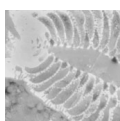


Ernstbrunn Limestone and Klentnice beds (Kimmeridgian–Berriasian; Waschberg-Ždánice Unit; NE Austria and SE Czech Republic): state of the art and bibliography

SIMON SCHNEIDER, MATHIAS HARZHAUSER, ANDREAS KROH, ALEXANDER LUKENEDER & MARTIN ZUSCHIN



This paper summarises the knowledge of the Ernstbrunn Limestone and Klentnice beds and provides a comprehensive scientific bibliography on these strata. At outcrop both lithostratigraphic units occur as so-called “tectonic klippen” inserted in the autochthonous sedimentary succession of the Waschberg-Ždánice Unit. The latter is a distal, transitional Alpine-Carpathian tectonic nappe that extends between the Danube and Thaya rivers in Lower Austria and southern Moravia. Both strata have also been identified from several drillings and belong to the autochthonous Mesozoic succession deposited on the southern slope of the Bohemian Massif. Ammonite biostratigraphy and micropalaeontology reveal a Kimmeridgian to early Late Tithonian age for the Klentnice beds and a Middle Tithonian to Berriasian (?Hauterivian) age for the Ernstbrunn Limestone. The Ernstbrunn-Pavlov Carbonate Platform gradually developed from the Klentnice beds and persisted during the Jurassic–Cretaceous transition. The rock record provides evidence for lagoonal and patch reef facies and fringing ooid-oncoid bars, all attributed to the Ernstbrunn Limestone. The gradual transition to more distal, siliciclastically-influenced settings is formed by the upper portion of the Klentnice beds that developed as lateral equivalents of the carbonates. In places, both strata are highly fossiliferous. The lagoonal limestones preserve a megadiverse, mollusc-dominated assemblage of more than 500 species of invertebrates and calcareous algae. Most abundant taxa include *Heterodicerias* and *Epidicerias* bivalves (basal rudists), nerineid gastropods, decapods, ammonites, corals, and dasycladaceans. As a result of diagenetic aragonite loss, the fauna of the Klentnice beds appears impoverished and is dominated by echinoderms, calcareous sponges, and brachiopods. A remarkably large portion of the complex depositional and natural environment of the Ernstbrunn Limestone and Klentnice beds is preserved both at outcrop and in subsurface and still awaits systematic scientific effort in various fields. • Key words: tectonics, stratigraphy, Tithonian–Berriasian, Upper Jurassic–Lower Cretaceous, northern Tethys margin, carbonate platform.

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This article intends to summarise the current state of knowledge on the facies, biota, and age of the Ernstbrunn Limestone and Klentnice beds both at outcrop and from drill cores, and to provide a bibliography for these strata, similar to the compilation on the coeval Štramberg Limestone (Silesian Unit, NE Czech Republic) by Vašíček & Skupien (2004, 2005). All Upper Jurassic klippen of the Waschberg-Ždánice Unit, stretching from Niederfellabrunn to Kleinschweinbarth in Lower Austria, and further

on to the Pavlovské vrchy (Pavlov Hills) of the Mikulov area in Czech Republic are considered, and data on their tectonic formation are compiled. The summary is split into four parts, covering (1) the geological overview and tectonic evolution, (2) the stratigraphy of the klippen, (3) the sedimentology and microfacies of the Ernstbrunn Limestone and Klentnice beds, and (4) the fossil flora and fauna that have been preserved in these rocks. Furthermore, we outline the geological and palaeontological significance of the

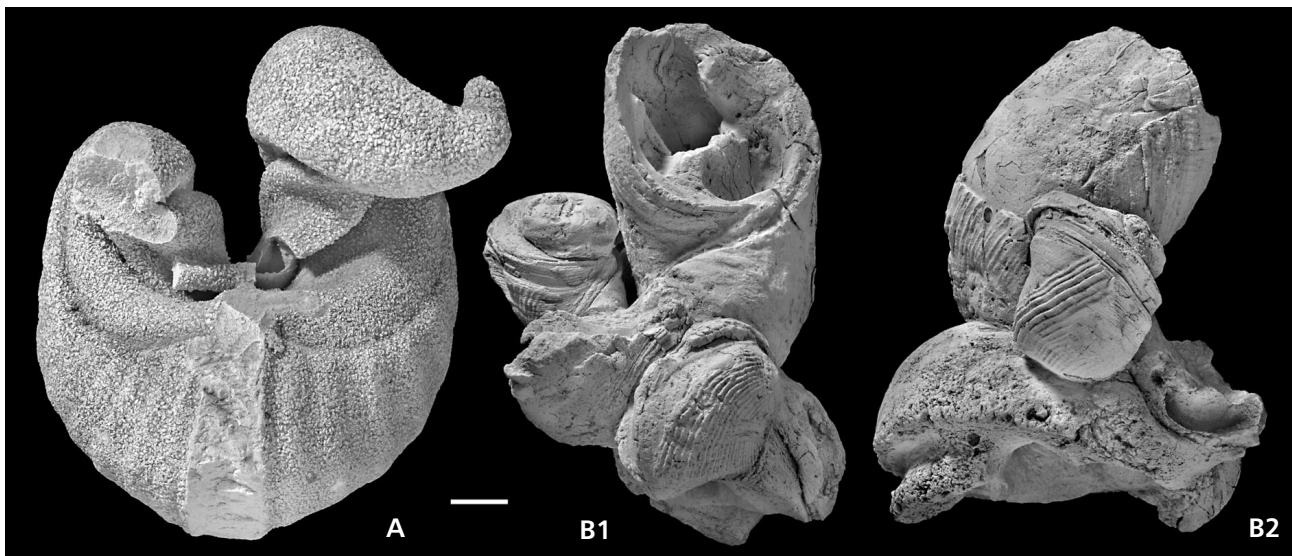


Figure 1. Epidiceratidae: Character fossils of the Ernstbrunn Limestone. • A – internal mould of *Epidiceras* sp.; Dörfles; NHMW 2012/0108/0002. • B – small cluster of five specimens of *Heterodicerias lucii* (DeFrance, 1819) from a karst fissure at Dörfles V quarry; NHMW 2012/0111/0001. • B1 – small double-valved specimen (upper left), adult left valve (upper right), and two fragmentary specimens (left- and right-central) growing on a single right valve (below). • B2 – same cluster as in B1; side view. Scale bar = 10 mm.

Ernstbrunn Limestone and Klentnice beds, and highlight potential future directions of research.

Most people familiar with the Upper Jurassic Ernstbrunn Limestone likely will think of epidiceratid bivalves when this unit is mentioned – and with a bivalve it all began. When Karl Haidinger (1782) reported on an epidiceratid bivalve unearthed from the carbonates of the Semmelberg near Ernstbrunn, he considered this find a rarity. In fact, he had discovered the character fossil of the stratum, *i.e.* a large internal mould of a basal rudist (Fig. 1A). However, it took almost 50 more years, until geological investigations on the Ernstbrunn Limestone started. It was Ami Boué, who “painted” a first picture of these carbonates in his “Geognostisches Gemälde von Deutschland” (Boué 1829) and established the term “Calcaire d’Ernstbrunn” (= Ernstbrunn Limestone) in his follow-up article on the Mesozoic stratigraphy of the “Austrian Alps” (Boué 1830). Since then, many famous Austrian and Czech geologists have contributed to the discussion about the nature and origin of the enigmatic Upper Jurassic hill chain that occurs to the north of Vienna, between the Danube and Thaya rivers (see bibliography below). Finally, these rocks were recognised as unrooted tectonic klippen that have been sheared off the Mesozoic basement below the Vienna Basin, and dragged up in the course of the thrusting of the Waschberg-Ždánice Nappe onto the Alpine-Carpathian Foredeep (= Molasse Unit; Figs 2, 3) (Poul *et al.* 2011, Wessely 2006).

Besides the vivid discussion on structural geology, first essays on the lithology and fauna of several outcrops of Ernstbrunn Limestone were compiled by Ferstl (1845),

Prinzinger (1851), Hingenau (1852), Foetterle (1853), and Hobza (1876). In the late 19th century, Abel (1899a, b) provided a comprehensive description of the sediments and listed the fossil fauna of the Ernstbrunn Limestone. Scattered over the 20th century, several classical, macroscopic facies descriptions of the stratum were published (*e.g.*, Jüttner 1922, 1942; Schön 1927; Tollmann 1963), until the microfacies of the Ernstbrunn Limestone was studied in detail in Moravia (Eliáš 1992; Eliáš & Eliášová 1984, 1986; Řehánek 1987a, b) and in Austria (Hofmann 1990a, Moshammer & Schlagintweit 1999). The latter authors provide modern lithologic characterisations of the Ernstbrunn Limestone at Dörfles and a few other small outcrops (Fig. 4). Information on the microfacies of several major outcrops (*e.g.*, Falkenstein, Staatz), however, is still wanting, and a comprehensive facies model for the Ernstbrunn-Pavlov Carbonate Platform has not been proposed.

After the first description by Haidinger (1782), the abundant, large fossils preserved in the Ernstbrunn Limestone soon had attracted both collectors and scientists (*e.g.*, Hoernes 1874; Makowsky 1874; Peters 1855, 1867; Suess 1858). In the 20th century, the fossil fauna of the Ernstbrunn Limestone was treated in several unpublished Ph.D. theses (Bachmayer 1940, Dürrmayer 1931, Matzka 1934, Moeller 1911). However, only a few peculiar species or genera were formally described, and several moderately speciose taxa were monographed (see palaeontology section below). A milestone for further investigation was set, when the ammonite fauna and biostratigraphy of the Ernstbrunn Limestone were revised (Zeiss & Bachmayer 1989, Zeiss 2001). Recently, a re-evaluation of the extraordinarily rich

