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Preliminary results on Jurassic and Lower Cretaceous formations in the Karavanke Mountains and Lienz Dolomites, Austria

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The paper summarizes the preliminary results of field studies carried out in the Northern Karavanke Mountains and the Lienz Dolomites during the last few years. Two sections have been measured in the Lienz Dolomites (Figs 3, 4) and eight in the Northern Karavanke Mts (Figs 5, 6, 8, 10–14). While briefly describing the sections, two formation names are introduced: the Toarcian Kisgerecse Marl Formation, well known in the Transdanubian Range and the Toarcian (or Lower Dogger) Wildenstein Breccia Formation, named after its type locality.

Two submarine high(s) and an intervening basin are outlined and their evolution is evidenced from the late Early Jurassic till the Late Jurassic.

As preliminary results, a few megafossil taxa from the Lower Jurassic (bivalve, gastropod, brachiopods) are listed in the paper, also indicating their ecological and stratigraphic importance. Some newly collected Upper Jurassic (Tithonian) ammonites are also listed and figured.

Keywords: Karavanke Mts, Lienz Dolomites, Jurassic–Lower Cretaceous, Submarine high, Tithonian ammonoids

Introduction

For Hungarian geologists it was always very important to know as much about the geology of the Eastern Alps as possible, for several reasons: a) from the very beginning, geologic research in Hungary had been largely built on the geologic knowledge obtained in the Alpine area, b) the Alps are an open book to read compared to the flat and partly covered areas of the Pannonian region, c) it was suggested that the Pelso unit was a direct continuation of the Drau Range and that it originated from between the Northern Calcareous Alps and the Southern Alps (Kázmér and Kovács 1985).

Whereas the paleogeographic reconstruction of the Paleozoic and Triassic formations has been based on widely accepted, well-distinguishable facies zones, the distribution of the Jurassic formations within the Tethyan realm shows more uniform character, or at least a less regular pattern. The main facies differences within the Tethyan shelves depend basically on the local morphology of the

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bottom: in the basinal part more or less complete but thin, reduced successions, on the highs lacunose, even more condensed sequences have been deposited. As a consequence more detailed information is needed for finding the original facies connections within the Jurassic than the Triassic of the Tethys. In principle the distribution of the Lower Cretaceous formations offers a better chance for recognition of the regularities in the facies distribution, but owing to the subsequent erosion at the beginning of the Late Cretaceous only a very small proportion of the successions has been preserved.

During the last two decades, Austrian geologists paid limited attention to the Jurassic and Cretaceous formations of the Drau Range area. In addition to geologic maps and explanatory notes (Bauer 1981; Bauer et al. 1983) there are only a few papers dedicated to the Karavanke Mts (Bauer 1970; Holzer and Polting 1980; Schröder 1988; Kuhlemann et al. 1993; Császár and Dosztály 1994; Krystyn et al. 1994; Schlaf 1995; Császár et al. 1998) and the Lienz Dolomites (Faupl 1977; Blau and Schmidt 1988; Blau and Meister 1991; Blau and Grün 1995). The geology of the Karavanke Mts and the Julian Alps attracted the attention of the Hungarian geologists due to their supposed direct paleogeographic links with the Transdanubian Range (Kázmér and Kovács 1985; Schmidt et al. 1991). This is the reason why the present study, promoted by the Geological Survey of Austria in the framework of joint research, is dedicated to this narrow tectonic zone along the Periadriatic Lineament.

Geologic setting

The Drau Range (Fig. 1) is composed of the following east-west oriented tectonic units: Northern Karavanke Mts, Gailtal Alps, Lienz Dolomites, Winnebach Kalkzug and Aschbach Horst in the Hochpustertal (Blau and Grün 1995). These units consist mainly of thrust sheets and nappe structures of northerly vergence called Basal Nappe ("Sockeldecke") and Obir Nappe by Stini (1938) and Basal Zone and Central Zone by Schröder (1988) in the Northern Karavanke Mts (Fig. 2). According to Tollmann (1977) the maximum overthrust (4 km) occurred during the Early Tertiary. Jurassic and Cretaceous formations are preserved in the Northern Karavanke Mts and the Lienz Dolomites only from among the units listed above. Owing to the Late Miocene culmination of the multiphase deformations (Bauer 1970; Siewert 1984) the nappes and imbrications composed of Middle and Upper Triassic formations piled up very high above the Jurassic and Cretaceous formations in the northern part of the zone. In addition to the nappes, a blanket of Triassic dolomite and limestone fragments derived from the Obir Nappe may also cover a considerable part of the narrow Jurassic and Cretaceous stripe. The dip of the younger Mesozoic formations is variable.

The Northern Karavanke Mts have similar stratigraphic and tectonic character in its Slovenian continuation (Ramovš and Rebek 1970; Mioč and Šribar 1975).

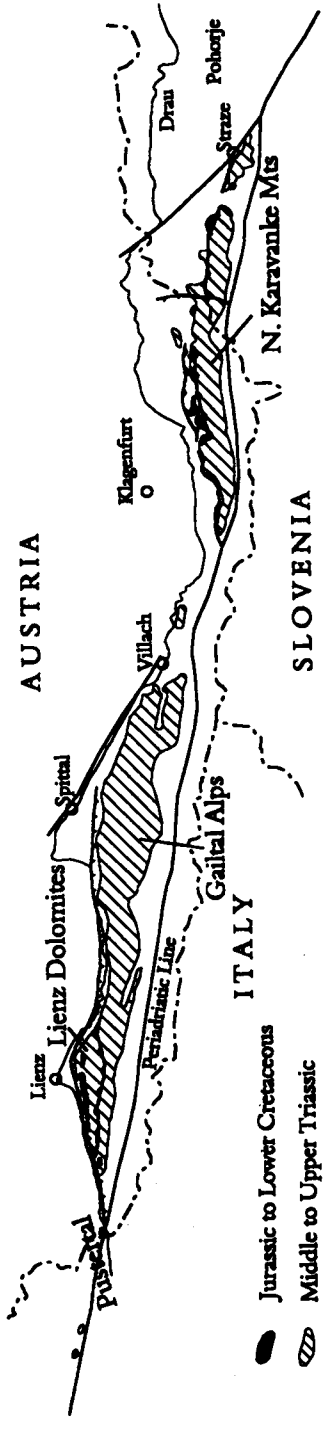

Fig. 1
Tectonic units and geologic sketch map of the Drau Range showing the extent of the Mesozoic formations (after Beck-Managetta and Braumüller 1964, simplified)

