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The St. Veit Klippen Unit in Vienna (Austria) – Jurassic to Cretaceous biostratigraphy and facies based on historical fossil collections

Alexander LUKENEDER[1)], Petra LUKENEDER[1)] and Mathias HARZHAUSER[1)]
[1)] Museum of Natural History Vienna, Burgring 7, 1010 Vienna, Austria
*) Corresponding author: alexander.lukeneder@nhm-wien.ac.at

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Abstract
Historical fossil assemblages from the Lower Jurassic to Lower Cretaceous of the Sankt Veit Klippen Unit (SVK) on the western outskirts of Vienna were re-evaluated. Collections of the material from the St. Veit Klippen Unit comprise 3497 specimens. An appropriate nomenclature was used, and the taxonomy was partly revised. Historical collections from Franz Toula (1845–1920) and Friedrich Trauth (1883–1967) were investigated in the collections of the Natural History Museum Vienna, the Geological Survey Vienna, the Department of Geology and the Department of Palaeontology (both University Vienna). Additional collections were studied in the district museums Hietzing (13th district Vienna) and Liesing (23rd district Vienna), in the district municipal office of Hietzing and in the Wienerwald Museum (Eichgraben, Lower Austria). The study area is situated in the easternmost part of the St. Veit Klippen Unit in the Wienerwald (Vienna Woods), part of the 13th Viennese district Hietzing. New data allowed a revision of the biostratigraphy of several lithological units of the SVK. Two main fossil complexes could be distinguished: 1) the Hohenauer Wiese assemblage from the wildlife park Lainz (= "Lainzer Tiergarten") and 2) the Glasauer quarry assemblage from St. Veit.

1. Introduction

The St. Veit Klippen Unit (SVK - the term "unit" is used herein to replace the ambigous term "zone" as used by former authors in "klippen zones") is one of the most enigmatic tectonic units in the Alpine area of Austria. The St. Veit Klippen Unit has been traditionally referred to as St. Veit Klippen Zone in the geological literature. In modern geological nomenclature the term "zone" should be restricted to biostratigraphy (e.g. Steiniger and Piller, 1999). A similar case is the so-called "Waschberg Zone", which is nowadays treated as Waschberg-Ždánice Unit or "Einheit" (Schneider et al., 2013; Gebhart, 2016; Knierzinger et al., 2018). We follow this strict use of the term "zone" and therefore, refer to the St. Veit Klippen Unit.

The SVK represents an intermittent element between the Rhenodanubian Flysch in the north and the Northern Calcareous Alps in the south. In fact, the SVK is draped by Flysch deposits of the Hütteldorf and Kahlenberg formations of the "Satzberg-Schuppe", whose tectonic relation within the Rhenodanubian Flysch is in discussion (pers. comm. W. Schnabel, August 2020). The generally NE/SW striking complex tectonic style, mirrored by intermingled rock complexes of siliceous limestones, radiolarites or crinodial limestones into sandstones and conglomerates of the Rhenodanubian Flysch units characterizes the Wienerwald (Vienna Woods) area (Vetters, 1910; Schaffer, 1904, 1906, 1942; Kober, 1955; Thenius, 1974; Prey, 1987; Plöchinger and Prey, 1992; Schnabel, 1992a, b, 2002; Ślączka et al., 2018). Complicated by disconnected tectonic elements of meter- to kilometer-sized blocks (= block-in-matrix structure of Ślączka et al., 2018) without visible contacts or continuation in lithological evidence the SVK is difficult to handle. This special tectonic feature was already described by Trauth (1907).

Since Czjžek (1849, 1852), who introduced the "St. Veiter Klippenhügel", referring to the village St. Veit near Vienna, the work and interest on the geology of the SVK has a long tradition. Hauer (1850) described red limestones from St. Veit with small fossil assemblages comprising aptychi. Peters (1854) also noted aptychi from St. Veit. Lower Jurassic deposits were reported by Paul (1859) from St. Veit with *Ammonites conybeari*, *Pleurotomaria expansa* and *Lima punctata*. Griesbach (1868, 1869) was the first who subdivided the limestones, since then called "Der Jura von St. Veit". He first distinguished 1) the Gresten limestone, 2) the Lower Jurassic (Liassic α), 3) the "Jura von St Veit" and 4) Upper Jurassic (= Malmian) above the Triassic Kössen Formation. Within the "Jura of St. Veit" he determined the *Ammonites sauzei*, the *Ammonites humphriesianus* and the *Ammonites parkinsoni* zones. Hochstetter (1898), Schaffer (1904, 1906), Vetters (1910)

and Spitz (1910) continued this work on the geology and tectonics of the SVK. More recently Götzinger (1954), Grill and Küpper (1954), Kober (1955), Janoschek et al. (1956), Küpper (1968), Thenius (1974), Prey (1985, 1987), Plöchinger and Prey (1992), Schnabel (1992a, b, 1999, 2002), Wessely (2006), Egger and Wessley (2014), Pfersmann (2013) and Ślączka et al. (2018) tried to solve the problematic SVK zone.

Fossil assemblages were described by Hochstetter (1898) and Trauth (1923a, b, 1928, 1948), who proposed a preliminary biostratigraphy. Trauth (1948) published material, which has been collected in 1900 by Franz Toula from the St. Veit Klippe for the "Mineralogisch-Geologische Lehrkanzel" of the Technical University Vienna. Janoschek et al. (1956), Prey (1975, 1979, 1987), Schnabel (1999, 2002), Schnabel et al. (1997), and more recently Pfersmann (2013) adapted largely Trauth's biostratigraphic concept of the SVK. Only Ślączka et al. (2018) presented new biostratigraphic data based on radiolarians and few nannofossils.

All published lithological schemes and logs were compiled from literature data or based on close-by but geographically separated historic outcrops and localities (e.g. Janoschek et al., 1956; Schnabel, 2002; Pfersmann, 2013; Ślączka et al., 2018). Today, no sections are available exposing lithological formations with lower or upper boundaries. Therefore, no formalization of lithostratigraphic units at Formation or Member rank can be performed, which would fulfil the formal requirements of Hedberg (1976), Salvador (1994) and Steininger and Piller (1999). For the sake of stability and readability, however, we use the established lithostratigraphic names as informal units.

Only temporary construction projects for tunnels, roads and houses serve as small, local windows into the deposits of the SVK. Compiled sections indicate a succession of Lower to Middle Jurassic sandy-silty grey marlstones and limestones of the Hohenauer Wiese Formation (pro parte), Middle to Upper Jurassic red radiolarites to cherts and red marly shales of the Rotenberg Formation, followed by Upper Jurassic to Lower Cretaceous grey marls to argillaceous limestones of the lower Fasselgraben Formation, and the Lower Cretaceous "Aptychus limestone" of the upper Fasselgraben Formation, comprising grey to white siliceous limestones and green cherts (Janoschek et al., 1956; Prey, 1975, 1979; Ślączka et al., 2018).

Jurassic deposits are known to form a small but significant tectonic element of the afforested and covered klippen terrain adjacent to the Northern Calcareous Alps (NCA; Janoschek et al., 1956; Prey, 1975, 1979, 1987; Schnabel, 1999, 2002; Schnabel et al., 1997; Pfersmann, 2013; Ślączka et al., 2018). In the SVK comprising the Lower Jurassic to Lower Cretaceous Sankt Veit localities, Lower Jurassic (= "Lias") and Middle Jurassic (= "Dogger") cephalopod-bearing deposits are mainly recorded in grey fine-grained deep-water limestones, hemipelagic variegated (red, grey) crinoidal limestones and grey silty crinoidal limestones.

The grey Lower Jurassic marly limestones show similarities to the Austroalpine Allgäu Formation (= "Lias Fleckenmergel"). Such Sinemurian sediments are composed of grey, intensely burrow-mottled limestones with intercalated marls and frequent allodapic crinoid limestone layers (Müller, 1987; Egger, 1988; Egger and van Husen, 2011; Lukeneder and Lukeneder, 2018). Lower Jurassic (i.e. Sinemurian) ammonite faunas are rare in the SVK and the Northern Calcareous Alps.

Fossil assemblages from red crinoid limestones from the "Teichhaus Klippe" in a wildlife preserve area of the western wildlife park Lainz are known since the late 19th century (Griesbach, 1869; Trauth, 1923a, 1948). The fauna is dominated by ammonites and brachiopods, which derive from red limestones with considerable quantities of crinoid fragments.

Most of the collected fossils like ammonites, nautilids, gastropods and bivalves derive from the historic Glasauer quarry (= Glassauer Steinbruch; Schaffer, 1906) in St. Veit. Unfortunately, the historical material was not collected bed-by-bed or with any information on position within the sections. Grey silicious, partly silty, limestones with sponge spiculae and radiolarians appear with remarkable amount of detrital quartz.

The SVK represents a tectonic key-area between the "Klippen zones" in Austria and the corresponding units in the Pieniny Klippen Belt in the Western Carpathians of Slovakia, Poland and Ukraine (Ślączka et al., 2018). Herein, we re-evaluate the existing fossil inventory with focus on the ammonite assemblages and partly revised previous taxonomic identifications. This resulted in a new biostratigraphic concept for the deposits of the SVK. Thus, the aim of this work is 1) to describe the lithologies of the SVK in the St. Veit and wildlife park Lainz areas, 2) to revise the taxonomy where appropriate, 3) to present an integrated stratigraphy based on data from lithology, microfacies (from thin sections) and biostratigraphy, 4) to record all data from official collections, 5) and to make the dataset available online in an open access database.

2. Geographical setting

Rock samples and fossils were investigated from two main outcrops located in the westernmost district of Vienna, the 13th district Hietzing (ÖK 1:50 000, sheet 58 Baden; Auto-Map Online 2020; Fig. 1). In the 1890ies, St. Veit was an independent municipality, which later became part of the City of Vienna. Today, St. Veit is one of 89 cadastre municipalities of Vienna. One locality, the so called "Teichwiese", "Teichhaus" or "Teichwiese Klippe locality" (295 m above sea level, N 48°9'55.9" E 16°14'39.9") is situated in the wildlife park Lainz ("Lainzer Tiergarten"; "Kaiserlicher Tiergarten" in Suess, 1897), a wildlife preserve covered by 80% of woodland. It is a protected area and sampling is prohibited without permit from the official municipality. The name refers to a small pond, the Hohenauer Teich, located near the Lainzer Tor entry (265 m, N 48°10'00.8" E 16°15'25.6"). Most of the fossil material was collected in the 1890ies until 1900. Nowadays, the historical outcrop is inaccessible and overgrown.

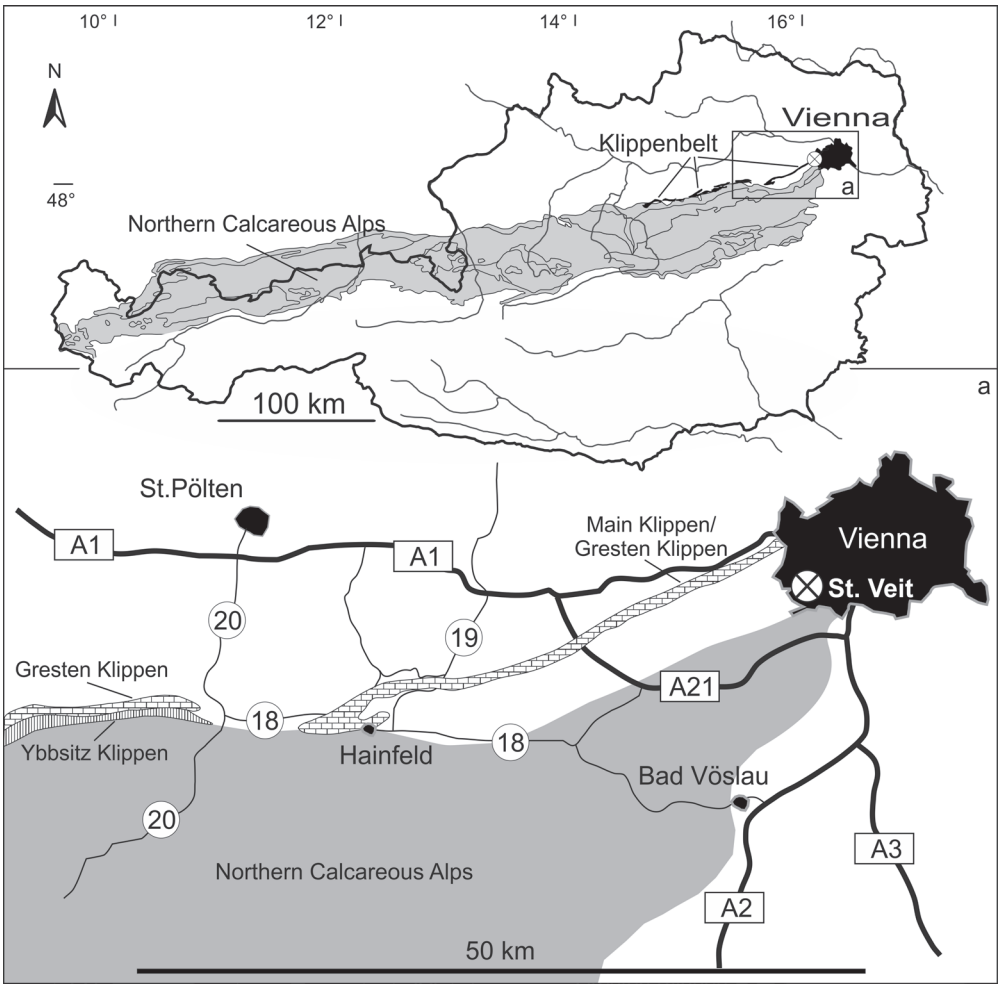

Figure 1: Map of Austria and the Northern Calcareous Alps with the indicated position of Sankt Veit (St. Veit). Inserted map a) shows the position of the Austrian Klippen units in Lower Austria and Vienna (including highways A1, A2, A3 and A21).

Two small localities in the area yielded also historic material: "Klippe 2" (290 m, N 48°09'50.3" E 16°14'50.5") approx. 300 m WNW of the Teichwiese Klippe locality and the "Doppelhügelklippe" ("double-hill-chain") another 200 m to the west, ranging from N 48°09'54.6" E 16°14'41.3") in the north (290 m) to N 48°09'46.9" E 16°14'41.9" in the south (320 m).