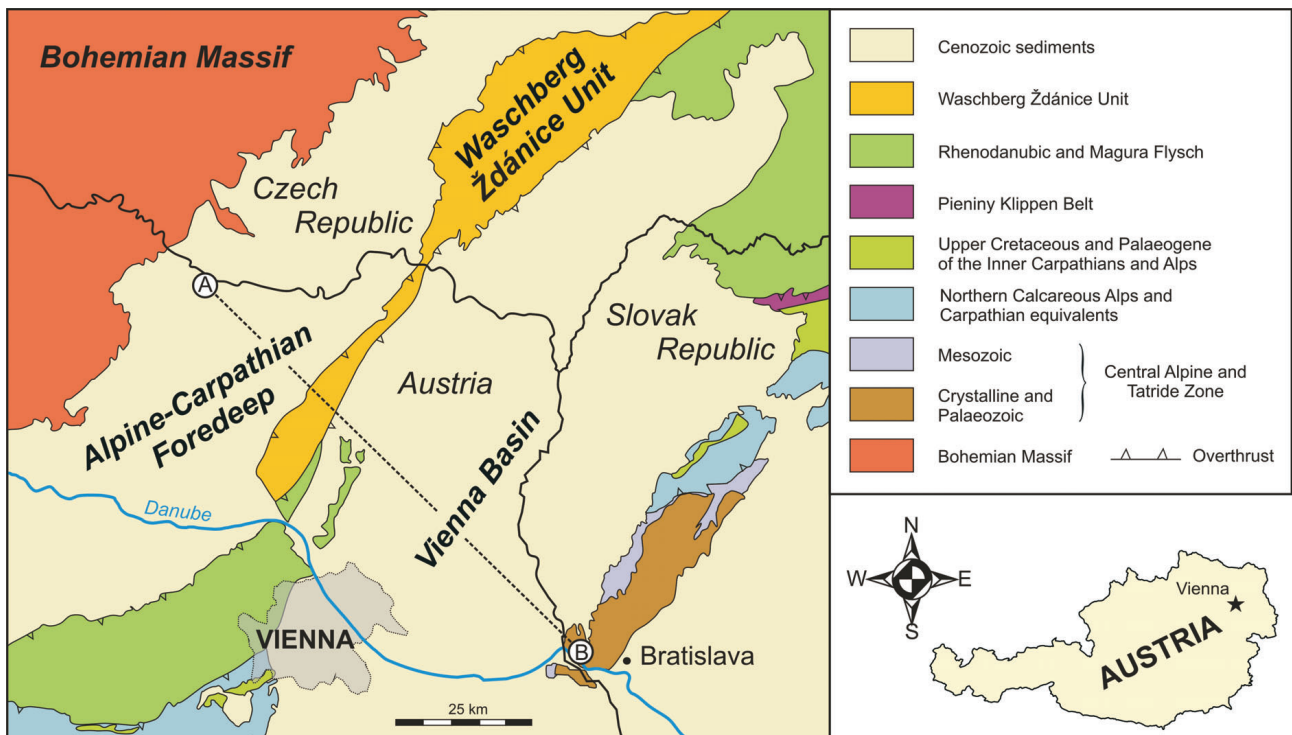


Figure 2. Main tectonic units of the study region, including the Waschberg-Ždánice-Unit (WZU). Dashed line (A–B) indicates position of cross-section in Fig. 3.

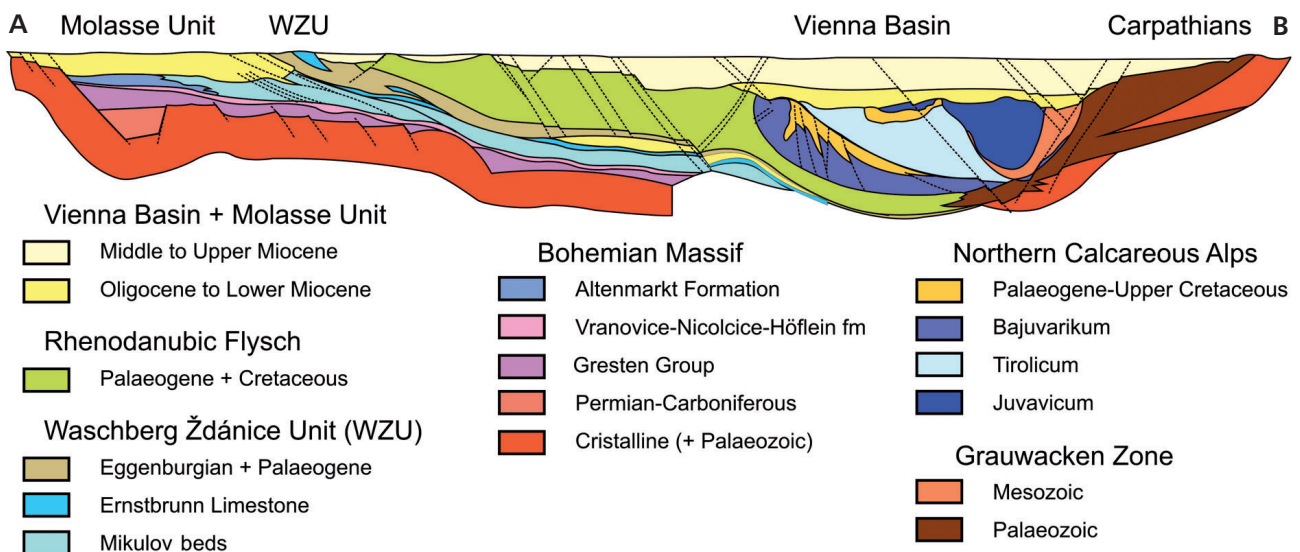


Figure 3. Schematic cross-section of the Molasse, Waschberg-Ždánice, and Flysch units and adjacent Vienna Basin. Modified from Zimmer & Wessely (1996).

decapod fauna of the Ernstbrunn Limestone has been started, which already produced a wealth of results (Feldmann & Schweitzer 2009; Robins *et al.* 2012, 2013; Schweitzer & Feldmann 2008a, b, 2009a–d, 2010a–d). Major portions of the fauna, however, including several of the most specious groups (*e.g.*, Scleractinia, Bivalvia, Gastropoda, Brachiopoda, Echinoidea), have never been

studied in detail. As a result, knowledge on the palaeobiodiversity and palaeoecology of the Ernstbrunn-Pavlov Carbonate Platform remains piecemeal, despite of more than 200 years of research.

Any comprehensive essay on the Ernstbrunn Limestone will necessarily also expand on the closely associated Klentnice beds. Generally, the Klentnice beds comprise a

Table 1. Locality names and GPS coordinates of current and former outcrops of Ernstbrunn Limestone (E) and Klentnice beds (K), inferred from labels of fossils in the collections of NHMW. Numbers in the first column correspond to Fig. 4. Localities without number and coordinates could not be matched with a particular outcrop.

NR	Stratum	Locality	Coordinates
1	E	Dörfles I	48°32' 43.81" N 16°21' 00.52" E
2	E	Dörfles II	48°32' 45.94" N 16°20' 58.67" E
3	E	Dörfles III	48°32' 53.77" N 16°20' 50.86" E
4	E	Dörfles IV	48°32' 57.21" N 16°20' 53.47" E
5	E	Dörfles V	48°33' 03.53" N 16°20' 47.59" E
6	E	Ernstbrunn Kalkwerk II, Ernstbrunn II	48°32' 52.34" N 16°21' 21.08" E
7	E, K	Ernstbrunn (Semmelberg)	48°31' 58.36" N 16°20' 54.76" E
–	E	Kottingneusiedl	– –
–	E	Grafensulz	– –
8	E	Michelstetten (Galgenberg)	48°35' 44.05" N 16°26' 38.05" E
9	E	Falkenstein (Steinbruch)	48°43' 38.86" N 16°35' 01.29" E
–	E	Falkenstein (not specified)	– –
10	E	Klafterbrunn I	48°33' 36.43" N 16°21' 07.68" E
11	E	Klafterbrunn II	48°33' 33.74" N 16°21' 09.40" E
12	E	Klafterbrunn III	48°33' 29.36" N 16°21' 13.42" E
13	E	Klafterbrunn IV	48°33' 25.36" N 16°21' 14.61" E
14	E, K	Klement I	48°34' 06.31" N 16°21' 02.43" E
15	E	Mikulov (Marienmühle)	48°48' 39.34" N 16°39' 31.21" E
–	E	Asparn an der Zaya	– –
16	E, K	Leiser Berg bei Niederleis	48°33' 33.25" N 16°22' 25.77" E
17	E	Staatz	48°40' 34.71" N 16°29' 17.14" E
18	K–E	Südmährerkreuz	48°45' 43.75" N 16°36' 48.35" E
19	K–E	Steinbruch bei Schletz	48°34' 49.78" N 16°27' 10.81" E
20	K	Niederfellabrunn	48°28' 04.64" N 16°18' 14.19" E
21	K	Buschberg NE Klement	48°34' 37.42" N 16°23' 44.84" E
22	K	Stützenhofen	48°44' 30.60" N 16°36' 30.90" E
23	K	Niederfellabrunn (Hundsberg)	48°28' 37.40" N 16°18' 28.70" E
24	K	Mikulov (Gemeindeberg)	48°48' 36.73" N 16°38' 15.59" E
25	K	Mikulov (Heiliger Berg)	48°48' 27.11" N 16°38' 55.39" E
26	K	Děvín (Maydenberg)	48°52' 09.94" N 16°38' 07.94" E
–	E	Perná N Nikolsburg [Makowsky 1874]	– –
27	K	Niederfellabrunn	48°27' 45.11" N 16°18' 12.13" E
28	E	Mikulov (Quarry Holy Mt.)	48°48' 31.06" N 16°39' 16.44" E
29	E, K	Mikulov (Turoid Quarry)	48°49' 00.51" N 16°38' 23.91" E
30	K	Klentnice (Table Mountain)	48°50' 56.38" N 16°38' 11.98" E

mixture of fossiliferous siliciclastics and carbonates (see sedimentology section below) and grade vertically and laterally into the pure carbonates of the Ernstbrunn Limestone (Glaessner 1931, Jüttner 1922; cf. Poul *et al.* 2011). The term “Klentnitzer Mergel” (= Klentnitz Marls) was introduced by Abel (1899a), who was among the first

scientists to provide a detailed description of this stratum, including a list and several drawings of the fauna (Abel 1897). The name refers to the informal type locality, Klentnice (Klentnitz), located to the north of Mikulov (Czech Republic).

Since the 1950s, the sediments of the Molasse and Waschberg units in Austria and Czech Republic have been penetrated by numerous wells reaching down to the crystalline basement of the Bohemian Massif. In several drill cores, the autochthonous Mesozoic succession on the crystalline slope contains both Ernstbrunn Limestone and Klentnice beds, which finally proved the tectonic scenario outlined above (*e.g.*, Adámek 1979, 1986; Eliáš & Wessely 1990; Malzer *et al.* 1993; Poul *et al.* 2011; Wessely 2006). Recently, new data retrieved from subsurface rocks and surface geology have been integrated, producing a more complete view of the klippen strata (Adámek 2005, Poul *et al.* 2011, Wessely 2006). Since the 1970s, an additional set of lithostratigraphic units and terms has been developed for the autochthonous Mesozoic strata in subsurface (see Eliáš & Wessely 1990 for an overview).