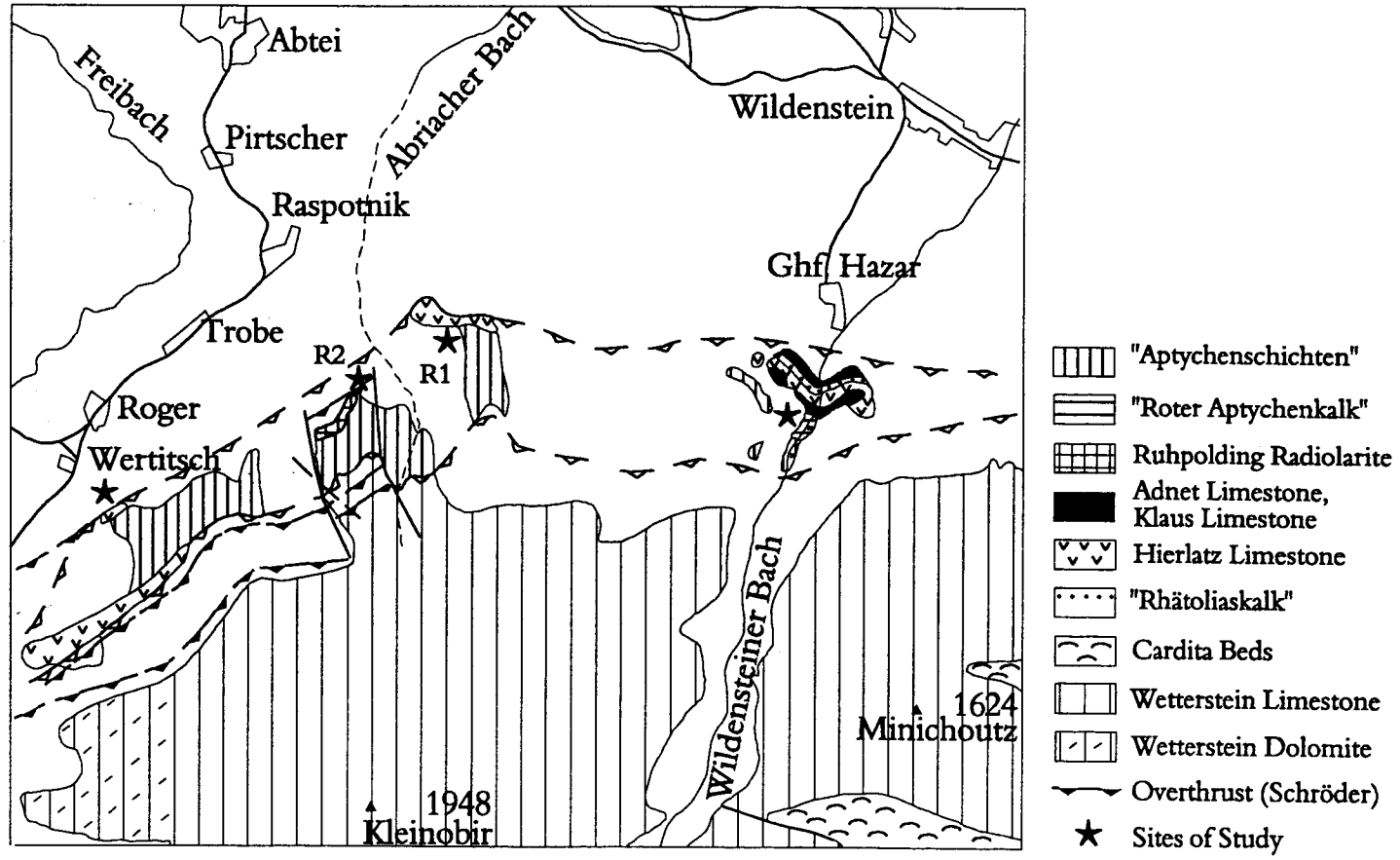

Fig. 2
Detail from the geologic map of the Northern Karavanke Mountains. Scale: 1:25 000 (after Bauer 1981, with the overthrust lines of Schröder 1988). R1 – site of Raspotnik section no 1; R2 – site of Raspotnik section no 2

Lithostratigraphy – description of the sections and localities under study

On the geologic map of the eastern part of the Northern Karavanke Mountains (Fig. 2; Bauer 1981) the following Jurassic and Cretaceous formations were distinguished: "Rhätoliaskalk" (Rhaetian to Liassic), "Hierlatzkalk" (Hierlatz Limestone – Liassic), "Adneter Kalk" (Adnet Limestone), "Klauskalk" (Lower to Middle Jurassic), "Ruhpoldinger Schichten" (Ruhpolding Radiolarite – lower Upper Jurassic), "Roter Aptychenkalk" (Red Aptychi Limestone – uppermost Upper Jurassic to Neocomian), "Aptychenschichten" (Aptychi beds – Neocomian), "Kalkbrekzie" (Albian). The Red Aptychi Limestone is subdivided into a "Saccocomakalk" and "Calpionellenkalk" by Bauer et al. (1983). They are called red Aptychi limestone s. str. and Biancone or Calpionella limestone respectively by Schröder (1988). He also named the Aptychi limestone Schrambachschichten (Schrambach beds). Császár and Dosztály (1994) noted Toarcian red marls (equivalent to the Kisgerecse Marl Fm. in the Transdanubian Range) with a rich ammonite assemblage at Raspotnik.

The Jurassic and Cretaceous formations in the Lienz Dolomites were described recently by Blau and Grün (1995), Blau and Meister (1991), Blau and Schmidt (1988). Blau and Grün (1995) distinguished a slope and basin and a ridge successions. In the former the following formations were recognized: "Lavanter Breccie" (? Hettangian–Sinemurian), "Bunte Kalke" (? Hettangian–Upper Sinemurian), "Allgäuschichten" (? Hettangian–Sinemurian), "Rotkalk" ("red limestone"–Pliensbachian to Upper Jurassic), "Biancone" (Upper Tithonian–Valanginian), "Kreidefleckenmergel" (Valanginian, Hauterivian–Aptian), Amlacher Wiesen Schichten (Aptian/Albian). According to Blau and Grün (1995) there are hardground(s) within the "red limestone" in the condensed ridge succession where no Middle Jurassic is evidenced.

The most significant difference between the Jurassic sequences in the Northern Karavanke Mts. and the Lienz Dolomites is that the Karavanke sequence is more calcareous and pelagic, whereas intercalation of the Allgäu Beds in the Lienz Dolomites indicates a stronger terrigenous influx.

Several Jurassic and Lower Cretaceous formations in the Drau Range area were either not known thus far or simply not named and described according to the rules of the international stratigraphic guide (Hedberg 1976; Salvador 1994). Since the sequences of the Transdanubian Range in Hungary are similar to those in the Drau Range, especially in the Northern Karavanke Mts, in the present paper we often use formal Hungarian lithostratigraphic names in addition to the informal local names, and also names defined in the Northern Calcareous Alps (NCA), if they are relevant (e.g. "Roter Aptychenkalk" = Pálihálás Limestone Fm or "Tegernseer Kalk", or "Agathakalk"). If a formation was thus far unknown in the Drau Range but was known in Hungary, the Hungarian formal name is used in addition to a name from the NCA (e.g. Kisgerecse Marl Fm. – "Saubachschichten"). If the newly recorded formation was previously not known in the NCA, or in the Transdanubian Range, a new local name is introduced as a

formal lithostratigraphic one (e.g. Wildenstein Breccia Fm). It should be noted that the informal Jurassic names in Austria often traditionally carry a chronostratigraphic meaning that may cause trouble in their application. There are various names for formations of more or less the same lithology, just because their ammonite content and age are (in part) different. A good example is the Pálihálás Limestone Formation in Hungary, a "dark or light red limestone, «Ammonitico Rosso» type argillaceous, nodular limestone with Saccocoma and with variable bedding, maybe cherty" (Knauer 1997b). It is equivalent to the "Rotensteinkalk", the "Agathakalk", and the "Tegernseer Kalk", formations which differ only in their age: the first one is Oxfordian, the second one is Kimmeridgian and the third one is Kimmeridgian to earliest Early Tithonian.

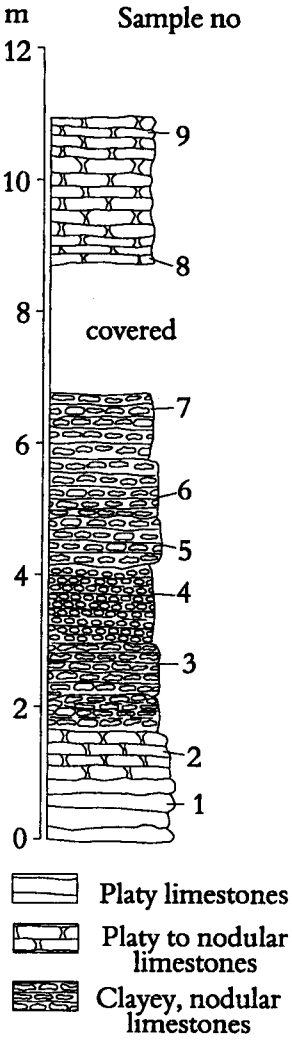

Fig. 3
Schematic columnar section (1) of the Lower Jurassic, Galitzen Klamm, Lienz Dolomites

Galitzen Klamm Section 1 and 2, Lienz Dolomites

There are only two short Lower Jurassic sections in the Lienz Dolomites (Fig. 4), which were rapidly surveyed in this project. According to Blau and Schmidt (1988) and Blau and Grün (1995) both of them can be placed within the basinal facies of the "Rotkalk" formation. Section 1 (Fig. 3) was measured at a rock fall, south of Galitzen Klamm, section 2 (Fig. 4) about 300 m away from the western end of the forest road going to Obertilliach. The basal and the topmost beds of section 1 are thick-bedded platy limestone of greyish and lilac brown color with fine-grained crystalline or micritic fabrics. The middle part of the section is made up of red or brownish-red, clayey, nodular limestone that turns both upsection and downsection into platy nodular limestone. No megafossils have been encountered in the section.

