E&G Quaternary Science Journal
Volume 63 / Number 1 / 2014 / 78-98 / DOI 10.3285/eg.63.1.05
www.quaternary-science.net

GEOZON SCIENCE MEDIA
ISSN 0424-7116

Holotype skulls, stratigraphy, bone taphonomy and excavation history in the Zoolithen Cave and new theory about Esper's "great deluge"

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How to cite: Diedrich, C. (2014): Holotype skulls, stratigraphy, bone taphonomy and excavation history in the Zoolithen Cave and new theory about Esper's "great deluge". – E&G Quaternary Science Journal, 63 (1): 78–98. DOI: 10.3285/eg.63.1.05

Abstract: The Zoolithen Cave, in the Wiesent River Valley of Upper Franconia, Bavaria, South Germany, has a very long excavation history. The site is of international paleobiological importance as the Type site for five Pleistocene top predators (cave bear, Ice Age hyena, lion, wolf, dhole). This large cave system has developed in three elevations and preserves three fluvial sedimentary sequences including two speleothem genesis phases representing changing ponor, dry and wet stages from the Oligocene/Miocene (Neogene), over the Pliocene/Early Pleistocene to Late Pleistocene. The cave bear *Ursus deningeri* used the cave as den during the MIS 6–9 (Holsteinian interglacial-Saalian glacial). Single P4 tooth and skull shape analyses ("= cave bear clock") date different cave bear species (*U. spelaeus eremus/spelaeus, U. ingressus*) within the Late Pleistocene (MIS 3–5d). Finally the bones of other Pleistocene megamammals were washed from two former cave entrances at elevations of about 455 m a.s.l. up to 30 meters deep into lower elevation cave parts, during the Last Glacial Maximum (Post-*U. deningeri* times or Postglacial), -historically believed to be the result of the "great deluge". The young "river terrace dolomite gravels" which occur as relic sediments at elevations of about 455 a.s.l in several caves around Muggendorf cannot be explained by natural erosion/river terrace stratigraphy, and must relate to an uncertain glacial context. Finally Iron Age (La Tène) humans left secondary burials (human skulls and long bones with pottery and after-life food animal donations) only in the first deep vertical shaft (Aufzugsschacht) similar to the situation in the nearby Esper's Cave.

Holotypen-Schädel, Stratigraphie, Knochen-Taphonomie und Ausgrabungs-Historie in der Zoolithenhöhle und eine neue Theorie über Esper's „biblische Sintflut"

Kurzfassung: Kurzfassung: Die Zoolithenhöhle liegt entlang des Wiesenttals (Oberfranken, Bayern, Süd-Deutschland) und hat eine lange „Spatenforschungs"-Historie. Die Fundstelle ist von internationaler Bedeutung aufgrund ihrer fünf validen Holotypen-Eiszeittier-Schädeln des „Höhlenbären" sowie Top-Prädatoren (Eiszeit-Löwe, -Hyäne, -Wolf und -Rotwolf). Das große Höhlensystem entwickelte sich auf drei Etagen und hat drei fluviale Haupt-Sedimentsequenzen inklusive zwei Haupt-Speleothem-Genesephasen unter wechselnden Ponor-, Trocken- und Nassphasen während des Oligozän/Miozän (Neogen) über das Pliozän/Frühpleistozän bis hin zum Spät-Pleistozän. Die ersten Höhlenbären-Populationen Oberfrankens mit *Ursus deningeri* nutzen die Höhle als Horst bereits im MIS 6–8 (Holstein-Interglazial/Saale-Glazial). Isolierte P4 Zahn- sowie die Schädelmorphotypen (= "Höhlenbären-Uhr") datieren verschiedene Höhlenbären-Arten/Unterarten (*U. spelaeus eremus/spelaeus, U. ingressus*) in das Spät-Pleistozän (MIS 3–5d). Ihre Knochen wurden in etlichen Fällen zuerst durch Top-Prädatoren beschädigt. Letztendlich wurden die Knochen aller pleistozänen Großsäuger während des Hochglazials (= Last Glacial Maximum, Post-*U. deninger*-Zeit oder Postglazial) von zwei ehemaligen Eingangsbereichen in Höhenlagen um 455 m NHN bis zu 30 Meter in tiefere Höhlenbereiche besonders über die Vertikalschäfte durch Hochflutereignisse verschwemmt. Dieses wurde in historischer Zeit als „biblische Sintflut" interpretiert. Die jüngsten „Flussterrassen-Dolomitkiese" in Höhlenlagen um 455 m NHN werden als Reliktsedimente in verschiedenen Höhlen um Muggendorf angetroffen und können in solchen extremen Höhenlagen 130 Meter über der heutigen Wiesent nicht mehr mit „natürlicher Erosion/Flussterrassenstratigraphie" erklärt werden. Sie müssen im noch unklaren glazialen Kontext stehen. Letztendlich hinterließen Eisenzeit-La Tène-Menschen Sekundärbestattungen (Schädel, Langknochen, Keramik und Jenseits-Nahrungs-Haustier-Beigaben) nur im ersten tiefen Vertikalschaft (= Aufzugschacht), ähnlich wie in der nahegelegenden Esperhöhle.

Keywords: *Holotype skulls, stratigraphy, bone taphonomy, excavation history of the Zoolithen Cave, new theory about Esper's "great deluge"*

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1 Introduction

The Franconian Karst in Germany is one of the most important regions for megafaunal and palaeoclimatic research of the Middle/Late Pleistocene in Europe due to its multiple archaeo-biological-archives. The extremely Pleistocene bone-rich caves, which also contain important sedimentary sequences, allow landscape and erosion modeling which is potentially important for comparisons within other regions of central Europe.

Upper Franconia (Bavaria) along the Wiesent and tributary valleys has the highest density of caves in the Franconian Alb (e.g. Kaulich & Schaaf 1993, Groiss et al. 1998) and is one of the most cave–rich regions of Europe, worthy of "speleopark" designation in the future. The caves are eroded into the massive Upper Jurassic reef and lagoon/inter-reef dolomites (Meyer & Schmidt-Kaler 1992, Groiss et al. 1998), which additionally are famous climbing areas. Most of the caves are only small clefts or cavities, with only a few larger caves are present.

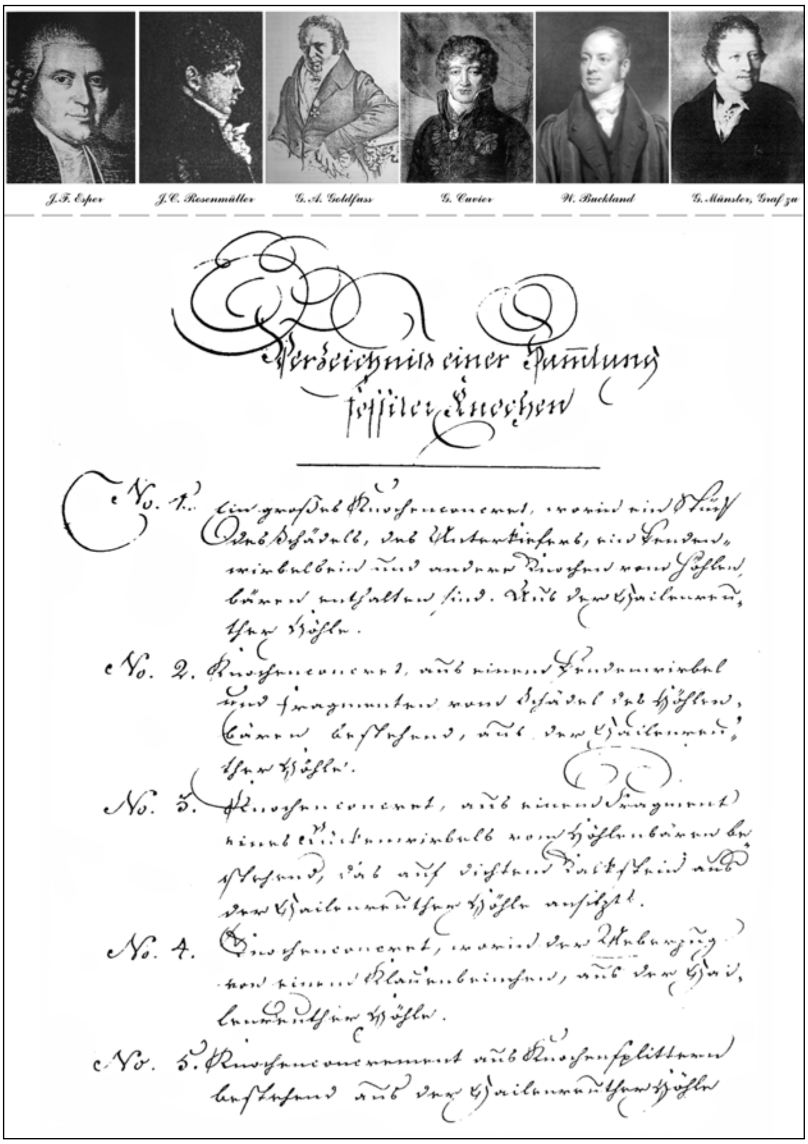

Fig. 1: The first Zoolithen Cave researchers of the „early spade research time: J.F. Esper, J.C. Rosenmüller, A. Goldfuss, G. Cuvier, W. Buckland and Graf zu Münster. Below: First page of the catalogue of the selling contract of the Rosenmüller-1794 collection (former times Preußische Geologische Reichsanstalt Berlin, today Naturkundemuseum der Humboldt-Universität Berlin).

Abb. 1: Die ersten Zoolithenhöhlen-Erforscher während der „frühen Spatenforschungszeit":, J.F. Esper, J.C. Rosenmüller, A. Goldfuss, G. Cuvier, W. Buckland und Graf zu Münster. Unten: Erste Seite der Kataloges des Kaufvertrages der Rosenmüller-1794-Sammlung (damals Preußische Geologische Reichsanstalt Berlin, heute Naturkundemuseum der Humboldt-Universität Berlin).

Those caves, and especially the Zoolithen Cave, was one of the first and most famously targeted fossil cave bear localities, where many famous German, French and English pioneering researchers excavated or studied material, including Esper, Rosenmüller, Goldfuss, Cuvier, Buckland & Graf zu Münster (Fig. 1). The most famous and largest fossil collection assembled by Rosenmüller (labeled in 1797) that contains several of the famous skulls, was thought to be lost, but has been relocated by the current author, in the Preußische Geologische Landesanstalt (see Rosenmüller catalogue, Fig. 1). During the DDR socialist Republic times this collection was forgotten but is now recognized to be of international importance. Further important researchers included Goldfuss & Buckland who provided the first illustrations of the cave and excavation areas (Fig. 2A). Sadly, in more recent times (after the Second World War), large newly discovered parts and old areas were emptied with old-style methods by Groiss (Fig. 2B).

Mainly cave bear remains have been found from the Pleistocene layers in the Zoolithen Cave as the first and most well-known and one of the richest cave bear bone site of Europe (Esper 1774, Rosenmüller 1794, Goldfuss 1810, 1818, 1821, 1823, Buckland 1823), which herein estimated has/had a half million of remains. This and other larger bone-rich caves in Upper Franconia (Fig. 3A) are all in higher elevations between 550 to 400 m a.s.l. (Zoolithen Cave former entrance 455 m NHN, Sophie's and Große Teufels Cave former entrances 410 m NHN) and contain mainly Late Pleistocene megafaunas in the Große Teufels Cave, Sophie's Cave, or Geisloch Cave such as the herein discussed Zoolithen Cave, which will be demonstrated to have been used by early cave bears even earlier already in the Middle Pleistocene. At minimum four larger Pleistocene cave bear dens are known today (Fig. 3A). Smaller and fewer cave bear remain containing caves are the Zahnloch Cave, Neideck Cave, Moggaster Cave, König-Ludwigs-Cave, Wunder Cave and Esper Cave (Diedrich 2013a, Fig. 3B).

1774–1794 – Esper to Rosenmüller – "surface collecting times"

The reports of Heller (1972) do contain a compilation of the history, but do not reflect the real situation. After the first reports of the cave fauna by Esper (1774), he collected, described and figured "bones of extinct animals" (= cave bears and others) from the Zoolithen Cave. These bones were not found in the Entrance Hall (455 a.s.l.), but in the area of the

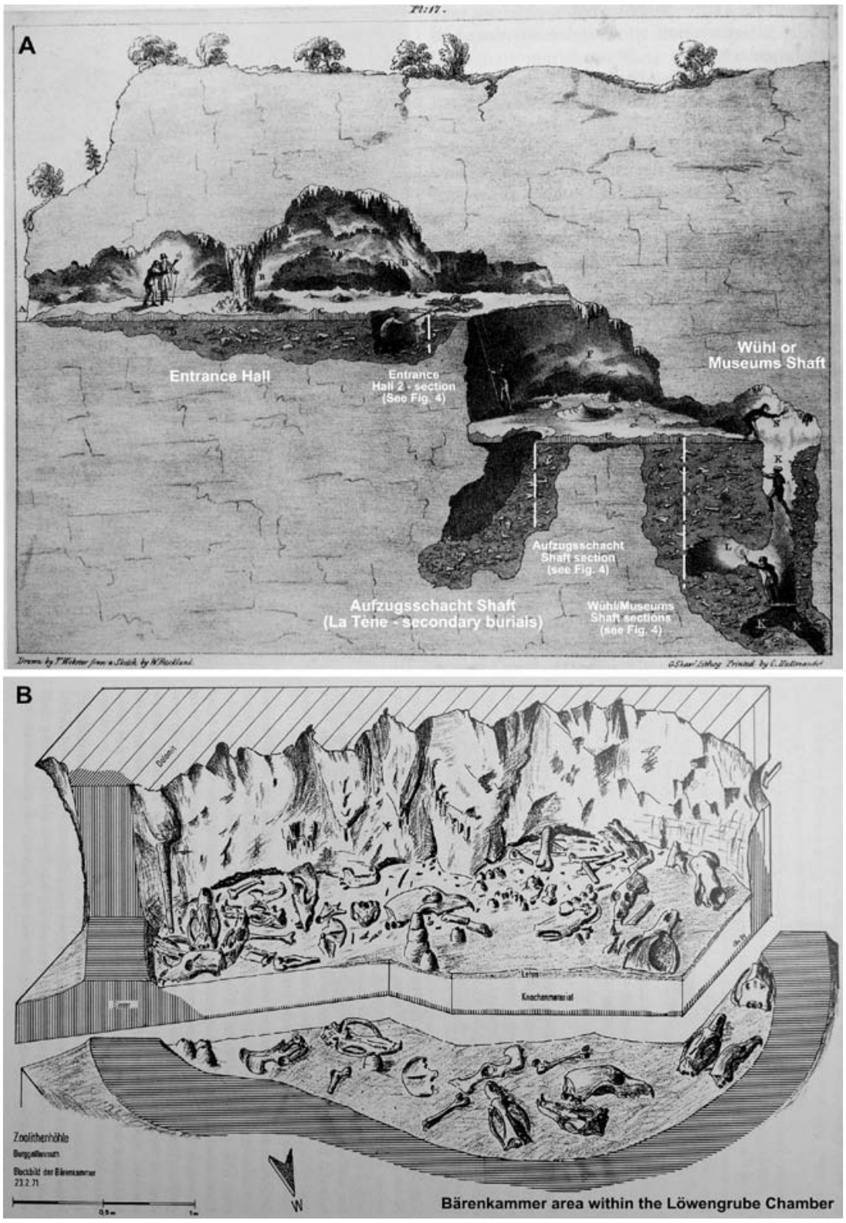

Fig. 2: A. Cross section of the historical excavation areas of W. Buckland (from Buckland 1823). This section Dieser Aufriss-Querschnitt shows the historic discoveries of the anterior cave parts and excavation areas in the Entrance Hall, Wühlschacht Shaft (= Iron Age secondary burials) and the Aufzugs-/Museumsschacht Shafts (sections cf. Fig. 4) of the "early spade research time". In the Museumsschacht-Shaft partly the herein illustrated wooden planks of the ladders are preserved until today in the Museumsschacht Saft.. B. Not time-adequate and sadly useless "finding map sketch" of the bonebed surface in the „Bärenkammer" of the Löwengruben Hall of the "late spade research time" (from Groiss 1971). The removed material can not be relocated today anymore to the places (lacking documentation due to quick-emptying action), nor were the nones osteologically determined.