Abbreviations used in the text. – GBA = Geologische Bundesanstalt, Vienna; NHMW = Natural History Museum Vienna; WZU = Waschberg-Ždánice Unit.

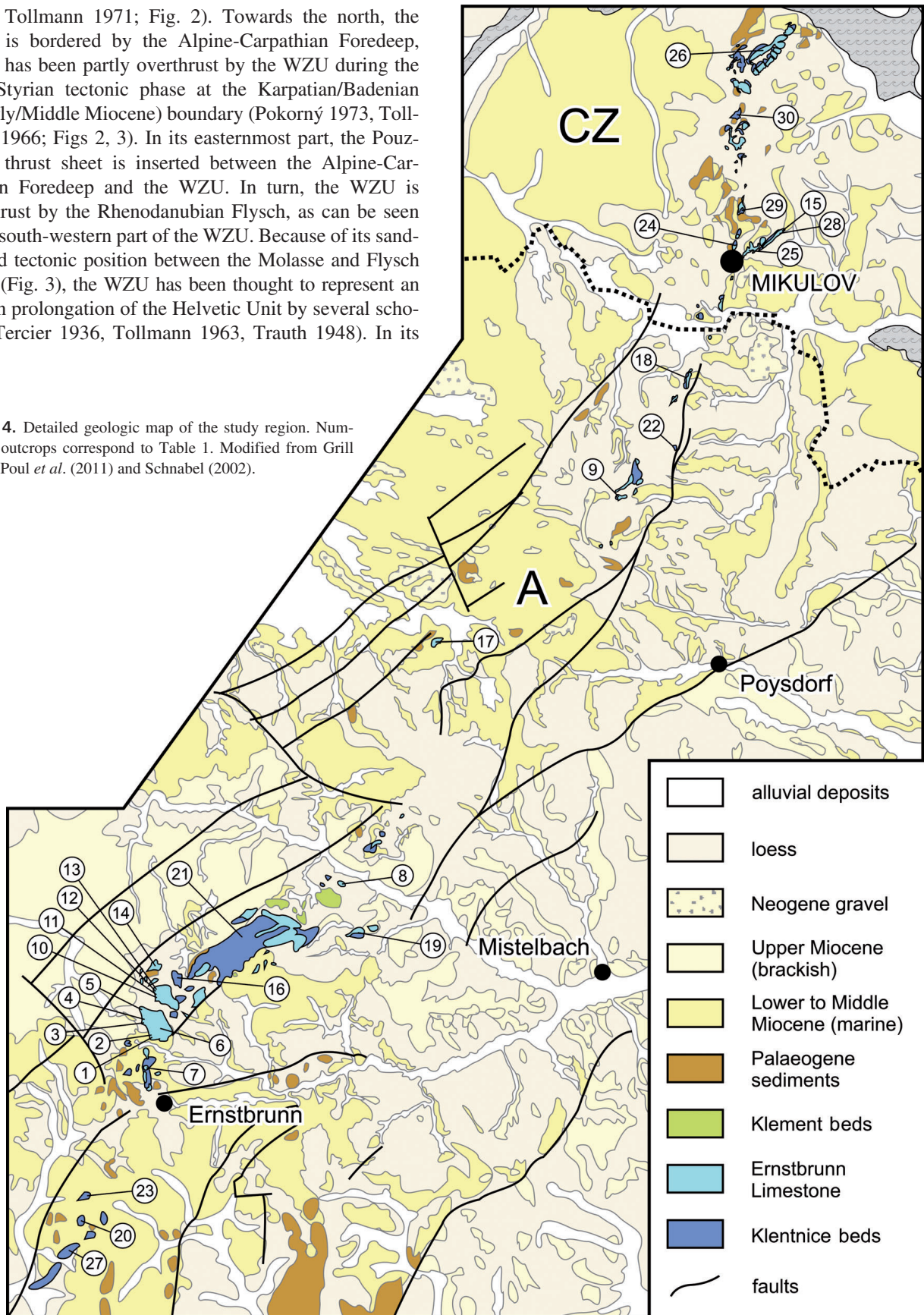
State of the art

Geographic overview, geology and tectonics

At surface, the Ernstbrunn Limestone and Klentnice beds occur within a SW–NE trending hill chain that starts at the Waschberg north of Stockerau (Lower Austria) and ends at the Děvín (Maydenberg) west of Pavlov (Pollau) in southern Moravia (Czech Republic), thus extending between the Danube and Thaya rivers over approximately 60 km (Fig. 2), and probably even a few kilometres further to the north (Pícha & Hanzlíková 1965). Together with the elongated strip of surrounding sediments these hills form a distinct tectonic unit, named Waschberg Zone according to the concepts developed by Tercier (1936) and Grill (1953) [note that at that time the strict restriction of the term “Zone” to the biostratigraphic nomenclature was not established]. Czech geologists have designed an alternative term, *i.e.* Ždánice “Zone” (also Ždánice-Subsilesian “Zone”), for the same unit (Roth 1962). Since there is no official agreement on a common name, a combination of both names is used herein. With regard to structural geology, the Waschberg-Ždánice Unit (WZU) represents the most distal Alpine-Carpathian nappe in the boundary region between these two orogens. Moreover, the WZU is the only structural element that forms a direct connection of the Alps and Carpathians at surface (Prey 1960, 1965; Roth

1967; Tollmann 1971; Fig. 2). Towards the north, the WZU is bordered by the Alpine-Carpathian Foredeep, which has been partly overthrust by the WZU during the Late Styrian tectonic phase at the Karpatian/Badenian (= Early/Middle Miocene) boundary (Pokorný 1973, Tollmann 1966; Figs 2, 3). In its easternmost part, the Pouzdřany thrust sheet is inserted between the Alpine-Carpathian Foredeep and the WZU. In turn, the WZU is overthrust by the Rhenodanubian Flysch, as can be seen in the south-western part of the WZU. Because of its sandwiched tectonic position between the Molasse and Flysch zones (Fig. 3), the WZU has been thought to represent an eastern prolongation of the Helvetic Unit by several scholars (Tercier 1936, Tollmann 1963, Trauth 1948). In its

Figure 4. Detailed geologic map of the study region. Numbers of outcrops correspond to Table 1. Modified from Grill (1961), Poul *et al.* (2011) and Schnabel (2002).



southern part, the Austrian WZU is tectonically partitioned into two subunits, *i.e.* the outer Roselsdorf Unit and the inner Waschberg Unit *sensu stricto*. Further partitioning into several blocks occurred along reactivated faults of Variscan strike (Poul *et al.* 2011, Wessely 2006).

The regular sedimentary succession of the WZU consists of Miocene strata. Several of the hills, which are composed of Oligocene, Eocene, Palaeocene, Upper Cretaceous, and Upper Jurassic rocks (Fig. 4), rear up as more or less steep blocks, and thus are termed “cliffs” in common speech. The Upper Jurassic strata form major parts of the Leis Hills complex (Leiser Berge), including Semmelberg, Dörfles (Fig. 5A, B), Klement, and Buschberg localities, and the hills of Staatz (Wessely & Hofmann 2007; Fig. 5D), Falkenstein (Fig. 5C), Stützenhofen (Fig. 5F), and Kleinschweinbarth in Lower Austria. In the Czech Republic, in and around Mikulov (Nikolsburg) in southern Moravia, they comprise (Fig. 4) the Pavlov Hills (Pavlovské vrchy, Pollauer Berge), *i.e.* the Saint Hill (Svatý kopeček, Heiligenberg), Tuold, Table Mountain (Stolová hora, Tafelberg), and Děvín (Maydenberg; Fig. 5E). Stratigraphically, both the Klentnice beds and the Ernstbrunn Limestone have not yet been formalised and type localities and sections have not been officially designated or described. Consequently, both units are not termed formations herein. Moreover, we favour the term “Klentnice beds” versus “Klentnice Marls”, since the stratum comprises a variety of different facies (see sedimentology section below). Recently, Poul *et al.* (2011) proposed a separate informal unit termed “nodular limestones” for a transitional zone between the Klentnice beds and Ernstbrunn Limestone in the Pavlov Hills. The term “nodular limestone” is commonly attributed to condensed limestone facies deposited around the calcite compensation depth (Jenkyns 1974). This does not account for the facies found in the Pavlov Hills. Moreover, any approach to separate different units along a gradual transition will remain arbitrary. Herein, we thus assign all well-bedded portions of Upper Jurassic rocks in the WZU to the Klentnice beds.

During the last 40 years, a series of lithostratigraphic units and terms have been established in order to characterise the subsurface, autochthonous Mesozoic strata on the southern slope of the Bohemian Massif (*e.g.*, Eliáš 1974, Ladwein 1976), which have been summarized and harmonized by Eliáš & Wessely (1990). According to the resulting scheme, the Upper Jurassic portion of the succession starts with the Vranovice limestones and dolomites, which have no equivalent at surface. These carbonates are overlain by the Mikulov Marls and the Kurdějov Arenite. The latter two units are considered equivalents of the Klentnice beds. Due to the lack of information on the typical succession of the Klentnice beds, however, it remains enigmatic whether these strata

are effectively facially equivalent. The Jurassic succession is topped by the Ernstbrunn Limestone, which is capped by erosion, and overlain by limestones of Late Cretaceous age (Adámek 1979, 1986; Eliáš & Wessely 1990; Pokorný 1958; Poul *et al.* 2011).