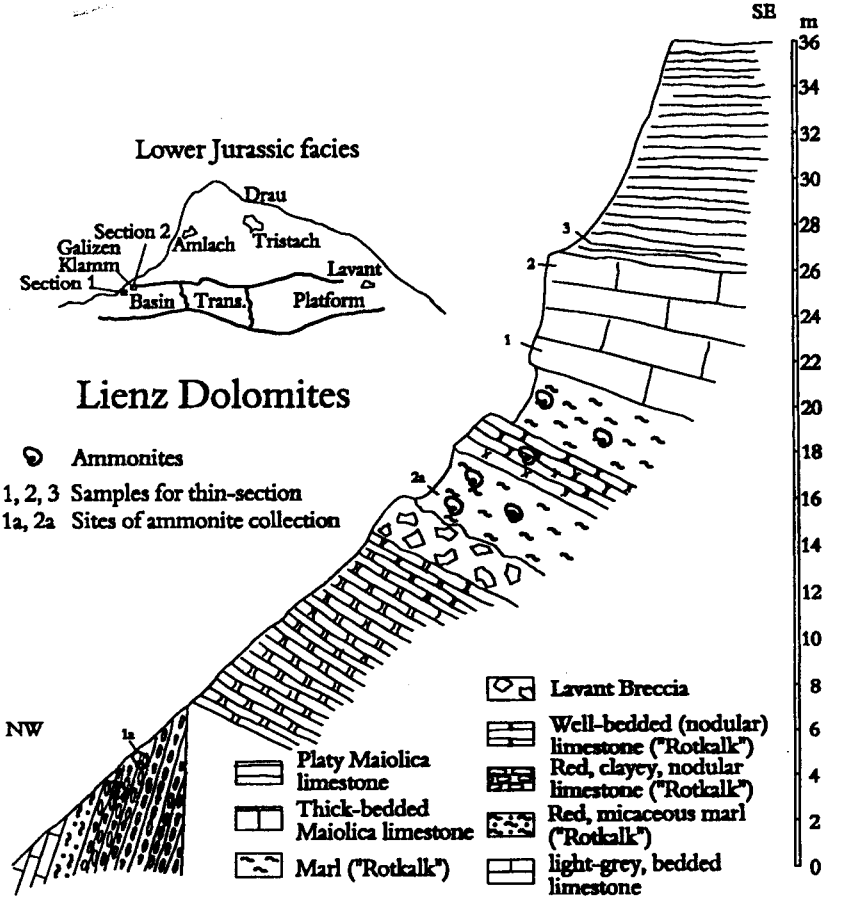

Fig. 4
Location map (after Blau and Grün 1995) and schematic lithological column (2) of the Jurassic, Galitzen Klamm, Lienz Dolomites

Section 2 is tectonically complicated. The steeply dipping lower part begins with limestone beds of grey color, followed by red, slightly micaceous marl and red, clayey, ammonite-bearing nodular limestone. Its heavy mineral content in % is as follows: epidote group: 7, garnet: 8, staurolite: 3, rhombic pyroxene: 6, clinopyroxene: 6, amphibole: 2, kyanite: 1, zircon: 1, rutile: 1, turmaline: 1, biotite: 5, chlorite: 4, hematite: 24, chromite: 1, magnetite: 26, pyrite: 2 (det. by B. Árgyelán). The association indicates mixed magmatic and metamorphic source rocks. Above the fault there is a well-bedded, grey or lilac limestone with red clay intercalations of a few cm thickness. The limestone is replaced by a limestone breccia bed in red, calcareous, clayey matrix (Lavant Breccia – Blau and Grün 1995). The overlying red marls and nodular limestone are rich in ammonites. The

marl is overlain by thick-bedded white limestone and then by white, platy limestone. The last two limestone units may belong to the Maiolica, which is equivalent to the Mogyorósdomb Limestone Formation in the Bakony Mts.

Wertitsch, Northern Karavanke Mts.

The studied section is situated at the foot of a rather steep slope to the south of Wertitsch (Fig. 2). According to Bauer et al. (1981) the "Hierlatz Limestone" is in contact with the "Aptychi beds". The columnar section (Fig. 5 – Császár et al. 1998) clearly indicates a thick Lower Jurassic succession and a poorly exposed Middle and Upper Jurassic one.

The Lower Jurassic "Hierlatz Limestone" (Bauer et al. 1983) that can be compared to the Pisznice Limestone in the Gerecse Mts, can be subdivided into two lithological units. The lower 15-m interval (Wertitsch II in Fig. 5) is made up of pink or red, thick-bedded, crinoidal limestone of variable grain size with scattered manganese-coated intraclasts. The nodular character is subordinate. The upper half of the formation (12 m) consists of pink limestone of wackestone, occasionally mudstone, texture with scattered, fine-grained crinoid ossicles. The uppermost half meter is a clayey limestone with abundant manganese-coated intraclasts. The peculiarity of the formation is the lack of other macrofossils. Based on this fact – even if the redefinition of the Hierlatz Formation has not yet been completed (Vörös 1991; Böhm et al. 1998) – the authors suggest using another lithostratigraphic name for this succession because its composition does not correspond to the definitive pattern of the Hierlatz Formation (Trauth 1950). Lithostratigraphically it could be better correlated with the Pisznice Limestone Formation, described in the Gerecse Mts, Hungary (Császár et al. 1998).

The above-described beds are followed by a formation not indicated in the latest geologic map by Bauer (1981). It is a brownish-red, clayey, nodular limestone that can be correlated with the Adnet Limestone, described from the Karavanke Mts by Schröder (1988).

The upper 3 m of the Wertitsch section is mostly covered by soil and vegetation; therefore the contacts of the formations are uncertain. Its lower part is formed by a 1 m-thick breccia unit. The rock fragments of this breccia reach up to 30 cm in size and derive from the yellowish-grey, oncoidal "Rhätoliaskalk" (similar to the Kardosrét Limestone Fm. in the Bakony Mts, Hungary). The matrix is a red, mudstone-type limestone with a few Bositra shells. This type of breccia is not unique in the Karavanke Mountains; it was first reported from the Wildenstein Valley (Császár et al. 1998). Therefore we propose calling it Wildenstein Breccia Formation. Although the precise age of the formation is not known, the Bositra shells suggest that it cannot be older than Toarcian. So far no other breccias are known from the Northern Karavanke Mts. Early Jurassic (Hettangian to Sinemurian) breccias were reported from the Lienz Dolomites (Blau and Schmidt 1988; Blau and Grün 1995). This kind of breccia also occurs in the

