GEOLOŠKI ANALI BALKANSKOGA POLUOSTRVA

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https://doi.org/10.2298/GABP241010014H
Original scientific paper
Оригинални научни рад

Middle to Late Jurassic pelagites and gravity mass flow deposits of a displaced Neotethyan margin: microfacies and biostratigraphical studies in Northeast Hungary

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Abstract. Microfacies, depositional age and sedimentary environment were characterised for two Jurassic successions, which were deposited on the Adriatic microcontinental margin of the Neotethys Ocean. Investigations were carried out mostly on cores drilled in the Mesozoic basement of the eastern part of the Mátra Mountains (Recsk area) and the westernmost part of the Bükk Mountains, NE Hungary. This area represents the continuation of the Inner Dinaric nappe-system, and was displaced along the Mid-Hungarian Shear Zone during the Late Oligocene to Early Miocene. The pre-Cenozoic basement of the area is characterised by three juxtaposed units: the lowermost Recsk Succession, the Tarna Olistostrome and the topmost Darnóhegy Mélange nappe. The Recsk Succession is made up of Upper Triassic, cherty carbonates of pelagic basin facies that are overlain by pelagic limestones of Early to early Middle Jurassic age. The carbonate sedimentation changed gradually into shale-dominated one during the late Bathonian to the early Callovian. In the Bajocian to early Callovian interval the Recsk area was located at the toe of a coeval carbonate platform, which provided gravitational mass flows reaching the investigated area. The external margin of this platform drowned and got covered by the pelagic shale in the late Bajocian. The Tarna Olistostrome is built up by a Tithonian pelagic mixed carbonatic and siliciclastic succession with breccia/olistostrome horizons. The clasts derived from the Upper Permian–Lower Jurassic succession of a distal Adriatic margin. The Darnóhegy Mélange is a typical sub-ophiolitic mélange comprising scrapped off blocks and slices from the lower plate and gravitationally redeposited / tectonically sheared blocks from the overriding ophiolite nappe. The age of the mélange is Callovian–Oxfordian. These inferences may serve as a base for new geodynamic evaluations of the studied region.

Key words: *microfacies, sedimentation, Middle Jurassic, Late Jurassic, biostratigraphy, Neotethys*

Апстракт. Микрофације, време и средине депоновања две јурске сукцесије, таложене на јадранској микроконтиненталној маргини океана Неотетис, приказане су у овом раду. Истраживања су вршена углавном на језгрима избушеним у мезозојској основи источног дела планине Mátra (подручје Recsk) и најзападнијег дела планине Bükk, СИ Мађарска.

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Ово подручје представља наставак система навлака Унутрашњих Динарида, које су измештене дуж средњемађарске зоне смицања током касног олигоцена до раног миоцена. Пре-кенозојска подина овог подручја представљена је следећим сукцесивним јединицама: најнижом Recsk сукцесијом, потом Tarna олистотром и највишом јединицом - меланж Darnóhegy. Recsk сукцесија изграђена је од горњотријаских пелашких фација представљених карбонатима са рожнацима, преко којих леже доње јурски до најстарије средње јурски пелашки кречњаци. Током горње батског до доње келовејског ката карбонатна седиментација је постепено замењена седиментацијом глиновитих седимената. У периоду бајски кат - келовеј, област Recsk се налазила на падини, у близини карбонатне платформе, која је омогућавала гравитационе масене токове који су доспевали у истраживано подручје. Спољна маргина ове платформе је постепено тонула током горњег дела бајеског ката и била прекривена пелашким финозрним силицијским седиментом. Олистостром Tarna је изграђен од титонских пелашких седимената, представљених сменом карбонатне и силикокластичне сукцесије са хоризонтима брече/олистострома. Класти су пореклом из горњопермских до доњојурских сукцесија дисталне маргине Адрије. Меланж Darnóhegy представља типичан суб-офиолитски меланж који се састоји од откинутих блокова и фрагмената доње плоче и гравитационо унешених или тектонски инкорпорираних блокова офиолитске навлаке. Старост меланжа је келовеј – оксфордска. Ови подаци могу послужити као основа за нове геодинамичке интерпретације истраживаног региона.