The initial, most controversial and still enduring discussion concerns the origin of the Jurassic rocks of the WZU, and several contrasting theories were proposed on that subject. The “island theory” – most popular during the early years of research – identified the Jurassic klippen as erosional relics of a formerly continuous cover of Jurassic rocks on the crystalline basement, which acted as islands in the Cenozoic Paratethys Sea (*e.g.*, Stejskal 1932, Suess 1929, Uhlig 1904). In this context, the Ernstbrunn Limestone has also been thought to represent a prolongation of the Upper Jurassic strata of the Ortenburg-Passau region (Lower Bavaria, SE Germany; Suess 1885), which, however, are true erosional relics of different facies and age resting directly on the crystalline slope (Gröschke 1985). Other scholars regarded the klippen as large olistolithes that were derived from a now eroded Jurassic shelf in superior position (*e.g.*, Stejskal 1928, 1930, 1931, 1935b; Uhlig 1903). When a first set of boreholes penetrated several unrooted Carpathian klippen in the Silesian flysch unit in the early 20th century, scientists began to discuss a similar tectonic model for the Ernstbrunn Limestone (Friedl 1927; Jüttner 1930, 1931, 1932, 1933b, 1934; Petrascheck 1914, 1921; Schnabel 1929, 1933a, b). Starting from 1948, numerous wells also penetrated the sedimentary successions of the Alpine-Carpathian Foredeep and WZU both in Austria and Czech Republic, mainly in order to explore the hydrocarbon resources of the region (Eliáš & Wessely 1990, Tollmann 1985). The new data confirmed the presence of Upper Jurassic strata identical to the Ernstbrunn Limestone and Klentnice beds in the autochthonous Mesozoic cover of the slope of the Bohemian Massif (Brix & Götzinger 1964; Brix *et al.* 1977; Eliáš 1977, 1981; Eliáš & Wessely 1990; Grill 1958; Kapounek *et al.* 1967; Kröll 1980; Malzer *et al.* 1993; Wessely 1993, 1997, 2006; Zimmer & Wessely 1996). It is therefore confirmed that the Upper Jurassic blocks originate from below the WZU and thus truly represent un-rooted tectonic klippen, but not olistolithes (Kapounek *et al.* 1967, Poul *et al.* 2011, Wessely 2006). Based on detailed geologic mapping, borehole data, and seismic analysis that were in part already presented by Stráník *et al.* (1979), Poul *et al.* (2011) recently developed a comprehensive model of the tectonic evolution of the Pavlov Hills expanding on details of the partitioning of the Jurassic rocks due to thrusting and strike-slip movements. The resulting scheme shows that the Pavlov klippen extend much further in subsurface than those in the southern part of the WZU, with only relatively small horst structures cropping out.



Figure 5. Major outcrops of Ernstbrunn Limestone (A–E) and Klentnice beds (F). • A – Ernstbrunn Kalkwerk II quarry. • B – Dörfles V quarry. • C – Falkenstein quarry. • D – Staatz Klippe. • E – Děvín north of Mikulov. • F – roadcut at Stützenhofen.

Stratigraphy

Biostratigraphy of the Upper Jurassic klippen strata is still not settled and alternative stratigraphic approaches, *e.g.*, sequence stratigraphy, isotope geochemistry, or palaeomagnetism, have never been tested for the Jurassic rocks of the WZU. The first author who clearly stated a Jurassic age for the Klentnice beds was Suess (1852). A few years later, Zittel (1868), based on the macrofauna of the Klentnice beds, regarded the Jurassic klippen as older than Tithonian.

Typically, Jurassic biostratigraphy is based on ammonites. They are, however, relatively rare in most outcrops of the Ernstbrunn Limestone and Klentnice beds and therefore ammonite biostratigraphy on the klippen strata started relatively late.

Most ammonites from the Klentnice beds have been unearthed from wine cellars at Niederfellabrunn. These relatively poorly preserved specimens and a few other finds have been extensively discussed, and determinations of earlier publications were usually emended by

subsequent authors (Abel 1897, Arkell 1956, Bachmayer 1957, Krafft 1897, Kutek & Zeiss 1988, Spath 1933, Vašíček 1971, Vetter 1905, Zeiss 1977). According to the latest update by Kutek & Zeiss (1988) and Zeiss (2001), the seven ammonite taxa known from the Klentnice beds largely suggest an early Late Tithonian age (*Micracanthoceras microcanthum* Zone, *Simplisphinctes* Subzone; Ogg *et al.* 2008).

Besides ammonites, different microfossils were locally employed for biostratigraphy. From a single locality in the Pavlov Hills a rich fauna of Foraminifera and Ostracoda from the lower part of the Klentnice beds was studied (Hanzlíková 1962, 1965; Pokorný 1973), which produced conflicting results. While a latest Oxfordian to Late Kimmeridgian age was deduced from the Foraminifera (Hanzlíková 1965), a Late Tithonian to Berriasian age was inferred from the Ostracoda (Pokorný 1973). A re-evaluation, however, confirmed a Kimmeridgian age for both groups (Gramann & Luppold 1991, Schudack & Schudack 1997).

Relatively sound biostratigraphic data are also available for the autochthonous Mesozoic in subsurface. Ammonites from several wells in southern Moravia described by Vašíček (1971, 1980) indicate a ?Calloviaian to Oxfordian age for the Vranovice limestones and dolomites, while Brix *et al.* (1977) report an Oxfordian to latest Kimmeridgian age for the same stratum in Austria. The overlying Mikulov Marls, corresponding to the lower portion of the Klentnice beds have been dated as Kimmeridgian to early Middle Tithonian (Holzknecht & Hamršmíd 1988; Vašíček 1980) or Early Tithonian (Brix *et al.* 1977). The Kurdějov Arenite, representing the upper portion of the Klentnice beds at subsurface, is interpreted to comprise upper Middle to lower Upper Tithonian deposits (*cf.* Brix *et al.* 1977, Vašíček 1980). Papp & Turnovsky (1964) studied the microfauna from drill cores from the Austrian part of the WZU and concluded on a Late Jurassic (?Tithonian) to Berriasian (?Hauterivian) age for the equivalents of the Klentnice beds. Brix *et al.* (1977) regard the microfauna derived from these cores as stratigraphically largely indistinct, but propose an exclusively Late Jurassic age for the Klentnice beds.

In contrast to the specimens from the Klentnice beds, the ammonites from the Ernstbrunn Limestone are usually well preserved. Up to the 1950s, only few specimens were available for study (Abel 1899a, b; Arkell 1956; Bachmayer 1957; Moeller 1911; Spath 1933). The most comprehensive assessment of the ammonites by Zeiss is mainly based on the extensive collections of Friedrich Bachmayer (Zeiss 1999, 2001; Zeiss & Bachmayer 1989). In conclusion, Zeiss (2001) proposes middle Middle to early Late Tithonian age (*Richterella richteri* Zone to *Micracanthoceras microcanthum* Zone, *Simplisphinctes* Subzone) for the Ernstbrunn Limestone. It should be mentioned that the

majority of the ammonite specimens were collected at Ernstbrunn-Dörfles Werk II quarry, while most of the other fossils, usually representing benthic taxa were found at other quarries. This suggests significant variation in facies between the different klippen and outcrops – and probably also differences in age.

An alternative biostratigraphic approach based on calpionellids is restricted to several exposures of Ernstbrunn Limestone in the Mikulov region, and revealed a much younger, Tithonian to Hauterivian age (Eliáš & Eliášová 1985, Houša & Řehánek 1987, Houša *et al.* 1963). Likewise, a study of microflora and microfauna from several small outcrops of Ernstbrunn Limestone (Kleinschweinbarth, surroundings of Ernstbrunn, Galgenberg, surroundings of Falkenstein and Schletz) points to a Tithonian to Early/Middle Berriasian age (Moshhammer & Schlagintweit 1999).

In conclusion, the Klentnice beds are thought to comprise the Kimmeridgian to early Late Tithonian, while the Ernstbrunn Limestone may have been deposited during the Middle Tithonian to Berriasian (?Hauterivian). According to this scenario, the Ernstbrunn-Pavlov Carbonate Platform persisted during the Jurassic–Cretaceous transition and is thus entirely coeval to the Štramberk Limestone of northern Moravia.

Sedimentology and facies

The sedimentology and microfacies of the Pavlov Hills have been explored in detail (Eliáš 1962; Eliáš & Eliášová 1984, 1986; Fabian & Jüttner 1937; Jüttner 1933a; Matějka 1926, 1929; Matějka & Stráník 1961; Řehánek 1987a, b), but published data from the Ernstbrunn Limestone and Klentnice beds in Austria are sparse. Comprehensive general sedimentological characterisation of several outcrops in Austria has been provided by Glaessner (1937). The texture and faulting of the Ernstbrunn Limestone are accurately described by Schön (1927) and Havíř & Stráník (2003). At several outcrops, for example at Staatz or the southern flank of the Děvín, large, severely brecciated rock portions provide evidence of the tectonic movements outlined above (Petrascheck 1921, Zapletal 1930).

In the 1980s, modern microfacies analysis of the Ernstbrunn Limestone of the Pavlov Hills started, and numerous carbonate thin sections were screened by Eliáš & Eliášová (1984, 1986) and Řehánek (1987a, b). In Austria, the microfacies of the five classical, now abandoned quarries at Dörfles was analysed in a diploma thesis by Hofmann (1990a). He provided schematic sections and identified different types of lagoonal microfacies, *i.e.* wackestones, packstones, grainstones, algal bindstones, and “diceratid” facies. However, only a brief overview of his results is published in Hofmann (1992b, 1993a, 2001).

Several small outcrops of Ernstbrunn Limestone in Austria have been more or less randomly sampled by Moshhammer & Schlagintweit (2003), who recorded different types of inner and outer platform carbonates. The microfacies of most of the important outcrops of Ernstbrunn Limestone (e.g., Falkenstein, Michelstetten, Klement, Staatz, Stützhofen), however, was never studied. Consequently, an integrative facies model for the Ernstbrunn-Pavlov Carbonate Platform is still lacking, as is a detailed comparison and correlation of autochthonous, subsurface rocks with those sediments available at outcrop.

According to the publications listed above, the Klentnice beds consist of claystones and marls, which dominate the lower portion of the stratum, while intercalations of limestone (oid-, intraclast-, and bioclast-wacke- to packstones; Fig. 6B, D, H) become gradually more abundant towards the top. These facies are interpreted as base-of-slope to pelagic mud facies by Eliáš & Eliášová (1984). However, because the shallow-water carbonates of the Ernstbrunn Limestone gradually developed from the Klentnice beds, the latter may rather represent shelf sediments deposited at moderate depth. This is underlined by the composition of the rich macrofauna (see below).

Similar to the Klentnice beds, the individual outcrops of Ernstbrunn Limestone are composed of several different types of facies (Fig. 6A, C, G). Fossiliferous or oncoidal wackestones and packstones, algal bindstones, and epidiceratid- and coral-framestones may represent different microhabitats of lagoonal settings, i.e. epidiceratid and coral patch reefs, and the carbonate sands and mud in between. Ooid-oncoid grainstones and packstones of variable grain size and degree of sorting may have been deposited in the form of fringing ooid-oncoid bars along the margins of the carbonate platform. Altogether, these sediments, preserved in numerous isolated klippen, provide a fairly complete view of the complex facies architecture of the Ernstbrunn-Pavlov Carbonate Platform.

In addition to the Jurassic rocks, the discordantly overlying Cretaceous strata and their relation to the Ernstbrunn Limestone were studied (Glaessner 1930). Moreover, several fissure fillings inserted in the carbonates at Staatz and Dörfles were analysed, and found to contain mixed assemblages of Tithonian, Late Cretaceous (Upper Campanian to Santonian), Palaeogene and Neogene micro- and microfossils (Bachmayer 1964a, Hofmann *et al.* 1999).