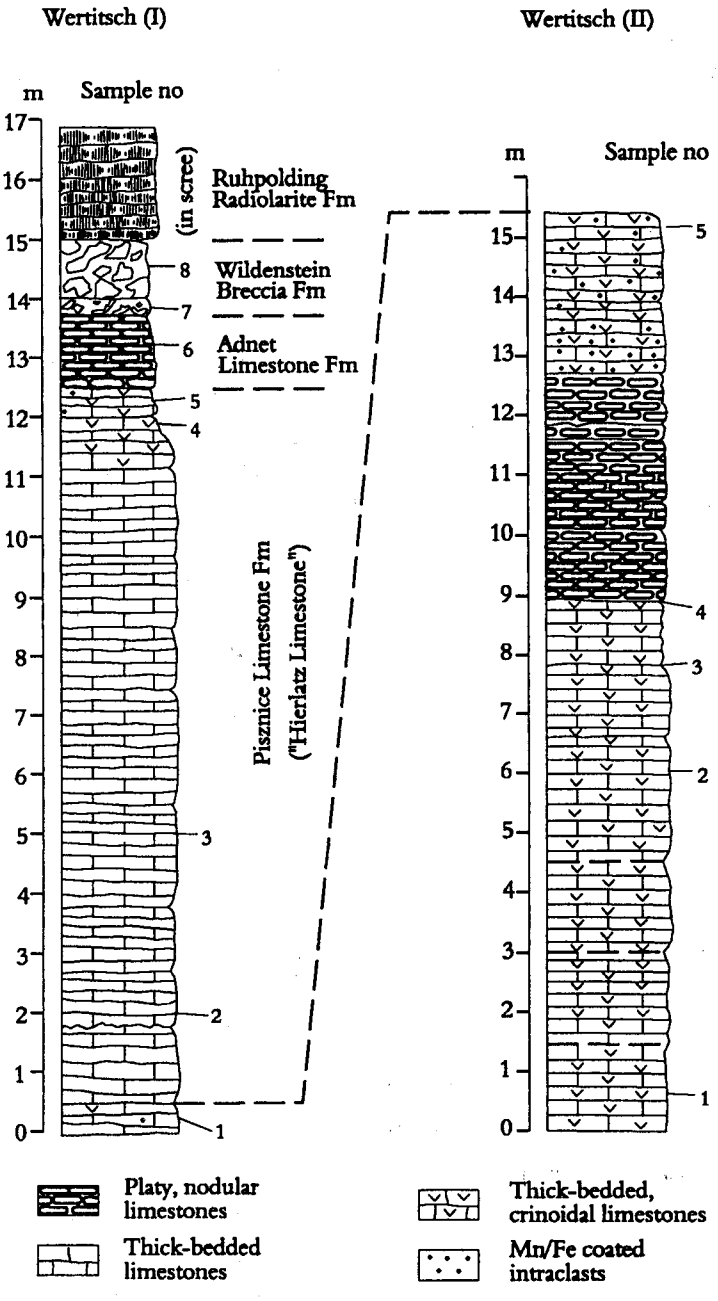

Fig. 5
Composite lithological column of the Jurassic sequence at Wertitsch, Northern Karavanke Mountains

Pliensbachian and Bajocian of the Transdanubian Range (Galácz and Vörös 1972; Vörös 1986; Vörös and Galácz 1998).

The section is capped by chert fragments of Ruhpolding Radiolarite (Fig. 5) found as scree on the surface. As chert fragments can move over considerable distances down the slope the supposed thickness of the Wildenstein Breccia may be underestimated in the columnar section.

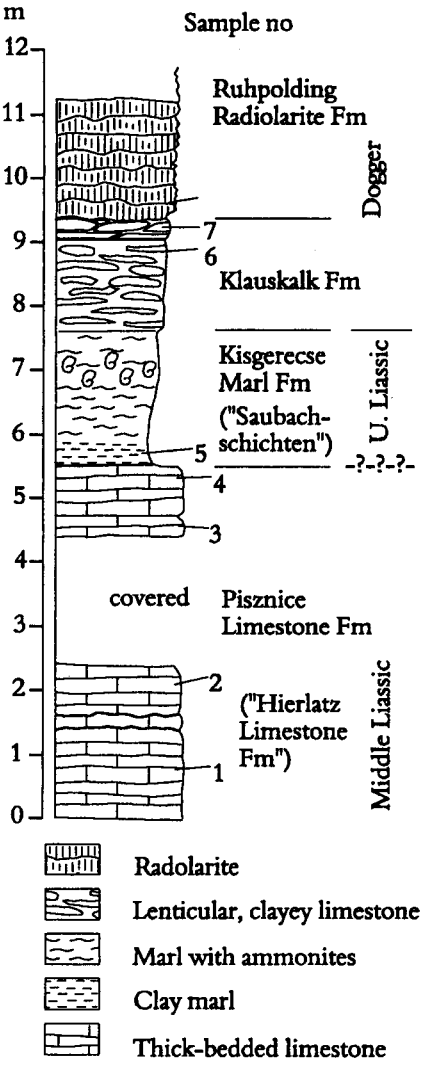

Fig. 6
Columnar section of the Lower to Middle Jurassic sequence in a road-cut, Raspotnik, Northern Karavanke Mountains (R 1 in Fig. 2)

Raspotnik section no. 1

Bauer (1981) indicates a direct contact between the "Hierlatz Limestone" and the Lower Cretaceous Aptychi beds on the detailed geologic map (Fig. 2). In the section (Fig. 6) the upper part of the "Hierlatz Limestone" crops out. Although it resembles the lower unit of the Wertitsch section its topmost beds, of slightly nodular character, contain a few ammonites and Fe/Mn-coated intraclasts in the micritic matrix; therefore it is better to call it either Pisznice Limestone or Adnet Limestone.

In an artificial trench, Császár and Dosztály (1994) discovered new formations above a hardground surface of the Pisznice or Adnet Limestone. Its lower 2-meter part consists of calcareous clay and marl and contains a rich ammonite assemblage belonging to the Hildoceras bifrons Zone (Géczy in Császár and Dosztály 1994; Császár et al. 1998). As in the Karavanke Mts this significant formation (indicating a rapid subsidence, and/or an overall sea level rise) was not specified or named, Császár et al. (1998) suggested using the name Kisgerecse Marl Formation, defined in the Transdanubian Range (Fig. 7) within the same tectonic zone. "The Kisgerecse Marl is a bright red, Ammonitico Rosso-type marl, and marl with limestone nodules" (Knauer

1997a). The "Saubachschichten", described from the NCA by Plöchinger (1982) and also by Böhm (1992), may be an equivalent formation.

The mineralogical composition of this formation at Raspotnik in wt.% is as follows: calcite: 61, (67), montmorillonite: 4 (3), illite/montmorillonite: (3), illite: 11 (8), kaolinite: 4 (4), quartz: - (9), K-feldspar: - (1), hematite: - (2), goethite 1 (trace), gypsum - (1). amorphous - (2) (the first numbers show the results of thermal analyses made by M. Földvári, numbers in brackets are results of X-ray analyses made by P. Kovács-Pálffy, both in the laboratory of the Geological Institute of Hungary).

The Kisgerecse Marl Formation is followed by a 2 meter-thick red marl and clayey limestone of lenticular bedding without macrofossils. Because of the gradual transition, it might be part of the Kisgerecse Marl (or "Saubachschichten") but more probably it is a clayey member of the "Klauskalk". These marly units are directly overlain by the Ruhpolding Radiolarite.

Raspotnik section no. 2

The section is situated south of the settlement along a road-cut, higher up the slope (Fig. 2). The section (Fig. 8) offers a good opportunity to study the transition between the following formations: Ruhpolding Radiolarite, Saccocoma limestone (equivalent to "Tegernseer Kalk" in the NCA and Pálihálás Limestone in the Transdanubian Range) and the Maiolica

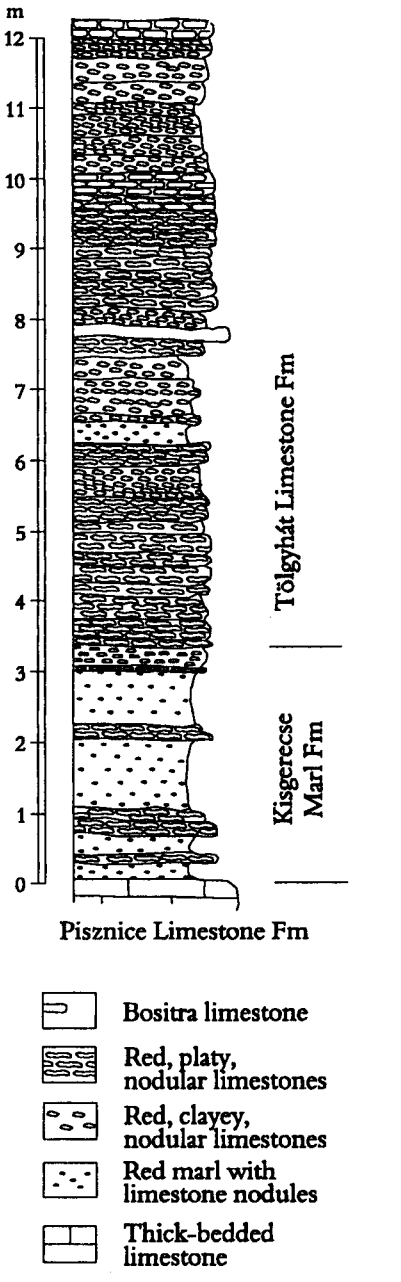

Fig. 7
Type-section of the Toarcian Kisgerecse Marl Formation, Mount Kis-Gerecse, Gerecse Mts, Hungary

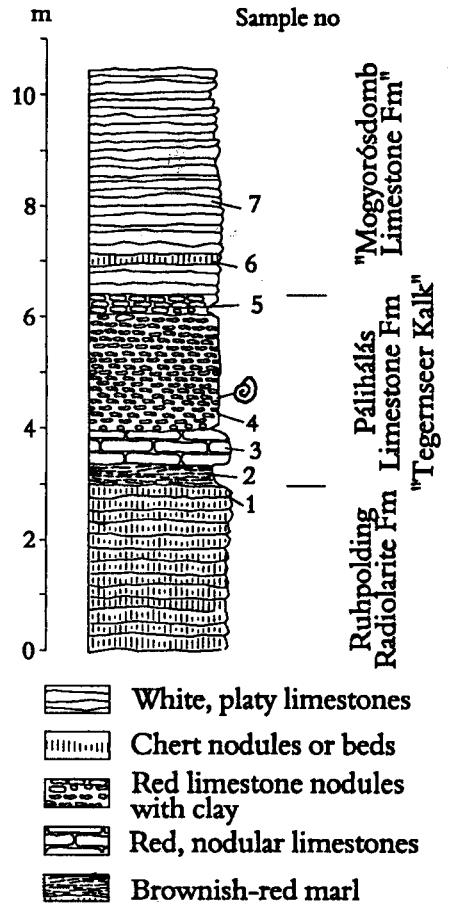

Fig. 8
Upper Jurassic at a forest road-cut, Raspotnik, Northern Karavanke Mountains (R2 in Fig. 2)

(Mogyorósdomb Limestone in the Bakony Mountains).