Кључне речи: *Микрофације, седиментација, средња јура, горња јура, биостратиграфија, Неотетис*

Introduction

The basement of the Miocene Pannonian basin comprises structural units of various origins that were juxtaposed during the Cenozoic era prior to the onset of back-arc basin formation (Balla, 1987; Csontos & Nagymarosy, 1998; Fodor et al., 1998). The Alcapa Megaunit includes the north-western part of the basement (Fig. 1a) and consists of Austroalpine and Central and Inner West Carpathian structural units derived from the former margins of the Mesozoic Neotethys Ocean toward Europe and Greater Adria. It is separated from the southern Tisza Megaunit by the latest Oligocene to Early Miocene Mid-Hungarian Fault Zone (Fig. 1a), which contains displaced elements from the imbricated Adriatic microplate as strike-slip duplexes (Csontos & Vörös, 2004; Haas et al., 2010). The Bükk Unit, which includes the Bükk Mountains and the pre-Neogene basement of the Mátra Mountains (Fig. 1b, c), is part of the strike-slip duplex system (Haas et al., 2010) or may form part of the Alcapa Megaunit (Kövér et al., 2018a).

This largely covered Mesozoic basement area (Fig. 1c) is the focus of this study, although the westernmost part of the Bükk Mountains (Fig. 1b) was also involved in the evaluation and interpretation of the results. More than ten wells, reaching depths of 1000 to 1200 m, with continuous coring (Fig. 1c) have been investigated in detail to reveal the depositional environment and stratigraphic age of the penetrated Mesozoic successions, which once belonged to the Adriatic microplate margin of the Neotethys Ocean. Furthermore, our goals included defining structural units, investigating their spatial relationships, and comparing the subsurface units with their possible surface equivalents in the Bükk Mountains.

Research history in the Recsk and Darnó area

The basement of the eastern part of the Mátra Mountains is the main target area of this study, although the south-westernmost part of the Bükk Mountains was also involved in the evaluation and the interpretation of the results (Fig. 1b, c). In the