Closely related to the sedimentology of the rocks, the present-day surface morphology and carstification of the Jurassic klippen, including several small caves, have been subjects of an unpublished Ph.D. thesis (Riedl 1958a) and several publications (Riedl 1957, 1958b, 1960). The geography and underlying geologic structures of the Pavlov Hills were detailed by Mikula (1927).

During the Middle Ages the Ernstbrunn Limestone has been used as a building stone, e.g., in the castles of Staatz

and Falkenstein and the church of Michelstetten (Rohatsch & Thinschmidt 1997). Since more than 100 years, the limestone is intensively mined at Ernstbrunn-Dörfles, and is used as a natural resource for various construction materials and technical products (Bullinger 1997, Ernstbrunner Kalktechnik 2011). For the first time, Moshhammer & Lobitzer (1997) have published data on the chemical composition of the Ernstbrunn Limestone along with its colorimetric properties, and thus provided important information on the technical applicability of the rocks.

Palaeontology

The first fossil described from the Upper Jurassic rocks of the Waschberg Unit is a “Gienmuschel” [old German trivial name for *Chama*; Adelung 1793–1801], i.e. a fossil bivalve of the genus *Epidiceras* (Haidinger 1782; Fig. 1A), which is a character fossil of the Ernstbrunn Limestone. Usually, these bivalves occur together with *Heterodicerias* (Fig. 1B) as major components of the epidiceratid-nerineid biofacies, and are preserved as internal moulds of double-valved specimens (Schneider 2012). According to Bachmayer (1957), the fossil fauna of the Ernstbrunn Limestone comprises more than 500 species, which is rather an underestimation according to our opinion (Fig. 7). Although several major taxonomic groups have not yet been studied in detail, more than 300 taxa have been identified and published.

As already outlined by Bachmayer (1940), the total abundance of fossils and composition of the fauna vary strongly among the different klippen and outcrops, which can easily be demonstrated by the following examples. (1) Corals are less diverse but much more abundant at Klafterbrunn 3 quarry than at any other locality. (2) In contrast, epidiceratids and nerineids typically occur in abundance in all quarries at Dörfles (Fig. 1A, B) as well as at Falkenstein and Mikulov Marienmühle (Mariánský mlýn) quarry, but have not been recorded from Klafterbrunn, Staatz, Turoid, or Děvín. (3) Pharyngeal teeth of *Lepidotes* are very common at Falkenstein (Fig. 8F), but rare at most other localities. (4) Decapods are particularly abundant at Dörfles I and Klement I quarries (Bachmayer 1940) (Fig. 8B). (5) A major portion of the ammonites described by Zeiss (2001) have been collected from Dörfles Werk II quarry (see list below; Fig. 8D); a single specimen (described as *Ernstbrunnia*) comes from Galgenberg near Michelstetten (Lower Austria).

In particular, the Dörfles quarries are famous for their numerous large bivalves (Fig. 8C) and gastropods (Fig. 8I) preserved as internal moulds. Careful investigation of the limestone from Dörfles, however, predominantly reveals molluscs preserved with shell. Due to complete lithification of the carbonate sediment, the shells cannot be

extracted and are thus usually not collected. Taking all these observations into account, the different klippen and outcrops of Ernstbrunn Limestone may represent different habitats and facies, which may have experienced different diagenetic histories (Schneider *et al.* 2011). Moreover, the individual klippen may deviate in age. Up to now, these differences have neither been systematically assessed nor discussed in the literature.

Flora and fauna described from the Ernstbrunn Limestone and Klentnice beds

In the following overview only those publications which employ scientific names at genus or species level are included.

Trace fossils. – Moshhammer & Schlagintweit (1999) recorded a single microcoprolite taxon from thin sections of Ernstbrunn Limestone. Several types of borings in shells or coral skeletons can be identified, which have been caused by *Lithophaga*, gastrochaenid bivalves, clionid sponges, and yet unidentified microborers (personal observation SS).

Nanofossils. – Stradner (1961) recorded “*Coccolithus cf. pelagicus* (Wallisch)” from unspecified “Tithonian strata” from a well. However, since *Coccolithus pelagicus* (Wallich, 1877) Schiller, 1930 is an entirely Cenozoic taxon (Bukry 1973), this is surely an artefact. Nine species of calcareous nanofossils were recorded by Holzknicht & Hamršíd (1988) from the Mikulov Marls derived from a borehole near Mikulov.

Microflora. – To date, no macrofloral remains have been discovered from the Ernstbrunn Limestone and Klentnice beds. However, major portions of the Ernstbrunn Limestone are characterised by abundant calcareous algae. Bachmayer (1944) described two new species of Dasycladales. Another two species of calcareous algae, again one of them new to science, are detailed by Kamptner (1951). Subsequently, Grill (1963) and Eliáš & Eliášová (1986) listed calcareous algae from the Ernstbrunn Limestone. Thirty-three different taxa of algae, some of them of enigmatic affinities, have been identified from the Dörfles

quarries by Hofmann (1990a, b, 1991a, b, 1992a, b, 1993b). Most of these taxa also belong to the Dasycladales and one of them is regarded as a new species by Hofmann (1994; emended by Schlagintweit 2011). Moshhammer & Schlagintweit (1999) also report five dasyclad species that were collected from several smaller outcrops of Ernstbrunn Limestone.

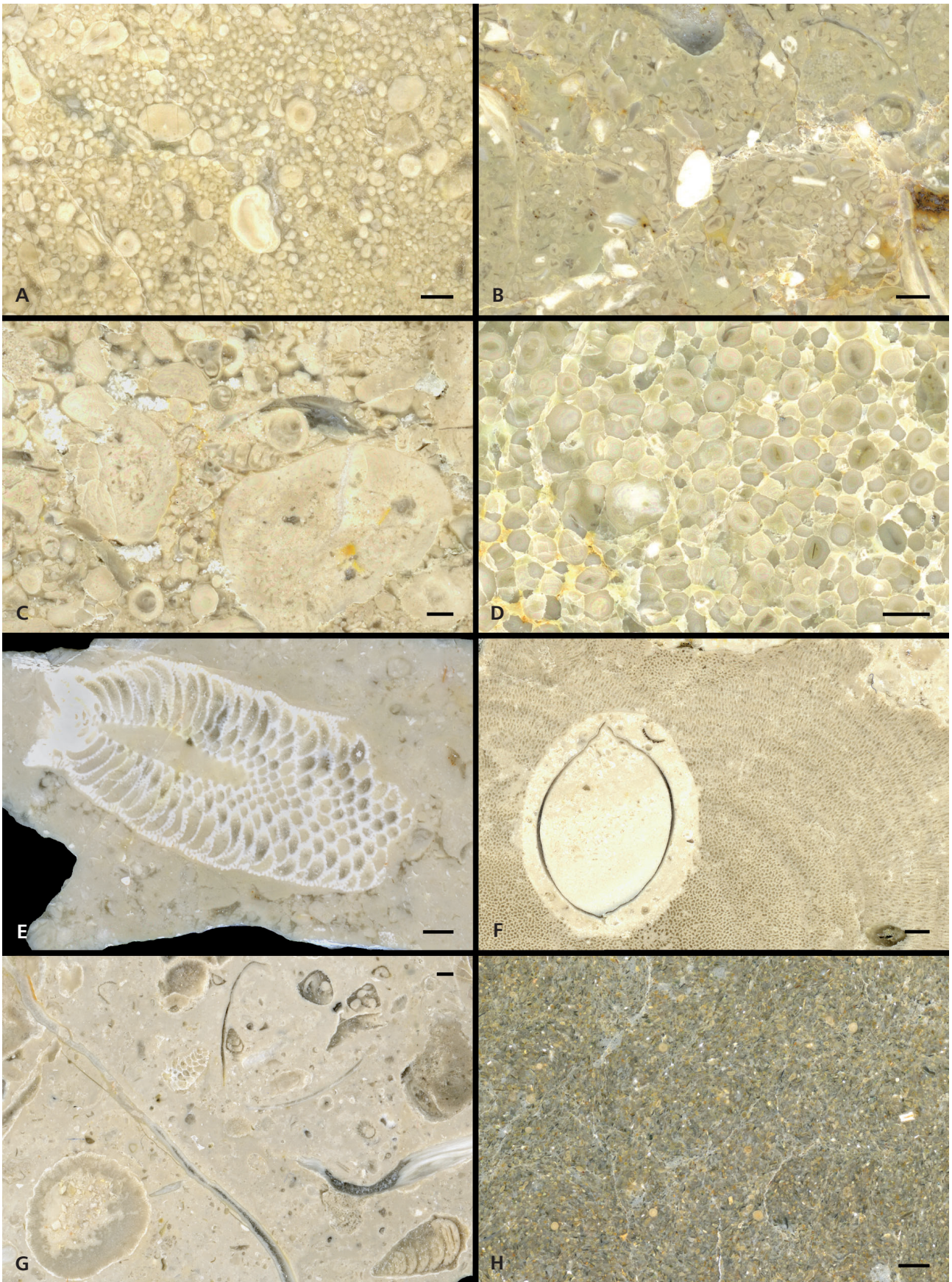
Foraminifera. – Similar to the algal flora, the microfauna of the Ernstbrunn Limestone can only be assessed by studying thin sections of the rocks. Grill (1963) was the first who studied Foraminifera from the Ernstbrunn Limestone and he reported several taxa in open nomenclature from Dörfles. Řehánek (1987a) listed six foraminifer taxa from the Pavlov Hills, Hofmann (1990a) identified seven taxa from Dörfles, and Moshhammer & Schlagintweit (1999) recorded five taxa from a few other localities. Noth (1951) mentions a foraminifer sample from the Upper Jurassic of Niederleis, but does not provide additional information. A list of Foraminifera from the Klentnice beds in Austria has been provided by Grill (1953), while the Foraminifera of an outcrop in Moravia have been monographed by Hanzlíková (1965). Moreover, Papp & Turnovsky (1964) and Holzknicht & Hamršíd (1988) provided data on microfauna from drill cores taken from autochthonous Mesozoic strata (Mikulov Marls).

Tintinnida. – Eliáš & Eliášová (1985) and Řehánek (1987a) list more than 30 species of calpionellids from the Ernstbrunn Limestone from the Pavlov Hills.

Porifera. – The “chaetetid” fauna of the Ernstbrunn Limestone comprises four species of these coralline sponges (Bachmayer & Flügel 1961b; Fig. 6F). However, during the following decades, many additional specimens have been collected by Bachmayer and are stored in the collections of NHMW. At several outcrops of the Klentnice beds a rich fauna of silicified calcareous sponges occurs (personal observation AK, SS; Fig. 9B, I, J), which is unstudied.