Abb. 2: A. Querschnitt der historischen Grabungsbereiche von W. Buckland (aus Buckland 1823). Dieser Aufriss-Querschnitt zeigt die damaligen Entdeckungen des vorderen Höhlenbereiches und Grabungsstellen in der Eingangshalle, dem Wühlschacht (= eisenzeitlicher Sekundär-Bestattungsschacht) und dem Aufzugs-/Museumsschacht (Profile vgl. Abb. 4) in der „frühen Spatenforschungszeit". Im Museumsschacht sind noch heute Balken der Leitern vorhanden, die hier teilweise eingezeichnet sind. B. Nicht zeitgemäße unbrauchbare „Befundplan-Skizze" der Bonebed-Oberfläche in der „Bärenkammer" der Löwengruben-Halle in der „späten Spatenforschungszeit" (aus Groiss 1971). Die geborgenen Funde können heute weder zugeordnet werden (fehlende Dokumentation aufgrund einer Schnell-Entleerungs-Aktion), noch sind die Knochen osteologisch bestimmt worden.

"Aufzugsschacht", which was a 2 m bone filled shaft, described as resulting from a "biblical flooding event" (Esper 1774). Initially, bones were easy to collect from the surfaces, starting in the Aufzugssschcht Shaft area. The cave bear, lion and dhole holotype skulls must have been collected by Rosenmüller from the surfaces in those first two larger shafts in the cave system before 1797, because the other cave parts (2/3 of the today's known cave) behind the Aufzugsschacht had not been discovered at that time (cf. Rosenmüller 1794, Buckland 1823, Niggemeyer & Schubert 1972).

1810–1823 – Goldfuss to Buckland – "first excavation period"

The sketch of Buckland (Fig. 2B) demonstrates the main bone excavation areas around 1823. Groiss (1979) believed this illustration not to be correct, but it is (see reidentifications in Fig. 2A), even the last shaft can be demonstrated to be the Museumsschacht (after illustrations with two speleothem layers, old ladder material and dump) and not the Wühlschacht. Even today preserved historical ladder material and dumps in the last shaft (Museumsschacht) prove the deep and extensive excavations at that time, being well figured by Buckland (1823). Those areas can be seen well until today in the cave. Buckland's excavations began in the Entrance Hall, which can be seen in his illustrations (Buckland 1823, Fig. 2B). The bones are there in primary positions (not water transported) in a silty medium brown and dolomite ash sediment (cf. section in Fig. 4), which minerals gave the bones a typical medium-to dark brown colour. Two preservation and bone colour types Goldfuss (1823) are known, the brown form and the more abundant "white yellowish" form. This old excavation area was partly reopened during the own studies (Fig. 4) and some bones (large proportions) and teeth (multiconed enamel surfaces) of *U. ingressus* were found, which are important for dating. The Entrance Hall was not – as wrongly believed – fully excavated, because the sections demonstrate autochthonous and dark-brown coloured cave bear bones, which form a loose bonebed. Furthermore larger speleothems still cover most of the hall, which is only overlain by few Iron Age period and Holocene sediments (Fig. 4). This Hall was less of interest, because in the first shafts (Wühlschacht/Aufzugsschacht/

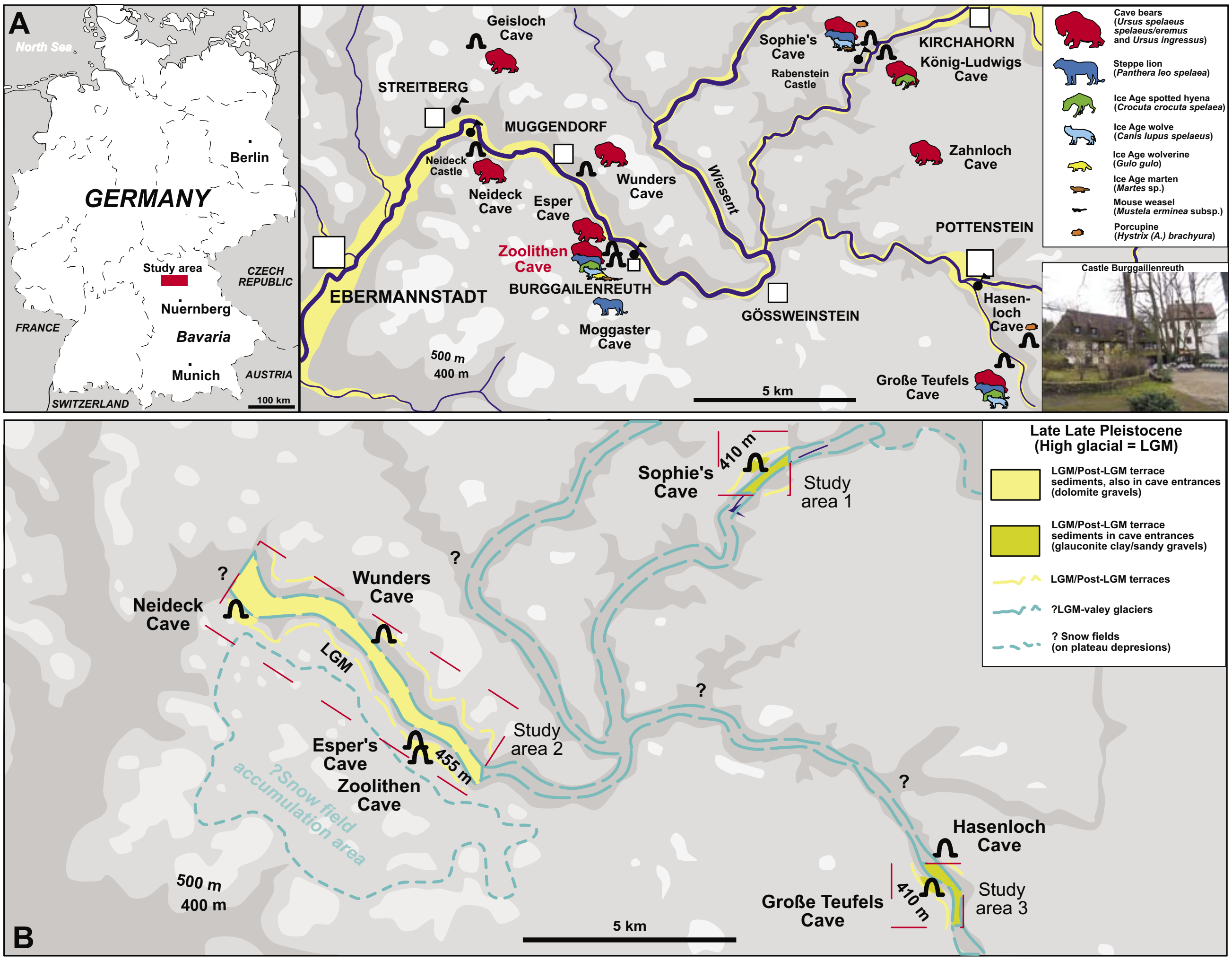

Fig. 3: A. Late Pleistocene cave bear, hyena, wolf, marten and weasel den cave sites in Upper Franconia (northern Bavaria). B. Three sedimentological studied areas in Upper Franconia (Große Teufels Cave, Sophie's Cave and Zoolithen Cave) with questionable "valley glacier situation" explaining best the high elevation of the Wiesent River terrace on 455 a.s.l. elevations and large gorges along during the late Late Pleistocene (high glacial) and terrace relict sediments (especially glauconite till sediments) explaining the possibilities of the flooding situation. The problem is the correlation of the different elevated Sophie's/Große Teufels caves (410 m a.s.l.) elevation and similar old different terrace sediments in the Muggendorf area (Neideck/Wunders/Zoolithen caves about 455 m a.s.l.).

Abb. 3: A. Spät-Pleistozäne Höhlenbären, Hyänen, Wolf, Marder und Wiesel-Horst-Höhlen in Oberfranken (Nord-Bayern). B. Drei sedimentologisch untersuchte Regionen in Oberfranken (Große Teufelshöhle, Sophienhöhle und Zoolithenhöhle) mit fraglicher „Tal-Vergletscherungs-Situation", die am besten die hohe Wiesent-Flussterrassenlage auf 455 m ü. NHN und tiefen Schluchten während des späten Ober-Pleistozäns (Hochglazial) und Terrassen-Reliktsedimente (besonders Glaukonit-Tillsedimente) und Flutung der Zoolithenhöhle erklären könnte. Das Problem ist die Korrelation der unterschiedlich hoch gelegenen Sophien-/Großen Teufelshöhle (410 m NHN) und gleichaltrige unterschiedliche Terrassensedimente in der Muggendorf-Region (Neideck-/Wunders-/Zoolithenhöhle ca. 455 m NHN).

Museumsschacht) the bone beds were extremely dense and material was easy to obtain. The material was found in the "bonebed breccias" (= cemented doloash sand-dolomite pebble layers cemented by speleothems) below the upper speleothem layer. Also Graf zu Münster collected there in the 19th century (Weiss 1937), with his collections now curated in the Urweltmuseum Oberfranken Bayreuth. The sediment of those excavations and further ones of the 19th century was back-filled into the Wühlschacht (pers. com. M. Conrad). This shaft was closed again after 1823 already historically with reworked sediments. These first discovered areas of the anterior cave separated for long the deeper cave parts which were discovered in 1971 after removal of the sediments (cf. Niggemeyer & Schubert 1972). The many hundreds of cubic meters of material protected the deeper parts of the cave and were reworked 25–20 years ago (pers. com. M. Conrad).

1971 – "second research period"

The second chimney (Wühlschacht) was also filled up with densely packed bones and was the key to today's much larger known cave system, the middle part of which was discovered in 1971 (cf. Groiss 1971, 1979). After the reopening of the Wühlschacht about 25 years ago, a new cave part and thousands (e.g. the University Erlangen collection of 100,000 bones) of untouched bonebeds were quickly removed. Those bones were taken without adequate documentation in the Knochenschacht and partly in the Bärenkammer (cf. Fig. 2B). The Guloloch and Wolfskammer shafts produced mainly cave bear bones, and many new skulls, but also other Pleistocene carnivore faunal remains (cf. Groiss 1979). From those excavations a perfectly preserved hyena skull subsequently became a paratype skull (Diedrich 2011a, 2014). Some thousands of other bones have been dumped after

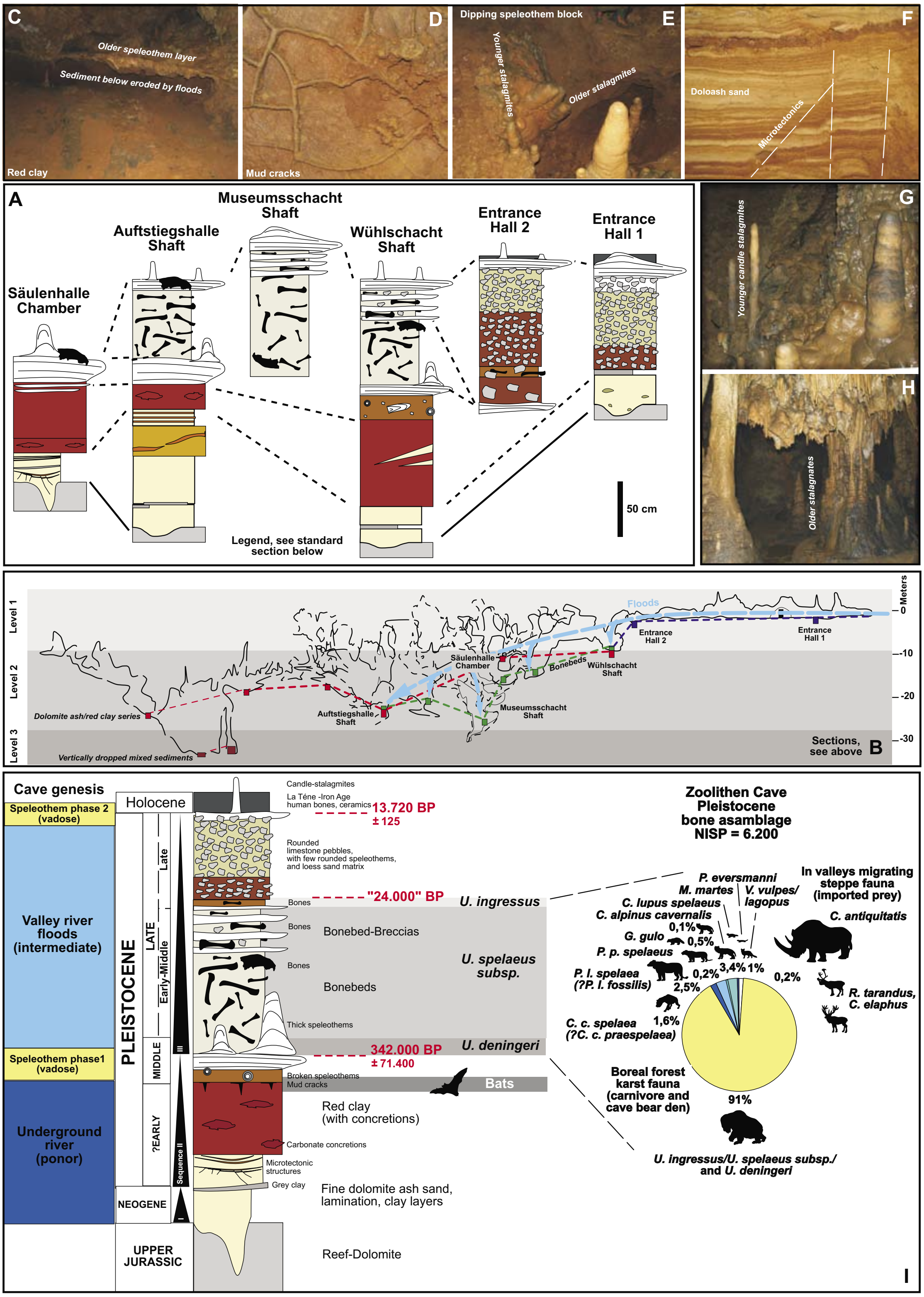

Fig. 4: Sections in the Zoolithen Cave, dating and interpretation of main sedimentary fluvial (underground river and valley river) series (absolute data from Kempe *et al. 2002,* Rosendahl *&* Kempe *2004). A. Important sections. B. Cave levels and similar elevated sedimentary sequences. C. Collapsed main speleothem layer, below eroded clay and present red clay of the sequence 2 in the Lehmhalle. D. Mud-crack negatives on the base of the main speleothem layer in the Löwengrube. E. Tipping speleothem layer in a vertical shaft, which moved downwards, and on which candle stalagmites with different angles developed. F. Dolomite ash sands/red clay layers of the sequence 2 with microtectonic horst structures. G. Candle stalagmites of the Alleröd humid phase (second speleothem generation) in the Löwengrube. H. Large stalagnates from the first speleothem phase in the Säulenhalle. I. Compiled generalized section, and faunal composition of the Late Pleistocene bonebeds.*