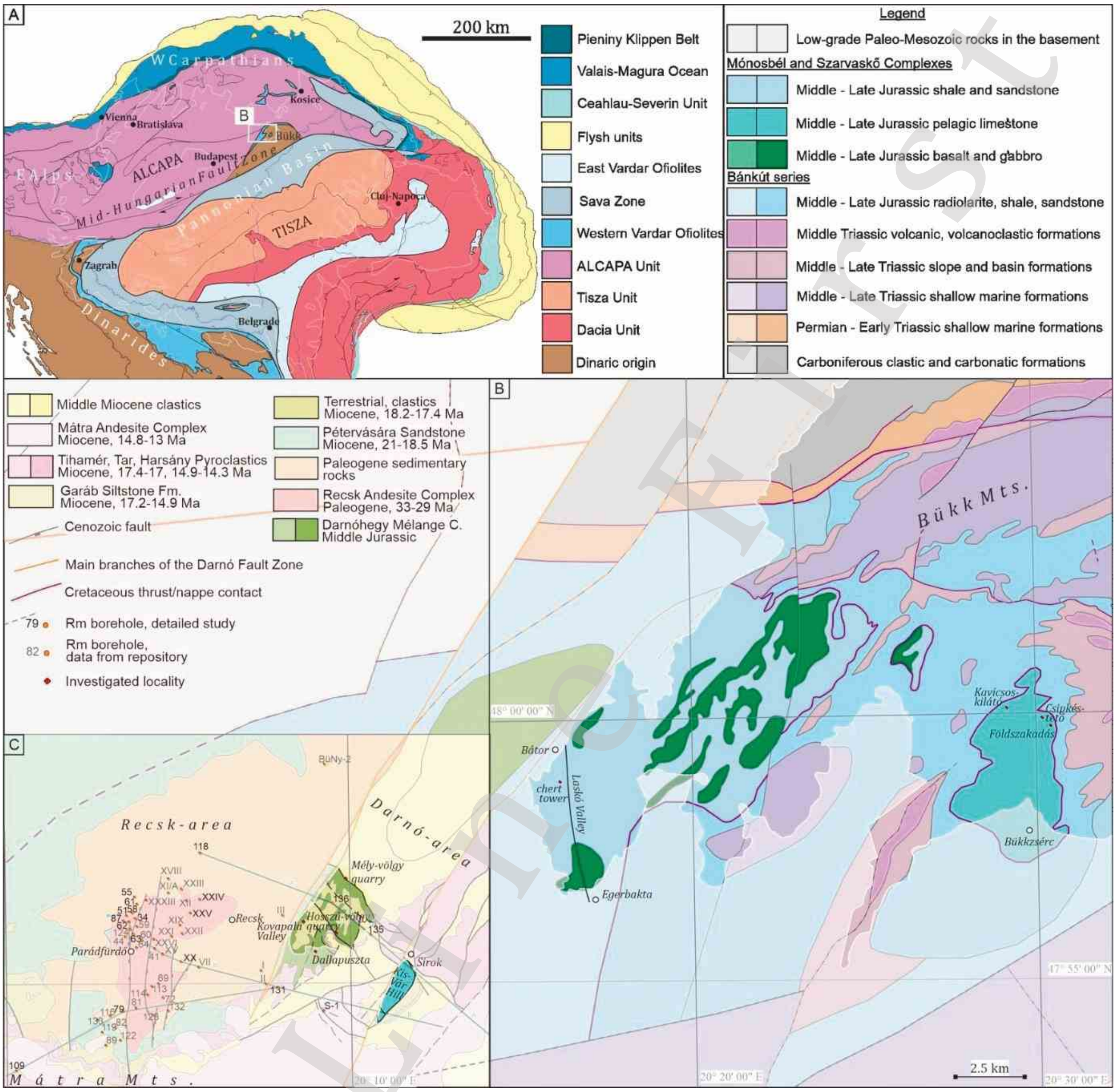


Fig. 1. Tectonic and geological maps of the investigated area. ***a)*** *Tectonic map of the Pannonian Basin and the surrounding orogenic belts (slightly modified from* Schmid *et al., 2008).* ***b-c)*** *geological map of the study area,* ***b)*** *Pre-Cenozoic basement map of the Western Bükk Mts and its surrounding foreland areas (slightly modified from* Kövér *et al., 2018a). Paler colours represent covered areas.* ***c)*** *Pre-Quaternary geological map of the Norhern Mátra foreland, the Recsk and the Darnó areas. (compiled from* Less *&* Mello*, 2004, the 1:100.000 scale geological map series of Hungary, sheet Eger (*Gyalog *&* Síkhegyi*, 2005), and from* Gál *et al., 2021). The investigated/reevaluated boreholes, surface localities and the constructed cross sections (Fig. 23) are indicated.*

1970 to 80s more than hundred 1000 to 1200 m deep wells were drilled with continuous coring for ore exploration in the eastern Mátra (Recsk Ore Field). Under Early Oligocene volcanic and sedimentary formations, these wells reached the pre-Cenozoic basement usually at 400 to 500 m and accordingly they explored Mesozoic rocks in a thickness of 500 to 800 m. After the ore exploration activity, the cores of 25 selected wells have been preserved in the repository of the Mining and Geological Survey of Hungary (Now Supervisory Authority of Regulatory Affairs).

In the advanced period of the ore exploration, the geology of the Pre-Cenozoic basement of the Recsk Ore Field was summarised by Földessy-Járányi (1975). She mentioned a Permian fossil-bearing limestone outcrop on the neighbouring Darnó Hill (Kiss 1958) and limestone-shale occurrences on Kisvárhegy and Nagyvárhegy at Sirok postulating their lithological similarity with the Triassic formations of the Bükk Mts. It must be emphasised that till the early eighties all of the slightly metamorphosed Mesozoic formations of the Bükk were assigned to the Triassic (Schréter, 1952; Balogh, 1964), and there was no evidence for the presence of Jurassic formations. As to the stratigraphic assignment of the basement rocks Földessy-Járányi referred to the report of Oravecz (1971) who observed the common presence of radiolarians, sponge spicules, ostracods, fragments echinoderms (mostly crinoids), and he also found Calcisphaerulids and Foraminifers in some samples. In accordance with the knowledge of that time, he declared that from among these microfossils only the foraminifera had age-diagnostic value and based on the fauna he assigned the basement rocks to the Ladinian to early Carnian interval.