The second important locality is the historical Glasauer quarry in St. Veit (250 m N 48°10'51.5" E 16°16'3.2") on the southeastern slope of the Girzenberg and the southwestern base of the Roter Berg (= Rother Berg, Schaffer 1942; Amon, 1930; Plöchinger and Prey, 1992) at the crossroad Jagdschloßgasse und Veitingergasse (approx. house number 68). The Glasauer quarry yielded the bulk of the entire ammonite assemblage. The historic quarry with a front wall of 15 metres height is now inaccessible and located within settlement area.

Numerous other fossil localities within the wildlife park Lainz are known from literature. The Stockwiese (325 m, N 48°9'32.8" E 16°13'34.9), the nearby Fasselgraben (310 m, 22°/135°, N 48°9'22.4" E 16°13'47.2), the Dorotheerwiese (305 m, 65°/113°; N 48°9'49.4" E 16°14'22.6), the Saulackentürl (295 m, N 48°10'18.4" E 16°15'22.7), and the Saulackenschütt (295 m, N 48°10'31.3" E 16°14'50.1). Fossil material from St. Veit is known from several localities as the Roter Berg (262 m, N 48°10'56.4" E 16°16'11.3), the Gemeindeberg (320 m, N 48°10'43.4" E 16°15'38.31), and numerous distinct but scattered localities from roadworks and house constructions in St. Veit (Schaffer, 1906; Götzinger, 1954). Additionally, there was a short-dated chance to sample during construction of the Lainz Tunnel ("Lainzer Tunnel") by the ÖBB Infrastruktur GmbH for rail traffic in 2007–2009 (Pfersmann, 2013).

3. Geological setting

The Mesozoic Klippen belt on western Vienna territory is referred to as St. Veit Klippen Unit (Geological map 1:50.000, sheet 58 Baden; Schnabel et al., 1997; Fig. 1). On the Stratigraphic Chart of Austria (Piller et al., 2004) the following Jurassic and Cretaceous lithologies and formations are given for the St. Veit Klippen Unit: bioclastic limestones (Hettangian-Bajocian), the Hohenauer Wiese Formation (Bajocian-Bathonian), red crinoidal limestones (Callovian), the Rotenberg Formation (Oxfordian-Kimmerdigian) and the Fasselgraben Formation (Tithonian-Valanginian; see Schnabel et al., 1997; Wessely, 2006; Egger and Wessely, 2014; Fig. 2).

The hilly ground of the St. Veit Klippen Unit has a strongly sheared tectonic contact with the surrounding Rhenodanubian Flysch units represented by the Hüttel-dorf and Kahlenberg formations. As noted by Ślączka et al. (2018), no primary sedimentary contact of the SVK with the Flysch nappes can be observed. The area is bor-dered in the south along the Lainzer Tor (Lainz Gate) by Miocene deposits of the Vienna Basin.

The Antonshöhe hill is located approximately 1 km southeast of the Stockwiese and 2 km south from the Lainzer Tor, and exposes Upper Jurassic deposits of the Northern Calcareous Alps. The Antonshöhe is tectoni-cally isolated from the main area of the St. Veit Klippen Unit and interpreted to be a northern tectonic alpine unit (see also Plöchinger and Prey, 1992; Ślączka et al., 2018). Contrastingly, Küpper (1968), Prey (1987, 1991), Schnabel (1992a, b) and more recently Egger and Wessely (2014) indicated a connection of the Antonshöhe area to the St. Veit Klippen Unit. Today, most of the historic outcrops are inaccessible (e.g. Glasauer quarry; Hohenauer Wiese Klippe) and are overgrown.

4. Material and methods

4.1 Fossil material

The historical material was collected in the late 19th century by Carl Ludolph Griesbach, in 1900 by Franz Toula (see Trauth, 1923a) and Egbert Wilhelm von Hochstetter. Recently, addi-tional findings were made by Oliver Schmitsberger, Martin Maslo, Alexander Lukeneder and Petra Lukeneder.

The aim of this project was to acquire all data of fossil and rock samples from the SVZ in public collection such as:

Natural History Museum in Vienna (NHMW): 2354 fossil remains comprising 1049 ammonite specimens, 151 apty-chi, 59 nautilids, 189 belemnites, 3 oegopsids, 328 bivalves, 20 gastropods, 3 polychaets, 32 echinoids, 29 crinoids, 11 indeterminate echinoderms, 420 brachiopods, 1 trace fos-sil, 1 vertebrate, 57 rock samples and 1 indeterminate fossil.

Geological Survey of Vienna (GBA): 518 fossil remains comprising 179 ammonite specimens, 116 aptychi, 9 nautilids, 78 belemnites, 1 oegopsid, 77 bivalves, 3 gas-tropods, 6 crinoids, 40 brachiopods, 1 trace fossil, 3 verte-brates, 1 rock sample and 3 indeterminate fossils.

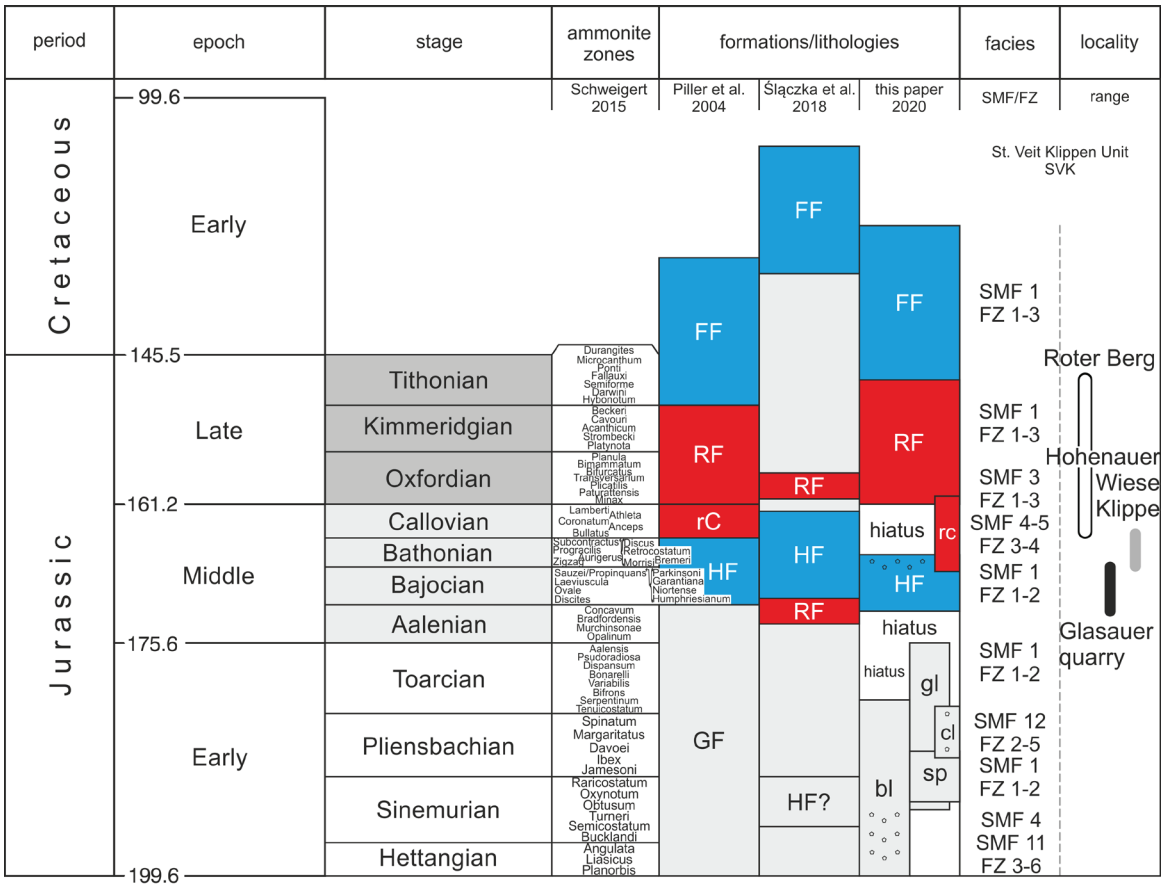

Figure 2: Composite vertical biostratigraphic and lithologic units of the St. Veit Klippen Unit in Vienna. Column 1 after the Austrian Stratigraphic Chart (Piller et al., 2004), column 2 after Ślączka et al. (2018): FF: Fasselgraben Formation; RF: Rotenberg Formation; HF: Hohenauer Wiese Formation; GF: Grest-en Formation; rC: red crinoidal limestones. Column 3 from data presented in this paper: bl bioclastic limestones; sp spiculites; rc red crinoidal limestones; sl silicious limestones; cl crinoidal limestones, gL grey limestones; Classification of facies zones and standard microfacies types (FZ types and SMF types, Dunham, 1962; Wilson, 1975; Flügel, 2004).

Department of Geology of the University Vienna (IGUW): 190 fossil remains comprising 98 ammonite specimens, 3 aptychi, 3 nautilids, 29 belemnites, 9 bivalves, 1 echinoid, 29 brachiopods, 1 vertebrate and 17 rock samples.
Department for Palaeontology of the University Vienna (IPUW): 336 fossil remains comprising 161 ammonite specimens, 20 aptychi, 4 nautilids, 12 belemnites, 7 oegopsids, 29 bivalves, 7 gastropods, 14 echinoids, 77 brachiopods, 1 vertebrate, 3 rock samples and 1 indeterminate fossil.

Smaller collections are stored in the district museums of Hietzing (13th district Vienna; 8 fossils and rock samples) and Liesing (23rd district Vienna; 8 fossils and rock samples), at the district municipal office of Hietzing (55 fossils and rock samples) and the Wienerwald Museum (Eichgraben, Lower Austria; 28 fossils and rock samples).

In total, 3393 fossil specimens and 104 rock samples were photographed in the collections comprising 1509 ammonites, 1 indeterminate cephalopod, 290 aptychi, 76 nautilids, 333 belemnites, 11 oegopsids, 452 bivalves, 30 gastropods, 3 polychaets, 47 echinoids, 38 crinoids, 11 indeterminate echinoderms, 574 brachiopods, 2 trace fossils, 4 porifera, 6 vertebrates, 1 plant remain and 5 indeterminate fossils from St. Veit and wildlife park Lainz. Ammonoids are moderately preserved (mostly compressed internal casts without shell but often with well-preserved suture lines) and account for almost half of the macrofauna (44%).

4.2 Thin sections

43 thin sections have been obtained from characteristic lithologies and fossils with matrix to examine microfossil content and microfacies (Figs. 3, 4, 5). Thin sections were taken from historical material and from recent field samples (construction sites in Ober St. Veit and the wildlife park Lainz) if possible. Digital high-quality photomicrographs of the thin sections were taken with a Discovery. V20 Stereo Zeiss microscope. Specific magnifications are x4.7, x10.5 and x40 in transmitted light mode. Data from the AxioCam MRc5 Zeiss were processed and documented by using the AxioVision SE64 Rel. 4.9 imaging system. Classification of facies zones and standard microfacies types (FZ types and SMF types) follows Dunham (1962), Wilson (1975) and Flügel (2004). Carbonate classification follows Dunham (1962).

All specimens in Figures 6, 7 and 8 were coated with ammonium chloride before photographing.

Abbreviations:

BST OSV, Baustelle Ober St. Veit
FZ, facies zone
GBA, Geological Survey of Vienna
IGUW, Department of Geology Vienna
IPUW, Department of Palaeontology Vienna
NCA, Northern Calcareous Alps
NHMW, Natural History Museum Vienna
OSV, Ober St. Veit
SMF, microfacies type
SVK, St. Veit Klippen Unit

5. Results

5.1. Lithologies and microfacies types in the St. Veit Klippen Unit

The lithological descriptions are arranged according to interpreted stratigraphic age, starting from older facies types. Detailed information to localities of analysed thin sections are given in figure captions of Figure 3 and Figure 4. Data were compared with lithological descriptions and columns given in Trauth (1939), Janoschek et al. (1956), Prey (1975), Tollmann (1985), Schnabel (1997, 2000), Piller et al. (2004), Pfersmann (2013), and Ślączka et al. (2018).

5.1.1. Transported crinoidal slope deposits

Bioclastic limestones (former Gresten Formation)

Samples: OSV 1 (Fig. 3A), OSV 4 (Fig. 3B), OSV 5 (Fig. 3C).
Validity: invalid, first mentioned by Hauer (1853).
Type area: Gresten Klippen/Main Klippen Zone
Type section: no type section defined.
Synonyms: Gresten limestone in Griesbach (1868, 1869), Gresten Formation, Grestener Kalke, Grestener Schichten.
Lithology: Brown to grey wacke-, pack- and grainstones; silty crinoidal limestones with micritic matrix (Götzinger, 1954).
Facies: crinoid-rich wacke- to packstone, reworked fragments and lithoclasts, shallow water and deeper water elements, ammonites (e.g. *Echioceras* cf. *quenstedti*), crinoids (e.g. *Pentacrinus*) show extensive dissolution on edges (Fig. 5A), frequent echinoid spines, rare foraminifera such as *Frondicularia*, *Nodosaria*, *Involutina liassica* (Figs. 5B, C), *Duotaxis metula*, *Trocholina turris* (Figs. 5D, 5E) and *Trocholina umbo* (Fig. 5F), frequent ostracods (Fig. 5G), numerous filaments, bivalves (*Gryphaea arcuata*, *Lima punctata*, *Lima gigantea*, *Cardinia* sp., *Pecten* ssp.), high amount of scattered pyrite grains, frequent detrital angular quartz grains.
Microfacies type and facies zone: SMF 4 and SMF 11; FZ 3-6.
Thickness: tens of metres.
Age: Early Jurassic, Hettangian-Sinemurian.
Underlying unit: Rhaetian Keuper (= "Rhät Keuper" in Piller et al., 2004).
Overlying unit: overlain in the St. Veit Klippen Unit by the Bajocian to Bathonian Hohenauer Wiese Formation.
Geographic distribution: Gresten Klippen Zone to St. Veit area.
References: Griesbach (1868), Hochstetter (1898), Toula (1897), Schaffer (1906), Trauth (1907, 1908, 1909, 1923a, b), Vetters (1910), Götzinger (1954), Grill and Küpper (1954), Küpper (1968), Tollmann (1963, 1976), Faupl (1975), Piller et al. (2004) and Egger and Wessely (2014).

5.1.2. Silicious hemipelagites

Silicious spicula rich limestones

Samples: BST OSV 1, BST OSV 1.2 m (Fig. 3D), and BST OSV Base.
Synonyms: Liasspongit, Liaskieselkalk, similar to Kirchstein limestone (Kalksburg beds; see Tollmann (1976).

