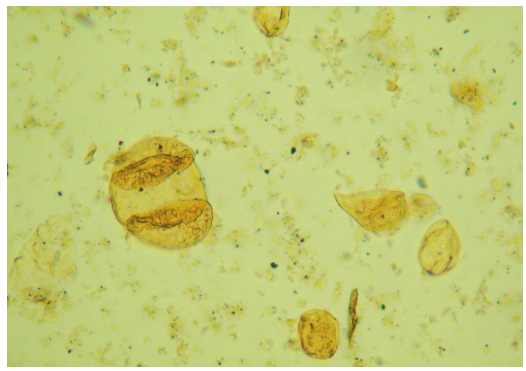

Plate 3 f) Pollen sample.

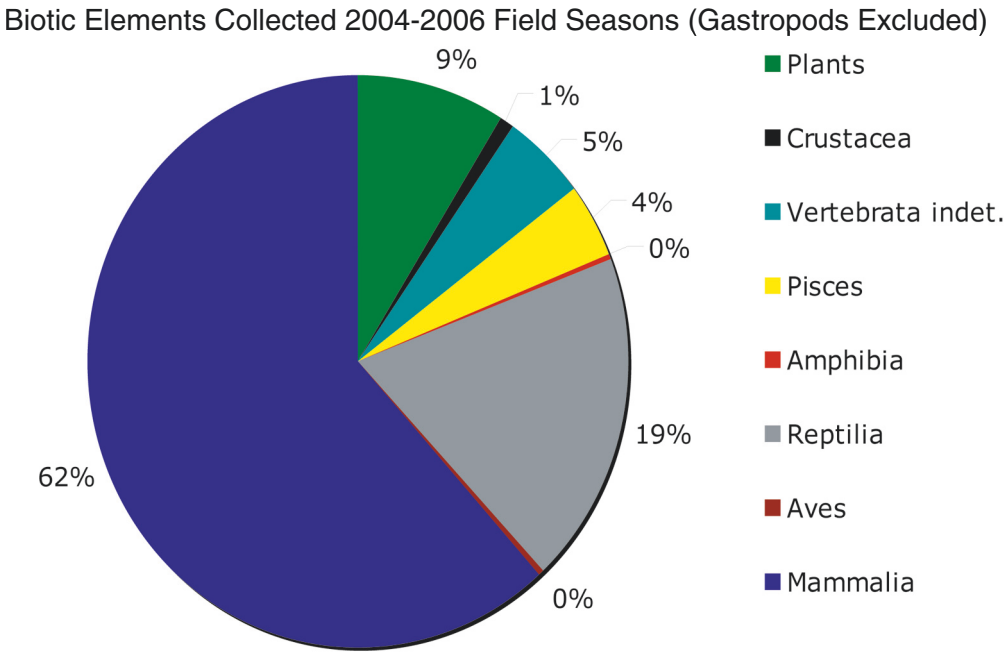

Plate 4 a) Pie percentage diagram of Höwenegg biotic elements.

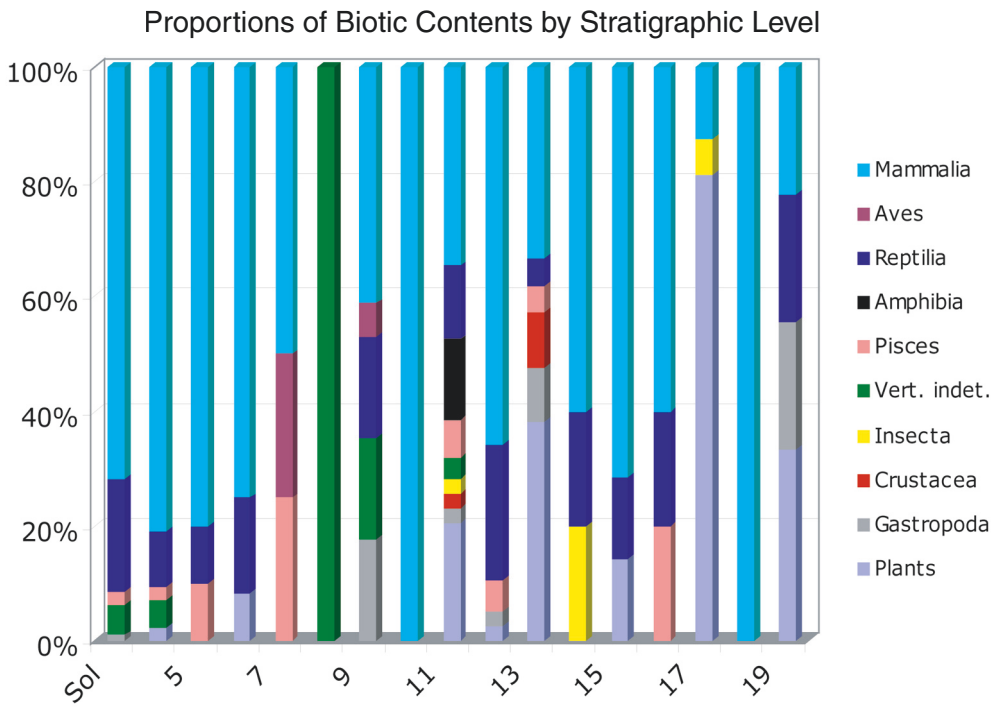

Plate 4 b) Percentage of biotic elements by stratigraphic level.