Abb. 4: Profile in der Zoolithenhöhle, Datierung und Interpretation von fluvialen (Untergrundfluss und Talfluss) sedimentären Hauptzyklen (Absolut-Daten nach Kempe *et al. 2002,* Rosendahl *&* Kempe *2004). A. Wichtige Profile. B. Höhlen-Etagen und in gleichen Höhenlagen vorhandene Sediment-Sequenzen. C. Eingestürzte Sinterdecke, unterhalb erodierter Lehm und vorhandener roter Lehm der Sequenz 2 in der Lehmhalle. D. Trockenriss-Negative auf der Unterseite der ersten Hauptspeläothem-Lage in der Löwengrube. E. In einem Vertikalschacht verkippte Sinterdecke, die sich gravitativ nach unten bewegte und auf der sich mehrere Kerzenstalagmiten-Generationen mit unterschiedlichen Winkeln entwickelten. F. Dolomite-Aschen/rote Lehm-Lagen der Sequenz 2 mit Mikrotektonik-Horststrukturen. G. Kerzenstalagmiten der humiden Alleröd-Zeit (zweite Speläothem-Generation) in der Löwengrube. H. Große Stalagnaten der ersten Speläothem-Generation in der Säulenhalle. I. Generalisiertes Gesamtprofil und Faunenkomposition der spätpleistozänen Bonebeds.*

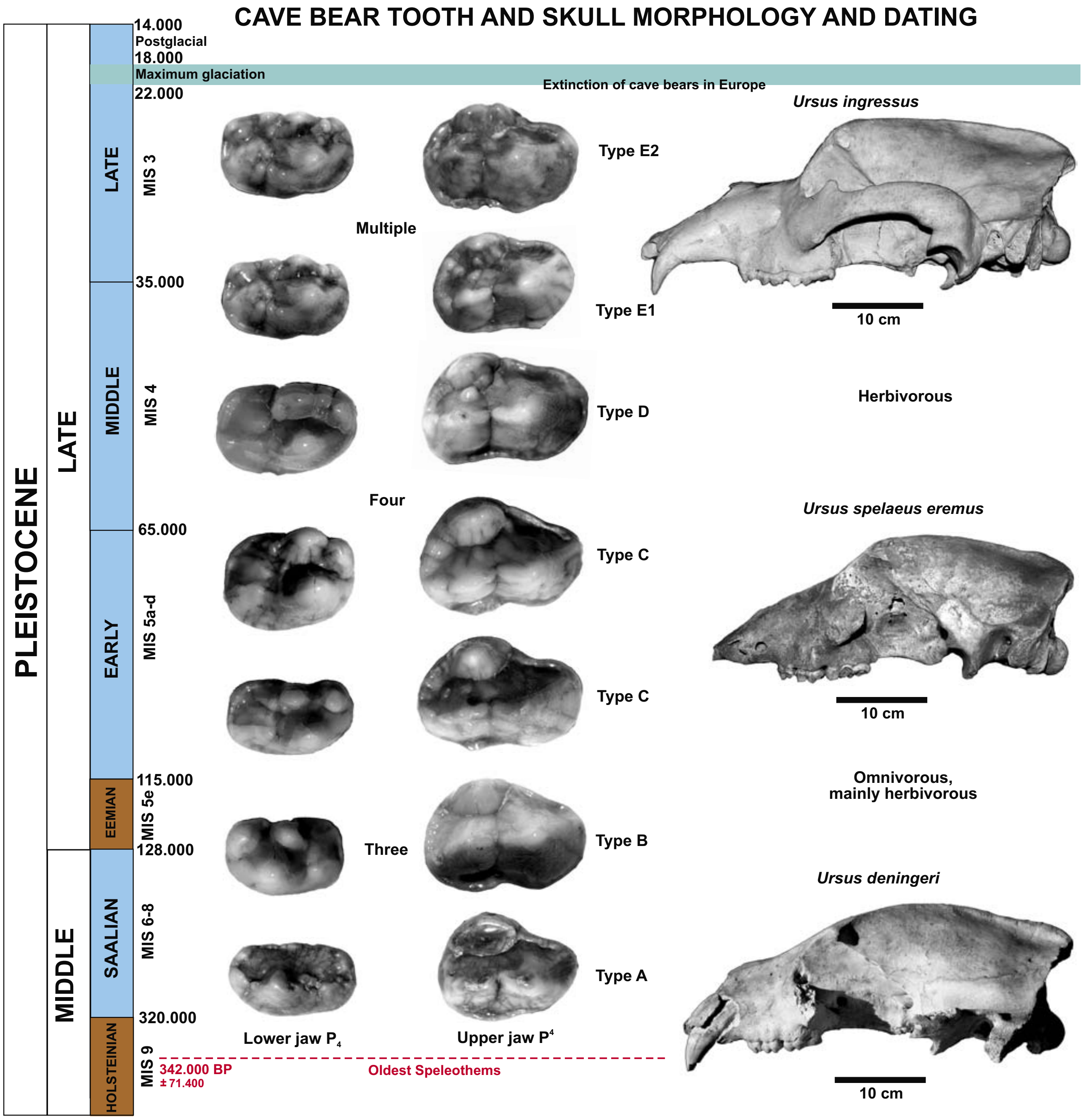

Fig. 5: "Cave bear clock" – dating the cave bears by P4 and skull shape morphologies. The tooth material is from the dump infront of the cave but demonstrate a cross-section through all primitive deningeri to ingressus cave bear tooth morphotypes sensu Rabeder *(1999). All teeth in occlusal view. U. ingressus skull Graf zu Münster-coll. Urweltmuseum Oberfranken Bayreuth; U. spelaeus eremus skull Buchhaupt-coll.; U. deningeri skull* Rosenmüller *1794-coll. MB).*

Abb. 5: „Höhlenbären-Uhr" – Datierung der Höhlenbären mit Hilfe der P4 und Schädel-Morphotypen. Das Zahnmaterial stammt aus der Halde vor der Höhle, zeigt aber den Querschnitt durch alle primitiven deningeri bis ingressus-Höhlenbärenzahn-Morphotypen sensu Rabeder *(1999). Alle Zähne in Occlusalansicht. U. ingressus-Schädel Graf zu Münster-Slg. Urweltmuseum Oberfranken Bayreuth; U. spelaeus eremus-Schädel Buchhaupt-Slg.; U. deningeri-Schädel* Rosenmüller *1794 Slg. MB).*

1971 due to the continuing excavations (FHKF = Forschungsgruppe Höhle und Karst Franken e.V., Nürnberg) in the "Museum" in the cave, and still remain there. This bone material is from the approximately two meter thick bonebeds of Aufzugsschacht/Wühlschacht and the Museumsschacht vertical shafts. Most of the sediment was simply transported in front of the cave, whereas the teeth were taken by the spelunkers, who dumped the "bad bones" in the Museums area. The new "old" reworked bone material is still of high importance in the reconstruction of the exact locations of lion and hyena remains (Fig. 14), to the understanding of the cave bear bone taphonomy, and to the compilation of the rare non-cave bear skeletons necessary to obtain complete faunal accounts.

2000–2010 – Modern Research

The descriptions of Heller (1966) do not fit this cave or other caves, where he believed, that those sites were "emptied". After the new discoveries of untouched bonebeds which are luckily still intact in at least some areas (Fig. 15), the cave was explored further in the past decade leading to the dis-

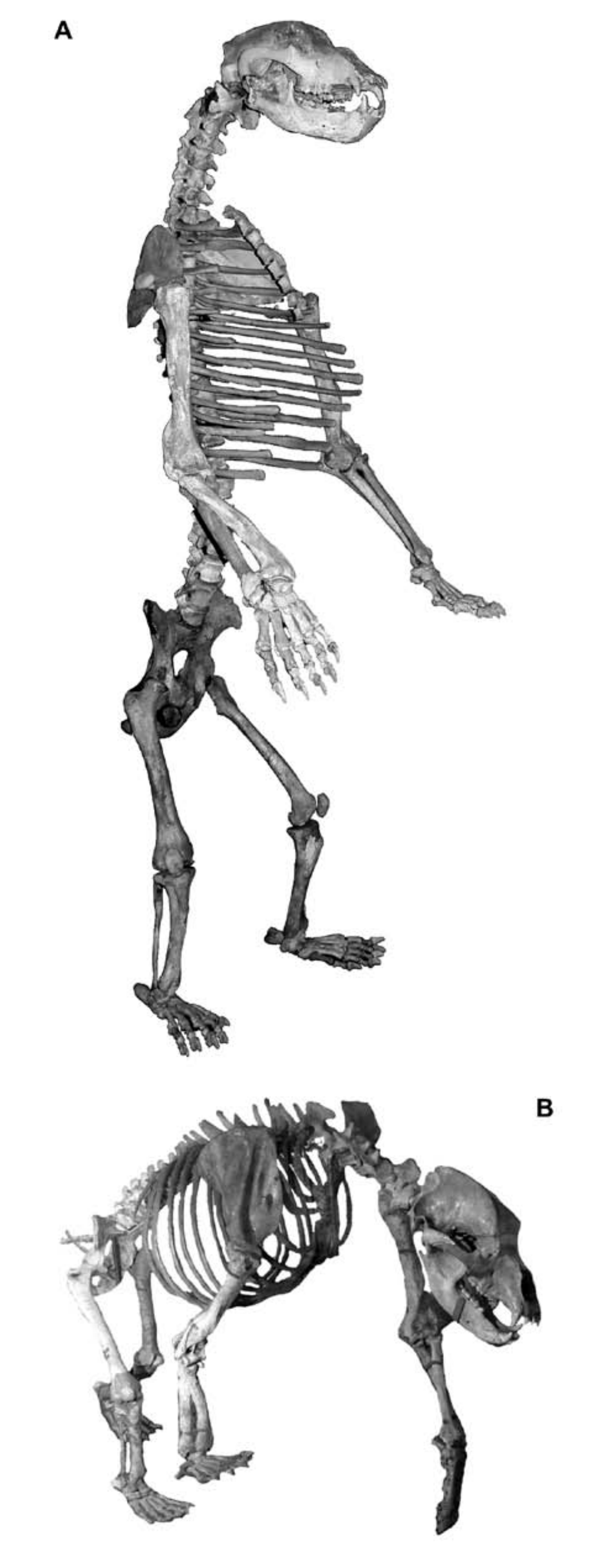

Fig. 6: A. Compiled cave bear skeleton of different individual remains and species of the Zoolithen Cave (exhibition of the Museum für Ur- und Ortsgeschichte Bottrop). B. Compiled cave bear skeleton of different individual remains of the Zoolithen Cave (skeleton exhibition of the Museum Tüchersfeld).

Abb. 6: A. Höhlenbären-Skelett-Komposit verschiedener Individuen und Arten aus der Zoolithenhöhle (Skelette-Ausstellung Museum für Ur- und Ortsgeschichte Bottrop). B. Höhlenbären-Skelett-Komposit verschiedener Individuen aus der Zoolithenhöhle (Ausstellung Museum Tüchersfeld).

covery of another extension to the south (= Dreyerhalle area, pers. com. M. Conrad, Fig. 14). Also, a few more bones and skulls were found even deeper in the cave system, obviously in secondary (carnivore caused scattering) or even third (floods, gravity-driven transport) positions. The Museums area dump was sorted by the author in 2010. During this preliminary collections management, all non-cave bear material was extracted (together with human remains, and pottery, and Holocene fauna). The hyenas and lion material has already been published, together with the accessible historical finds (cf. Diedrich 2011a/b, 2014).

The international important forgotten Pleistocene holotype skull collection

Two "cave bear" skeletons were compiled of bones from different individuals and even cave bear subspecies/species as known today (Fig. 5, 6A–B). In total five Pleistocene species (Figs. 7–13) were named based on the Zoolithen Cave skulls – which make this site to the most important Pleistocene cave megafauna locality in Europe. Today only five of the six holotype skulls remain as valid Pleistocene species. The holotype of the "cave bear *Ursus spelaeus*" described by Rosenmüller (1794) was identified in his collection (Diedrich 2009, Fig. 7). Newly identified here is the *Ursus deningeri* Reichenau 1904 skull (Fig. 8) of the Rosenmüller collection, which was historically believed to represent a "brown bear". A larger bone collection including most of the known large lions remains and the holotype of *Panthera leo spelaea* (Goldfuss 1810) (Fig. 9) from the Zoolithen Cave was collected/excavated by Rosenmüller himself since the end of the 18th century. Also the rediscovered hyena *Crocuta crocuta spelaea* (Goldfuss 1823) (Fig. 10) holotype skull (Diedrich 2008, 2014), revalidated wolf *Canis lupus spelaeus* (Goldfuss 1823) (Fig. 11), the new rediscovered dhole skull of *Cuon alpinus cavernalis* (Rosenmüller 1797) (Fig. 12), and the subsequently invalidated *Gulo gulo spelaea* (Goldfuss 1818) (Fig. 13) must have been found in the first two vertical shafts (Aufzugs-/Wühlschacht). However, the invalid "cave tiger *Panthera tigris spelaea* (Goldfuss)" holotype material described by Groiss (1996) was revised to represent subadult individual remains of *P. l. spelaea* (cf. Diedrich 2011b).