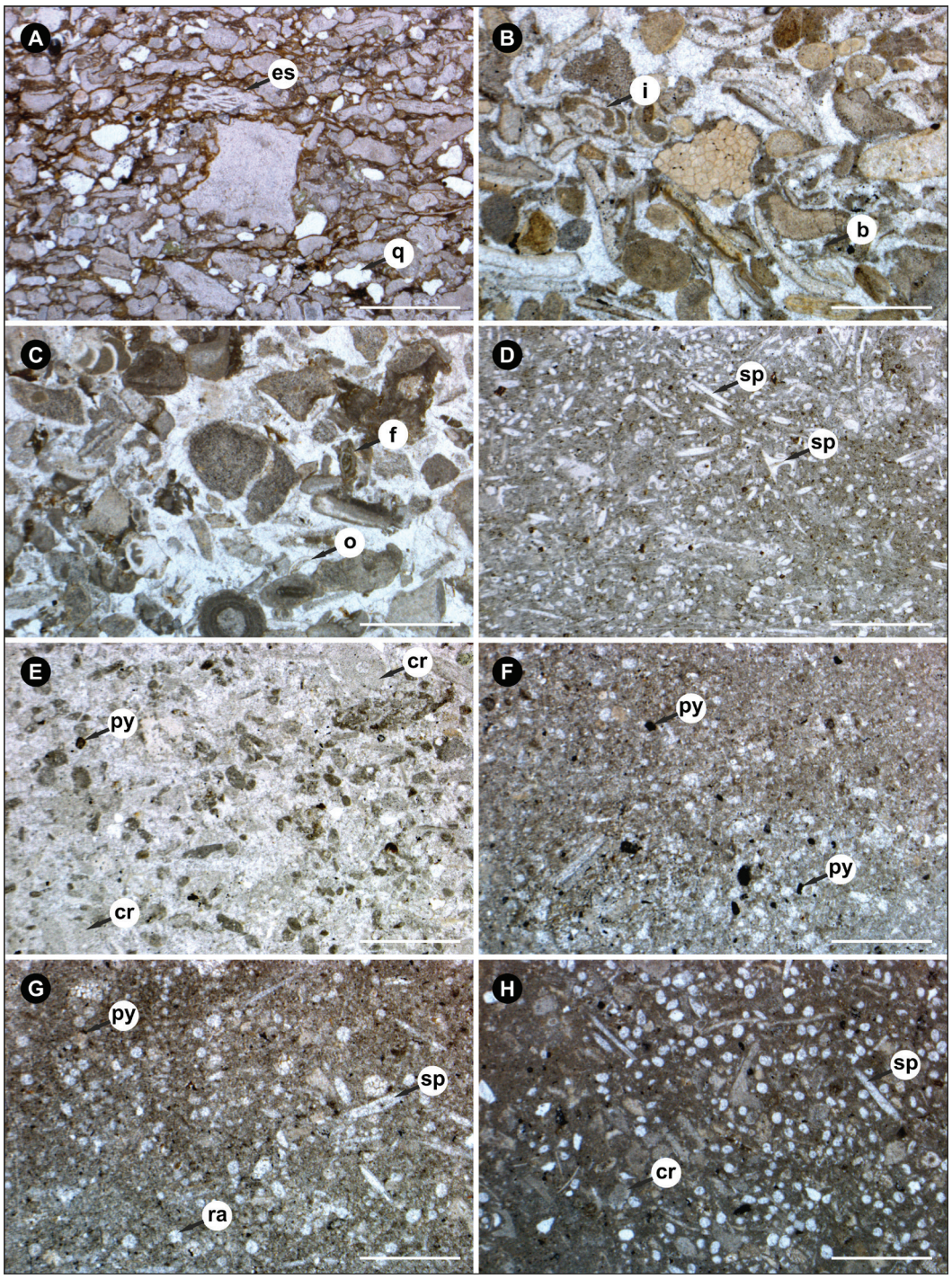

Figure 3: Thin sections from the Jurassic deposits St. Veit Klippen Unit in St. Veit and wildlife park Lainz, Vienna. A – crinoid-rich packstone to grainstone to encrinites, fragments with dissolution seams, frequent echinoid spines (es), rare foraminifera, frequent detrital angular quartz grains (q), Lower Jurassic, Veitingergasse St. Veit, OSV 1 – bioclastic limestone; B – redeposited biogenous grainstone, with frequent crinoids, gastropods, bivalves (b), ostracods, serpulid tubes, and oncoids, lithoclasts, detrital angular quartz grains, note the presence of *Involutina liassica* (i), Lower Jurassic, SW Teichhaus LT, OSV 4 - bioclastic limestone; C – redeposited biogenous grainstone, with frequent crinoids, gastropods, bivalves, ostracods (o), serpulid tubes, and oncoids, lithoclasts, detrital angular quartz grains, frequent foraminifera (f) with *Trocholina turris* and *Trocholina umbo*, Lower Jurassic, Saulackenschütt LT, OSV 5 – bioclastic limestone; D – spiculite wackestone, silicious limestones, predominantly composed of monaxone megascleres (sp), frequent triaxone spicules (sp) and radiolaria, with disseminated pyrite, Lower Jurassic, Josef-Heinzl-Gasse, BST OSV 1.2 m - grey spiculite limestones; E – redeposited crinoid-rich wackestone to packstone, encrinites with oncoids and lithoclasts, detrital angular quartz grains, high amount of scattered pyrite, with echinoid spines, ostracods and foraminifera (various types), Lower Jurassic, Josef-Heinzl-Gasse, BST OSV 0 – gray allodapic encrinites; F – bioturbated wackestone, with frequent spicula and frequent radiolarians, rare crinoids, ostracods, foraminifera and filaments, recrystallized radiolaria and spiculae, high amount of scattered pyrite grains (py), frequent detrital angular quartz grains, Middle Jurassic, St. Veit, OSV 9 – Lower Hohenauer Wiese Formation; G – bioturbated wackestone, with abundant spicules (sp) and frequent radiolarians (ra), rare crinoids, filaments and ostracods, recrystallized radiolaria and spiculae, high amount of scattered pyrite grains (py), frequent detrital angular quartz grains, cloudy appearance of cherty areas, Middle Jurassic, Glasauer quarry, OSV 10 - Lower Hohenauer Wiese Formation; H – silicious wackestone to packstone, rich in biogenes, transported and partly reworked elements, abundant spiculae (sp) and crinoids (cr), strong bioturbation, frequent recrystallized spiculae and rare radiolaria, rare foraminifera with *Planispirillina* sp., high amount of scattered pyrite grains, frequent detrital angular quartz grains, wackestones to packstones, Middle Jurassic, Glasauer quarry, OSV 14 - Hohenauer Wiese Formation. Scale bars 1 mm.

Lithology: Grey silicious spiculite wackestone, spiculites.
Facies: spicula-rich wacke-to packstone with radiolarians, morphologies of spiculae in different samples vary from fine and coarse, spiculae of soft-bodied demospongae with floating spicules and no rigid skeleton (so called loose-spicule demosponges, Figs. 5L, M), rare echinoderm fragments, rare foraminifer fragments, numerous filaments, high amount of scattered pyrite grains, radiolarians recrystallized, partly filled by amorphous silicium.
Microfacies type and facies zone: SMF 1; FZ 1-2.
Thickness: tens of metres.
Age: Early Jurassic.
Underlying unit: tansported crinoidal slope deposits.
Overlying unit: Lower Jurassic crinoidal limestone.
Geographic distribution: St. Veit.
Remarks: Tollmann (1976); Gawlick et al. (2009).

5.1.3. Biosparites

Silicious crinoid-rich limestones
Samples: BST OSV 0 (Fig. 3E), BST OSV B.
Synonyms: No synonyms.
Lithology: Grey silty crinoidal limestones.
Facies: redeposited crinoid-rich wacke-to packstone, encrinites, oncoids, lithoclasts, detrital angular quartz grains, high amount of scattered pyrite grains, crinoids, echinoid spines, bryozoans, foraminifera (e.g. *Duotaxis* cf. *metula*; Figs. 5J, K), frequent gastropods, serpulids.
Microfacies type and facies zone: SMF 12-crin; FZ 2-5.
Thickness: tens of metres.
Age: Early Jurassic.
Underlying unit: Bioclastic limestones (partly).
Overlying unit: marly radiolarian/spiculae limestones.
Geographic distribution: St. Veit.
References: Tollmann (1976), Gawlick et al. (2009).

Crinoid/brachiopod limestones
Samples: OSV 6, SE Teichhaus A (*Nannolytoceras*), SE Teichhaus B (*Parkinsonia*, Fig. 4A).
Synonyms: red crinoidal limestones (Piller et al., 2004; Pfersmann, 2013) and/or partly Hohenauer Wiese Formation, Vils limestone of St. Veit (Trauth, 1948).
Lithology: red and grey crinoidal packstones to grainstones.
Facies: transported and partly redeposited crinoid-rich packstones to grainstones, matrix sparry calcites, with lithoclasts, coated grains, oncoids, oolites, high amount of scattered pyrite grains, frequent detrital angular quartz grains, crinoids and lithoclasts are strongly affected by bioerosion (borings are filled by pyrite), frequent ammonites, frequent brachiopods with terebratulids, *Loboidothyris perovalis* and *Cymatorhynchia quadriplicata*, rare spiculae, rare foraminifera with *Trocholina* (Figs. 5H, I), rare radiolarians, rare bivalves, frequent filaments. Most of the ammonites collected from the wildlife park Lainz derive from these deposits (Trauth, 1948).
Microfacies type and facies zone: SMF 9; FZ 2 and 8.
Thickness: tens of metres.
Age: Early to Middle Jurassic, Toarcian to Bajocian.
Underlying unit: marly radiolarian/spicula limestones.
Overlying unit: crinoidal limestones.
Geographic distribution: St. Veit Klippen Unit.
References: Trauth (1948), Schnabel (2002), Pfersmann (2013).

5.1.4. Pelagic radiolarites/spiculites

Radiolarian/spiculae limestones
Samples: OSV 7, OSV 9 (Fig. 3F), OSV 10 (Fig. 3G), OSV 14 (Glasauer quarry; Fig. 3H).
Synonyms: partly Hohenauer Wiese formation; Neuhaus beds in Grill and Küpper (1954) and Götzinger (1954); "graue Ammonitenkalke" (grey Ammonite limestones) in Vetters (1910).
Lithology: grey silicious spiculae rich wackestone to packstones, crinoidal limestones.
Facies: bioturbated wackestones to packstones, with abundant spiculae and frequent radiolarians, frequent crinoidal fragments, partly redeposited crinoid-rich spiculites, recrystallized Radiolaria and spiculae, micritic matrix, high amount of scattered pyrite grains, frequent detrital angular quartz grains, frequent ammonites, rare to frequent crinoids, rare foraminifera (e.g. *Planispirillina* sp.), rare ostracods, rare filaments, bioturbation. Most of the ammonites collected from St. Veit derive from these deposits exposed in the Glasauer quarry.
Microfacies type and facies zone: SMF 1; FZ 1-2.
Thickness: 10-30 m thick layers, dipping 30-35°/290°.
Age: Middle Jurassic, Bajocian.
Underlying unit: silicious crinoid-rich limestones and marly radiolarian/spiculae limestones.
Overlying unit: silicious crinoid/radiolarian limestones, red marls and radiolarites of the Rotenberg formation.
Geographic distribution: St. Veit Klippen Zone; Glasauer quarry, wildlife park Lainz and Hohenauer Wiese.
References: Vetters (1910), Trauth (1928), Schaffer (1906, 1942), Thenius (1974), Faupl (1975), Pfersmann (2013).

Grey limestones
Samples: OSV 8.
Synonyms: comparable to the "Lias Fleckenmergel" from St. Veit.
Lithology: Grey spiculae rich limestones.
Facies: mud-, wacke- to packstones, micritic matrix, rare microfossil content with spiculae, radiolarians, and foraminifera, frequent scattered pyrite grains, frequent detrital angular quartz grains, frequent ammonites, *Arnioceras ceratitoides*, *Echioceras* cf. *quenstedti*.
Microfacies type and facies zone: SMF 1; FZ 1-2.
Thickness: tens of metres.
Age: Early Jurassic, Sinemurian to Toarcian.
Underlying unit: marly radiolarian/spiculae limestones.
Overlying unit: siliceous crinoidal limestone of the Glasauer quarry.
Geographic distribution: St. Veit Klippen Unit.
References: Trauth (1908, 1909, 1948).