The studies of radiolarians led to a breakthrough in the age determination in the Bükk (Kozur, 1984; Csontos et al., 1991; Dosztály, 1994) and in the Darnó-Recsk area (De Wever, 1984; Dosztály, 1989, 1994; Kozur, 1991) providing evidence for the presence of Jurassic sedimentary rocks along with the previously known Triassic formations. The radiolarian biostratigraphy from exploratory cores drilled on the Darnó Hill (Rm-131, -135, -136) revealed that both Middle to Late Triassic and Middle Jurassic deep sea and slope deposits occur (Dosztály & Józsa, 1992; Kovács et al., 2008). Later, radiolarians (Dosztály, 1994) and conodonts (Kovács et al., 2013) were encountered in some cores derived from the Recsk Ore Field. These crucial new stratigraphic results and the significant development in the evaluation of sedimentological data initiated the revisiting and reassessment of several cores of key importance. However, the new data also revealed that due to the sedimentological conditions and the syn- and post-depositional deformations, stratigraphic setting of the basement is rather complex, and deciphering the history of deposition is challenging. In the present paper, we try to get through this problem, and summarise all the previous knowledge, describe our new observations, add a new model for the depositional environment and sedimentation processes of this area. The huge amount of core material and thin sections gave an exceptional opportunity for an insight to the anatomy of Jurassic sequences formed partly on the Adriatic passive margin and partly related to the Neotethys subduction during the Middle to Late Jurassic.

Geological setting

Bükk Mts.

The study area is in the westernmost part of the Bükk Mountains and in the north-eastern foreland of the Mátra Mountains (Fig. 1b, c).

The lowest structural unit of the Bükk Mountains is made up of a Palaeozoic–Mesozoic succession affected by very low to low-grade Cretaceous metamorphism (Árkai, 1983; Árkai et al., 1995). This unit was referred to as “Bükk paraautochton” in the former literature; however, its allochthonous position is widely accepted. To get across this deceptive nomenclature, we suggest the name Bánkút Succession for that part of the Bükk Unit, which contains a Middle Carboniferous–Middle Jurassic low-grade metamorphosed dominantly sedimentary rock association (Fig. 2).

The overlying Mónosbél, Szarvaskő and Darnóhegy Complexes form separate sequences with most probably tectonic contacts (Csontos, 2000) although an autochthonous continuous sequence was also suggested (Peilkán et al., 2005). Within the Bánkút Succession deep marine Middle Carboniferous shale is the oldest explored formation that is followed by shallow marine Upper Carboniferous formations and after a gap by a continental to shallow marine Middle to Upper Permian sequence. It is overlain by a Lower Triassic calcareous–siliciclastic ramp succession and Anisian shallow marine dolomite. Upcoming and a related short-term subaerial exposure was followed by an intense andesitic volcanism dur-

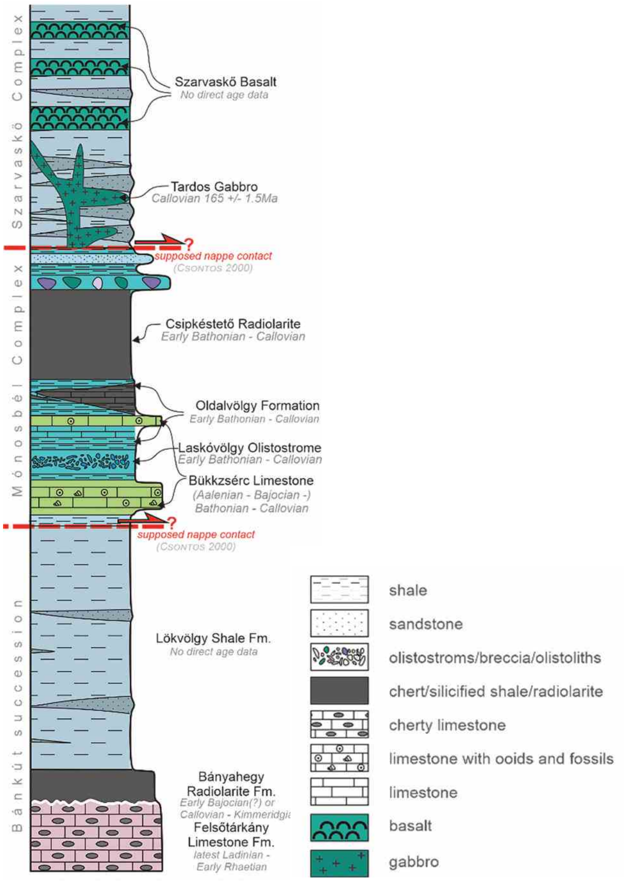


Fig. 2. *Stratigraphy of the SW Bükk Mts. from the Late Triassic to Middle Jurassic (drawn after* Csontos*, 1999,* Haas *et al., 2011,* Pelikán *et al., 2005 and own observations).*