2 Material and methods

To understand the cave bear bone taphonomy and distribution of the "bone breccias" (= bone beds), and to document two articulated skeletons (Fig. 14), a new cave survey was made in spring of 2010, in parallel with a History Channel film project. Open sections in the cave, that resulted from historical digs (cf. Buckland 1823, Fig. 2B) and also the digs of the FHKF since 1971, were studied sedimentologically and stratigraphically to allow the presentation of a generalized overview section for the currently known cave system (Fig. 4). The most complete Middle to Late Pleistocene (MIS 3–9) section was found in the "Aufzugsschacht". Some thinner sections at other places allow the reconstruction of three main fluvial sedimentary cave filling sequences and two main speleothem genetic phases in three cave levels (Fig. 4). The bone material in the "Museum" (= sorted bones from the 1971 and later reworked sediments from FHKF activities)

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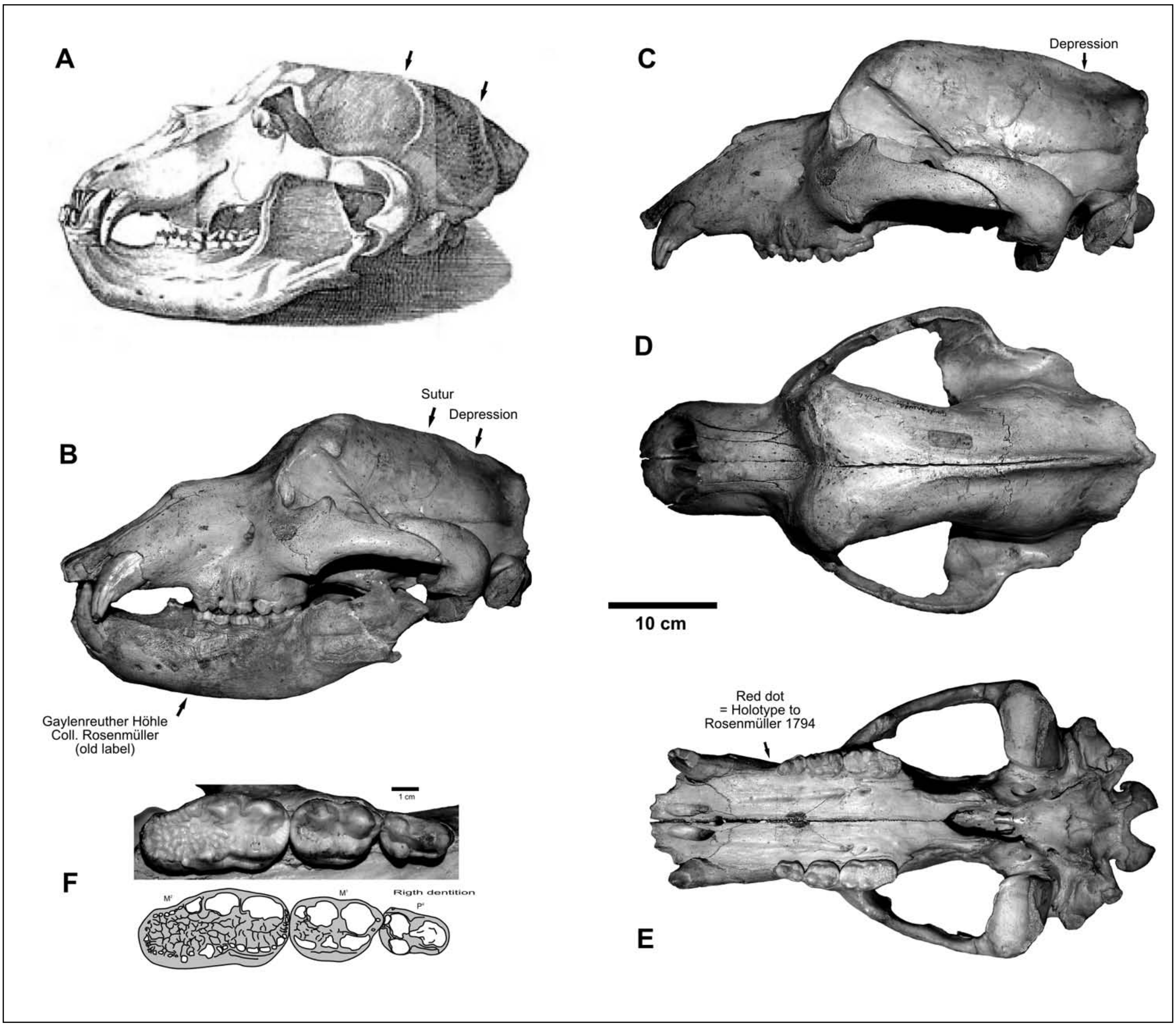

Fig. 7: Ursus ingressus Rabeder & Hofreiter *2004 holotype skull of "the cave bear Ursus spelaeus" of an early adult male. Latest Late Pleistocene (which seems to be a subadult Ursus ingressus; coll. MB, from* Diedrich *2009).*

Abb. 7: Ursus ingressus Rabeder & Hofreiter *2004 Holotyp-Schädel „des Höhlenbären Ursus spelaeus" eines frühadulten männlichen Bären, späteres Spät-Pleistozän (Ursus spelaeus spelaeus* Rabeder & Hofreiter *2004, vermutlich ein subadulter Ursus ingressus; Slg MB, aus* Diedrich *2009).*

was sorted and protected against further trampling damage by spelunkers. Non-cave bear bone material was extracted (Pleistocene carnivores, Holocene fauna, human bones). About 2,000 bones remain until today there behind a locked door. Furthermore the dump in front of the cave was checked for its contents with a smaller trench. From this about 1,500 finds (Pleistocene bones, pottery and human teeth) were rescued from the illegal excavation activities of private collectors.

The 1971 and later excavated and already twice redeposited bones and fragments of the non-cave bears are in the Ziegler-collection (former owner of the cave at that time) of the Forschungsgruppe Höhle und Karst Franken e.V., Nürnberg (= **FHKF**). The collection of Esper cannot be relocated. The most famous and largest collection, that of Rosenmüller, who labelled the site as "Gaylenreuther Höhle, 1797" (cf. Fig. 1B) was formerly stored in the collection of the "Preußische Geologische Landesanstalt", and then in the "Bundesanstalt für Geowissenschaften und Rohstoffe", Berlin (= **BGR**). These collections were recently moved to the "Museum für Naturkunde der Humboldt-Universität Berlin" (= **MB**). The Goldfuss collection, which was taken from the cave between 1810–1823, is partially housed in the Goldfuss-Museum Bonn (e.g. hyena holotype skull, possibly also "lost wolf skull" there). The Graf zu Münster collection which containing well preserved hyena, lion and wolf material is in the Urweltmuseum Oberfranken Bayreuth (= **U-OB**). A composite skeleton was studied in the Museum Ur- und Ortsgeschichte Bottrop (= **MUOB**), and the Museum in Tüchersfeld (= **MT**). One hyena skull and several cave bear skulls are in the British Museum (Natural History), London (= **BMNHL**). The Buckland collection was not relocated in Oxford in the University Museum after requests, but might be hidden somewhere. The largest collection (estimated at 100,000 bones after pers. com. Ministry of Culture of Bavaria) is housed in the University Erlangen (= **UE,** 1971 Groiss "excavations" = cave owner property of R. Ziegler until today).

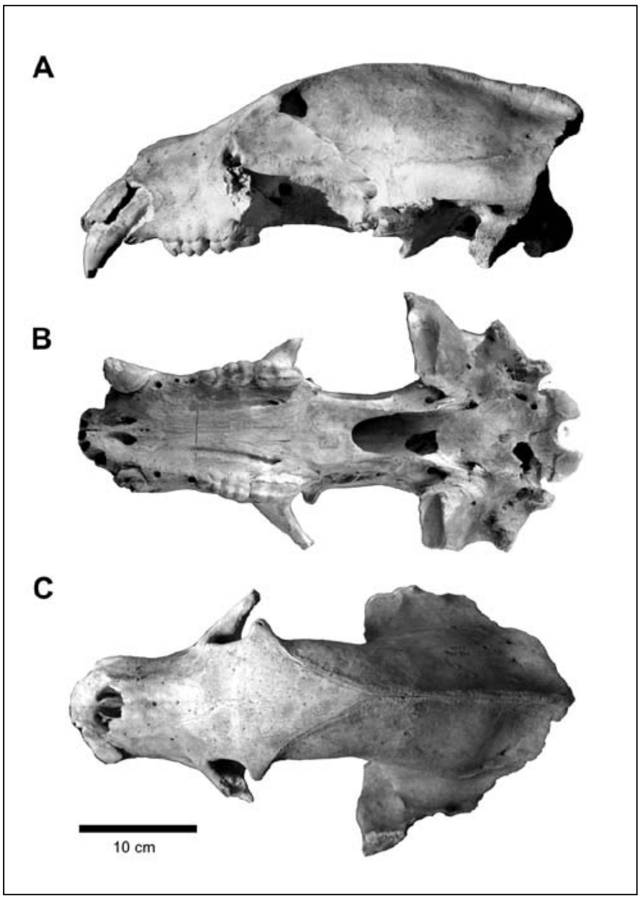

Fig. 8: A-E. Early Deninger cave bear Ursus deningeri Reichenau *1904 skull, Middle Pleistocene ("Ursus arctoideus" in the* Rosenmüller *1794-coll. MB).*

Abb. 8: A-E. Früher Deninger-Höhlenbär Ursus deningeri Reichenau *1904 Schädel "Ursus arctoideus", Mittel-Pleistozän ("Ursus arctoideus"* Rosenmüller *1794-coll. MB).*

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*Fig. 9: A-E. Steppe lion Panthera leo spelaea (*Goldfuss *1810) holotype skull "Felis spelaeus", Late Pleistocene (*Rosenmüller *1794-coll. MB,drawing from* Goldfuss *1810, original from* Diedrich *2011b).*

*Abb. 9: A-E. Steppenlöwe Panthera leo spelaea (*Goldfuss *1810) Holotyp-Schädel "Felis spelaeus", Spät-Pleistozän (*Rosenmüller *1794-Slg. MB, Zeichnung aus* Goldfuss *1810, Original aus* Diedrich *2011b).*

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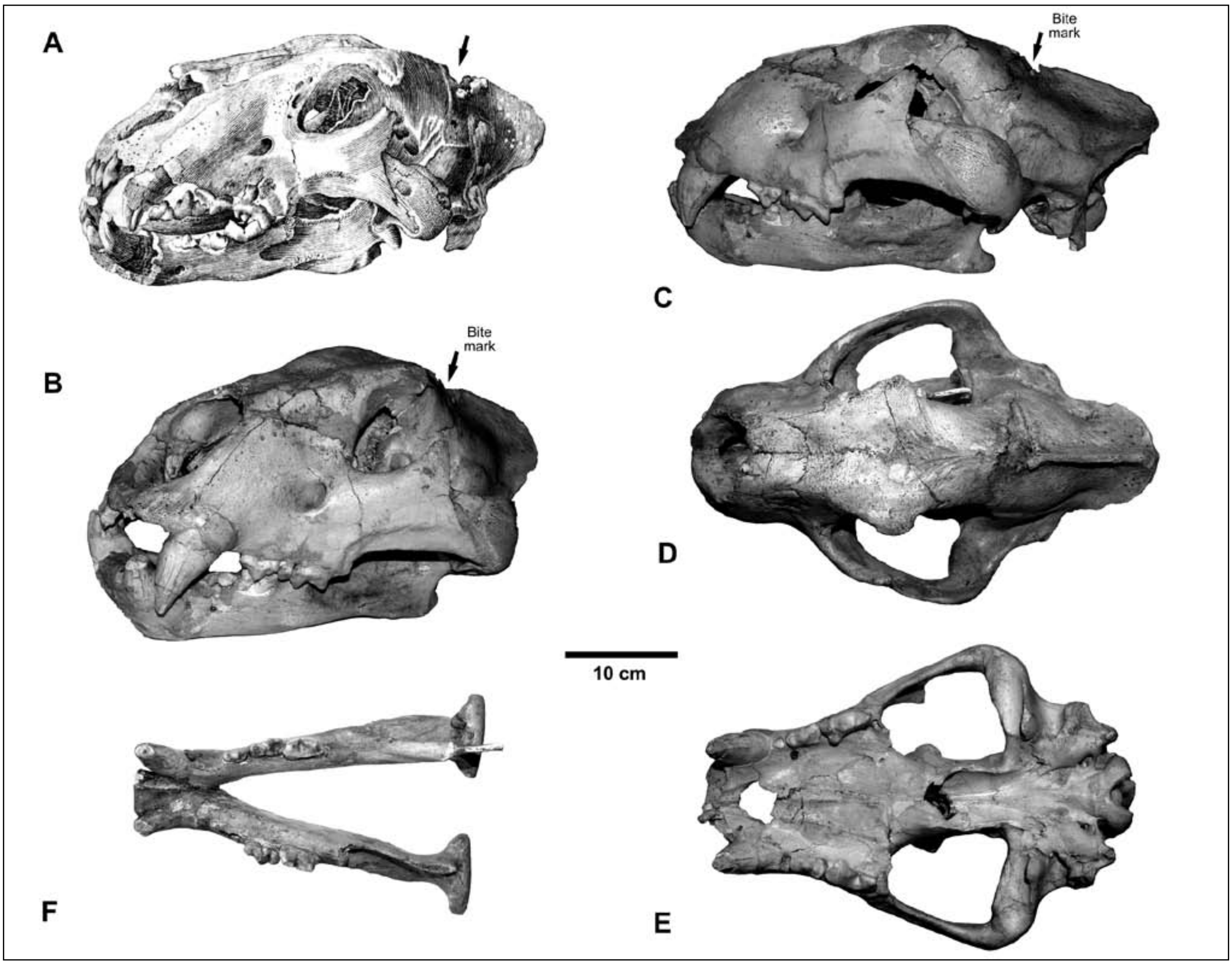

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3 Results and discussion

River terrace relicts in caves and valley genesis in Upper Franconia

Neischl (1904) remarked first, that sediments in caves along Upper Franconia river valleys are important for the landscape and glacial dewatering system reconstruction. The first identifications of river terraces and their possible elevations were discussed by Spöker (1952) for the Franconia Pegnitz valley. Problems of the valley genesis and dating including micromammal fauna containing caves (e.g. Brunner 1933, 1954) were reviewed (Habbe 1989). Only coarse karst evolution models were presented, especially for the earlier "Cretaceous to Tertiary" periods, but not in detail for the Pleistocene valley genesis (cf. Groiss et al. 1998). A new discussion about Plio-/Pleistocene river terraces in the valleys of Upper Franconia appeared with the new sedimentological research at Sophie's Cave of the Ahorn Valley (Diedrich 2013a). At Zoolithen Cave along the Wiesent Valley, the entrance is 130 m above modern river level and must have been flooded postglacially in the Late Pleistocene, as dated by cave bear tooth morphology and stratigraphy (Diedrich 2011a, 2013a; Fig. 2). This presented a new idea in the understanding of the much more rapid valley genesis which is further discussed here, but can be completed only with further studies of the many caves along the river valleys. A first model for the Wiesent Valley branching Ahorn Valley has already demonstrated the exact elevation estimates of Middle (one terrace) to Late Pleistocene (three terraces, Diedrich 2013a) Ailsbach River terraces, whereas the different cave bear species/subspecies are highly important for the sediment dating. Those cave sections cannot yet be correlated herein simply to the Wiesent Valley terraces, but both have similar sedimentary sequences in the Late Pleistocene. Important for the understanding of the valley genesis in Upper Franconia are the bonebeds (and different cave bear species/subspecies) and faunal remains in general with their taphonomic record, found especially in caves along the valleys.