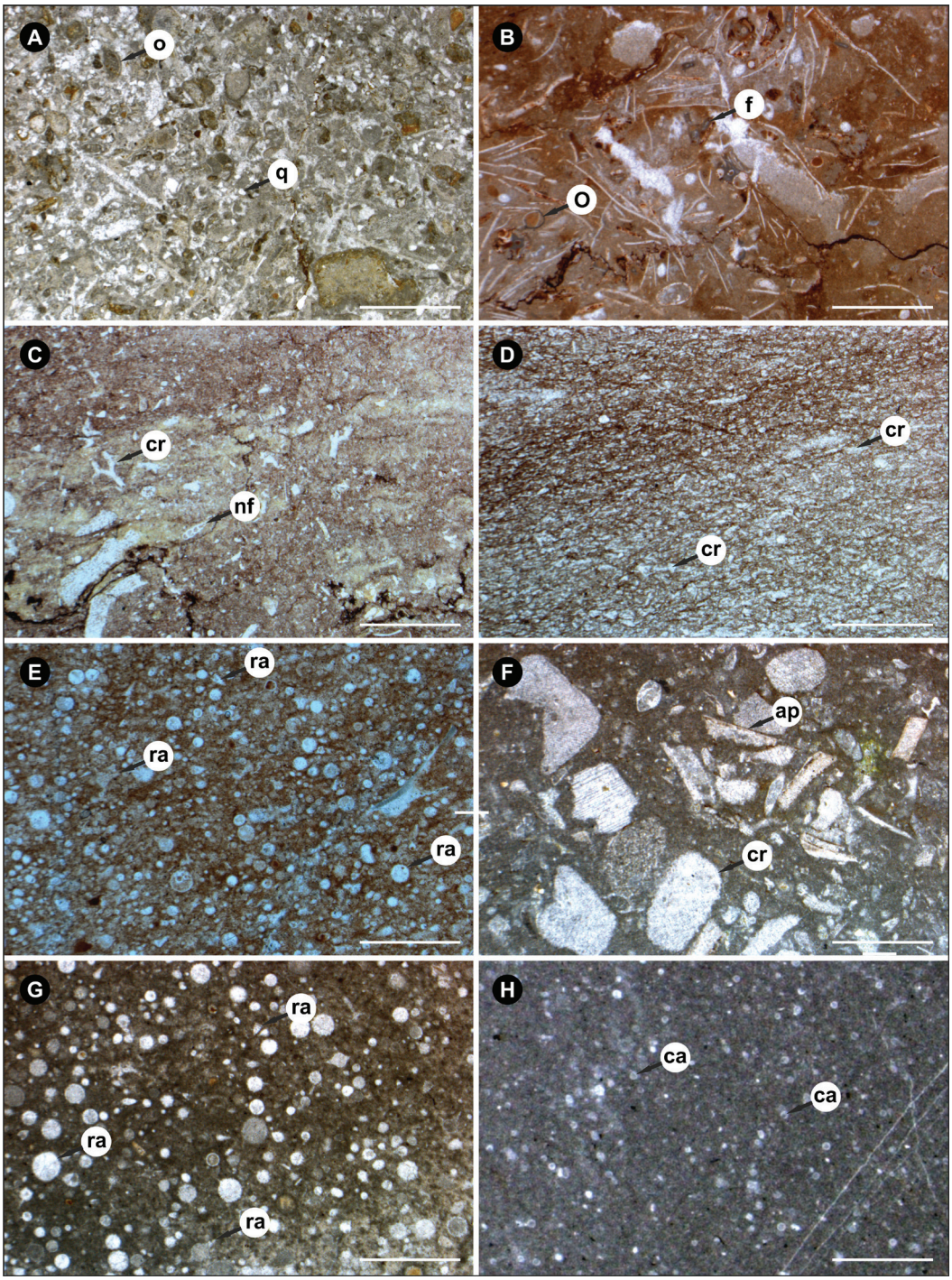

Figure 4: Thin sections from the Jurassic deposits St. Veit Klippen Unit in St. Veit and wildlife park Lainz, Vienna. A – crinodial packstone to grainstone, redeposition of lithoclasts and oncoids, bioerosion of fragments, with frequent crinoids and brachiopods, gastropods, bivalves, ostracods (o), lithoclasts, detrital angular quartz grains (q), frequent foraminifera, Middle Jurassic, Bajocian, SE Teichhaus, SE Teichhaus *Parkinsonia* – Upper Hohenauer Wiese Formation. B – red condensed biogenous wackestone to packstone, nodular fabric of "Klaus-Formation" type, abundant bivalve filaments, frequent ammonite fragments and juvenile specimens, frequent gastropods, frequent planktonic foraminifera (f), rare ostracods (o), frequent spiculae and in situ sponge skeletons visible, extensive bioerosion on shell fragments, strong dissolution seams an stylolites, Middle Jurassic, St. Veit, OSV 2 - Hohenauer Wiese Formation; C – red condensed biogenous wackestone, with fine disseminated crinoid fragments (cr), frequent echinoid spines and nodosarid foraminifera (nf), numerous filaments, solution seams in sediment impregnated with residual material, lower Middle Jurassic, SW Teichhaus, OSV Ammo Oli - Hohenauer Wiese Formation; D – fine red crinoidal packstone, crinoidal hash from saccocomid fragments (cr), abundant *Laevaptychus*, Upper Jurassic, Kimmeridgian to Tithonian, Roter Berg in St. Veit, OSV 12 - Rotenberg Formation; E – red wackestones to packstones, cherty radiolarites and silicious radiolarian-rich limestones, radiolarians (ra) partly filled by calcite and amorphous silicium, *Podobursa* sp., *Hiscocapsa* sp. and *Spongocapsula* sp., cloudy appearance of silicious material, Upper Jurassic, Roter Berg in St. Veit, OSV 11 - Rotenberg Formation; F – wackestone to packstone, crinoid-rich (cr) biogenous limestones, with frequent aptychi (ap) of *Lamellaptychus* sp. and *Laevaptachus* sp., scattered grains of pyrite, redeposition and transport indicated, Upper Jurassic, Kimmeridgian to Tithonian, Stockwiese LT, OSV 3 – lower Fasselgraben Formation; G – cherty radiolarian-rich packstone, radiolarian (ra) partly filled by calcite and amorphous silicium, *Sethocapsa* sp. and *Striatojaponocapsa* sp., cloudy appearance of siliceous material, Upper Jurassic, Saulackentürl quarry LT, OSV 13 - Fasselgraben Formation; H – fine calpionellid mudstone to wackestone, mictritic matrix, abundant calpionellids (ca), frequent radiolarian, rare foraminifera, late Berriasian, ÖBB tunnel St. Veit, LT31-869,5 m – upper Fasselgraben Formation. Scale bars 1 mm.

5.1.5. Bathypelagic radiolarites and cherts

Red radiolarites with cherts

Samples: OSV 11 (Fig. 4E).
Synonyms: Hornsteinkalke, Rotenberg Schichten (Rotenberg beds), Rotenberg Formation (Schnabel, 2002; Pfersmann, 2013).
Lithology: red radiolarites, cherts and silicious packstones.
Facies: cherty radiolarites and radiolarian-rich limestones, abundant radiolarians with *Archaeodictyomitra* sp., *Pantanellium* sp., *Spongocapsula* sp. and *Tritrabs* sp., radiolarian partly filled by calcite and amorphous silicium, frequent spiculae, rare aptychi, cloudy appearance of siliceous material.
Microfacies type and facies zone: SMF 1; FZ 1-3.
Thickness: tens of metres.
Age: Late Jurassic, Oxfordian to Early Tithonian.
Underlying unit: silicious crinoid/radiolarian limestones.
Overlying unit: grey limestones of the Fasselgraben Formation.
Geographic distribution: St. Veit.
Note: Archaeological artefacts from the St. Veit area from these deposits (Schmitsberger et al., 2019).
References: Grill and Küpper (1954), Schnabel (2002), Pfersmann (2013), Ślączka et al. (2018), Ožvoldová and Faupl (1993).

Cherty limestones with aptychi of the lower Fasselgraben Formation

Samples: OSV 13 (Fig. 4G), BST OSV A.
Synonyms: Fasslgraben beds, Fasselgraben formation; Aptychenkalke, see also Blassenstein Schichten in Kühn (1962) and Trauth (1948).
Lithology: grey mudstones, radiolarian-rich wacke- to packstones with chert nodules.
Facies: mudstones to cherty radiolarian-rich limestones, radiolarians with different morphologies (Fig. 5P) are partly filled by calcite and amorphous silicium, cloudy appearance of siliceous material, packstone, rare aptychi, frequent spiculae.
Microfacies type and facies zone: SMF 1; FZ 1-3.
Thickness: tens of metres.
Age: Late Jurassic, Tithonian.
Underlying unit: red radiolarites with cherts.
Overlying unit: grey limestones of the upper parts of the Fasselgraben formation.
Geographic distribution: wildlife park Lainz at Fasselgraben, east of Stockwiese, Gemeindeberg hill in St. Veit Klippen Unit.
References: Trauth (1948), Grill and Küpper (1954), Kühn (1962), Decker (1987, 1990), Ožvoldová and Faupl (1993), Schnabel (2002), Pfersmann (2013), Ślączka et al. (2018).

5.1.6. Red condensed cephalopod limestones

Red limestone

Samples: OSV 2 (Fig. 4B).
Synonyms: Klaus beds (= "Klaus Schichten"), "ammonitenreiche Klauskalke" of Vetters (1910, see Fig. 11 therein).
Lithology: red limestones.
Facies: red filament rich biogenous wacke- to packstones, with lithoclasts, extensive signs of reworking and dissolution seams at stylolites, partly graded, abundant bivalves and filaments, frequent ammonite fragments and juvenile specimens, frequent gastropods, frequent benthic ophthalmid foraminifera (Fig. 5N), rare ostracods, frequent spiculae and in situ sponge skeletons, extensive, bioerosion on shell fragments. The facies shows similarities to the "Klaus-Formation" from the Northern Calcareous Alps.
Microfacies type and facies zone: MF 4-5; FZ 3-4.
Thickness: approx. ten metres.
Age: Middle Jurassic, Bajocian and younger.
Overlying unit: red radiolarites with cherts.
Underlying unit: crinoid/brachiopod limestones.
Geographic distribution: St. Veit Klippen Unit.
References: Vetters (1910), Hochstetter (1898), Schaffer (1906).

5.1.7. Crinoid/aptychi limestones

Grey crinoid/aptychi limestone

Samples: OSV 3 (Fig. 4F).
Synonyms: intercalations in lower part of the Fasselgraben formation.
Lithology: grey wackestone to packstone with abundant crinoids and aptychi.
Facies: crinoid-rich biogenous limestones, abundant fragments of aptychi with *Lamellaptychus* and *Laevaptychus*, rare fragmented foraminifera, rare radiolarians, scattered grains of pyrite, redeposition and transport indicated.
Microfacies type and zone: SMF 3; FZ 1-3.
Thickness: tens of metres.
Age: Late Jurassic, Tithonian.
Underlying unit: crinoid/brachiopod limestones.
Overlying unit: grey limestones of the Lower Cretaceous part of the Fasselgraben Formation.
Geographic distribution: St. Veit Klippen Unit.
References: Hochstetter (1898), Trauth (1948), Pfersmann (2013).

Red marlstones with aptychi

Samples: OSV 12 (Fig. 4D).
Synonyms: "rote Aptychenmergel" (Spitz, 1910).
Lithology: red packstones with abundant crinoids and aptychi.
Facies: crinoid rich biogenous limestone, abundant crinoids preserved as crinoidal hash from saccocomid fragments, abundant *Laevaptychus*, laevaptychi in articulated preservation, scattered grains of pyrite, frequent redeposition and transport, rare detrital quartz grains.
Microfacies type and facies zone: SMF 3 or SMF 12-crin; FZ 2-4.
Thickness: tens of metres.
Age: Late Jurassic, Kimmeridgian to Early Tithonian.
Underlying unit: silicious crinoid/radiolarian limestones.
Overlying unit: grey limestones of the Fasselgraben Formation.
Geographic distribution: St. Veit.
References: Hochstetter (1898), Trauth (1948), Pfersmann (2013).