The upper 3 meter-thick part of the Ruhpolding Radiolarite is visible in the section. It consists of 10 to 15 cm-thick brownish-red cherty beds with thin clayey interlayers. The Radiolaria assemblage of the formation gave an Oxfordian age, according to Dosztály (in Császár and Dosztály 1994). The age of the radiolarite at Unterort (a few kilometers east of Wildenstein) is Kimmeridgian, providing evidence for heterochronous onset and termination of radiolarite sedimentation in the Karavanke Mts, just as in the Transdanubian Range.

The Pálihálás Limestone begins with a 40 cm-thick brownish-red marl layer followed by a 60 cm brownish-red, grey-spotted, nodular limestone interval. The remaining 2.5 m of the formation is lilac-red, clayey, nodular limestone with an ammonite-rich horizon. This level yielded a few very poorly preserved phylloceratids, numerous fragments of lytoceratids (most likely belonging to *Protetragonites quadrisulcatus* (D'Orbigny 1840), and some densely ribbed, strongly dissolved perisphinctids, insufficient for precise determination. Two specimens were determined as *Hybonoticeras hybonotum* (Oppel 1863). This species is the zonal index of the widely-used Hybonotum Zone of the lowermost Tithonian. The specimens were relatively large fragments of body chambers. The strong, distant, simple or bifurcating ribs, the ventrolateral tubercles and the bicarinate, concave venter are visible.

In the scree, another important ammonite, *Pseudowaagenia acanthomphala* (Zittel 1870) was found. The specimen – a moderately well-preserved body chamber – shows the typical internal row of tubercles; the flanks are flat and the venter is rounded with a flat band in the middle. According to Checa (1985) the species is characteristic for the middle-upper part of the Kimmeridgian, with a maximum abundance in the uppermost Kimmeridgian Beckeri Zone.

The upper half meter of the formation shows characteristics transitional to the Maiolica. This bed is reddish pale-grey, sometimes greenish in color and less nodular but lenticular, and resembles the "Anzenbach Schichten" in the NCA.

The Maiolica (equivalent to the Mogyorósdomb Limestone in Southern Bakony, Hungary and "Schrambach-schichten" – Schröder 1988) is here a greyish-white platy, micritic limestone with dark-grey chert nodules or thin beds cropping out only in 4 m of thickness.

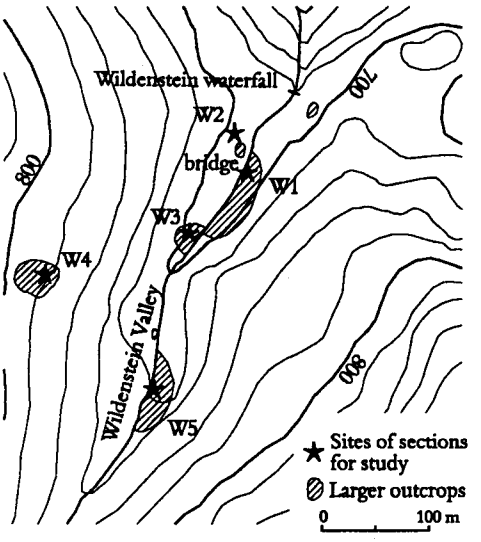

Fig. 9
Wildenstein Valley with outcrops of Jurassic and Lower Cretaceous formations and with the indication of the sites of sections studied, Northern Karavanke Mountains

Wildenstein Valley, section W 1

According to Bauer (1981), in the Wildenstein Valley and its closer surroundings (indicated as Wildersteiner Bach in Fig. 2) the Adnet Limestone is directly overlain by the "red Aptychi beds". In the creek level, close to the wooden bridge, a breccia unit was discovered in red, muddy and calcareous matrix (Császár and Dosztály 1994; Császár et al. 1998). The maximum size of the breccia components exceeds 1 m. The prevailing rock type of this Wildenstein Breccia is the "Rhätoliaskalk" but a few Lower Jurassic crinoidal limestone fragments of smaller size were also found. In an artificial trench at the base of the small cliff on the eastern side of the creek (Figs 9, 10), in addition to the Ruhpolding Radiolarite, the Wildenstein Breccia was also revealed below the Saccocoma limestone. Here the breccia contains smaller rock fragments (2–25 cm). The very poor heavy mineral content of the clayey, marly matrix of the Wildenstein Breccia in % is as follows: epidote group: 0.7, garnet: 7.1, staurolite. 2.9, rhombic pyroxene: 2.9, amphibole: 0.7, zircon: 0.7, magnetite: 85 (det. by B. Árgyelán).

The thickness of the brownish-red, platy radiolarite with thin clay intercalations is less than 1 m. The Ruhpolding Radiolarite is separated by a few cm-thick red clay of lenticular bedding from the Saccocoma limestone (Pálihálás Limestone). The red or brownish-red limestone is micritic, often fine-grained biodetrital, occasionally with red chert nodules or just siliceous impregnation. The lower part of this limestone yielded the following megafossils: *Ptychophylloceras ptychoicum* (Quenstedt 1847), *Phylloceras* sp., *Protetragonites*

quadrisulcatus (D'Orbigny 1840), *Haploceras carachtheis* (Zeuschner 1846), *Virgatosimoceras micrum* Olóriz 1978, *Lamellaptychus* sp., *Punctaptychus* sp., *Triangope* sp. Approximately 3 m above the radiolarite in addition to phylloceratids and lytoceratids (*Protetragonites* sp.), *Haploceras* sp. and *Lemencia* sp. were found (the fossiliferous layer is some 0.5 m above the top of the column in Fig. 10 and indicated in the column of Fig. 6 in Császár et al. 1998). All fossils are poorly preserved, fragmentary and strongly dissolved. Ammonites are internal moulds, only the brachiopod shells and aptychi are preserved.

The lower assemblage (including the relatively well-preserved *Virgatosimoceras*, an adult, nearly complete body chamber) is characteristic for the lower part of the Lower Tithonian, probably for the Darwini Zone of Enay and Geyssant (1975). In certain horizons of this level, small aptychi are abundant.

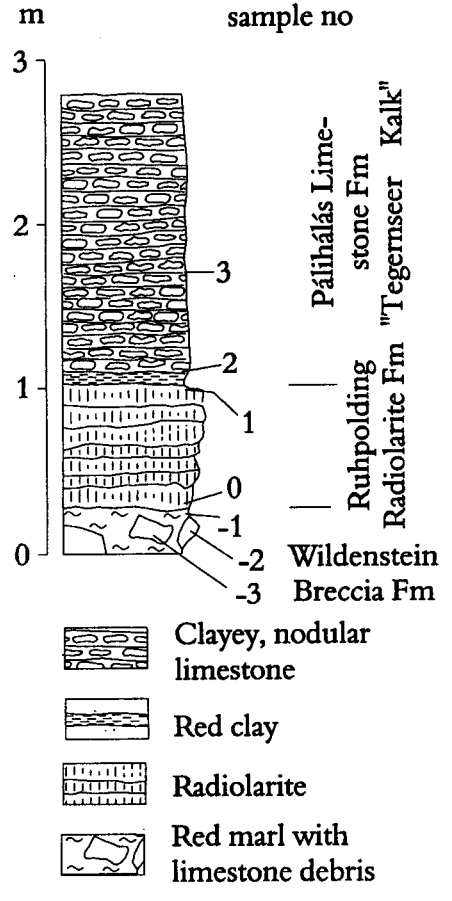

Fig. 10
Columnar section with Jurassic formations at the bridge, Wildenstein Valley, Northern Karavanke Mountains (W1)

Lemencia sp., collected higher in the section, represents the upper part of the Lower Tithonian – probably Ponti Zone (Olóriz 1978).