Cave genesis, refill stages and animal den use

After a new systematic exploration of the cave in the spring of 2010, its sedimentology/morphology, cave history and geology can be reconstructed including former speleothem and micromammal age determinations, starting with its development in the Tertiary, when the cave was eroded into Upper Jurassic massive dolomites (cf. Groiss et al. 1998, Meyer & Schmidt-Kaler 1992). The lower cave areas and the upper parts whose levels developed under phreatic underground

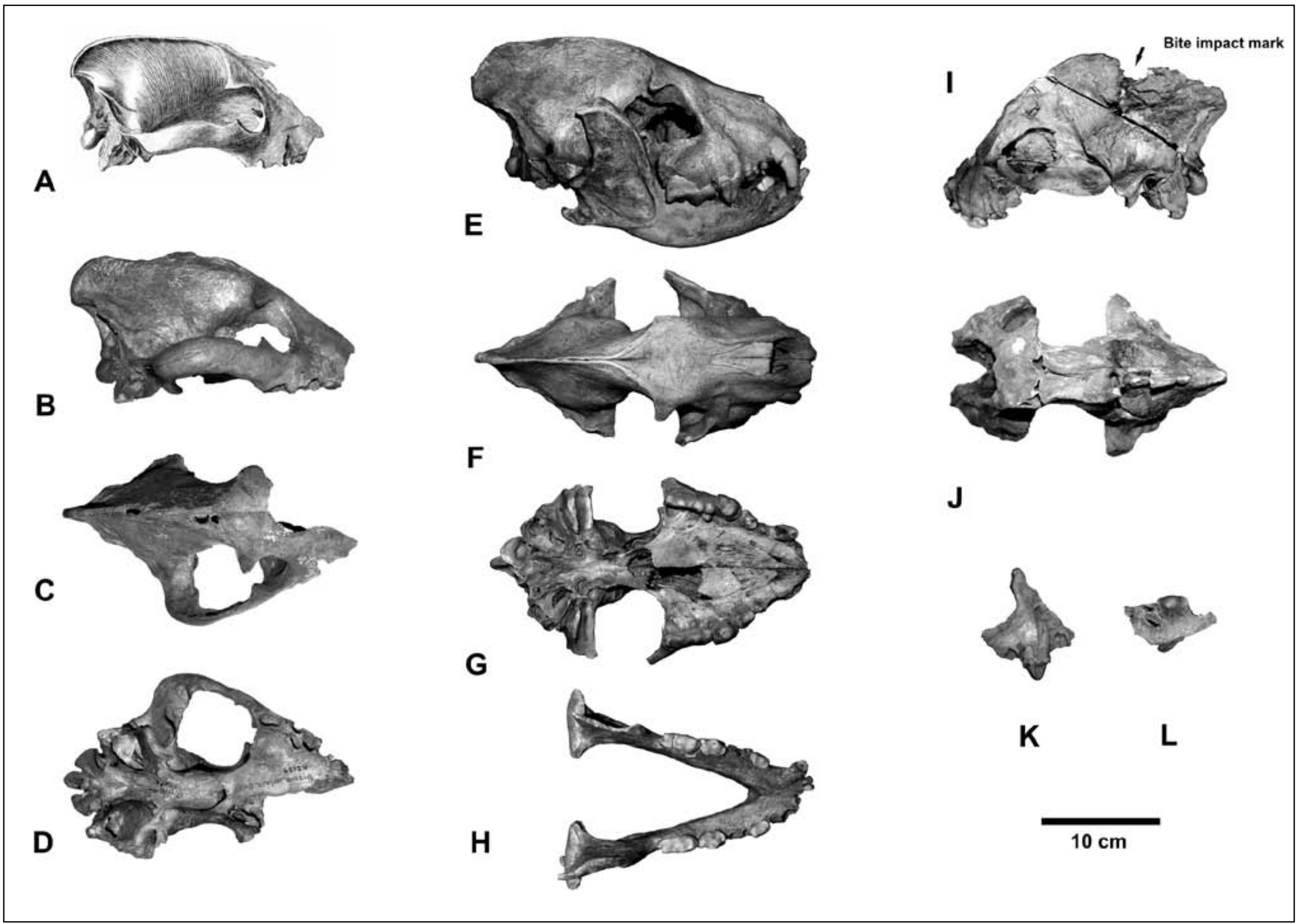

Fig. 10: A-D. Hyena Crocuta crocuta spelaea (Goldfuss 1823) holotype skull "Hyaena spelaea", mirrored, Late Pleistocene (Goldfuss -coll. GMB, drawing from Goldfuss 1823), E-H. New paratype skull (Ziegler-coll UE, from Diedrich 2011a), I-J. Skull with bite damage, original of Soemmering, 1828 (from Diedrich 2011a), K-L. Maxillary, original of Cuvier, 1822 (coll GZG).

Abb. 10: Hyäne Crocuta crocuta spelaea (Goldfuss 1823) Holotyp-Schädel "Hyaena spelaea",, gespiegelt, Spät-Pleistozän (Goldfuss-Slg. GMB, Teichnung aus Goldfuss 1823), E-H. Neuer Paratyp-Schädel (Ziegler-Slg. UE, aus Diedrich 2011a), I-J. Schädel mit Bissverletzung, Original von Soemmering, 1828 (aus Diedrich 2011a), K-L. Maxillare, Original von Cuvier 1822 (coll. GZG).

river conditions seem to have been connected by vadose speleogenesis, following the cleft system (cf. Poll 1972), which explains the often small and vertical partly-branched shafts which connect the three known cave levels (Fig. 2). There must be a deeper active system, resulting in gravity movements in vertical shafts deeper than the lowermost level (about 30 m).

A. Initial ponor cave ("Oligocene/Miocene")

The 550 a.s.l. high elevated Franconian Moggaster Cave was filled during the Early to Middle Palaeogene (= Palaeocene - Eocene, Groiss et al. 1998). The Zoolithen Cave (455 .a.s.l.) is intermediate in elevation between Moggaster Cave (550 a.s.l., Palaeocene/Eocene genesis) and Sophie's Cave (410 a.s.l., Pliocene genesis, cf. Diedrich 2013a) and seem to have been filled with their first sediments no earlier than the Neogene. Here an Oligocene/Miocene age for Zoolithen Cave is expected based on the elevations and dated refill history of Moggaster and Sophie's caves (cf. Groiss et al. 1998, Diedrich 2013e). The first fluvial sedimentary cycle of the Zoolithen Cave is the so-called "dolomite residuum/grey clay sequence" (sequence 1, Fig. 2), whereas those dolomitic sands and silts are typical products of dolomite weathering and fluvial erosion (Burger 1989). This series was deposited in level 1 in the Entrance Hall (Fig. 2) by an underground river of a Neogene Upper Frankonian Plateau landscape origin, which seem to have been present until the Pliocene (Diedrich 2013a).

B. Final ponor cave (Pliocene-Early Pleistocene)

In the Zoolithen Cave, the underground river continued creating two deeper ponor cave levels reaching 25 m deep. Typical scallops (cf. Jenning 1985) on the cave walls are best visible and preserved (i.e. without vadose overprint) in then lowermost level 3 (Fig. 2) in the newest discovered last third of the cave system (branching horizontal parts around the "Siebenschläfer" chamber). The dolomite sands are overlain by up to several meters of red homogenous clay, which contains up to 20 cm large caliche-like concretions in some areas. Those clays are sometimes covered by mud cracks on the

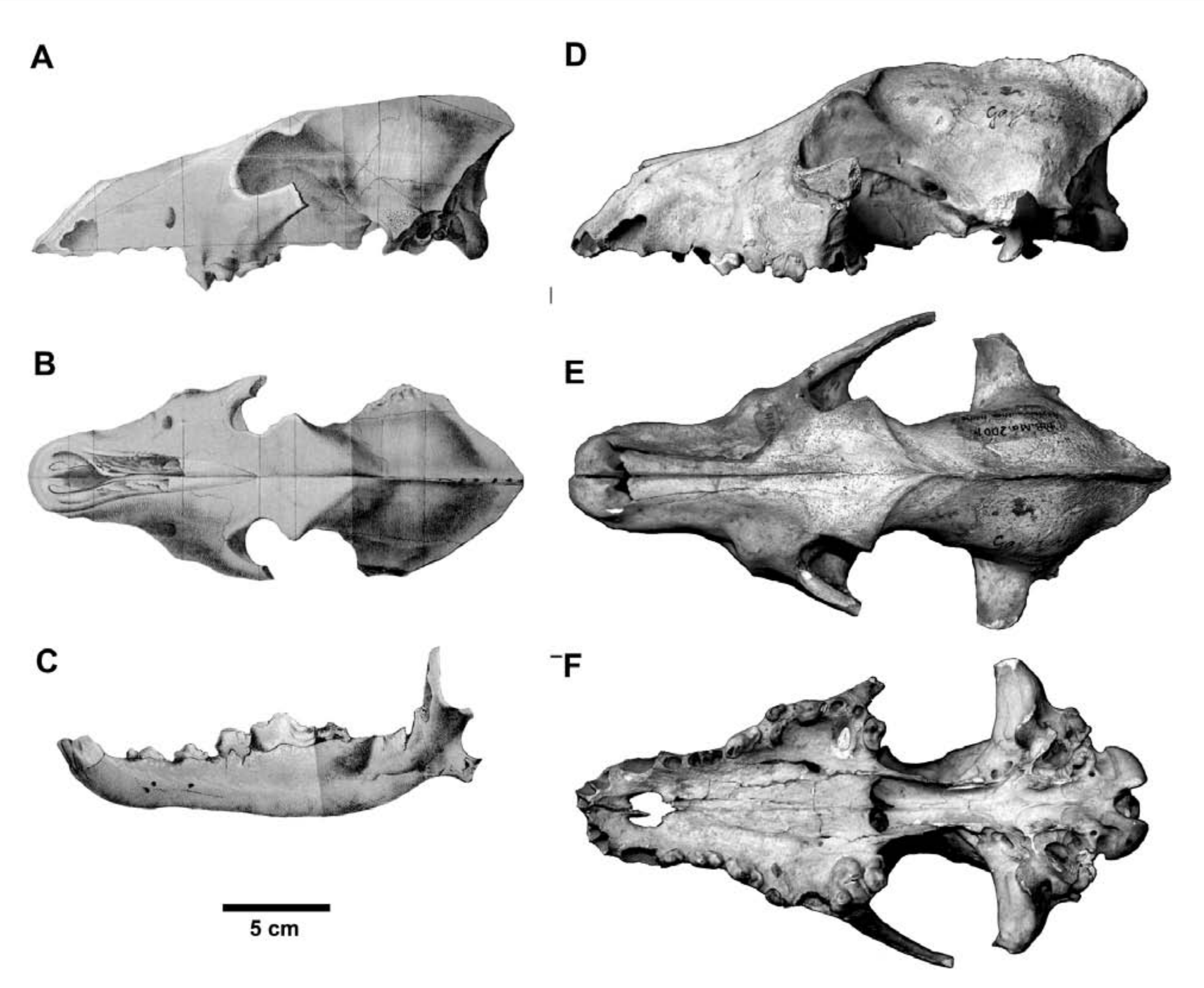

Fig. 11: A-C. Wolf Canis lupus spelaeus (Goldfuss 1823) lost holotype skull "Canis spelaeus" of a cub and mandible of an adult wolf (from Goldfuss, 1823). D-F. New lectotype skull (Rosenmüller 1794-coll. MB).

Abb. 11: A-C Wolf Canis lupus spelaeus (Goldfuss 1823) Verlorener Holotyp-Schädel „Canis spelaeus" eines Jungtieres und Unterkiefer eines adulten Wolfes (aus Goldfuss, 1823). D-F. Neuer Lectotyp-Schädel (Rosenmüller 1794-Slg. MB).

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uppermost surfaces (Fig. 2) which might date into Pliocene/ Early Pleistocene. Absolute dating is not yet available, but a comparison to the Pliocene/Early Pleistocene similar fluvial dolomite sand/clay sequence series sediments of the Sophie's Cave (Diedrich 2013e) and the Bing Cave (Brand 2006) underground river sediments permits a coarse preliminary dating. In the Zoolithen Cave those fluvial series are at higher elevations of about 445–420 a.s.l. (Fig. 2, therefore expected to be older) and in Sophie's Cave at an elevation of 410–400 a.s.l. (expected to be younger). The elevation of this sediment series is even different within the Zoolithen Cave, and sediments are found undisturbed below speleothem layers only in the "second cave level" (Fig. 2), which is some meters deeper than the sedimentary series of the Neogene (level 1 = Entrance Hall). First gravitational vertical transport below the massive speleothem layer (well seen in the Lehmgrube and Siebenschläferkammer, Fig. 2) of those sediments or even possibly earthquakes are documented by micro-horst structures (branch of Säulenhalle, Fig. 2) within the yellowish-white silt/fine sand layers. Such earthquake signs in caves are also reported for the "Middle Pleistocene" of Franconia by Spöker (1952) and Diedrich (2013a), which would indicate an uplift of Franconia even in the Ice Age, which explains fractured speleothems, or speleothem fragment layers (e.g. in Zoolithen Cave layer below first speleothem phase in the Aufzugsschacht, Fig. 2).

C. Vadose Cave (Middle Pleistocene – first speleothem deposition)

The red and mud-cracked clays demonstrate the drying of the cave, followed by a humid warm period. During this time the main (thickest) Middle Pleistocene speleothem layer developed, and also formed the larger stalagmites/stalactites in the cave. A stalagmite age determination (sample ZooH-Si2; first speleothem generation) is reported around 342,050 ± 71.400 years for samples of the Aufzugsschacht section (cf. Kempe et al. 2002) which corresponds to the MIS 9 interglacial period after the Holstein Interglacial at the early Saalian of the Late Middle Pleistocene (cf. Gibbard & Cohen 2008). After the speleothem deposition at the end of the Middle Pleistocene gravitational sediment transport happened all over the cave and more extensively later in the Late Pleistocene, whereas at many places today spaces between the clay surface and speleothem layer are between 0.5 to 2 meters. Damages like shedding on cracked and healed stalagmites (Fig. 2), seem to result from such earthquakes or gravity movements on the clay sediments, and are not to interpret as signs of an "Ice Cave".