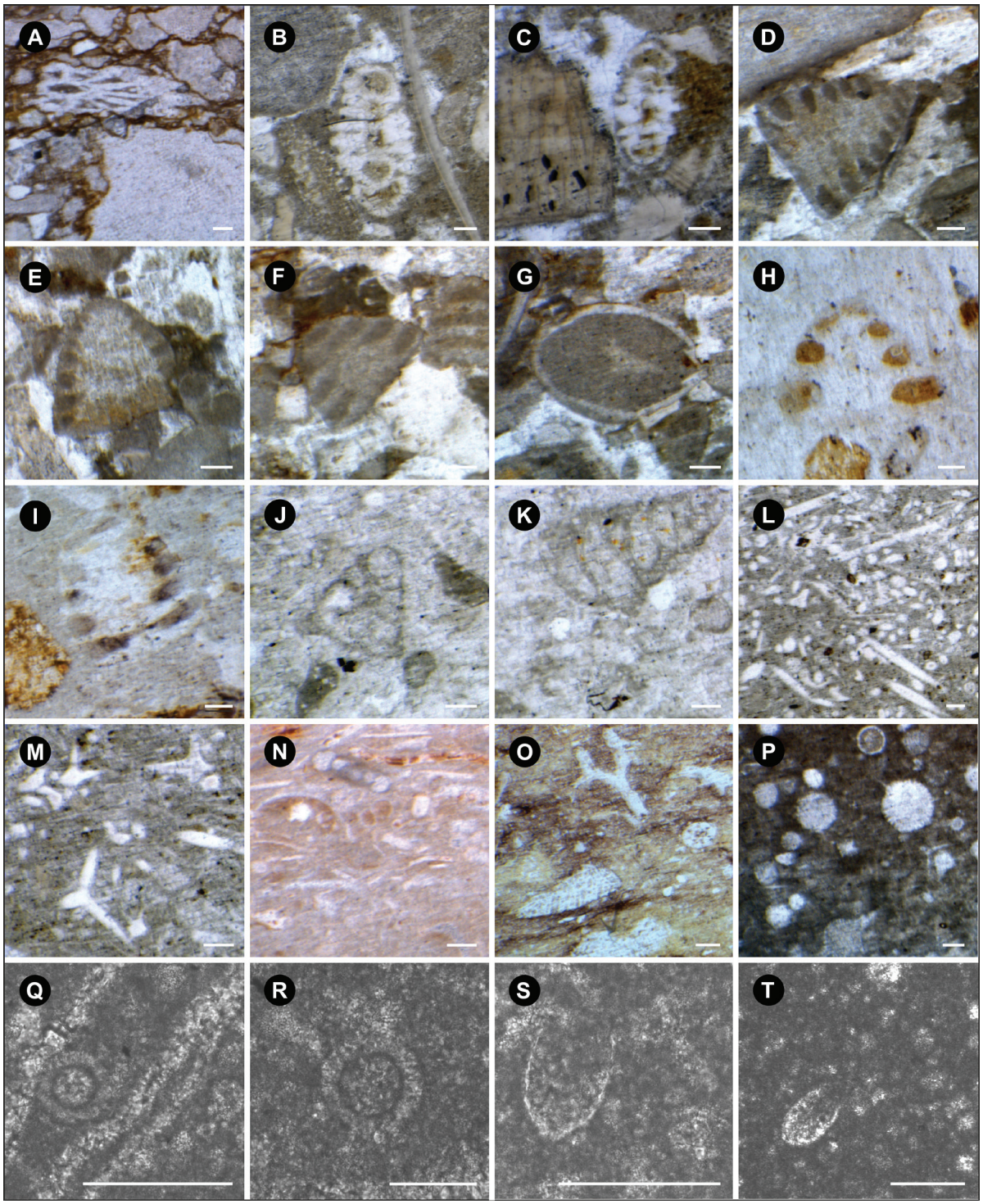

Figure 5: Significant microfossils from thin sections of Jurassic deposits in the St. Veit Klippen Unit in St. Veit and wildlife park Lainz, Vienna. **A** – crinoid fragments and echinoid, Lower Jurassic, OSV 1 - bioclastic limestone; **B** – benthic foraminifera *Involutina liassica*, Lower Jurassic, OSV 4 – bioclastic limestone; **C** – *Involutina liassica* and bivalve fragment left, Lower Jurassic, OSV 4 – bioclastic limestone; **D** – foraminifera with *Trocholina turris*, Lower Jurassic, OSV 5 – bioclastic limestone; **E** – benthic foraminifera *Trocholina turris*, Lower Jurassic, OSV 5 - bioclastic limestone; **F** – benthic foraminifera *Trocholina umbo*, Lower Jurassic, OSV 5 – bioclastic limestone; **G** – double valved ostracod, Lower Jurassic, OSV 5 – bioclastic limestone; **H** – *Trocholina* sp., Lower Jurassic, OSV 5 – crinoidal limestone; **I** – *Trocholina* sp., Lower Jurassic, OSV 6 – crinoidal limestone; **J** – *Duotaxis metula*, Lower Jurassic, Josef-Heinzl-Gasse, BST OSV 0 – grey allodapic encrinites; **K** – *Duotaxis metula*, Lower Jurassic, Josef-Heinzl-Gasse, BST OSV 0 – grey allodapic encrinites; **L** – predominantly monaxone megascleres, frequent triaxone spicules and radiolaria, with disseminated pyrite, Lower Jurassic, Josef-Heinzl-Gasse, BST OSV 1.2 m - grey spiculite limestones; **M** – frequent triaxone spicule, Lower Jurassic, BST OSV 1.2 m - grey spiculite limestone; **N** – filaments and benthic ophthalmid foraminifera, Middle Jurassic, OSV 2 - Hohenauer Wiese Formation; **O** – crinoid fragments, lower Middle Jurassic, SW Teichhaus, OSV Ammo Oli - Hohenauer Wiese Formation; **P** – various radiolaria types, Upper Jurassic, OSV 13 - Fasselgraben Formation; **Q** – *Colomisphaera carpathica* (Borza, 1946), late Berriasian, OSV LT31-869,5 m – upper Fasselgraben Formation; **R** – *Colomisphaera carpathica* (Borza, 1946), late Berriasian, OSV LT31-869,5 m – upper Fasselgraben Formation; **S** – *Tintinnopsella carpathica* (Murgeanu and Filipescu, 1933), late Berriasian, OSV LT31-869,5 m – upper Fasselgraben Formation; **T** – *Calpionella elliptica* Cadisch 1932, late Berriasian, OSV LT31-869,5 m – upper Fasselgraben Formation. Scale bars 0.1 mm.

Red condensed limestones with ammonites
Samples: OSV Ammo Oli (Fig. 4C).
Synonyms: red crinoidal limestones (Piller et al., 2004; Pfersmann, 2013) and partly Hohenauer Wiese Formation.
Lithology: Red crinoid-rich wackestones.
Facies: crinoids show extensive dissolution on edges, frequent echinoid spines, frequent crinoids (Fig. 5O), frequent foraminifera with *Nodosaria* sp., rare ostracods, rare radiolarian, numerous filaments, high amount of scattered pyrite grains, frequent detrital angular quartz grains, ammonites partly with manganese crusts.
Microfacies type and zone: SMF 3; FZ 1-3.
Thickness: tens of metres.
Age: Middle Jurassic, Aalenian to Bajocian.
Underlying unit: Bioclastic limestones.
Overlying unit: Bajocian to Bathonian Hohenauer Wiese Formation.
Geographic distribution: St. Veit Klippen Unit.
References: Hochstetter (1898), Trauth (1948), Pfersmann (2013).

Grey limestones of the upper Fasselgraben Formation
Samples: LT31-869.5 m (ÖBB tunnel, Fig. 4H).
Synonyms: upper part of the Fasselgraben Formation.
Lithology: grey to reddish and reddish brown mud- to wackestones.
Facies: foraminifera, rare aptychi, rare crinoids and bivalves, rare ostracods and radiolarians, frequent calcareous dinoflagellate cysts with *Colomisphaera carpathica* (Figs. 5Q and R), partly abundant calpionellids with e.g., *Calpionella alpina*, *C. elliptica* (Fig. 5T), *C. minuta*, *Tintinnopsella carpathica* (Fig. 5S), *Calpionellopsis oblonga*, *Remaniella borzai*, *R. cadischina*, *Lorenziella hungarica*).
Microfacies type and zone: SMF 3; FZ 1-3.
Thickness: tens of metres.
Age: Calpionellid assemblage indicative for the *Calpionellopsis* Zone in the Late Berriasian, quantity of calpionellids vary in distinct biostratigraphic levels. Late Jurassic to Early Cretaceous, Tithonian to Valanginian.
Underlying unit: red marls and cherts of the Rotenberg Formation.
Overlying unit: upper parts of the Fasselgraben Formation.
Geographic distribution: wildlife park Lainz at Fasselgraben, east of Stockwiese, Gemeindeberg hill in St. Veit, ÖBB tunnel in St. Veit.
References: Hochstetter (1898), Trauth (1948), Schnabel (2002), Pfersmann (2013).

6. Historical collections and fossil material

The studied material (Figs. 6, 7, 8) derives mainly from two neighbouring areas in the west of Vienna. Both localities are historical and due to overgrowth or housing cannot be resampled today. The first one is in the east of the wildlife park Lainz near the Lainzer Tor entrance, called the Teichhaus Wiese or Hohenauer Wiese Klippe (Hochstetter, 1897; Trauth, 1923a, 1948; Janoschek, 1956; Schnabel1992a, b). The second one is located two kilometres to the northeast at the historic Glasauer quarry (abandoned since mid of 20th century; Schaffer, 1906). Both localities were described by Schnabel et al. (1997) and Schnabel (2002) who listed the deposits as "Hohenauer Wiese-Formation", following the lithostratigraphic concept of Prey (1975). This unit, however, has never been formalized; lower and upper boundaries are unknown, and no type section can be designated. Therefore, we use the Hohenauer Wiese Formation as informal term. Re-evaluated taxa are given in brackets following original designations in historical papers as for example the original *Ammonites tenuicostatum* and the new assigned (= *Lokuticeras* cf. *lissajousi*).

Ammonite zones used in the following: Lower Jurassic with *Echioceras raricostatum* Zone = *Raricostatum* Zone; Middle Jurassic *Hyperlioceras discites* Zone = *Discites* Zone, *Concavum* Zone, *Witchellia laeviuscula* Zone = *Laeviuscula* Zone, *Stephanoceras humphriesianum* Zone = *Humphriesianum* Zone, the *Strenoceras niortense* Zone = *Niortense* Zone, the *Garantiana garantiana* Zone= *Garantiana* Zone, *Parkinsonia parkinsoni* Zone = *Parkinsoni* Zone (for zonation see Schweigert, 2015; Fig. 2).

6.1 Hohenauer Wiese Klippe and Teichhaus Klippe area

Fossil assemblages from red crinoid limestones from the area around the western "Teichhaus Klippe" or the southern "Hohenauer Wiese Klippe" in a wildlife preserve area of the western wildlife park Lainz are known since the late 19th century (Čžjžek, 1849; Griesbach, 1868; Trauth, 1923a, b; 1948; Schaffer, 1942). Čžjžek (1849, 1852) described the small klippen summit (approx. 75 m length and 25 m width, Trauth, 1923a) in the wildlife park Lainz as "rich in crinoid fragments, sometimes entirely made of them", but he mentioned no other fossils. The fauna from the main locality, approx. 280 m SE of the foresters house Teichhaus (e.g., SE Teichhaus on original labels from Toula, 1900) is dominated by ammonites and brachiopods (Figs. 6, 7, 8), which derive from red limestones with considerable quantities of crinoidal fragments (dipping 20°-30°/135°). As noted by Trauth (1923a), the fauna described by Griesbach (1869) and the collected material by Toula (1900) is from the same locality at SE Teichhaus (= Juraklippe der Hohenauer Wiese Klippe in Trauth, 1923a). Griesbach (1869) already noted the presence of 26 different mollusc taxa, such as *Belemnites* sp., *Nautilus* sp. (= *Cenoceras* sp., Fig. 8A), *Ammonites haloricus*, *Lytoceras adelae*, *A. tripratitus* (= *Nannolytoceras polyhelictum*, Figs. 6D, E, F), *A. subradiatus*, *A. parkinsoni*, *Hamites baculatus* ("Baculatenlager", = *Spiroceras* aff. *baculatum*; Fig: 7L) and numerous specimens of bivalves and brachiopods. Griesbach (1869) assigned the deposits of that area to the Zone of *Ammonites parkinsoni*. Trauth (1923a, 1928) revised this fauna and identified "*A. haloricus*" as *Phylloceras rosiwali* (Fig. 6A), "*A. tripartitus*" as *Lytoceras tripartitus* (= *N. polyhelictum*) and "*A. subradiatus*" as *Oppelia subradiata*. Trauth (1923a) described 95 taxa of echindoderms with *Collyrites ovalis* (= *Pygomalus* cf. *ovalis*, Fig. 8P; see Hochstetter, 1897) and *Pseudodiadema* sp. (= *Diplopodia* cf. *jobae*, Fig. 8Q), serpulids, brachiopods

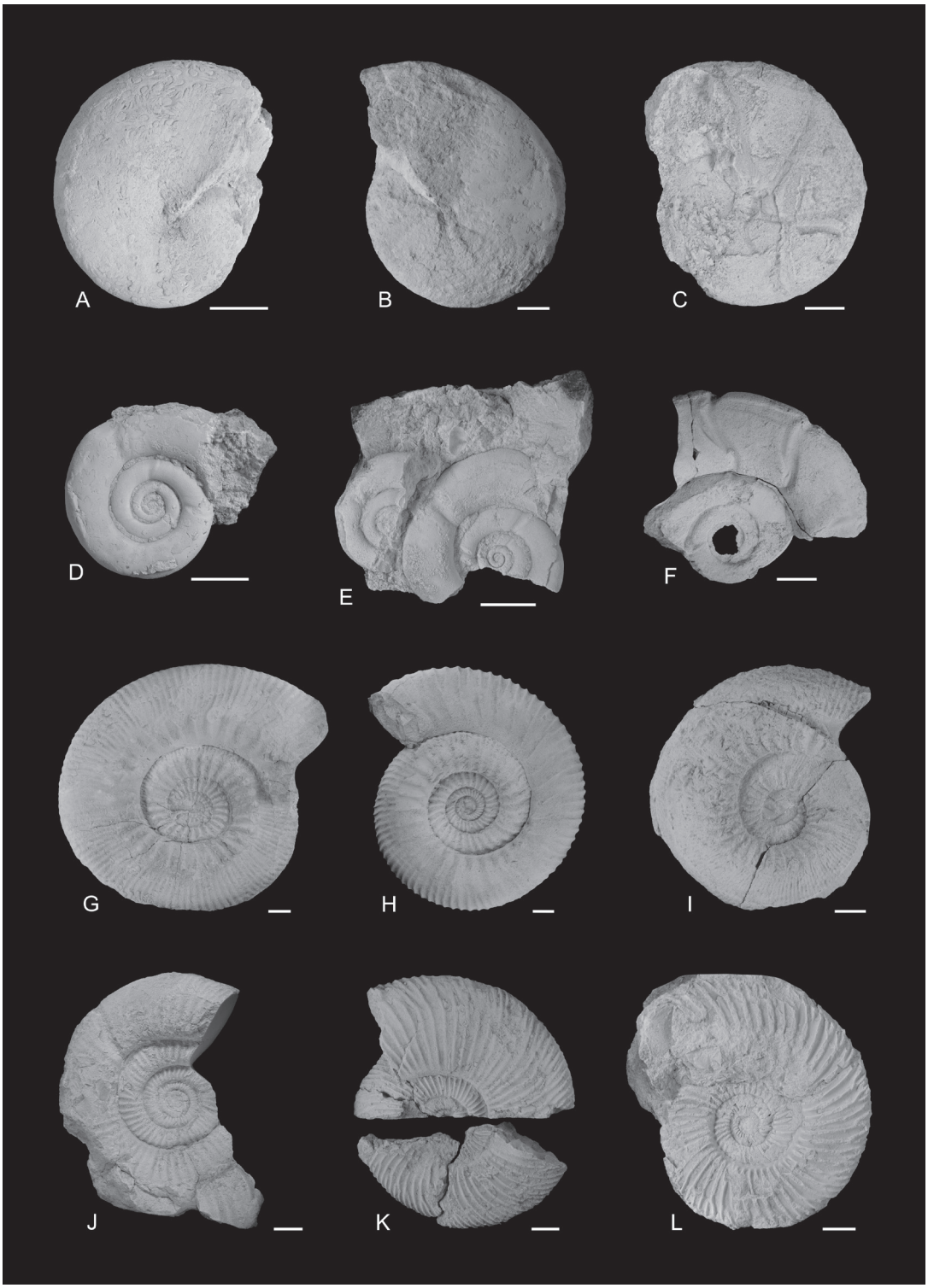

Figure 6: Ammonite fauna from the Lower Jurassic to Middle Jurassic of O. St Veit (OSV) and the Lainzer Tiergarten (LT), St. Veit Klippen Unit. **A** – *Phylloceras rosiwali* Trauth 1923a, upper Bajocian, *Garantiana* Zone or *Parkinsoni* Zone, SE Teichhaus, LT, NHMW 1927/0004/0108. **B** – *Holcophylloceras zignodianum* d'Orbigny 1848, Bajocian, *Humphriesianum* Zone, Glasauer quarry, OSV, NHMW 2019/0184/0462. **C** – *Calliphylloceras disputabile* (Zittel, 1869), upper Bajocian, *Garantiana* Zone or *Parkinsoni* Zone, SE Teichhaus, LT, NHMW 1927/0004/0102. **D** – *Nannolytoceras polyhelictum* (Böckh, 1881), upper Bajocian, SE Teichhaus, LT, NHMW 1927/0004/0123f. **E** – *Nannolytoceras polyhelictum* (Böckh, 1881), upper Bajocian, *Garantiana* Zone or *Parkinsoni* Zone, SE Teichhaus, LT, NHMW 1927/0004/0126b. **F** – *Nannolytoceras polyhelictum* (Böckh, 1881), originally figured in Trauth (1923a, Pl. 2, Fig. 6), upper Bajocian, *Garantiana* Zone or *Parkinsoni* Zone, SE Teichhaus, LT, NHMW 1927/0004/0121. **G** – *Stephanoceras* cf. *humphriesianum*, lower Bajocian, *Humphriesianum* Zone, Glasauer quarry, OSV, NHMW 2015/0344/0304. **H** – *Stephanoceras* aff. *vindobonense* (Griesbach, 1868), originally figured in Suess (1897, p. 3, Fig. 1), lower Bajocian, *Humphriesianum* Zone, Glasauer quarry, OSV, NHMW 1934/0002/0011. **I** – *Lokuticeras* cf. *lissajousi* Roche, 1939, upper Bajocian, *Niortense* Zone, Glasauer quarry, OSV, NHMW 1934/0002/0005. **J** – *Vermisphinctes martiusii* (d'Orbygny, 1845), originally figured in Trauth (1923a, Pl. 2, Figs. 7a, b) as holotype of *Perisphinctes leederi*, upper Bajocian, *Garantiana* Zone or *Parkinsoni* Zone, SE Teichhaus, LT, NHMW 1927/0004/0148. **K** – *Parkinsonia toulai* Trauth 1923a, originally figured in Trauth (1923a, Pl. 2, Figs. 8a, b and Fig. 9), upper Bajocian, *Garantiana* Zone or *Parkinsoni* Zone, SE Teichhaus, LT, NHMW 1927/0004/0162. **L** – *Parkinsonia ferruginea* (Oppel, 1857), upper Bajocian, *Parkinsoni* Zone, SE Teichhaus, LT, NHMW 1927/0004/0155