The section is clear evidence for the lack of "Klauskalk" in the valley. On the other hand both the Wildenstein Breccia and the Ruhpolding Radiolarite occur.

Wildenstein Valley W 2

The section is located on the western side of the valley, close to the base level (Fig. 9). It exposes the topmost beds of the Pálihálás Limestone "Tegernseer Kalk" and the lower beds of the Szentiványhegy Limestone. The upper beds of the succession can be considered as a transitional facies between the "Haselbergkalk" and the "Mühlbergkalk" (Fig. 11). The former is a fine-grained, reddish or pale-grey, nodular limestone with a few red chert nodules, while the latter is a micritic and stylolitic, lilac, reddish or white limestone with scattered crinoidal ossicles. The significance of this section is that the Upper Jurassic and lowermost Cretaceous part of the Calpionella limestone is biodetrital

only here (akin to the Szentivánhegy Limestone in the Transdanubian Range) replacing the widespread Maiolica-type Mogyorósdomb Limestone that is barren of biodetritus.

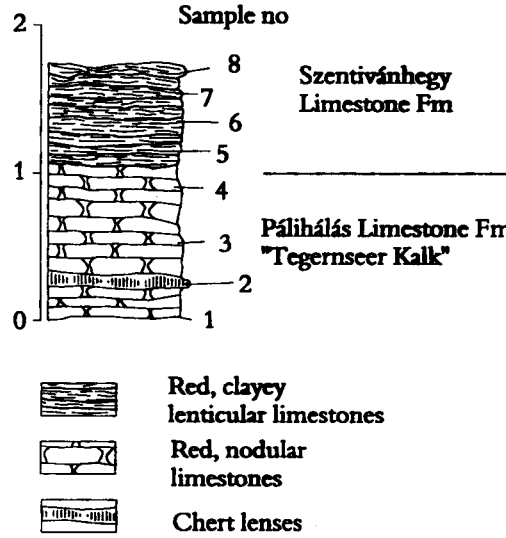

Fig. 11
Transitional beds of the Saccocoma limestone (Pálihálás Limestone Fm.) and the Maiolica beds (Szentivánhegy Limestone) at the bridge, Wildenstein Valley (W 2)

Wildenstein Valley W 3

This section was measured on the western side of the valley, approx. 170 m to the south of the waterfall (Fig. 9). The 21 m-thick section exposes the basal part of the Neocomian Maiolica (equivalent to the Mogyorósdomb Limestone Formation) consisting of well-bedded, mainly platy, occasionally laminated micritic limestone (Fig. 12). Its lower 2.1 m thick part is pale lilac or brownish-lilac in color resembling the "Anzenbach Schichten" in the NCA, and provided a few poorly-preserved ammonites (*Berriasella* sp.). Above this level the color turns into light grey or greenish grey. Dark grey clay laminae or seldom cm-thick layers intercalate up to 4 m. Black or dark grey chert nodules are restricted to the 2.1 and 6.2 m interval. The thicker upper part of the section (approx. above 6 m) is called "Schrambachschichten" by Schröder (1988). Due to its considerable thickness the formation is well represented and recognized in the Northern Karavanke Mts. (Suette 1978; Holzer and Suette, in Bauer et al. 1983; Császár and Dosztály 1994) and also in the Lienz Dolomites (Blau and Grün 1995).

Wildenstein Valley W 4

The section is situated high on the western slope of the valley (Fig. 9) and it forms an upsection continuation of the Mogyorósdomb Limestone introduced in the previous section (W 3). Lithologically the sequence of this section (Fig. 13) is similar to that one in section W 3 but the stratification is more varied: there are several thicker beds and the laminated intercalations are also rather frequent. Black chert nodules are restricted to the lower 6 m and bioturbation, that made the limestone spotty, can be recognized throughout the sequence.

Wildenstein Valley W 5

The section (Fig. 14) represents the uppermost part of the Lower Cretaceous sequence of the Northern Karavanke Mts (Fig. 9). Between the grey or dark grey limestone beds dark grey clay and marl intercalations become more and more frequent upsection. The entire section was also assigned to the "Schrambach-schichten" by Schröder (1988). According to Császár and Dosztály (1994) these

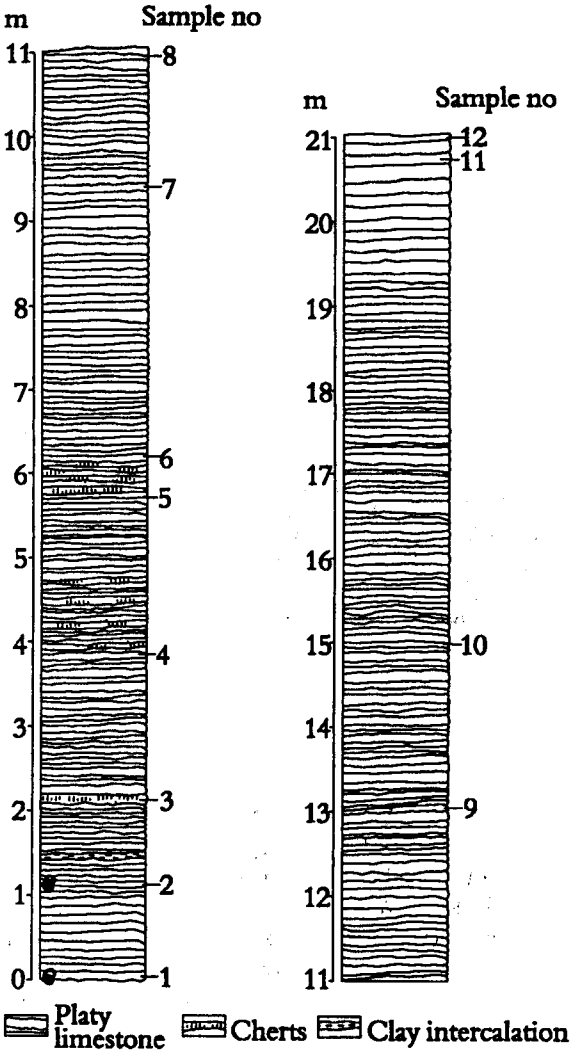

Fig. 12
Columnar section of the (Maiolica) Mogyorósdomb Limestone Fm. in the Wildenstein Valley (W 3)

beds correspond to the Sümeg Marl Formation in the Bakony Mts. By definition the Sümeg Marl is a grey, occasionally greenish, or brownish silty marl, siltstone and calcareous marl of shallow bathyal basin facies with sandy intercalations in the upper part in some cases with a significant amount of ammonites, radiolarians and planktonic foraminifers. The bottom part is calcareous marl, whereas the middle part is predominantly calcareous siltstone or silty marl [Császár and Haas in Császár (ed.) 1997].

Wildenstein Valley W 6

This is not a measured section but a locality, where particular and distinctive rock types, otherwise unknown in the area, occur. On the top of a nearby hill east of the Wildenstein Valley, a few large boulders have been found. One of them, a red, micritic, finely crinoidal, massive limestone block provided the following fossils: plenty of tiny gastropods (*Ataphrus*? sp., det. by J. Szabó); a dozen small brachiopods (*Koninckodonta* sp., *Phymatothyris cerasulum* (Zittel 1869), det. by A. Vörös) and one bivalve (*Praechlamys* sp., det. by I. Szente). This fauna points to a Pliensbachian age. The other block of pink, micritic limestone contained cm-thick, black Fe-Mn-oxide crusts and a large specimen of Lytoceras sp., corroded on one side and encrusted by manganese oxide. Though this ammonoid taxon has a very long stratigraphic range, this limestone can probably be assigned to the Toarcian or Bajocian, by analogy with similar rock types frequently found in the condensed sections of the Bakony Mts.