D. Dry cave – cave bear, hyena, wolf den (Early-Middle Late Pleistocene)

One articulated early-adult male cave bear skeleton and one skeleton of a cub, still being present in-situ, were mapped in the central but high elevation cave area ("Säulenhalle" and "Zaunikhalle", Fig. 14). These are important to understand the cave bear bone taphonomy and possible original hibernation areas, and the flood directions. Those are in areas which are difficult to access, and isolated by vertical shafts. Their positions would fit to the theory that cave bears hibernated as deep in caves as possible to protect themselves against top predators, especially lions (Diedrich 2011b). The

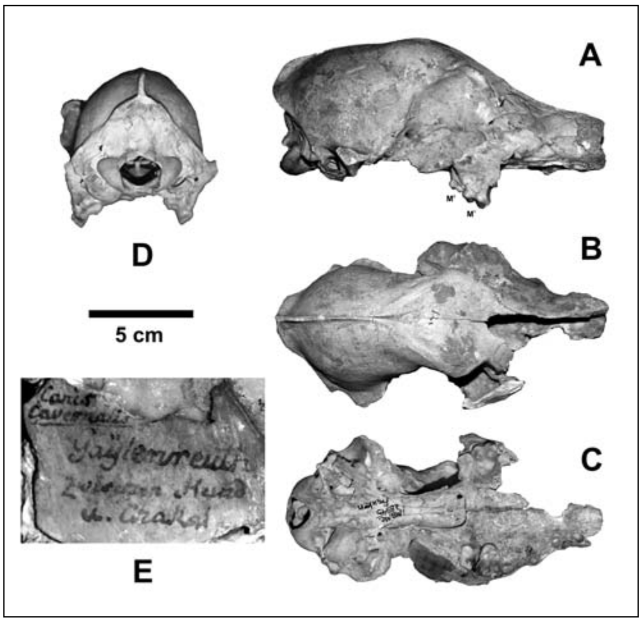

Fig. 12: Dole Cuon alpinus cavernalis (Rosenmüller 1794). A. Holotype skull "Canis cavernalis" of an early adult, Middle or Late Pleistocene (Rosenmüller 1794-coll. MB).

Abb. 12: Rotwolf Cuon alpinus cavernalis (Rosenmüller 1794). A. Holotyp-Schädel "Canis cavernalis" eines subadulten Tieres, Mittel- oder Spät-Pleistozän (Rosenmüller 1794-Slg. MB).

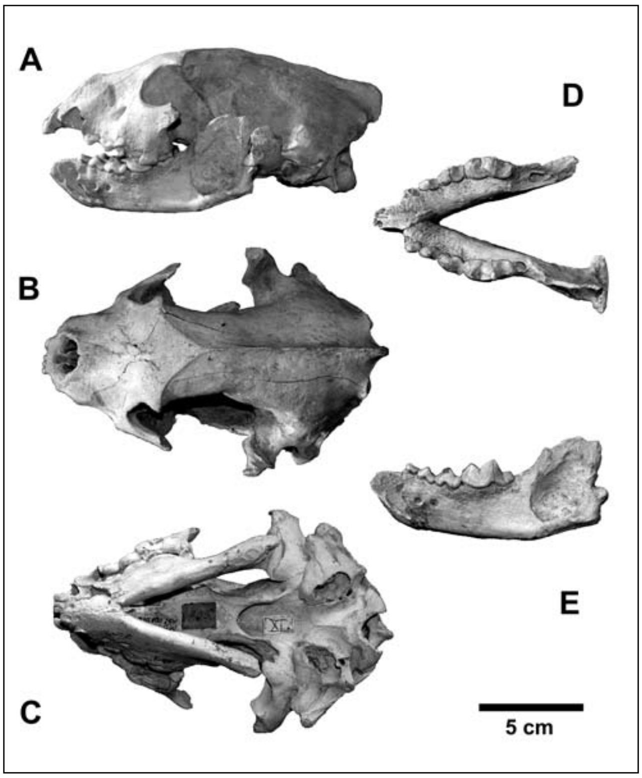

Fig. 13: Wolverine Gulo gulo spelaea (Goldfuss 1818) holotype skull (coll. MB), today attributed to Gulo gulo Linnaeus, 1758 (therefore no longer valid holotype).

Abb. 13: Vielfraß Gulo gulo spelaea (Goldfuss 1818) Holotyp-Schädel (Slg. MB), heute zu Gulo gulo Linnaeus, 1758 gestellt (daher kein valider Holotyp).

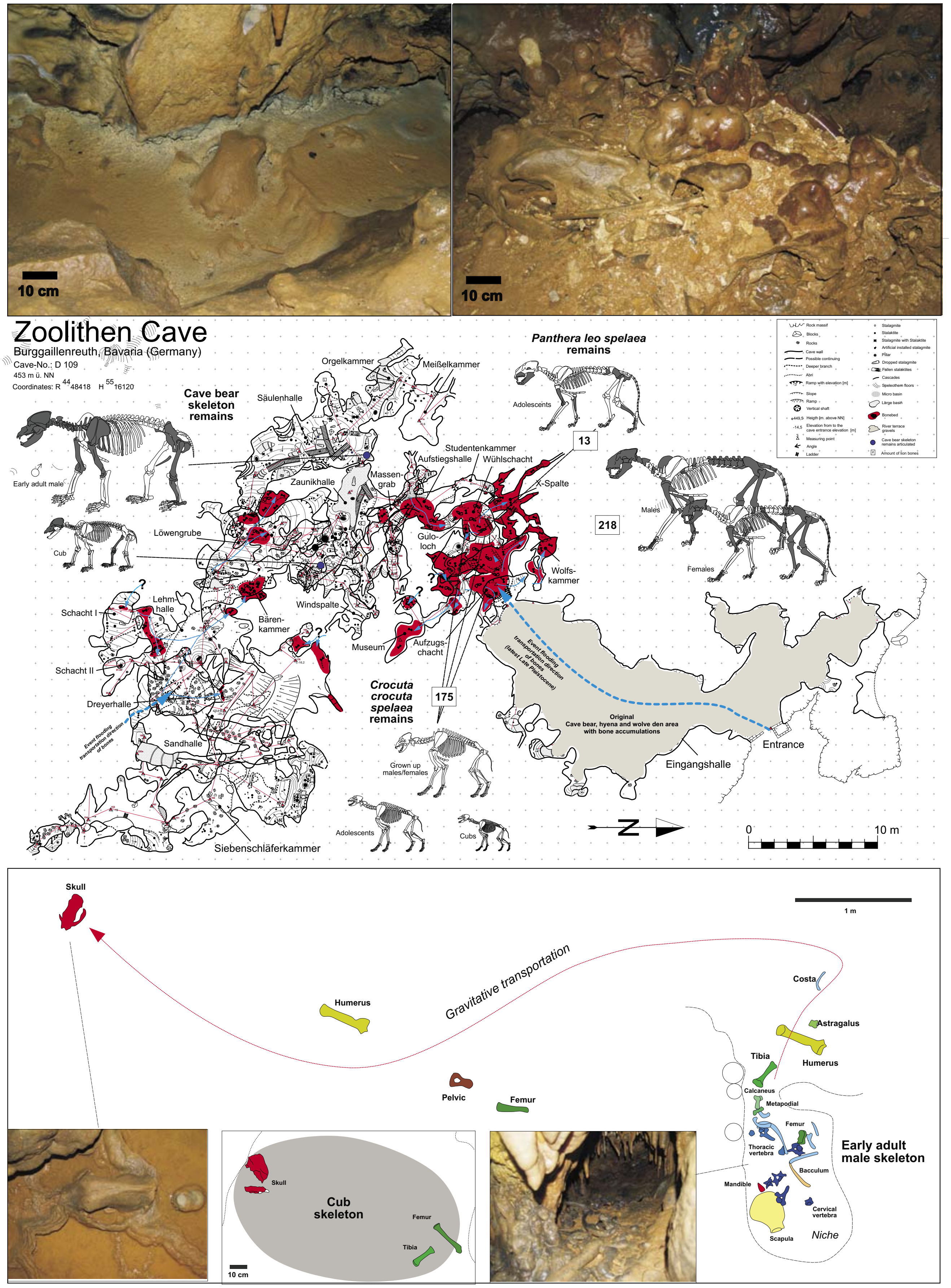

Fig. 14: Different cave bear taphonomy in Zoolithen Cave. Bones redeposited by floods accumulated in bonebeds (red) and two more or less articulated skeletons of a cub and early adult male, which skeleton parts are still on place.

Abb. 14: Unterschiedliche Höhlenbären-Taphonomie in der Zoolithenhöhle. Durch Flutung umgelagerte Knochen, akkumuliert in Bonebeds (rot), und zwei mehr oder weniger artikulierte Skelettreste eines Jungtieres und eines frühadulten Bären, die in situ liegen.

two incomplete skeletons were found on the "upper cave level", where the Late Pleistocene floods obviously had no impact at all, so it remains unclear how those bears could have reached the "Säulenhalle" and "Zaunikhalle". The vertical shafts surrounding those are deep and nearly impossible to climb. The early adult male skeleton is most probably of an *U. ingressus* species (skull shape and large bone proportions, covered and fixed by speleothem layer) in a niche – which was his hibernation "nesting area" (Fig. 14), and shows well the slow gravitational movement on speleothem surfaces in chambers. First the skull and larger bones such as the limb bones or the pelvic drifted downwards, through the action of dripping waters.

The hyena and lion remains in the cave bear bonebeds must have accumulated by primary deposition most probably over some thousands of years, from several hyena populations over many generations during the early to beginning of the late Late Pleistocene (Diedrich 2011a/b). Already in the Entrance Hall, most probably cannibalistic chewed hyena bones (Figs. 16) indicate carcass movements and damages of the material. Cave bear, hyena or lion bones themselves have sometimes well-preserved irregular chewed margins (= zigzag margins) and bite marks (Fig. 16) resulting from large carnivore activities (resulting from the breaking/scissor dentition). Similar bone bed taphonomic studies have been recently performed at Sophie's Cave, where cave bear scavenging was convincingly proven on partly articulated vertebral columns of individual skeletons which were found with many other scattered and often bite-damaged bones or articulated body parts (Diedrich 2013e). Fragmentation and damage of cave bear bones must have resulted mainly from the well-known hyena scavenging activities (especially bone crushing, Fig. 16, Diedrich 2011a), and also by a few lion predatory activities (only joint chewing) and finally by wolf scavenging activities (cf. Diedrich 2013b). The Zoolithen Cave taphonomic study and model (Fig. 17) of the "historically non-collected" incomplete cave bear bones shows the same incomplete bone preservations that is being reported from many European caves (Diedrich 2009, 2013a/b/c), if incomplete material is included in the studies in such cave bear dens. The new interpretation of scavenging activities by hyenas, and the specialization in middle mountainous boreal forest regions of cave bears as a result of the absence or scarcity of steppe megafauna prey animals (especially mammoth, rhinoceros and steppe bison) in the Zoolithen Cave was recently proven by the large hyena population and den use as a cub raising and commuting den type (Diedrich 2011a), and also the very large lion population (Diedrich 2011b).

Skull pathologies – Neanderthal or animal conflicts?

Groiss (1978) believed the figured frontal holes and damages to adult cave bear skulls (two different species: *U. spealeus* subsp., *U. ingressus*, Fig. 17) were the result of "Palaeolithic human hunters" (i.e. cave bear hunting and "spear attack" signs), but in the surrounding cave not one stone tool or Palaeolithic site is known. The only two small Middle Palaeolithic cave sites in the area are near Große Teufels Cave (Diedrich 2013a). The incomplete bear skulls are obviously in a hyena and lion predatory context and have damage to each left frontal; in one case the deep penetration is nearly healed, whereas in the other skull the hole is still open

Fig. 15: Cave bear bone taphonomy in the "Massengrab Chamber" of Zoolithen Cave with untouched and still on-place preserved non-sediment containing packed and loose cave bear bonebeds (Photos H. Schabdach, FHKF).

Abb. 15: Höhlenbären-Knochentaphonomie im „Massengrab-Raum" der Zoolithenhöhle mit unangetasteten und noch Original ohne Sediment dicht gepackten und lose erhaltenen Höhlenbären-Knochenschichten (Photos H. Schabdach, FHKF).

and only the surrounding bone shows an early stage of the healing process (Fig. 17). The interpretation here is different in presenting a cave use model including all three large carnivores (lions, hyenas and wolves) and herbivorous cave bears (Fig. 17). There, mainly lions and possibly hyenas and wolves produced osteological damage during their attacks on the cave bears, although mostly during scavenging activities. Overlooked completely by Groiss (1971, 1978) are bite wounds on the sagital crests of the steppe lion holotype skull from the Zoolithen Cave (Diedrich 2008, 2011b). The most famous hyena skull with a really deep sagital bite wound (Soemmering von 1828; Diedrich 2011a) is another excellent case of a skull with bite damage from Zoolithen Cave. All three specimens have canine tooth bites damage in the areas of the skull where carnivores/bears typically inflict damage during predatory or defensive attacks – the head is the main focus of attack – as in modern hyena/lion conflicts (Diedrich 2011c, Rothschild & Diedrich 2012).

Ursus ingressus or Ursus spelaeus spelaeus – what is the holotype skull?