with *Terebratula perovalis* (= *Loboidothyris perovalis*, Fig. 8N) and *Rhynchonella quadriplicata* (= *Cymatorhynchia quadriplicata*, Fig. 8O), bivalves with *Pholadomya corrugata* (Fig. 8K) and gastropods with *Amberleya elongata* (Fig. 8J) and *Pleurotomaria elongata* (= *Pyrgotrochus elongatae*, Fig. 8I) and frequent cephalopod elements with 333 specimens (299 ammonites, 21 belemnites and 16 nautilids). Most important are the occurrences of the parkinsoniids *Parkinsonia toulai* (Fig. 6K) and *Pa. ferruginea* (Fig. 6L), *Pa. neuffensis*, *Pa*. aff. *acri* and *Pa*. sp. Additional *Stephanoceras* aff. *baylei*, *S. braikenridgi*, *St. humphriesianum* and *S. rectelobatus* (= *Cadomites rectelobatus*) and *Perisphinctes* aff. *triplicata*, *Pe. leederi* (= *Vermisphinctes martiusii*, Fig. 6J) and *Pe*. sp., *Sphaeroceras* cf. *sauzei* was reported by Trauth (1923a; = *Otoites* sp.).

Trauth (1923a, 1928) reported extensive macrofossil assemblages from the SVK of the natural reserve wildlife park Lainz and St. Veit (see Grill and Küpper, 1954; Götzinger, 1954). Trauth's faunae comprise ammonites with *Phylloceras demidoffi* (= *Calliphylloceras disputabile*, Fig. 6C), *Phylloceras viator* (= *Phyllopachyceras viator*), *Oppelia fusca*, *Perisphinctes leederi* (= *Vermisphinctes martiusii*, Fig. 6J), *Parkinsonia toulai* (Fig. 6K), *Arietites* (*Arnioceras*) *falcaries* (= *Arnioceras ceratitoides*), aptychi, nautilids with *Nautilus clausus* (= *Somalinautilus clausus*), *N. obesus*, gastropods, bivalves with *Pecten (Chlamys) ambiguous* (= *Chlamys textoria*, Fig. 8L), and brachiopods with *Rhynchonella plicatella* and *R. pseudoobsoleta*. Trauth (1923a, 1928) indicated the presence of the typical Middle Jurassic ammonite *Strigoceras dorsocavatum* (= *Phlycticeras aenigmaticum*, Fig. 7A). A single specimen was found in 2019 by a private collector west of the SW Teichhaus outcrop which appears to be a specimen of the lowermost Bajocian *Graphoceras* cf. *limitatum* (Fig. 7B), of the *Discites* Zone.

Red crinoidal limestones with frequent brachiopods like *Terebratula* aff. *bifrons*, *Terebratula antiplecta* and *Rhynchonella* sp. were defined as being younger, hence Callovian in age, similar to the Vils Limestone of the NCA. On the top of the Middle Jurassic sequence red and grey Upper Jurassic "Aptychen Schichten und Kalke" from the Tithonian to the Lower Cretaceous can be found.

Based on the publications of Trauth (1928, 1930, 1938), Götzinger (1954) reported lamellaptychi with *Lamellaptychus bajociensis* (Fig. 8E), *Lamellaptychus beyrichi*, *L. crassicauda*, *L. lamellosus*, *L. rectecostatus*, *Lamellaptychus submortilleti* var. *retroflexa longa* (= *Mortilletilamellaptychus bicurvatus*, Fig. 8H), and *Laevptychus laevis* (= *Laevaptychus longus*) from red Upper Jurassic deposits of the Roter Berg and from the wildlife park Lainz. White limestones yield *Lamellaptychus beyrichi* (= *Beyrichilamellaptychus beyrichi*; Figs. 8F, G), *L. didayi*, *L. angulocostatus*, *L. lamellosus* and *Laevptychus laevis*. A nodular red limestone facies from the Tithonian to Berriasian was reported from the Stockwiese with *Phylloceras* sp. and *Lytoceras* cf. *quadrisulcatum* (Götzinger, 1954).

6.2 The Glasauer quarry area

Most of the collected fossils derive from the historic Glasauer quarry (= Glassauer Steinbruch, figured on Plate II in Schaffer, 1906) in St. Veit (Čžjžek, 1849; Stur, 1894; Trauth, 1907). It must be noted that in most ammonite specimens only one side (lower flank to sediment) is preserved. The top side was eroded. Čžjžek (1849, p. 72) described a specimen of "*Ammonites Humphresianus*" (= *Stephanoceras* cf. *humphriesianum*, Fig. 6G) from sandstones, which he considered to be the easternmost extensions of the "Alpenkalke" (= alpine limestones) and assumed a Middle Jurassic age for the "Cephalopodenkalke" of that locality. In contrast, Trauth (1928), Götzinger (1954), Grill and Küpper (1954) and Faupl (1975) correlated the deposits with the sandy Neuhaus Formation of the Helvetic Gresten Klippen Zone. These beds range from the Bathonian to the Lower Callovian (Piller et al., 2004), and therefore, belong to a different tectonic element.

Griesbach (1869) reported ten ammonite and two belemnite species, accompanied by the first illustration of "*Ammonites Vindobonensis*" (refigured in Suess, 1897; see Schlögl and Zorn, 2012). Griesbach (1868, 1869) assigned the deposits to the *Ammonites sauzei* Zone and the *Ammonites humphriesianum* Zone. Griesbach (1868) discussed the presence of the *Parkinsoni* Zone, based on the identification of "*Ammonites parkinsoni inflatus*" from red crinoidal limestones with numerous specimens of *Ammonites tripartitus* (= *Nannolytoceras polyhelictum*) and described a small fauna from the Upper Jurassic red aptychi limestones around the Einsiedelei area with *Aptychus laevis latus* (*Laevaptychus longus*), *Aptychus lamellosus*, *Aptychus crassicauda*, *Aptychus profundus*, *Belemnites canaliculatus*, and *Belemnites hastatus* (= *Hibolites hastatus*). The youngest deposits were treated by Griesbach (1868) to be "Neocome Fleckenmergel with *Aptychus didayi*" from the Lower Cretaceous in this area. The "Aptychenkalke" are red limestones with abundant aptychi and lay discordant above the Middle Jurassic cephalopod limestones of the SVK.

Hochstetter (1898) later described ammonites from the SVK and stated that more than 400 specimens were distributed to the NHMW and other institutes of earth sciences in Vienna. 37 ammonite species and eight belemnite species (e.g. *Belemnites* sp., Fig. 8C) including the most important taxa like *Arietites conybeari* (= *Arnioceras ceratitoides*, Fig. 7J), *Aegoceras* sp. (= *Echioceras* cf. *quenstedti*, Fig. 7K), *Harpoceras mesacanthus* (= *Papilliceras mesacanthum*, Figs. 7G, H), *Harpoceras deltafalcatum* (= *Dorsetensia* aff. *deltafalcata*, Fig. 7D and *Nannina romani*, Fig. 7E), *Harpoceras romanoides* (= *Sonninia* sp., Fig. 7I), *St. humphriesianus*, *Stephanoceras vindobonensis* (= *Stephanoceras* aff. *vindobonense*, Fig. 6H), *Spiroceras baculatus*, *Morphoceras polymorphum*, *Lytoceras tripartitus* (= *Nannolytoceras polyhelictum*), *Phylloceras haloricus* and *Reineckia anceps* were mentioned in Hochstetter (1898). Additionally, this author designated a new species with *Ammonites tenuicostatum*

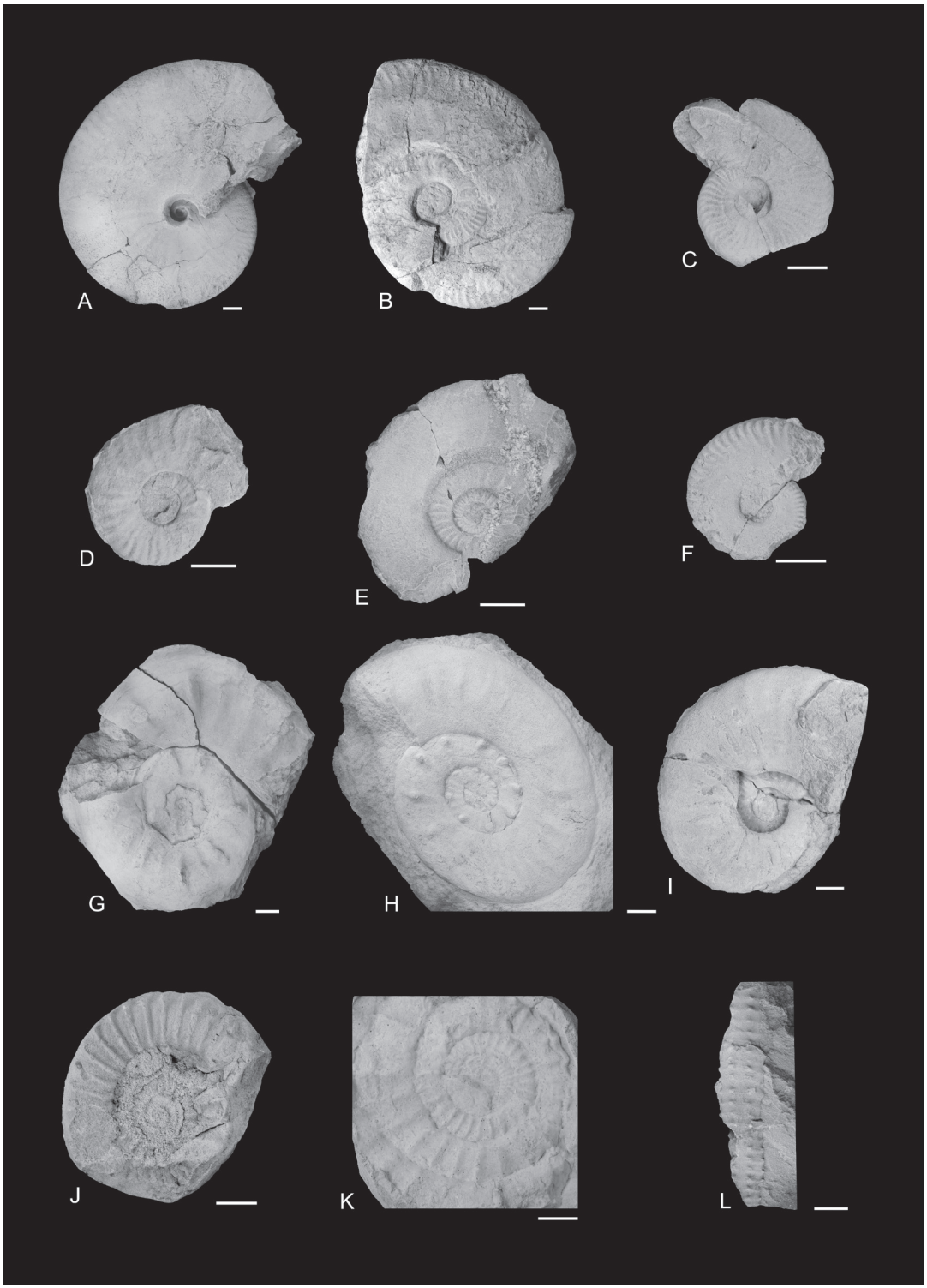

Figure 7: Ammonite fauna from the Lower Jurassic to Middle Jurassic of St Veit (OSV) and the wildlife park Lainz (LT), St. Veit Klippen Unit. **A** – *Phlycticeras aenigmaticum* (Fernández-López, 1985), originally figured in Scheurlen (1928, Pl. 2, Figs. 1, 2), upper Bajocian, *Garantiana* Zone or *Parkinsoni* Zone, SE Teichhaus, LT, NHMW 1927/0004/0132. **B** – *Graphoceras* cf. *limitatum* (Buckman, 1902), lowermost Bajocian, *Discites* Zone, SW Teichhaus, LT, NHMW 2019/0184/0557. **C** – *Graphoceras* cf. *limitatum* (Buckman, 1902), juvenile, lowermost Bajocian, *Discites* Zone, Glasauer quarry, OSV, NHMW 2019/0184/0179. **D** – *Dorsetensia* aff. *deltafalcata* (Quenstedt, 1858), lower Bajocian, *Humphriesianum* Zone, lower Bajocian, Glasauer quarry, OSV, NHMW 2019/0184/0179. **E** – *Nannina romani* (Oppel, 1856), lower Bajocian, *Humphriesianum* Zone, Glasauer quarry, OSV, NHMW 2019/0184/0252. **F** – *Oppelia* aff. *subradiata* (Sowerby, 1823), macroconch M, upper Bajocian, *Niortense* Zone, SE Teichhaus, LT, NHMW 1927/0004/0137. **G** – *Papilliceras mesacanthum* (Waagen, 1867), lower Bajocian, *Laeviuscula* Zone, Glasauer quarry, OSV, NHMW 1843/0030/0340. **H** – *Papilliceras mesacanthum* (Waagen, 1867), lower Bajocian, *Laeviuscula* Zone, Glasauer quarry, OSV, NHMW 1843/0030/0340. **I** – *Sonninia* sp., lower Bajocian, *Humphriesianum* Zone, Glasauer quarry, OSV, NHMW 2019/0184/0389. **J** – *Arnioceras ceratitoides* Quenstedt, 1848, Sinemurian, OSV Ebner-Rofensteingasse, NHMW 2019/0184/0421. **K** – *Echioceras* cf. *quenstedti* (Schafhäutl, 1847), Sinemurian, OSV, NHMW 2019/0184/0558. **L** – *Spiroceras* aff. *baculatum* (Quenstedt, 1858), upper Bajocian, *Niortense* Zone or *Garantiana* Zone, OSV Einsiedeleigasse, NHMW 2019/0184/0212.