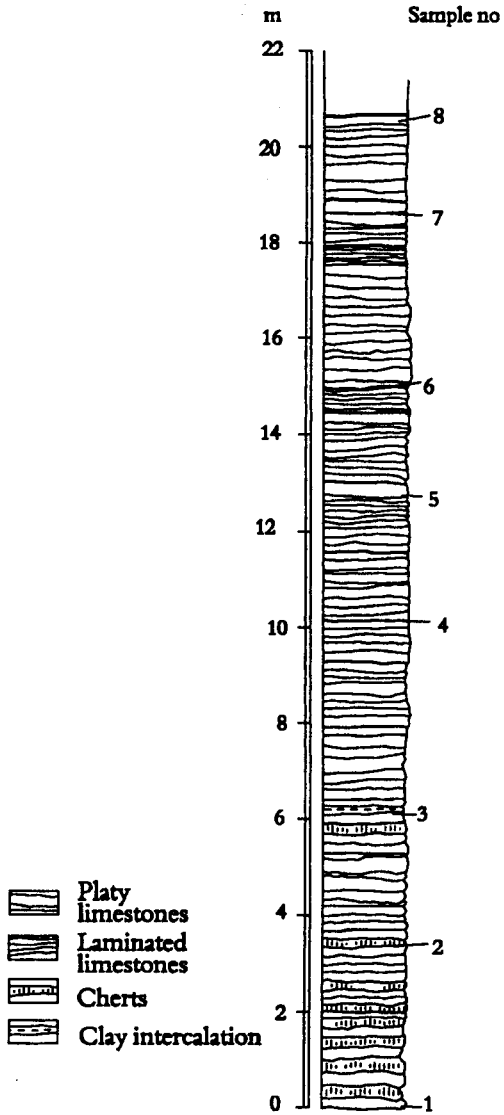

Fig. 13
Columnar section of the (Maiolica) Mogyorósdomb Limestone in the Wildenstein Valley (W 4)

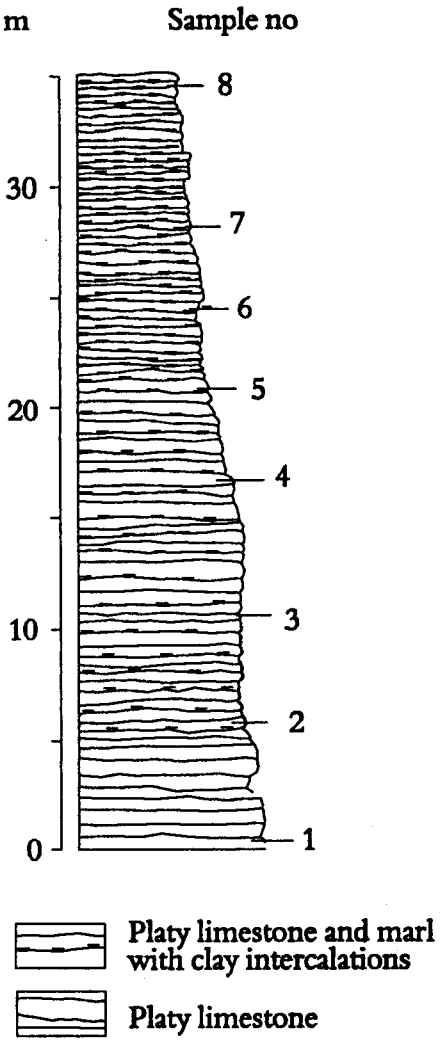

Fig. 14
Uppermost beds of the Lower Cretaceous sequence in the Wildenstein Valley. Transitional beds to the Sümeg Marl Fm. (W 5)

Discussion

The lowermost formation of the Jurassic, the Pisznice Limestone ("Hierlatz Limestone" of earlier authors) is widespread all over the region and shows relatively little thickness variation. The frequent crinoid ossicles of the limestone indicate a relatively shallow submarine source area. The topmost part of this limestone sequence is usually more clayey, reddish and nodular and may turn into the Adnet Limestone (see Wertitsch column I – Fig. 5), which may suggest a gradual deepening of the sedimentary basin. The predominance of less clayey layers within the Wertitsch section may indicate a short-term and less significant sea-level rise during the Early Jurassic epoch.

The silty and micaceous Lower Jurassic limestone units in their westernmost occurrence in the Drau Range (Lienz Dolomites) is a clear indication of a relative proximity of the land that is supposed to have been located to the west or northwest.

A sudden lithological change can be recorded in the Raspotnik R 1 column (Fig. 6) at the beginning of the Toarcian where the clayey, Kisgerecse Marl ("Saubachschichten") appears. It can be substituted by the coeval Wildenstein Breccia. Rhätoliaskalk extraclasts of the breccia occur in red, marly matrix in the Wildenstein Valley (Fig. 10) and in red calcareous marl and limestone matrix at Wertitsch (Fig. 5).

So far two breccia horizons have been recorded in the Jurassic sequences of the Drau Range area. The older one, the Lavant Breccia (Hettangian–Sinemurian, sometimes early Pliensbachian – Blau and Grün 1995), is restricted to the Lienz Dolomites; the younger one, the Toarcian (or perhaps Bajocian?) Wildenstein Breccia, occurs in the Northern Karavanke Mountains. The breccias in both cases

are clear evidence for the tectonic differentiation of the basement within the sedimentary basin. The peculiarity of the phenomenon is the different age of the formation of breccia in two neighboring tectonic units within the Drau Range. In both tectonic units, the appearance of the breccia is in connection with changes in lithology. In the sequence of the Lienz Dolomites "the Bunte Kalke" and Allgäu beds are replaced by the red, clayey, nodular "Rotkalk", whereas in the Northern Karavanke Mts the "Hierlatz Limestone" or Adnet Limestone is followed by the "Saubachschichten" (Kisgerecse Marl). The lithological change indicates a deepening of the sedimentary basin that can be attributed primarily to tectonic subsidence. The overall and crucial lithological change at the beginning of the Toarcian might express a combined effect of a tectonic subsidence and a eustatic sea-level rise.

The Wildenstein Breccia indicates the margin of a submarine high at the Wildenstein Valley and at Wertitsch as well, from where the rock fragments of Rhätoliaskalk were transported gravitationally to the foot of the submarine high. There is evidence for an edge of a submarine high on the eastern side of the Wildenstein Valley. The rock types and fossils in the boulders found on the top of a nearby hill represent the facies characteristic to the top of submarine highs. The brachiopods (especially the koninckodonts) are typical for the submarine highs in the Transdanubian Range (Vörös 1986). According to Szabó (pers. comm.) the gastropods were herbivorous and lived in the photic zone. The Toarcian (or Bajocian) limestone, with corroded and Mn-oxide-encrusted ammonites, is also characteristic to the condensed facies of the submarine highs. This proves a submarine high environment on the eastern side of the Wildenstein valley from the Pliensbachian to the Toarcian (or perhaps to the Bajocian).

The lack of "Klauskalk" and the unusually thin radiolarite in the Wildenstein Valley (Fig. 10) is in accordance with the idea of a neighboring submarine high during the Middle Jurassic.

The lateral facies change in the Late Jurassic (crinoidal Szentivánhegy Limestone in the Wildenstein Valley sections instead of the eupelagic Maiolica facies in the more western areas) is another indication of a submarine high (as source of the coarser biodetrital material) to the east of the Wildenstein Valley.

Because the Jurassic beds are exposed only in a narrow strip in the Northern Karavanke Mts, the above data are insufficient for a detailed, local paleogeographic reconstruction. The submarine highs to the east of Wildenstein Valley and at Wertitsch could be two independent highs or parts of a larger, dissected one. In any case it can be stated that, between the two sites, at Raspotnik, a basinal succession was deposited throughout the entire Jurassic period.

Except for the Wildenstein Breccia, which is a new phenomenon at the top of the Lower Jurassic, both complete and incomplete Jurassic and also Lower Cretaceous successions of the Northern Karavanke Mountains highly resemble the successions of the South Bakony Mountains (Fig. 15).