Hydrozoa. – Four species of Hydrozoa from the Ernstbrunn Limestone, including a new species, were described by Bachmayer & Flügel (1961a). Similar to the “chaetetids”, there is rich additional, unstudied material in the collections of NHMW.

Figure 6. Typical (micro-) facies of Ernstbrunn Limestone and Klentnice beds. • A – ooid-onkoid grainstone; Ernstbrunn Limestone; southern end of Děvín; NHMW 2012/0106/0003. • B – bioclast-ooid packstone; upper part of Klentnice beds; eastern flank of Děvín; NHMW 2012/0106/0001. • C – onkoid-grainstone; Ernstbrunn Limestone; Falkenstein quarry; NHMW 2011/0309/0001. • D – macro-ooid packstone; upper part of Klentnice beds; eastern flank of Děvín; NHMW 2012/0106/0004. • E – calcareous sponge (*Barroisia* sp.); longitudinal section; Dörfles; NHMW 2012/0108/0006. • F – coralline sponge (*Chaetetopsis krimholzi* Javorskij, 1947; det. F. Bachmayer); vertical section, with boring lithophagid bivalve *in situ*; Ernstbrunn Limestone; Dörfles I; NHMW 2012/0110/0002. • G – bioclast wackestone; Ernstbrunn Limestone; Dörfles I; NHMW 2012/0110/0001. • H – marlstone with ooids, peloids and sponge spicules; upper part of Klentnice beds; western flank of Děvín; NHMW 2012/0106/0002. Scale bars = 2 mm.



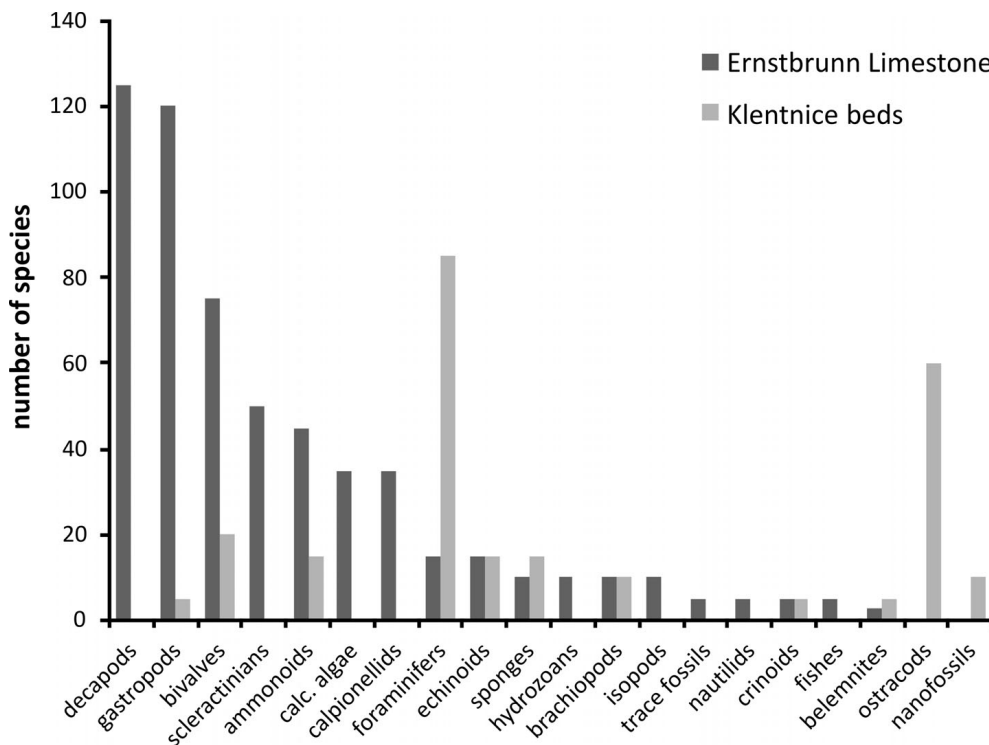


Figure 7. Bar chart showing estimated numbers of species for higher taxonomic groups occurring in the Ernstbrunn Limestone and Klentnice beds. Estimates are based on literature and collection surveys.

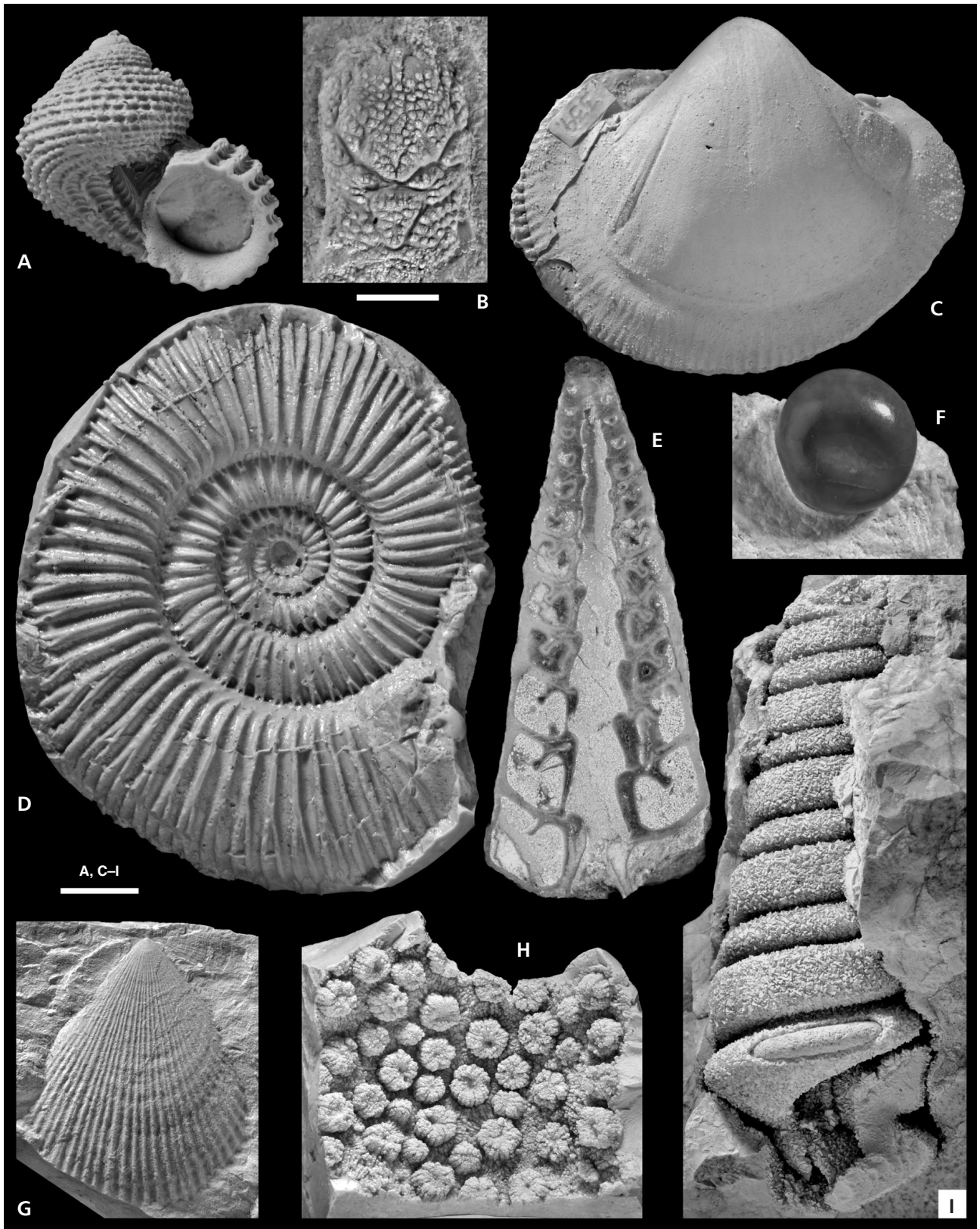
Scleractinia. – Moeller (1911) described 29 taxa of corals from the Ernstbrunn Limestone, but did not provide figures. A single coral from the Ernstbrunn Limestone of Staatz was reported by Kühn (1939). Only a small portion of the rich fauna of Scleractinia from the Ernstbrunn Limestone (Fig. 8H) has been studied by Eliášová (1986, 1990), since she solely considered material from localities in the Czech Republic. Although the major outcrops of this unit do not preserve proper coral reefs, corals must have occurred in small patch reefs (Eliášová 1986) or in non-biohermal assemblages, because they are present in considerable abundance and diversity. The now restored outcrop at Klafferbrunn likely exposed a proper coral reef (as interpreted by Bachmayer 1940) or at least its parautochthonous debris, since samples from this locality are predominantly composed of several taxa of well-preserved branching Scleractinia.

Bivalvia. – Epidiceratid bivalves were the first fossils to be described and figured from the Ernstbrunn Limestone (Haidinger 1782) and represent the dominant macrofossils of the epidiceratid-nerineid facies at Dörfles (Fig. 1A, B).

They were mentioned by numerous authors working on the stratum, and figured by several of them (e.g., Hofmann 1992b, Plöching & Karanitsch 2002, Wessely 2006). An overview of the bivalve fauna was given in the unpublished theses of Dürmayer (1931), who identified 24 taxa, and Bachmayer (1940), who extended this list to 35. Moreover, Bachmayer (1948a) speculated about the mode of life of the Epidiceratidae from Ernstbrunn. A survey of the material stored at the NHMW revealed approximately 70 species of Bivalvia (Fig. 8C, G).