Whereas the systematics of all the bears of the Zoolithen

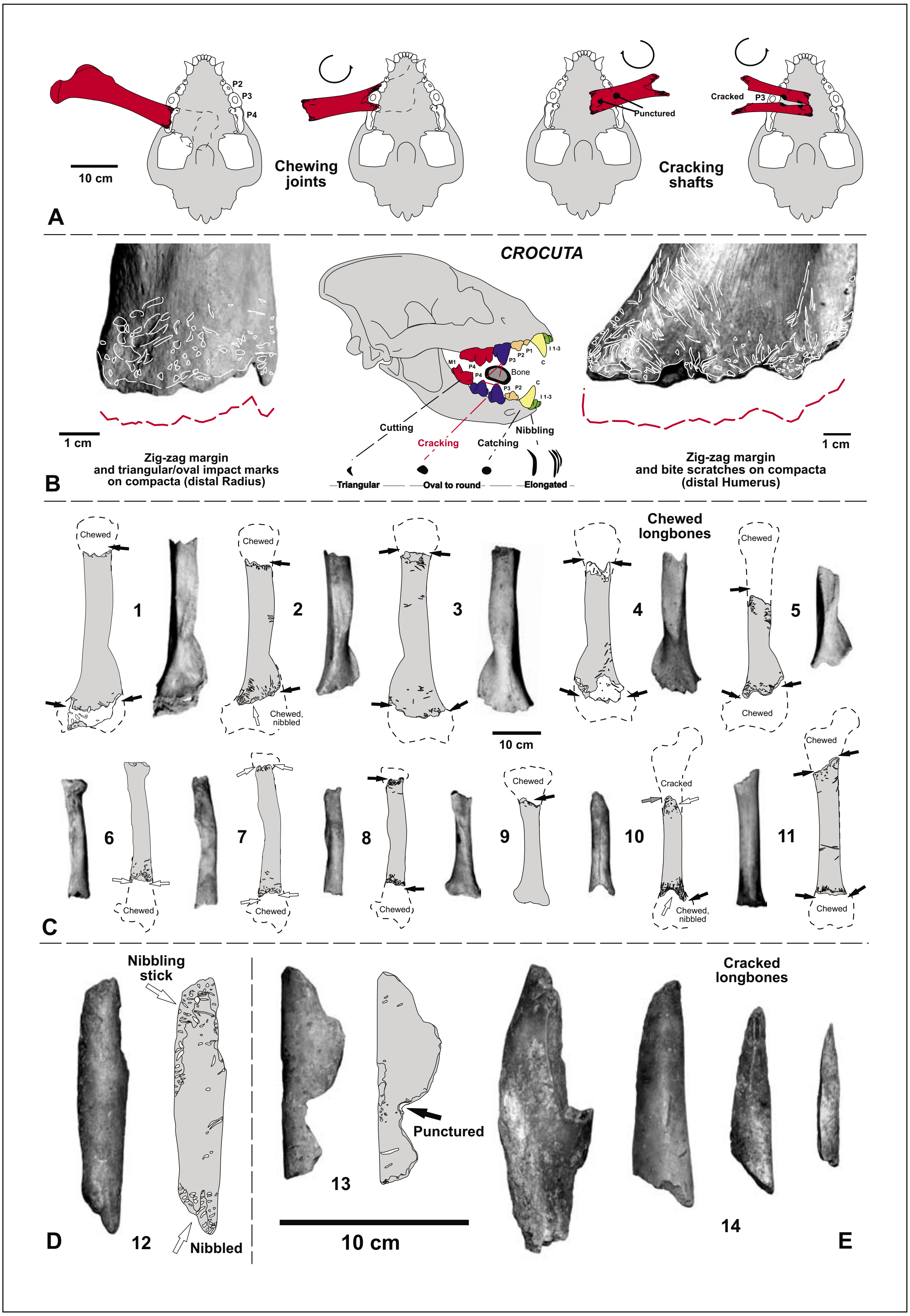

Fig. 16: Postcranial cave bear bones from the Zoolithen Cave and damage history by chew, bite and crush damages (mainly caused by Ice Age spotted hyenas). A. Damaging of a cave bear cub femur. B. Typical triangular, oval and elongated bite mars resulting of different teeth on distally chewed longbone shafts. C. Selected samples of chewed cave bear longbones. D. "Nibbling stick" – a bone fragment used mainly by hyena cubs for teething purposes. E. Fragments of cracked cave bear longbones.

Abb. 16: Postcraniale Höhlenbären-Knochen aus der Zoolithenhöhle und Zerstörungsgeschichte durch Abschneiden, Verbeißen und Zerknacken (primär verursacht durch eiszeitliche Fleckenhyänen). A. Zerstörungsgeschichte eines Jungbären-Femurs. B. Typische triangulare, ovale und längliche Bissspuren, die von unterschiedlichen Zähnen der Hyänen herrühren und an den distalen abgefressenen Langnochenschäften zu finden sind. D. „Knabberstick" – ein Knochenfragment, das besonders von Junghyänen zum Abzahnen verwendet wurde. E. Langknochenfragmente zerknackter Höhlenbärenknochen.

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Cave has not yet been completely solved, the most recent DNA-analysis of cave bears distinguished at least two different species/subspecies, with *Ursus spelaeus spelaeus* (Rabeder & Hofreiter 2004), and *U. ingressus* (Rabeder & Hofreiter 2004) extant during the Late Pleistocene. The „cave bear" holotype (Fig. 3C) seems to belong to the latter species/subspecies. Similar results have been published for the Sophie's Cave cave bears (Diedrich 2013). Finally, even *Ursus arctos* (Holocene) and another brown bear type of the Late Pleistocene seem to be represented in Zoolithen Cave.

Dating of the cave bears and species taxonomy

Some cave bear teeth in the bonebeds (*Ursus spelaeus spelaeus sensu* Hofreiter et al. 2001) were dated by radiocarbon reaching nearly the limit of this method (around 40.484 BP, Hofreiter et al. 2001) suggesting cave bears have used the cave as a den until the early Late Pleistocene. Other direct and indirect dating methods, which have to be verified with new methods, dated all bonebed material within the early to late Late Pleistocene between "72,000–24,000" BP (cf. Groiss et al. 1998). Rosendahl & Kempe (2004) dated with modern methods some speleothems at the bottom of the cave (Aufzugsschacht) and suggested a mixed bonebed-fauna to range from the MIS 3–8 (late Middle Pleistocene, late Saalian to late Late Pleistocene). However, the megafauna was present already as herein now corrected by the rediscovery of a nearly complete *Ursus deningeri* skull (Fig. 8), which was misidentified as "*Ursus arctoides* Reichenau 1904" (brown bear, after Rosenmüller 1794). This skull is securely dated as MIS 6–8 (late Holsteinian interglacial or late Saalian glacial). Also the P4 tooth morphotypes (Type A) newly presented here after first studies by Rabeder (1999), that are intermediate between deningeroid and spelaeoid cave bears (see also Fig. 5) support the view that older cave bear populations were present. The Zoolithen Cave is the earliest known cave bear den in Upper Franconia, starting with cave bear denning in the cave during MIS 8-9 (Holsteinian-beginning of Saalian, Fig. 5). Using cave bear skull morphotypes (cf. the new compiled "cave bear clock" in Diedrich 2013b), cave bears seem to have established peak populations during the Eemian interglacial (126,000 BP). These smaller classical cave bears (most P4 are of Type C–D) of *Ursus spelaeus eremus/spelaeus* (cf. Fig. 5) occupied the cave during the early to middle Late Pleistocene (MIS 3–5d), whereas *U. ingressus* forms seem to have used the Entrance Hall during the late Late Pleistocene (32–25,000 BP), but also seem to have climbed deeper into the "Säulenhalle" (cf. Fig. 14). The cave use by carnivore and cave bear megamammals ended with the glacial peak around 25,000 BP, following climate change, flood events and cave entrance collapses.

E. River terrace floods (early post glacial peak of the Latest Pleistocene)

In the largest room of the cave, the Entrance Hall, the section starts above a speleothem layer with a medium-brown, large, well-rounded, limestone pebble layer (Fig. 4). In this ~60 cm thick layer, a few cave bear bones or teeth (also P4) have been found only in the lower part, all dark brown (iron/manganese mineral impregnation) in their color. Above those gravels a dark-brown, medium-sized, dense-packed gravel layer (including rounded reworked speleothem gravels) is similar, but the yellowish, loess-like, one meter thick gravel sediment, is without any bone records. Those gravels are isochronous to the bone beds. The Late Pleistocene sedimentary fluvial cycle continues with the bone beds which vary in thickness as a result of their occurrence mainly in the vertical shafts and its branches (Fig. 4, 14, Diedrich 2011a). The sediment between the densely-packed bones (Fig. 15) is coarse grey-greenish mixed dolomite silt/sand, often consisting of very small white speleothem pieces. All the bones are in secondary positions (Groiss 1979), and must have been washed at some places up to 30 m deep (e.g. Wolfskammer). They are in most cases non-rounded and even chewing marks are well preserved (Fig. 16), indicating only short-distance and rapid redeposition within the cave. In total, on all the megafaunal and hyena bones fluvial damage or polishing of edges is rarely observed, which supports the idea of rapid transport of bones, not of "animals and carcasses as described by the "great deluge flood scenario" by Esper (1774), but who was correct in the general idea of "floods". The bone material was washed from two different areas and directions of the cave into its central parts (Fig. 14). Most material must have been transported from the Entrance Hall to the central vertical and diagonal shafts (= Aufzugsschacht, Wühlschacht, Guloschacht, Museumsschacht, Wolfsschacht areas, Fig. 14). In the Entrance Hall, the original bone-layers were nearly completely replaced by the river terrace gravels, which were deposited only in the upper layers also in the first vertical shaft, the Aufzugssschacht, but not deeper. The other flooding direction was estimated to have washed bones from their primary deposition site in the Dreyer Hall area into the Löwengrube Chamber and other parts of the western cave (Fig. 14), but there, the river gravels are absent. Nearly all the bones must have been transported in the final Upper Pleistocene (LGM/early Postglacial) into the middle cave part by floods due to a highly elevated Wiesent River terrace and braided Pre-Wiesent River system which must have risen enormously to an elevation of 455 a.s.l. – today's entrance level is now 130 above the today's Wiesent River valley elevation (Diedrich 2011a), which cannot be explained by natural river terrace stratigraphy, and only by glaciation models. The floods and river gravels being present only as "Pre-Wiesent River terrace relicts" in only the Entrance Hall area can be dated indirectly into the high to early post high glacial period with cave bear remains which were found below the river terrace gravels in the Entrance Hall (Fig. 3). Those large cave bears (bones brown in colour) are of *U. ingressus* which existed about 32,000–25,000 BP in Europe (Hofreiter 2002, Pacher & Stuart 2008, Stiller et al. 2010, Münzel et al. 2011). In similar elevated caves (e.g. Oswald Cave, opposite Wiesent Valley side) similar river terrace dolomite gravels are preserved again in relicts, and are absent along the steep valley margins. The final Late Pleistocene flooding events caused further gravitational vertical transport which caused speleothem collapses and sliding of those fragments into the vertical shafts. Different speleothem generations with different growth angles (well seen in the Lehmgrube, Fig. 4) on such moving speleothem slabs prove long-term mass-movement activity.

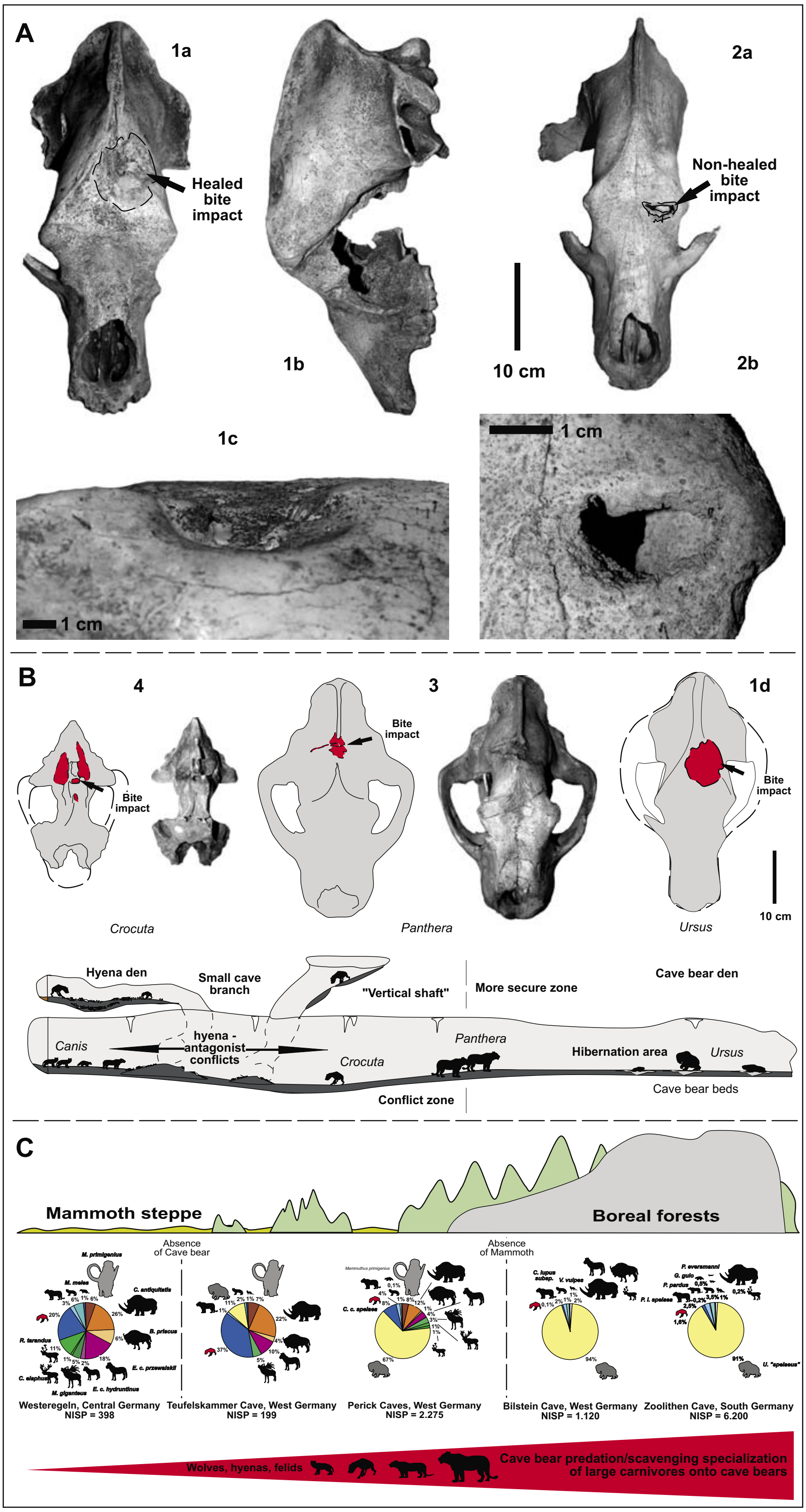

Fig. 17: Bite pathologies on skulls and conflict model for the Zoolithen Cave. A. 1. Senile male cave bear skull (Ursus ingressus) with bite damage in the frontal being partly healed (UE no. 142), 2. Early adult cave bear skull (Ursus spelaeus subsp.) with non-healed bite damage in the frontal (UE no. 132). B. 3. Lion Panthera leo spelaea holotype skull with bite scratch on the saggital crest (original to Goldfuss *1810). 4. Hyena Crocuta crocuta spelaea skull with massive bite damage on the saggital crest (original to* Soemmering *1828). Cave model with conflict zones and antagonism between all three large predators (lions, hyenas, wolves) and herbivorous cave bears hibernating as deep as possible in their den cave to protect against the carnivores. C. Cave bear hunt/scavenging specialization in boreal forest mountainous regions (modified after* Diedrich *2011a).*

Abb. 17: Bissverletzungen an Schädeln und Konfliktmodell für die Zoolithenhöhle. A. 1. Seniler männlicher Höhlenbären-Schädel (Ursus ingressus) mit teilverheilter Bissverletzung im Frontalbereich (UE no. 142), 2. Frühadulter Höhlenbärenschädel (Ursus spelaeus subsp.) mit unverheilter Bissverletzung im Frontalbereich (UE no. 132). B. 3. Löwen Panthera leo spelaea Holotyp-Schädel mit Biss auf dem Scheitelkamm (Original von Goldfuss *1810). 4. Hyäne Crocuta crocuta spelaea-Schädel mit massivem Bissschaden auf dem Scheitelkamm (original von* Soemmering *1828). Höhlen-Modell mit Konfliktzonen und Antagonismus zwischen allen drei großen Prädatoren (Löwen, Hyänen, Wölfe) und herbivoren Höhlenbären, die tief in Höhlen zum Schutz gegen die Raubtiere überwinterten. C. Spezialisierung auf Höhlenbären-Jagd/Fressen in borealen Nadelwald-Gebirgsgebieten (verändert aus* Diedrich *2011a).*

F. The Alleröd (second speleothem genesis and humid cave)

Loose limestone gravels in the Entrance Hall area on the top of the river gravels which are partly cemented by the younger speleothem generation indicate a final Late Pleistocene frost impact. Speleothem dates (uranium/thorium) of a candle stalagmite (last speleothem generation) on the bone breccias (Aufzugsschacht) give ages on the upper and last speleothem layer of about 11,720 ± 125 BP (older data from 1950, see Poll 1972), which is calibrated now 13,720 ± 125 BP. Those final Upper Pleistocene aged thin candle-like stalagmites are typical throughout the cave system (Fig. 4).