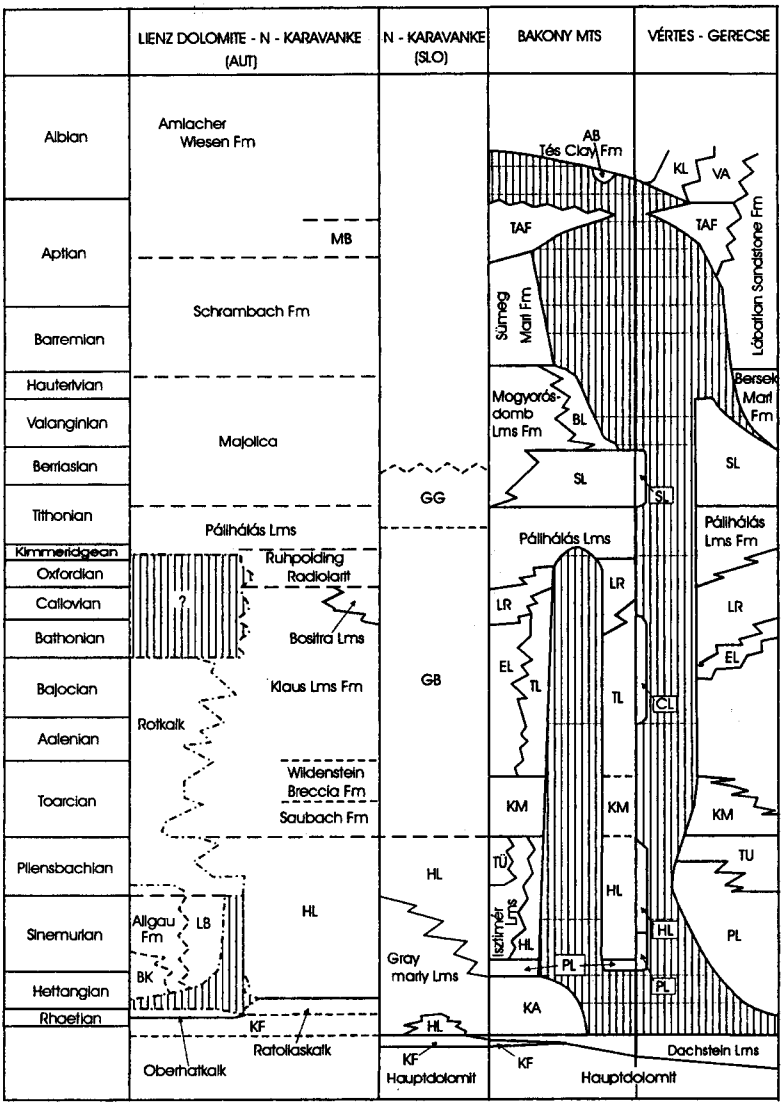

Fig. 15
Correlation chart of the Jurassic to Lower Cretaceous sequences between the Drau and Transdanubian Ranges. AB – Alsópere Bauxite Fmé BK – "Bunte Kalke"; BL – Borzavár Limestone Fm; CL – Csókakő Limestone Fm; EL – Eplény Limestone Fm; GB – Garyish-green and reddish brown platy, marly limestone; GG – Grrenish-gray and reddish platy limestone; HL – Hierlatz Limestone; KA – Kardosrét Limestone Fm; KF – Kössen Fm; KL – Környe Limestone Fm; KM – Kisgerecse Marl Fm; LB – Lavant Breccia; LS – Lábatlan Sandstone Fm; LR – Lókút Radiolarite Fm; MB – "Microbreccia" (N. Karavanke); PL – Pisznice Limestone Fm; SL – Szentiványhegy Limestone Fm; TAF – Tölgyhát Limestone Fm; TL – Tölgyhát Limestone Fm; TŰ – Tűzkövesárok Limestone Fm; VA – Vértessomlói Aleurolit

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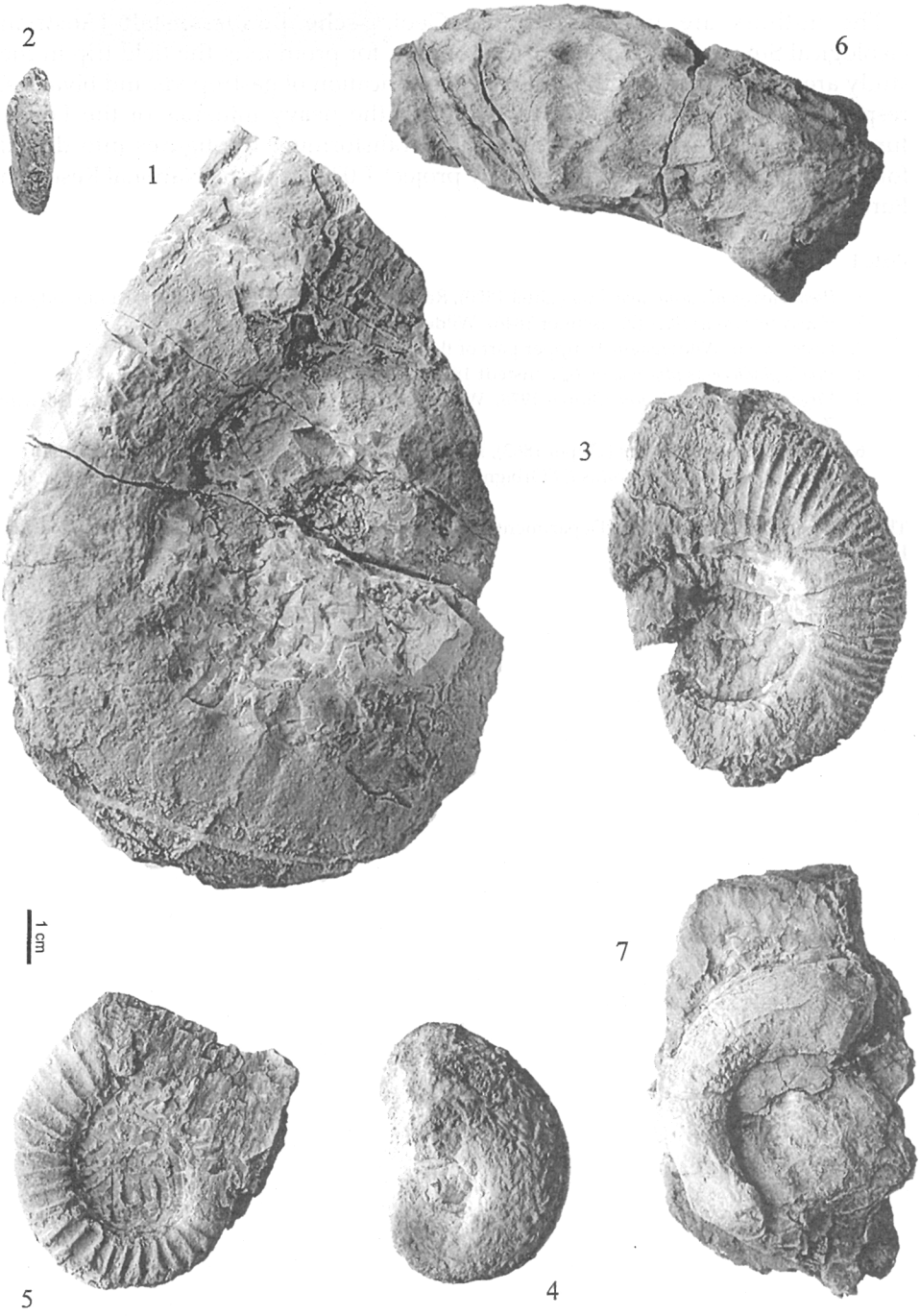
Plate I

1. *Pseudowaagenia acanthomphala* (Zittel 1870), Raspotnik 2, collected from debris, Kimmeridgian
2. *Haploceras carachtheis* (Zeuschner 1846), Wildenstein 1., Lower Tithonian
3. *Lemencia* sp. Wildenstein 1., upper part of the Lower Tithonian (? Ponti Zone)
4. *Ptychophylloceras ptychoicum* (Quenstedt 1847), Wildenstein 1., Lower Tithonian
5. *Virgatosimoceras micrum* Olóriz 1978, Wildenstein 1., Lower Tithonian (probably Darwini Zone)
6. *Hybonoticeras hybonotum* (Oppel 1863), Raspotnik 2, Lower Tithonian (Hybonotum Zone)
7. *Protetragonites quadrisulcatus* (D'Orbigny 1840), Raspotnik 2., Lower Tithonian

The specimens are housed in the Department of Geology and Paleontology of the Hungarian Natural History Museum.

Plate I



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