Due to the loss of aragonite, the bivalve fauna of the Klentnice beds is usually restricted to oysters and pectinids. In places, however, relatively well-preserved, mainly infaunal bivalves occur, which may reach a diversity of some 20 species (personal observation SS). A few bivalves from the Klentnice beds at Niederfellabrunn have been reported by Abel (1897), who also described a new propeamussiid species. Furthermore, he recorded a species of “*Aucella*”, which is a junior synonym of *Buchia*, a genus that is regarded a typical constituent of boreal Upper Jurassic faunas (e.g., Kelly 1990). Together with several new

Figure 8. Typical fossils from the Ernstbrunn Limestone. • A – *Metriomphalus transitorius* (Zittel, 1873); rubber cast of external mould; Dörfles; NHMW 2012/0108/0005. • B – *Gastrodorus neuhausense* von Meyer, 1864; specimen figured by Feldmann & Schweitzer (2009, fig. 3.8); Dörfles; NHMW 1990z0041/4244. • C – *Fimbria* sp., internal mould. Dörfles; NHMW 2012/0108/0004. • D – *Kutekiceras* aff. *steinbergense* Zeiss, 2001; microconch; rubber cast of external mould; Dörfles; NHMW 2012/0108/0001. • E – *Eunerinea hoheneggeri* (Peters, 1855); original of Wieczorek (1997, pl. 1, fig. 8); Dörfles?; NHMW 1997z/0166/0005. • F – *Lepidotes maximus* Wagner, 1863; pharyngeal tooth; Falkenstein; NHMW 2012/0109/0001. • G – *Chlamys* cf. *textoria* (von Schlotheim, 1820); Dörfles; NHMW 2012/0108/0007. • H – indeterminable colonial coral; internal mould; Dörfles I quarry; NHMW 2012/0110/0003. • I – nerineid gastropod; internal mould; Dörfles; NHMW 2012/0108/0003. Scale bars: A, C–I = 10 mm; B = 1 mm.



discoveries, these specimens were redescribed and refigured by Vetters (1905). Vašíček (1971) documented nuculoid and gryphaeid bivalves from drill cores penetrating the autochthonous Klentnice beds below the Alpine-Carpathian Foredeep in the Czech Republic.

Gastropoda. – The largest fossils preserved in the Ernstbrunn Limestone are the more than 250 mm high *Leviathania gigantea* (Makowsky, 1874), which were first described from the Pavlov Hills (Makowsky 1874), figured by several authors (e.g., Bachmayer 1964b, 1969; Plöching & Karanitsch 2002; Wessely 2006), and recently revised by Harzhauser & Schneider (accepted). Most abundant, however, are nerineid gastropods (Fig. 8E, I), several taxa of which were recorded from the Ernstbrunn Limestone of the Mikulov area by Peters (1855). Recently, the nerineids from the Ernstbrunn-Dörfles quarries have been revised by Wiczorek (1998), who recognised 16 species. The total number of 45 gastropod species described by Dürrmayer (1931) was raised to 52 by Bachmayer (1940). The gastropod fauna of the Ernstbrunn Limestone (Fig. 8A) still awaits a comprehensive description, which would likely more or less double the number of species.

Because aragonitic shells have usually been dissolved, no gastropods have been recorded from the Klentnice beds so far, but a few unspecific internal moulds of turreted shells from Südmährerkreuz (see Fig. 4 for location) are stored in the collections of the NHMW.

Cephalopoda. – Altogether, four species of nautilids (*Hercoglossa* spp.) have been reported from the Ernstbrunn Limestone (Bachmayer 1940, 1957; Dürrmayer 1931). An exceptionally well preserved specimen was figured by Bachmayer (1964b, 1969). The ammonite fauna of the Ernstbrunn Limestone was revised by Zeiss (2001), who also provided a review of earlier work dealing with these fossils. These are the unpublished theses of Moeller (1911), Dürrmayer (1931), and Bachmayer (1940), as well as the fauna listed by Bachmayer (1957) and Zeiss & Bachmayer (1989). Altogether, Zeiss (2001) reported 37 species of ammonites in 14 genera from Dörfles Werk II quarry (Fig. 8D), and a single specimen of *Ernstbrunnia* from the Galgenberg. Additionally, he recognised 13 more or less dubious taxa from

the literature, where specimens have been lost. The most celebrated ammonite from the Ernstbrunn Limestone is *Ernstbrunnia fasciculata* Zeiss, 2001, since it was figured on a stamp issued on the occasion of the 100th anniversary of the Naturhistorisches Museum Wien in 1976 (Bachmayer 1976, Thenius & Vavra 1996) and formed the template of a logo of the Naturhistorisches Museum Wien in the 1980s. The specimen was refigured by Hofmann (1995) and Wessely (2006).

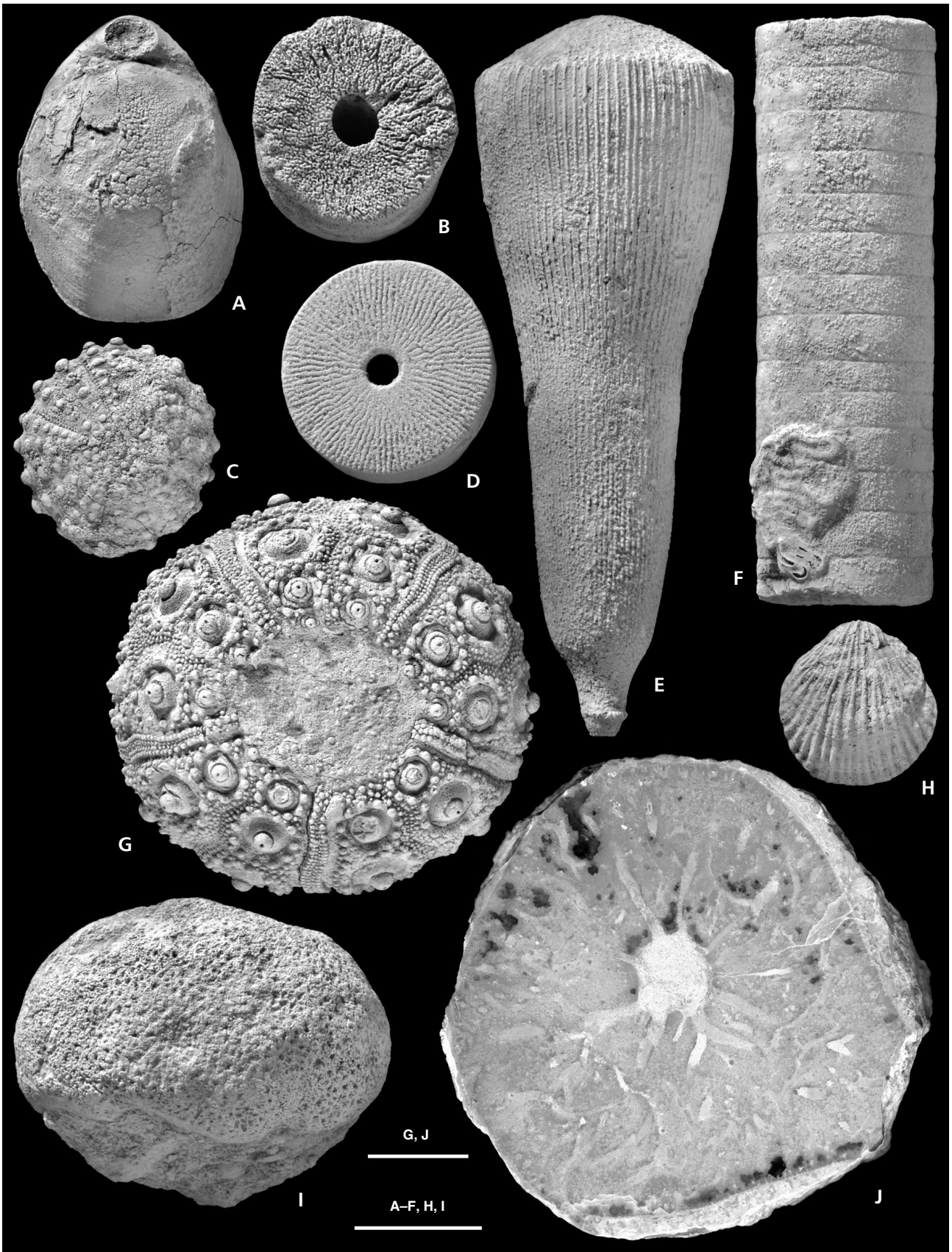
Ammonites from the Klentnice beds, namely from the surroundings of Niederfellabrunn, have been described by Abel (1897), Krafft (1897, dealing with a single specimen), Vetters (1905), Spath (1933), and Arkell (1956). Additionally, Vašíček (1971, 1980) detailed several species from boreholes in southern Moravia. The latest revision of the fauna was produced by Zeiss (1977) and recollected by Kutek & Zeiss (1988). Additionally, several types of aptychi from outcrops and drill cores were detailed (Bachmayer 1963; Vašíček 1971, 1980; Vetter 1905).

Furthermore, Abel (1897) lists several belemnite species from the Klentnice beds of Niederfellabrunn, but does not provide figures. From the same outcrops, Vetter (1905) reported on five species of belemnites and described and illustrated three of them as new.

Brachiopoda. – A few brachiopods from the Ernstbrunn Limestone are listed by Prinzing (1851). Suess (1858) mentions three species from the Ernstbrunn Limestone (one from Ernstbrunn and two from Mikulov) and four from the Klentnice beds. Dürrmayer (1931) lists a single species from the Ernstbrunn Limestone. Large terebratulids are relatively common at Dörfles V quarry, but have never been studied. Brachiopods from the Klentnice beds (Fig. 9A, H) are also mentioned by Hoernes (1874). Vetter (1905) described and illustrated three species of terebratulids, while Jüttner (1922) provided figures of a single rhychonellid taxon.

Ostracoda. – Ostracods have so far only been recorded from the Klentnice beds of a single outcrop in the Mikulov region. In two papers Pokorný (1959, 1971) provided preliminary results on the ostracod fauna from this locality and formally described a new genus and a new species. Subsequently, Pokorný (1973) monographed the Ostracoda and recorded a total of 56 species.

Figure 9. Typical fossils from the Klentnice beds. • A – terebratulid brachiopod; Klentnice (Table Mountain); NHMW 1931/0001/0041. • B–J – all specimens (presumably) from Ernstbrunn (Semmelberg). • B – *Corynella* sp.; NHMW 2012/0107/0007. • C – *Acropeltis aequituberculatus* L. Agassiz in L. Agassiz & Desor, 1846, aboral view; NHMW 2012/0107/0002. • D – millericrinid pluricolumnal, articular surface; NHMW 2012/0107/0004. • E – *Hemicidaris (Sphaerotiaria)* sp. [= *Hemicidaris crenularis* auctt.]; lateral view of spine; NHMW 2012/0107/0005. • F – millericrinid pluricolumnal, lateral view; with serpulid (lower left); NHMW 2012/0107/0006. • G – *Plegiocidaris crucifera* (L. Agassiz, 1840); oral view; NHMW 2012/0107/0001. • H – rhychonelliform brachiopod; NHMW 2012/0107/0009. • I – calcareous sponge; NHMW 2012/0107/0003. • J – calcareous sponge; polished section; NHMW 2012/0107/0008. Scale bars = 10 mm.



Isopoda. – Bachmayer (1949) described three species of Isopoda from the Ernstbrunn Limestone, including a new genus and two new species. Two additional species were newly established by Bachmayer (1955b) and the total number of isopods was updated to seven taxa.