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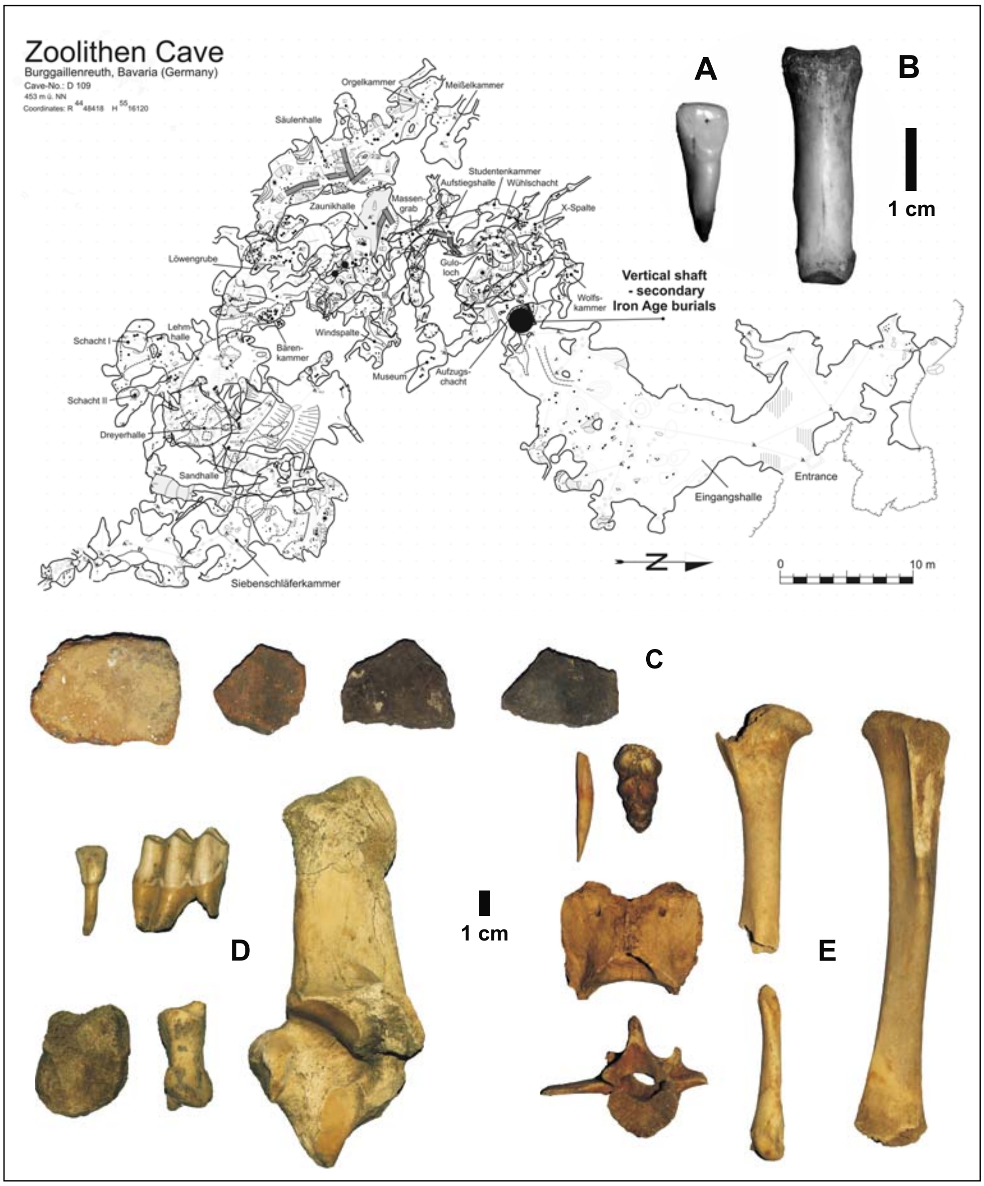

Fig. 18: Iron Age (La Tène) and Holocene bone finds – from the dump infron tof the cave (originating from the Wühlschacht which was secondary burial place). A. Human incisive tooth and B. Human hand phalanx I. C. Some selected pottery sheds. D. Domestic small cattle teeth and bones. E. Domestic or wild pig teeth and bones.

Abb. 18: Eisenzeit (La Tène) und Holozän-Knochenfunde – aus der Halde vor der Höhle (ursprünglich aus dem Aufzugsschacht der der Sekundärbestattungsort war). A. Menschen-Incisivus-Zahn und B. Menschen-Hand-Phalanx I. C. Einige selektierte Keramikscherben. D. Kleines Hausrind, Zähne und Knochen. E. Haus- oder Wildschwein, Zähne und Knochen.

These seem to be the result of the latest Upper Pleistocene Alleröd climatic change to a warmer period (13,500–12,700 BP; cf. Kempe et al. 2002). At this time, higher vadose water activity resulted the last speleothem generation all over the Zoolithen Cave. This represents the end period of the massive Pre-Wiesent River terrace erosion in the Pre-Wiesent Valley, now at 130 m lower elevation (measured from Entrance Hall level). As demonstrated for Upper Franconia during the end of the Alleröd Epipalaeolithic, human reindeer hunters had already settled on rock shelters few meters above the today's river valley elevations (e.g. Ahorn and Wiesent Valleys, Diedrich 2013a). Possibly the bone beds also moved further downwards by gravity in some vertical shafts, and must have dropped at some places up to 30 m deep (e.g. Wolfskammer).

G. Holocene – Iron Age

The Holocene material was not well distinguished at all from the Pleistocene bones by Groiss (1971, 1979) giving an incorrect view of the "Pleistocene forest fauna" because it included domestic or Holocene wild animal remains (cf. Fig. 18). The Holocene bones were imported mainly by badgers, foxes and martens (*Meles, Vulpes*, *Martes*) to their cave den with different animals (*Felis*, *Lepus*, *Cervus*, *Capreolus, Sus*). Also Iron Age humans deposited domestic animal bones (*Bos*, *Sus*, *Ovis/Capra, Canis*), which were left in the Aufzugssschacht together with human bones (juvenile and adult longbones, mainly) and pottery (Fig. 18). Also in the Entrance Hall remains of the already known La Tène (Iron Age) culture (cf. Sommer 2006) are still present in the black sediments.

Conclusions

The sedimentological research gives a first overview of 12 accessible sections in the Zoolithen Cave along the Wiesent River Valley (Bavaria, Upper Franconia Karst, south-Germany). The cave has three main fluvial (two underground river, one valley river) sedimentary sequences, and two main speleothem phases. The first Neogene (Oligocene/Miocene) sediments are only found in the uppermost level of the Entrance Hall and consist of dolomitic sand/grey clay beds resulting from the early ponor cave stage and underground river. The second and third levels, up to 25 m deeper, formed in further underground rivers, which left facets and a second sedimentary series with a yellow dolomite sand/red clay series, being most probably of Pliocene/Early Pleistocene in age. Microtectonic structures in dolomite silt/sand layers and clay beds document tectonic activities, such as fractured stalagmites or a speleothem fragment layer. The top of the several meters thick red clay has mud cracks on the surface, and bat remains, indicating a dry cave stage. This changed to a vadose cave in which the first massive speleothem layer developed, dated about 342,050 ± 71,400 in the late Middle Pleistocene warm MIS 9 zone. From this time the oldest Upper Franconian cave bears, of *Ursus deningeri,* used the cave during MIS 6–8 as a den site, especially during the dry late Saalian period. The cave continued to by dry and was used mainly during the Eemian to late Late Pleistocene (MIS 3–5e) by cave bears for hibernation. P4 tooth morphology and skull shapes allow the separation of three species/subspecies during the Late Pleistocene: smaller *U. spelaeus eremus/spelaeus* and large *U. ingressus.* Two incomplete skeletons are still on place in the middle of the cave, indicating hibernation as deep as possible to protect against top predator attacks. Hyena clans used the Entrance Hall periodically as a cub-raising and commuting den, and are mainly responsible for the cave bear bone damage resulting from a scavenging specialization in boreal mountain forests regions. A large steppe lion population indicates also those lions to have specialized on cave bears, but with active hunts deep in the caves. Wolves must have also sporadically used the entrance area as den site, and must have fed on cave bears, too, as has been well demonstrated at the nearby Sophie's Cave. All megafaunal bones are of a boreal forest assemblage accumulated mainly in the Entrance and Dreyer Hall areas. At the High Glacial (= LGM, about 20,000 BP), a possible valley glacier situation model is presented here using three cave sites and sedimentary sequences around Muggendorf. Pottenstein and Kirchahorn. The Pre-Wiesent River valley was filled only at Muggendorf and the terrace built at 455 a.s.l. In the other areas, glauconitic sandy clays/gravels were found only at 410 a.s.l. elevation (Sophie's Cave, Große Teufels Cave), which makes correlations difficult. The dewatering direction might also have been opposite of the today's direction but more cave sections are needed to develop a more detailed model. The dolomite gravels are found today only as relicts in the caves on both valley sides around Muggendorf. In the Zoolithen Cave, the gravels replaced at least parts of the bone beds in the Entrance Hall, when the bones were washed by flood events into the middle part of the cave and, also from another side of a today's blocked entrance close to Dreyer Hall. This bone material was transported into the Löwengrube, Bärenkammer, and other parts surrounding the Lehmhalle and contains nearly no hyena, lion or wolf remains – those mainly used the Entrance Hall area. Stronger corrosion on speleothems (especially well below Dreyer Hall) and collapsed speleothem plateaus underline the massive flood impact at the end of the Ice Age (around LGM/Postglacial). Most of the bones were redeposited quickly by those floods (glacier melting waters and seasonally in spring time) in some cave parts and accumulated mainly in the vertical shafts and branching areas where they built up into bone beds several meters thick. With such an unexpected high river terrace position (if those gravels are river terrace layers and not side moraine till deposits flooded over glaciers into the caves), and high ground water level at the LGM, the "great deluge theory" of Esper becomes nearly "true" – he was right about the floods, but not with the transport of "live animals and complete carcasses" – indeed only animal bones were washed into the deeper parts of the cave.

There are no "Ice Age human" (Neanderthal or Cromagnons: Middle to Late Palaeolithics) records from the cave. After the floods the river terrace moved rapidly down (also demonstrated at Sophie's and Große Teufels caves – 50 meters deep erosion LGM/Post LGM) which can only be explained by the presence of valley glacier. Water masses from these valley glaciers caused the steep valley morphology and 130 m of lowering within only about 10,000 years. Finally at the end of the Ice Age in the in the Alleröd humid phase, another speleothem generation with typical candle-like speleothems developed in the Zoolithen Cave around 13,720 ± 125 BP. During the Holocene, in the first and second vertical shafts (Aufzugsschacht), Iron Age La Tène humans left numerous secondary burials (skulls and long bones with pottery and after-life food animal donations), but those were thrown only into the first deep vertical shaft. Many new finds of human bones including children and old persons found between the old excavation bone dumps, prove the use of this cave and surrounding caves (e.g. Esper Cave), as burial places – but only in the vertical shafts, this being typical for that time.

Remarks to the future – problems of cave protection and fossil collection

In the dump in front of the cave today, visitors are able to take "souvenirs", whereas professionals are prevented from saving remaining small bones and teeth by the "Archaeological Monument Survey of Bavaria" legislation. These remains are potentially important for the "region" (local museums project) and an international Natural Monument and potential UNESCO-world fossil heritage site designation. The cave is still in private hands and under control of the FHKF (rented the cave from recent owner). The public collections of the University Erlangen and Urweltmuseum Oberfranken or the Museum Tüchersfeld remain difficult to access, even for professionals, whereas even the Ministry of Culture and Education does not act at all positively. More positively, the Bavarian Landtag recently discussed the problems of collection accessibility in Bavarian Museums and Universities, the protection of the excavation spoil dump and the proposal of the author to make a "paleontological/archaeological" monument by purchasing the cave by the province and thereby preserving Europe's most famous Pleistocene cave fossil site (protection rejected by the Bavarian Landtag Petition no. HO.0594.16).

Acknowledgements

Access to the historic Rosenmüller collection of the Museum für Naturkunde Berlin of the Humboldt University was possible due to PD Dr. O. Hampe. Dr. B. Hilpert supported the study of the Groiss material from 1971 in the University Erlangen. The material study in the Goldfuss-Museum of the Rheinische Wilhelms University Bonn of the Goldfuss collection was possible by Dr. G. Heumann. The curator A. Currant of the Pleistocene collection in the British Museum of Natural History London gave access to the material from the Zoolithen Cave. Bone material was studied with support of T. Rathgeber in the Staatliches Naturhistorisches Museum Stuttgart. Dr. R. Rabold supported the work on the Graf zu Muenster collection in the Urweltmuseum Oberfranken in Bayreuth. H. Buchhaupt allowed to the author to figure material from his private collection. I thank especially J. and M. Conrad, B. Nerreter, H. Schabdach, M. Harder, and others of the Forschungsgruppe Höhle und Karst Franken e.V. Nürnberg for the new exploration and cave survey support and collection access, and also when History Channel was filming the "lions of the Zoolithen Cave" there in 2010. Furthermore I thank Dr. F. Knolle and D. Mol for their critical and helpful reviews of the first manuscript draft such as Prof Dr. D. McFarlane for a spell-check and comment support of the final version. Final supporting comments were made by PD Dr. H. Freund.

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