ing the late Anisian to Ladinian. The coeval extensional tectonic deformations led to a segmented topography whereby carbonate platforms and intraplatform basins were developed. From the Ladinian to the latest Triassic platform carbonates were formed on the submarine highs and grey, cherty limestone with thin marl interlayers (Felsőtárkány Limestone Fm.) in the basins (Csontos, 1988, 2000; Velledits, 2000, 2006; Pelikán et al., 2005). In the pelagic carbonates the sponge spicule – ostracode and the radiolarian – "filament" microfacies types are the most characteristic. Based on conodonts the age-range of the Felsőtárkány Fm. extends from the early Carnian to the early Rhaetian (Velledits, 2000). A red radiolarite unit (Bányahegy Radiolarite Fm.) either of early Bajocian (Haas et al., 2013) or Callovian–Kimmeridgian (Csontos et al., 1991) age covers both the shallow and deep marine formations which are conformably overlain by a fine-grained siliciclastic turbidite succession of uncertain age assignment (Lökvölgy Fm., Fig. 2). In the area of the western and south-western Bükk Mts. (Fig. 1b), this is overthrust by the Mónosbél Complex consisting of redeposited slope and pelagic basin deposits and the Szarvaskő Complex which is made up predominantly of fine-grained siliciclastic rock with shallow mafic intrusions and lava rocks.

The Mónosbél Complex comprises the following major lithofacies/lithostratigraphic units (Fig. 2).

The Bükkzsérc Limestone is made up predominantly of grainstone beds consisting of redeposited platform-derived grains (ooids, oncoids, peloids and bioclasts). Cherty limestone interbeds of thin-shelled bivalve and/or radiolarian wackestone microfacies also occur, locally. This succession was deposited at the toe of a carbonate platform foreslope and on the floor of the related basin during the Aalenian (?) to Bathonian interval (Haas et al., 2006, 2013). Pebble to cobble-sized clasts and even large olistoliths of this lithofacies commonly occur in the Laskóvölgy Olistostrome.

The Oldalvölgy Formation is characterised by alternation of black shale, siltstone (shale-dominated lithofacies), dark grey limestone and cherty limestone usually of mudstone texture (limestone-dominated lithofacies), although thin ooidic limestone layers and polymictic olistostrome intercalations rarely occur (Pelikán et al., 2005; Pelikán, 2012). Lenses and interbeds of dark grey laminated radiolarite and radiolarian chert commonly occur within the shale or limestone successions; Pelikán et al. (2005) defined them as the Csipkéstető Radiolarite. The estimated thickness of the partly silicified shale and limestone sequence is several hundred metres. It was formed in a pelagic basin which was occasionally reached by gravity flows that originated partly in a carbonate platform area (ooidic redeposited layers). Based on radiolarians and foraminifera this unit can be assigned to the Bathonian to early Callovian (Haas et al., 2013).

The Laskóvölgy Olistostrome (Mónosbél Formation in the earlier literature) is made up predominantly of matrix-supported, poorly sorted, angular to subrounded, polymictic breccia (olistostrome) bodies which are surrounded by dark grey to black shale or clayey siltstone (Pelikán, 2012). The limestone clasts are predominant; most of them are individual ooides or ooidic–bioclastic limestone. Along with the carbonate clasts, fragments of acidic and basic vulcanites, sandstone, phyllite, mica schist, and quartzite also occur locally (Csontos, 2000; Pelikán et al., 2005; Pelikán, 2012; Haas et al., 2013). These debris flow deposits were deposited on or at the toe of a slope. Most of the clasts derived from proximal carbonate rocks (Bükkzsérc Limestone) but some of them from various rock types indicating significantly different provenance. Since based on foraminifera, some of the limestone clasts could be assigned to the Bathonian (Haas et al., 2013), the age of the Laskóvölgy Olistostrome is Middle Jurassic (probably Bathonian–Callovian?).