Decapoda. – The first decapod species from the Ernstbrunn Limestone has been listed by Moericke (1897). Later, Glaessner (1931) and Bachmayer (1945, 1955c) provided more or less comprehensive lists of crustaceans. Moreover, Bachmayer (1948b) reported on teratologic decapod specimens. Bachmayer (1958b, 1959) described a single new decapod. Wehner (1988) mentioned several taxa from Ernstbrunn in her Ph.D. thesis on the “Prosopidae” (Brachyura). A few years ago, the several thousands of carapaces collected by Friedrich Bachmayer during four decades were “rediscovered” in the collections of the NHMW Vienna and a wealth of species was treated in numerous publications since then (Feldmann & Schweitzer 2009; Robins *et al.* 2007, 2010, 2012, 2013; Schweitzer & Feldmann 2008a, b, 2009a–d, 2010a–d). Nevertheless, numerous additional forms are hitherto unpublished.

Echinodermata. – The first short list of echinoderms from the Ernstbrunn Limestone was provided by Prinzinger (1851). Much later, Bachmayer (1958a) reported two crinoid species, one of them described as new. Remains of *Saccocoma* were mentioned from Tithonian strata from a borehole by Řehánek (1987a). Besides, the Ernstbrunn Limestone yields a moderately diverse fauna of echinoids, including exceptionally large “regular” and irregular taxa. From the Klentnice beds, Rolle (1855) describes 9 species of “regular” echinoids. Moreover, crinoids and echinoids from the Klentnice beds are listed by Hoernes (1874) and Jüttner (1922), who also figures several species. Within this unit large hemicyclid spines (Fig. 9E) are most common, as are stem fragments of millericrinid crinoids (Fig. 9D, F). Apart from *Plegiocidarid* (Fig. 9G) other echinoderm remains (Fig. 9C) are generally rare.

Pisces. – Dürrmayer (1931) and Bachmayer (1940) list a single species of fish, *i.e.* *Lepidotes maximus* Wagner, 1863. The typical circular teeth of these large fishes occur in high abundance at Falkenstein (Fig. 8F) and were obviously also quite common in particular outcrops of the Mikulov region, judging from old collections at Vienna (NHMW, GBA). Occasionally, the teeth are preserved more or less *in situ*, while the bony parts of the skeleton disintegrated entirely during diagenesis. Several small pharyngeal teeth of unknown affinity and a few poorly preserved shark teeth are present in the collections of NHMW.

Significance of the biota

Anybody having a close look at the “classical” Ernstbrunn Limestone, *i.e.* the lagoonal facies of Dörfles, Falkenstein, or Marienmühle at outcrop will easily recognize the outstanding palaeontological significance of this stratum, simply because of its unusual richness in fossils (Fig. 7). Looking at detail, the assemblage yields not just an enormous number of partly remarkably large specimens but also an extraordinarily high diversity. Estimated to comprise more than 500 species (Bachmayer 1957), the fossil assemblage of the Ernstbrunn Limestone ranges among the most speciose Mesozoic environments ever recorded and certainly deserves to be termed an Upper Jurassic marine biodiversity hotspot (*sensu* Roberts *et al.* 2002; Fig. 7). However, up to the 21st century, this has largely remained “hidden diversity”, since despite of more than 40 years of intense, enthusiastic, and accurate collecting by Bachmayer none of the most speciose groups of fossils was detailed. First and most important from a stratigraphical point of view, the ammonites of the Ernstbrunn Limestone were monographed (Zeiss 2001). Recently, the decapod faunas from Ernstbrunn-Dörfles (represented by more than 10.000 specimens in the collections of the NHMW) and from the coeval Štrambersk Limestone (Silesian Unit, northern Moravia, Czech Republic) have been found to be of extraordinary significance for phylogenetic studies. The Tithonian reefs and reef-associated strata at the northern Tethys margin may comprise an ancient radiation centre of the Decapoda and accordingly acted as a cradle for several major clades of modern crabs (Feldmann & Schweitzer 2009; Schweitzer & Feldmann 2008a, b, 2009a–d, 2010a–d). Likewise, the Jurassic-Cretaceous lagoons on the Tethys shelf may have played a key role in the development of the Requienioidea, *i.e.* the left-valve-attached clade of rudist bivalves (Hippuritida). Basal representatives of this group, now placed in the family Epidiceratidae (Bieler *et al.* 2010), flourished in the lagoons of the Ernstbrunn-Pavlov Carbonate Platform, forming small, paucispecific patch reefs. Together with the highly abundant Nerineidae (Gastropoda), which also came to bloom during the Tithonian–Berriasian, and with a rich flora of dasyclad algae, the Epidiceratidae dominate the biofacies of these lagoons.

Although the fossil assemblage preserved in the Klentnice beds is much less spectacular due to the near-complete diagenetic loss of aragonite, the stratum is well-known for its more or less strongly silicified, originally calcitic skeletons, *i.e.* mainly echinoderms, brachiopods, and calcareous sponges. At places ammonites or bivalves add to a more complex view of the fauna, providing valuable insight into bottom life of the outer shelf area dominated by siliclastic sediments.

Information on inner and outer platform carbonates (= Ernstbrunn Limestone) and on their intergrading with

siliciclastic sediments of the outer shelf (= Klentnice beds, Mikulov Marls, Kurdějov Arenite) is available from several localities at surface and numerous cores. As a whole, they offer an exceptionally complete view on the facies architecture on and around a Tithonian–Berriasian marginal carbonate platform in the Tethys Ocean.

Strata of similar age and composition are fairly restricted in occurrence but geographically widespread, which increases the scientific importance of the Jurassic–Cretaceous klippen of the WZU. A coeval highly diverse assemblage has been reported from the Štramberg Limestone, cropping out in several klippen associated with the Silesian and Subsilesian nappes of the Carpathians in the Štramberg (NE Czech Republic) and Andrychow (S Poland) regions (*e.g.*, Boehm 1883; Zittel 1868, 1873). However, the Štramberg Limestone predominantly preserves near-shore strata, and the more distal facies, well-known from the Ernstbrunn Limestone and Klentnice beds, is lacking. Lagoonal fossil assemblages of similar age, diversity, and composition have been described from Mont Salève (Hauté-Savoie, SE France; *e.g.*, Joukowsky & Favre 1913), Valfin (W Switzerland, Loriol & Bourgeat 1886–1888), southern Ukraine (Alth 1881, 1882) and the Crimea peninsula (*e.g.*, Pčelinzev 1924, 1963). Slightly older, Lower Tithonian assemblages are reported from the Palermo region (Sicily, Italy; Gemmellaro 1868–1876) and the southern Franconian Alb (Kelheim and Ingolstadt regions; *e.g.*, Boehm 1882). Most of these outcrops were less intensely sampled and/or are significantly smaller than the Ernstbrunn, Falkenstein and Pavlov klippen, making the Ernstbrunn Limestone one of the most important strata for exploration of these facies and their typical biota.

Future directions

Due to intensive drilling in the course of hydrocarbon exploration, knowledge of the standard geologic succession of the Upper Jurassic rocks at the southern slope of the Bohemian Massif and the tectonic evolution of the WZU klippen seem largely settled. With regard to sedimentology, a next crucial step would be a comprehensive study of the (micro-)facies of all major and minor outcrops of the Ernstbrunn Limestone, in order to identify the total range of existing lithofacies and to develop a facies model. Additionally, outcrops and historical wine cellars exposing the Klentnice beds need to be systematically accessed and/or excavated in order to figure out stratification and sedimentology.

With regard to palaeontology, a systematic account of the Ernstbrunn fossil fauna and flora would be necessary, to establish a solid base for comprehensive studies of palaeoecology, palaeoclimatology and palaeobiogeography. Extensive collections of fossils are stored in the palaeontological

repositories of the Natural History Museum Vienna and the Moravian Museum at Brno, and to a minor extent at the Geologische Bundesanstalt Wien, the University of Vienna, and the Krahuletz Museum at Eggenburg. Preliminary data from Bivalvia, which are usually reliable indicators of (palaeo-)ecology suggest close faunistic and ecologic relationships to the coeval Štramberg Limestone, but also indicate significant differences in community structure, which need to be evaluated in detail. Likewise, all other groups of fossil organisms may add important information about the Ernstbrunn ecosystem.

Finally, sedimentological and palaeontological data should be integrated to enable a preferably complete reconstruction of the (1) size and extent, (2) facies architecture, and (3) palaeoenvironment of the former Ernstbrunn-Pavlov Carbonate Platform. The resulting model may be compared to those from coeval carbonate platforms, in order to identify their typical as well as unique features. Finally, data may also be checked against those from earlier or later ecosystems of similar composition to distinguish directional from non-directional developments.

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As far as we are aware, this bibliography covers all aspects of geoscientific research particularly concerned with the Ernstbrunn Limestone and Klentnice beds at surface and subsurface. Furthermore, compilations of regional geology (*e.g.*, Andrusov 1959; Cicha *et al.* 1964; Fuchs 1976; Hauer 1875, 1878; Kober 1926;

Kohn 1911; Neumayr 1870, 1887; Oberhauser 1980; Paul 1898; Pícha *et al.* 2006; Rasumovsky 1830, 1831; Roth 1980; Roth & Hanzlíková 1968; Rzehak 1902–1903; Seifert 1993; Stejskal 1935a; Straník *et al.* 1999; Thenius 1974; Uhlig 1907; Zapfe 1963), geologic maps and mapping reports (Abel 1910; Abel *et al.* 1907; Bachmayer 1954b, 1955a; Beck *et al.* 1980; Čtyroký *et al.* 1988, 1995; Glocker 1842; Grill 1952, 1958, 1961, 1962, 1968; Grill & Küpper 1954; Hauer 1869; Jüttner 1940; Kolenati 1852; Matějka 1963; Partsch 1844; Roetzel 2002; Schnabel 2002; Vettors 1910), excursion guides (Bachmayer & Grill 1958; Grill & Kapouněk 1964; Grill *et al.* 1963; Hofmann 1992b, 1997; Rögl *et al.* 2009; Sauer *et al.* 1992), and a few popular articles (Bachmayer 1954a, 1964b, 1969; Hofmann 1995; Kroh 2010; Plöching & Karanitsch 2002; Schneider 2012; Stojaspal 1984) and abstracts (*e.g.*, Poul & Melichar 2003, 2005, 2006; Schneider *et al.* 2011) are included. Certainly, the Ernstbrunn Limestone and Klentnice beds are mentioned in additional textbooks or larger scale geologic overviews, which are not considered herein, since they only comprise secondary sources rarely adding new data. If not indicated otherwise (= [not seen]), all publications have been personally checked by the authors. Any information on significant contributions supplementary to this list is highly welcome!

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