(= *Lokuticeras* cf. *lissajousi*, Fig. 6I). The majority of the Middle Jurassic ("Dogger") taxa described by Hochstetter (1898), also reproduced by Schaffer (1906), comes from the Glasauer quarry on the southern slope of the Girzenberg in the SVK of St. Veit. On the figure from the Glasauer quarry by Schaffer (1906) strong tectonic folding, disruptions of layers and shear planes can be observed in the approximately 15 metres high front wall. Hochstetter (1898) noted the presence of the Lower Bajocian "*Harpoceras (Sonninia) sowerbyi*" and "*Stephanoceras (Sphaeroceras) sauzei*" zones. From the Middle Bajocian the "*Sonninia Romani* Zone, also suggested by Hochstetter as "*Stephanoceras*-Schichten" with *St. humphriesianum*, *Stephanoceras vindobonense*, *Stephanoceras tenuicostatum* (Fig. 1 and Pl. 3, Figs. 3a, b in Hochstetter 1898; = *Lokuticeras* cf. *lissajousi*, Fig. 6I), *Ammonites baculatus* and *Hamites baculatus* (= *Spiroceras* aff. *baculatum*; Fig. 7L). The Upper Bajocian was described with *Cosmoceras subfurcatum* and *Cosmoceras (Parkinsonia) parkinsoni* zones. A Lower Bathonian was reported with the *Oppelia fusca* and the *Cosmoceras (Stephanoceras) ferrugianum* Zone and an Upper Bathonian *Oppelia aspidoides* Zone. He noted the Lower Bathonian as being similar to the Klausschichten (= "Klaus Formation") of the NCA.

The fauna list from Trauth's papers was partly reproduced in Götzinger (1954) and notes for the fine, sandy grey limestones and grey crinoidal limestones (Neuhauser Schichten of Götzinger, 1954) at the Hohenauer Wiese Klippe of the wildlife park Lainz a Bajocian to Bathonian age. These sandy limestones had their most prominent occurrence at the Glasauer quarry in St. Veit at the southern hillside of the Girzenberg. The fauna was firstly reported by Trauth (1923a), listed again by Götzinger (1954), and comprised *Sonninia mesacantha* (= *Papilliceras mesacanthum*, Figs. 7G, H), *Harpoceras discites* (= *Graphoceras* cf. *limitatum*, Fig. 7C), *Coeloceras* cf. *anguinum*, *Lytoceras rasile* (= *Megalytoceras rasile*), the middle assemblage with *Posidonomya alpina*, *Nautilus clausus*, *Stephanoceras humphriesianum*, *St. subcoronatum* and *Belemnites giganteus* (Fig. 8B), and the younger *Phylloceras viator* (= *Phyllopachyceras viator*), *Oppelia subradiata* (= *Oppelia* sp.) and *Cosmoceras baculatum*.

Silicious limestones with cherts overlay these sandy parts at the Gemeindeberg and Girzenberg (Schaffer, 1906; Trauth, 1928) with *Posidonomya alpina*, *Waldheimia* cf. *margarita*, *Phylloceras kudernatschi*, *Phylloceras viator* (= *Phyllopachyceras viator*), and *Stephanoceras linguiferum* given as Middle and Upper Bathonian from Götzinger (1954).

Grill and Küpper (1954) figured Middle Jurassic Bajocian ammonites with *Phylloceras zignodianum* (= *Holcophylloceras zignodianum*, Fig. 6B) and linked them to the Glasauer quarry of St. Veit and the Hohenauer Wiese Klippe in the wildlife park Lainz. Additionally, *St. humphriesianum* of the Glasauer quarry and the Hohenauer Wiese Klippe was refigured from Trauth (1923a).

6.3 The Roter Berg area

Čžjžek (1849, p. 72) described a small fauna from a small quarry in red cherty limestones with wavy bedding, east of the Glasauer quarry in the SVK, today known as the Roter Berg summit of St. Veit (Plöchinger and Prey, 1992). The fauna is dominated by aptychi ("*Aptychus latus*" = *Laevaptychus longus*, Fig. 8D, "*Aptychus lamellosus*") and belemnites ("*Belemnites canaliculatus*"), originally assigned to the Oxfordian (Čžjžek, 1849).

Hauer (1850) described red limestones as „Oxfordthon" from St. Veit with small fossil assemblages comprising "*Aptychus latus*", "*Aptychus lamellosus*" and belemnites with "*Belemnites hastatus*" = *Hibolites hastatus*. From the Roter Berg area Grill and Küpper (1954) figured *Belemnites (Belemnopsis) canaliculatus* and aptychi with *Laevaptychus latus* and *Lamellaptychus beyrichi*.

The presented data from the SVK of the wildlife park Lainz and St. Veit localities allow a more precise biostratigraphy and subsequently the reconstruction of the palaeogeographic setting of the studied section. The described lithologies and facies types represent deep-water deposits of a Lower to Middle Jurassic basin, which was situated in the northernmost areas of the Jurassic Adriatic (Alpine-Apennine) Plate (Fourcade et al., 1993; Lukeneder, 2010) of the western Tethys.

The studied fauna offers one of the few opportunities to investigate historical Middle Jurassic ammonite faunas from Austria. Hence, the St. Veit and wildlife park Lainz localities represent key localities for a detailed investigation of an ammonite fauna affected by an environmental turnover during the opening of the Penninic Ocean (= Alpine Tethys), reflected by the facies change from terrestrial influenced bioclastic limestones to deeper slope environments of the Middle Jurassic limestones. The almost Tethyan-wide or at least Western Tethyan (including the Mediterranean Province) [= alpin-mediterrane Juraprovinz in Trauth, 1923a] occurrence of the present Jurassic ammonite taxa from the SVK Unit makes these cephalopods suitable for biostratigraphic correlations within the Tethyan Realm. The occurring taxa and biostratigraphy are mainly matched to well-known and described faunas from Austrian localities (e.g. Hödl-Kritsch; Krystyn, 1970, 1971, 1972), Spain (Fernández-López et al., 2009; Sandoval, 2016), France (Pavia, 1983; Pavia and Fernández-López, 2008; Pavia et al., 2008), S Germany (Schlegelmilch, 1985; Dietze et al., 2007; Schweigert et al., 2007), Switzerland (Scheurlen, 1928), and Bulgaria (Metodiev, 2019).

In the case of the SVK cephalopod assemblages a Mediterranean character can be fixed for the ammonite fauna. The Jurassic ammonite fauna from the SVK Unit mirrors the connective palaeoceanographic position of the easternmost Austrian Klippen Unit north to the Alpine-Apennine Plate between the westernmost occurrences from Spain to the easternmost occurrences of the Mediterranean province in Bulgaria and Poland.

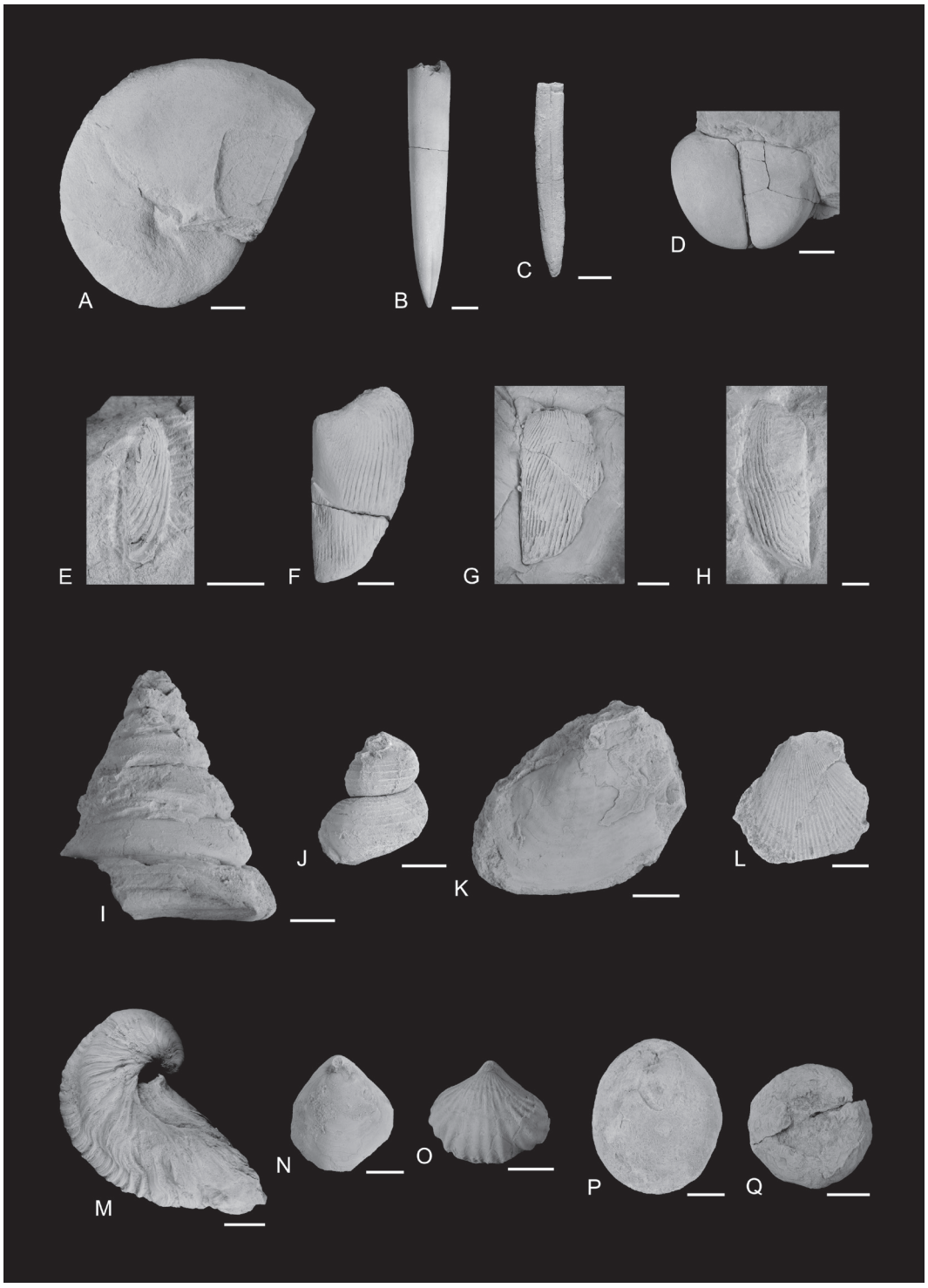

Figure 8: Everterbrate fauna from the Lower Jurassic to Middle Jurassic of St Veit (OSV), Roter Berg (RB) and the wildlife park Lainzer Tiergarten (LT), St. Veit Klippen Unit. **A** – *Cenoceras* sp., lower Bajocian, *Humphriesianum* Zone, Glasauer quarry, OSV, 2019/0184/0301. **B** – *Belemnites giganteus* Schlotheim 1820, Bajocian, lower Bajocian, lower Bajocian, *Humphriesianum* Zone, Glasauer quarry, OSV, NHMW 2019/0184/0560. **C** – *Belemnites* sp., Bajocian, lower Bajocian, *Humphriesianum* Zone, Glasauer quarry, OSV, NHMW 2019/0184/0308. **D** – *Laevaptychus longus* (Meyer, 1829), Kimmeridgian to Tithonian, OSV, NHMW 2019/0184/0559. **E** – *Lamellaptychus bajociensis* Trauth 1930, lower Bajocian, *Humphriesianum* Zone, Glasauer quarry, OSV, 2019/0184/0307. **F** – *Beyrichilamellaptychus beyrichi* (Oppel 1865), Tithonian, RB OSV, NHMW 2019/0184/0101. **G** – *Beyrichilamellaptychus beyrichi* (Oppel, 1865), Tithonian, SE of Faniteum OSV, NHMW 2019/0184/0529. **H** – *Mortilletilamellaptychus bicurvatus* (Renz and Habicht, 1985), originally figured in Trauth (1938, Pl. XIV, Fig. 7), Tithonian, OSV, NHMW 1941/0001/0013. **I** – *Pyrgotrochus elongatae* (Sowerby, 1818), upper Bajocian, *Garantiana* Zone or *Parkinsoni* Zone, SE Teichhaus, LT, NHMW 1927/0004/0082. **J** – *Amberleya elongata* (Hudleston, 1892), upper Bajocian, *Garantiana* Zone or *Parkinsoni* Zone, SE Teichhaus, LT, NHMW 1927/0004/0086. **K** – *Pholadomya corrugata* Koch and Dunker 1837, Sinemurian to Pliensbachian, OSV, NHMW 2019/0184/0021. **L** – *Chlamys textoria* (Schlotheim, 1820), upper Bajocian, *Garantiana* Zone or *Parkinsoni* Zone, SE Teichhaus, LT, NHMW 1927/0004/0056. **M** – *Gryphaea arcuata* Lamarck 1801, Hettangian-Sinemurian, OSV Veitingergasse, NHMW 1985/0045/0001. **N** – *Loboidothyris perovalis* (Sowerby 1823), Bajocian, LT, NHMW 1927/0004/0024. **O** – *Cymatorhynchia quadriplicata* (Zieten 1832), upper Bajocian, *Garantiana* Zone or *Parkinsoni* Zone, LT, NHMW 1927/0004/0018. **P** – *Pygomalus* cf. *ovalis* (Leske, 1778), Bajocian, OSV, NHMW 2019/0184/0064. **Q** – *Diplopodia* cf. *jobae* (d'Orbigny, 1850), upper Bajocian, *Garantiana* Zone or *Parkinsoni* Zone, LT, NHMW 1927/0004/0005.

From the Lower Jurassic of Gresten, Hochstetter (1898) reported a *Schlotheima charmassei* (= *Angulaticeras charmassei*), that would today be assigned to the Lower Sinemurian. Hochstetter reported from his "Arietitenkalk" *Arietites conybeari* (= *Arnioceras ceratitoides*) from the Lias α along with *Pleurotomaria expansa*, *Pl. anglica*, *Pl. princeps*, *Lima punctata*, *L. deslongchampsi*, *L gigantea*, and *Cardina listeri*, *Cordinia gigantea*, *Rhynchonella* sp., *Ostrea* sp. and belemnite fragments. The "Fleckenmergel" were interpreted to be an equivalent of the Alpine "Lias Fleckenmergel" (Hochstetter, 1897). From the base of these marly, sandy limestones Trauth (1928) reported an *Aegoceras*, which is in fact a Sinemurian *Echioceras* cf. *quenstedti*. The most prominent and often reported bivalve *Gryphaea arcuata* is typical for the Sinemurian (Fig. 8M; Hochstetter, 1897; Trauth, 1923, 1928).

7. Palaeogeography and provincialism

The original palaeogeographic position of the St. Veit Klippen Unit is strongly debated (Trauth, 1948; Prey, 1965, 1975, 1979; Decker, 1990; Faupl and Wagreich, 1992; Schnabel, 1992, 2002; Faupl, 1996; Trautwein et al., 2001; Wagreich and Neuhuber, 2007; Mattern and Wang, 2008; Pfersmann and Wagreich, 2009; Pfersmann, 2013; Egger and Wessely, 2014). Recently, a direct connection with the western Ybbsitz Klippen Unit as assumed by Schnabel (1979, 1992a, b) and Decker (1990) was rejected by Ślączka et al. (2018). It is not well understood to which palaeogeographic realm the St. Veit Klippen Unit (mostly cited as St. Veit Klippen Belt; see Ślączka et al., 2018) should be attributed. The European shelf (= Helvetic Unit), the Penninic Ocean *sensu lato* (= Penninic Unit; PO = Alpine Tethys, see Stampfli and Hochard, 2009) and the Austroalpine Unit with comparable facies of the Northern Calcareous Alps are possible candidates. The Gresten Klippen Unit is interpreted to be of Helvetic origin, the Ybbsitz Klippen Unit of Penninic origin, whereas the St. Veit Klippen (SVK) Unit was correlated with southern areas of the Pieniny Klippen Belt (PKB; Neumayr, 1871a, b; Uhlig, 1891; Schnabel, 1999; Pfersmann, 2013; Ślączka et al., 2018; Trauth, 1928; Prey, 1965; Hók et al., 2009). The PKB was formed on an intercalated swell south of the Gresten Klippen Zone and north of the Alpine elements (pers. comm. M. Wagreich, 2019). From the lithological and fossil data presented herein a mixture of deposits from Klippen units and northernmost Australpine lithologies including the NCA it cannot be ruled out that the complicated structure of the SVK is a mixture of deposits from the original palaeogeographic depositional area of the Klippen Unit and parts of the northernmost Austroalpine complex. Bauer (1987) marked the position of the Klippen Unit south of the expanded new Northern Penninic Ocean and north of the Ultrapienidic Ridge and the Northern Calcareous Alps even more to the south during the Early and Middle Jurassic to Early Cretaceous (Fig. 1 in Bauer, 1987; Dercourt et al., 2000; Mandic and Lukeneder, 2008; Stampfli and Hochard, 2009). Schnabel (2002) noted a possible palaeogeographic position for the Klippe of Mauer (Antonshöhe) from a deeper slope passing into the Penninic Ocean (= Alpine Tethys) north to the Austroalpine plate.

The Penninic Ocean or Alpine Tethys was initiated during the Late Triassic by rifting and disjunction of the Austroalpine microcontinent from the southern European Plate margin in the Alpine-Carpathian domain (Mandic and Lukeneder, 2008; Stampfli and Hochard, 2009). It was the easternmost extension of the North Atlantic Rift-System affecting the final disintegration of the Permotriassic Pangea Supercontinent (e.g., Faupl, 2003). The formation of the oceanic crust and the sea floor spreading lasted from the Middle Jurassic to the Early Cretaceous, terminating with the introduction of its southward-directed subduction beneath the northern Austroalpine plate margin (Faupl and Wagreich, 2000). According to Stampfli and Hochard (2009) the Alpine-Carpathian domain including the SVK zone to the north of the Austroalpine complex was in that period at a tectonically active position between the northern latitudes of 30°-40°. From the Cretaceous on, the active plate margin including the transpressional accretionary wedge and the northern parts of the Austroalpine microplate thereby underwent accelerated uplift and erosion, reflected by siliciclastic input into the southern adjoining marine environments (Wagreich, 2003).

From a palaeontological point of view the macrofaunal assemblage can be assigned to the Jurassic Mediterranean Province of the Western Tethyan Realm ("alpin-mediterrane Juraprovinz" in Trauth, 1923a; see Fernández-López et al., 2009; Schweigert, 2015; Pavia and Fernández-Lopez, 2019). The cephalopod fauna is almost identical with isochronic assemblages from other localities of Austria (Northern Calcareous Alps; Krystyn, 1970, 1971, 1972), southern Spain (Betic Cordillera; Fernandez-Lopez, 1985; Fernández-López et al., 2009; Sandoval, 2016), southeast France (southern Subalpine Chains; Pavia, 1983; Fernández-López, 2007; De Baets et al., 2008; Pavia et al., 2008; Fernández-López et al., 2009), northern France (Pavia et al., 2013), from Italy (Apennine Mountains and Sicily; Cresta and Galácz, 1990), southern Germany (Scheurlen, 1928; Schlegelmilch, 1985; Schweigert and Dietze, 1998; Schweigert, 2007; Dietze et al., 2007; Schweigert et al., 2007), Slovakia (Western Carpathians; Schlögl et al., 2009), Hungary (Bakony and Mecsek Montains; Galácz, 1980, 1991; Cresta and Galácz, 1990; Galácz and Kassai, 2012; Galácz et al., 2015), Poland (Polish Jura Chain; Zatoń, 2010; Birkenmajer and Gedl, 2017), and Bulgaria (Western and Central Balkan Mountains; Metodiev, 2019). Especially the Middle Jurassic Bajocian to Bathonian sections yield the same ammonite families and partly even the identical species.

8. Biostratigraphy

From a macrofossil point of view two different main ammonite assemblages point to two distinct time intervals present in the SVK Zone of Vienna. One Early Jurassic (late Hettangian-Sinemurian) with the indicative

ammonites *Arnioceras ceratitoides* (early Sinemurian) and *Echioceras* cf. *quenstedti* (late Sinemurian, *Raricostatum* Zone; Schlegelmilch, 1985; Blau, 1998; Lukeneder and Lukeneder, 2018; zonations according to Ogg et al., 2012; Schweigert, 2015) accompanied by the Early Jurassic bivalve *Gryphaea arcuata* (Hettangian to Sinemurian).

The second time interval is of Middle Jurassic age, ranging from the Bajocian to Bathonian. The oldest fossiliferous deposits of this interval start with the outcrop area of the historic Glasauer quarry exhibiting deposits from the lowermost Bajocian *Discites* Zone (Ogg et al., 2012) marked by the ammonite assemblage with *Graphoceras* cf. *limitatum* (Cresta and Galácz, 1990; Galácz et al., 2015). It must be noted that *G. limitatum* was also reported from the upper Aalenian from SE France by Baets et al. (2007). However, the overall assemblage from the Glasauer quarry points to an early Bajocian age near the transition from the late Aalenian. The lower Bajocian *Laeviuscula* Zone appears with *Papilliceras mesacanthum* and the *Humphriesianum* Zone (Ogg et al., 2012) with *Holcophylloceras zignodianum*, *Stephanoceras* cf. *humphriesianum*, *Stephanoceras* aff. *vindobonense*, *Dorsetensia* aff. *deltafalcata*, *Nannina romani*, *Sonninia* sp. (Galácz, 1980, 1991; Fernandez-Lopez, 1985; Schlegelmilch, 1985; Baets et al., 2007; Dietze et al., 2007; Galácz and Kassai, 2012; Pavia et al., 2013; Galácz et al., 2015), and the upper Bajocian *Niortense* Zone with *Lokuticeras* cf. *lissajousi* (Metz, 1992; Galácz, 1994).

Slightly younger deposits are found at the Teichhausklippe and the Hohenauer Wiese Klippe area in the wildlife park Lainz. The deposits at the SE Teichhaus outcrop start with rare faunae of the lower upper Bajocian *Niortense* Zone (Ogg et al., 2012) with *Oppelia* aff. *subradiata*, the upper *Garantiana* or *Parkinsoni* zones with *Phylloceras rosiwali*, *Calliphylloceras disputabile*, *Nannolytoceras polyhelictum*, *Vermisphinctes martiusii*, *Parkinsonia toulai*, and *Phlycticeras aenigmaticum* and *Parkinsonia ferruginea* from the uppermost Bajocian *Parkinsoni* Zone (Illies, 1956; Krystyn, 1972; Schweigert and Dietze, 1998; Dietze et al., 2007; Schweigert et al., 2007). More to the west the SW Teichhaus outcrop appears with lowermost Bajocian *Graphoceras* cf. *limitatum* of the *Discites* Zone. An additional upper Bajocian faunal element is *Spirocera*s aff. *baculatum*, which appears in numerous localities in St. Veit. It belongs either to the *Niortense* Zone or the *Garantiana* Zone (Ogg et al., 2012).

The biostratigraphic classification of the Jurassic deposits from the St. Veit Klippen Unit is accompanied by microfossil analyses. Foraminifera and calpionellids are the most important groups used during this study. An Early Jurassic age (Sinemurian) of the lowermost bioclastic limestones is indicated for several samples by the presence of the benthic foraminifera *Involutina liassica*, *Trocholina turris* and *Trocholina umbo*. *Trocholina* sp. also occurs in Lower Jurassic crinoidal limestones and *Duotaxis metula* in grey allodapic encrinites from St. Veit localities. Typical associations of predominantly monaxone megascleres with frequent triaxone spicules and radiolarians indicate the presence of Lower Jurassic grey spiculite limestones. Dominance of filaments with abundant benthic ophthalmid foraminifera points to a Middle Jurassic age, corresponding to the Klaus Formation-like parts of the Hohenauer Wiese Formation.

Upper Jurassic silicious limestones and cherts from the Rotenberg Formation appear as red radiolaria dominated deposits with characteristic occurrences of aptychi with *Laevaptychus longus* from Kimmeridgian to Tithonian, and Tithonian species as *Beyrichilamellaptychus beyrichi* and *Mortilletilamellaptychus bicurvatus* (Měchová et al., 2010). The fine grey to red limestones of the upper Fasselgraben Formation yield late Berriasian assemblages of calcareous dinoflagellates with *Colomisphaera carpathica* and calpionellid taxa as *Tintinnopsella carpathica* and *Calpionella elliptica* (Lukeneder and Reháková, 2004; Lukeneder et al., 2019).

The entire lithological sequence from the St. Veit Klippe in St. Veit and the wildlife park Lainz show a range from the Lower Jurassic (Sinemurian) bioclastic limestones and crinoidal/spiculite sequences, via Middle Jurassic (Bajocian to Bathonian) silicious crinoidal/brachiopod/ammonite limestones of the Hohenauer Wiese Formation to Upper Jurassic (Kimmeridgian and Tithonian) deep water deposits of the Rotenberg Formation (Oxfordian to Tithonian) and hemipelagic to pelagic Upper Jurassic (Tithonian) to Lower Cretaceous (Berriasian) deposits of the Fasselgraben Formation.

9. Conclusions

The so far imprecisely reported macrofauna of localities from St. Veit and the wildlife park Lainz (St. Veit Klippe, Hietzing, western area of Vienna) is mainly represented by abundant ammonites, frequent aptychi, belemnites, brachiopods, bivalves and gastropods. 3393 fossil specimens and 104 rock samples were photographed.

During the Jurassic the SVK lithologies and facies types document a significant facies change from the Lower Jurassic shallow water influenced bioclastic limestones, to the deep-water marly limestones and limestones of the Lower Jurassic "Lias Fleckenmergel" (comparable to the Allgäu Formation of the NCA). The Lower Jurassic grey deep-water limestones are accompanied by spiculite and crinoidal limestone deposits influenced by transport and redeposition by deep water currents. After an assumed significant hiatus, characteristic silicious spiculaea and radiolaria rich wackestone to packstones and crinoidal limestones of the Glasauer quarry and red to grey crinoidal limestones of the Hohenauer Wiese Klippe appear. The latter Middle Jurassic lithologies are accompanied by rare occurrences of red condensed cephalopod limestones of „Klaus Formation" type. The Upper Jurassic follows with deep water sedimentation of the Rotenberg Formation with cherty radiolarites and radiolarian-rich limestones. From the uppermost Jurassic to Lower Cretaceous cherty grey limestone and radiolaria-rich limestones of the Fasselgraben formation prevail. Overall, the depositional sequence is similar to sections from the Northern Calcareous Alps.

The faunal assemblages are by far dominated by ammonites, hence being the base of the biostratigraphic interpretation. The ammonite fauna consists of 18 different genera, each represented by one or two species. Stephanoceratidae are the most frequent element (*Stephanoceras*, *Lokuticeras*) followed by the Phylloceratidae (*Calliphylloceras*, *Holcophylloceras*, *Phylloceras*), and Lytoceratidae (*Nannolytoceras*). Perisphinctidae (*Vermisphinctes*), Parkinsoniidae (*Parkinsonia*), Strigoceratidae (*Phlycticeras*), Graphoceratidae (*Graphoceras*), Sonniniidae (*Dorsetensia*, *Nannina*, *Sonninia*), Otoitidae (*Otoites*), Oppeliidae (*Oppelia*), Arietidae (*Arnioceras*) and Echioceratidae (*Echioceras*), and the heteromorph Spiroceratidae (*Spiroceras*). For the first time, the fauna allows a more detailed biostratigraphy of the Jurassic deposits from the St. Veit Klippen Unit. Lower Jurassic (Sinemurian) deposits with *Gryphaea* assemblages are correlated with the *Raricostatum* Zone. The Middle Jurassic commences with the upper Aalenian *Concavum* Zone, the lower Bajocian with the *Humphriesianum* Zone, the *Niortense* Zone and the *Laeviscula* Zone and the upper Bajocian with the *Garantiana* Zone and *Parkinsoni* Zone.

Biogeographically, the SVK assemblage is reminiscent of other faunae from the Mediterranean Province in the Western Tethyan Realm. Most similarities appear with isochronous assemblages from west to east of S Spain, S France, N France, Switzerland, S Germany, Austria, Slovakia, Hungary, Poland, and Bulgaria. Georeferenced locality details for the historical sampling areas, digital images and data sets are available online at https://www2.nhm-wien.ac.at/LukenederA/OberStVeit/.

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