The Szarvaskő Complex is built up mostly by the alternation of shale and fine to medium-grained sandstone (Fig. 2). It contains subvolcanic gabbro, microgabbro and small wherlite and felsic intrusions, (Balla, 1983; Árváné Soós et al., 1985; Harangi et al., 1996; Józsa, 1999). It also contains well-developed pillow basalt sheets in a thickness of a few hundred metres (Aigner-Torres & Koller, 1999; Csontos, 2000; Kiss et al., 2011,). The continuous outcrops of this unit are known in the western Bükk (Fig. 1b) (Szarvaskő synform; Balla, 1983); while in the south-eastern Bükk it appears above the Mónosbél Complex in the form of several small nappe outliers (Csontos, 1988, 1999). The age of this complex is poorly constrained. Poorly preserved radiolarians from the sedimentary part suggest late Bathonian–early Callovian age (Csontos et al., 1991), which is in agreement with the K/Ar ages obtained from the gabbro intrusions (165±5 Ma, Árváné Soós et al., 1985).

Darnó area

The Darnó Hill and its surroundings, east of the Darnó Fault is an area of critical importance for the analysis of the relationship of several units (Fig. 1c). The Darnó Hill forms the westernmost surface outcrops of the Dinaric-related units. Further westward, the next surface outcrop is 60km further and belongs to the uppermost part of the Austroalpine nappe-stack (Transdanubian Range) (Fig. 1a). The surface exposures and the upper parts of exploratory boreholes are composed mostly of redeposited clasts and large blocks of basalts with minor amount of gabbros (Harangi et al. 1996; Józsa et al., 1996) surrounded by shale and radiolarite matrix (Józsa, 1999; Dosztály et al., 1998) that can be assigned to the Darnóhegy Mélange (Kovács et al., 2008; 2011a). The age of the basalt blocks is latest Anisian–Ladinian on the bases of conodonts and radiolarians dissolved from those sedimentary rocks, which were closely associated with one group of the basalt blocks (Kozur & Krahl, 1984; De Wever, 1984; Haas et al., 2011). On the other hand, the radiolarian assemblage associated with either the matrix of the mélange or with basalt blocks of different geochemical characteristics (Kiss et al., 2012) showed Bajocian–Callovian (Kozur, 1991) or Callovian age (Gawlick pers. comm). These age intervals can be interpreted as minimum ages for the mélange formation. Previous research considered this mélange as a true ophiolite-derived mélange (Schmid et al., 2008) and correlated it with the Dinaridic counterparts (Haas & Kovács, 2001; Dimitrijević et al., 2003; Kovács et al., 2011b).

Below this unit, the exploratory wells exposed dominantly sedimentary rocks which were assigned to the Mónosbél Complex (Haas et al., 2006; 2011; Kovács et al., 2008). However, only a few boreholes were subject of detailed investigations earlier; the current contribution extends largely this database.

Recsk area and Northern foreland of the Mátra Mts.

The Mesozoic basement of the area west of the Darnó Fault in the northern foreland of the Miocene volcanites of the Mátra Mountains near Recsk is in the focus of the current paper (Fig. 1c). There are no surface exposures of the pre-Cenozoic rocks in this region, but numerous continuously cored ore exploratory wells reached the Mesozoic rocks below Oligocene volcanic and sedimentary formations providing data on the geological characteristics of the basement. Only a few point-like information has been published so far, (Dosztály & Józsa, 1992; Kovács et al., 2008, 2013; Haas et al., 2012) describing the main lithological characteristics and age of the penetrated basement rocks.

Materials and Methods

Location of the studied wells and sections are displayed in Fig 1c. For the characterisation of the exposed succession, along with the newly collected samples the thin sections of previous studies were utilised. Determination of petrographic properties and microfacies characteristics of the sedimentary rocks were in the focus of our microscopic investigations, however the diagenetic features and signs of deformations were also observed. Radiolarian and nannofossil samples were collected from cores and occasionally from surface outcrops to define the sedimentary ages of different lithofacies units. Revision of the previous collections was also made.

Materials

In the cases of some wells only those thin sections were available which were made in the 1970 to 80s during the ore exploration project. These are the following: Rm-20 (37 thin sections), -24 (60) -25 (48), -34 (61), -51 (4) -55 (3) -58 (20), -61(108), -62 (133), -87 (166). In other cases, in addition to the thin sections made for the ore exploration project, the cores (or parts of the cores) were preserved allowing collection of new samples. In the middle of 1990s detailed documentation and sampling of three key-wells drilled near the Darnó Hill was performed by Kovács; 93 thin sections were made from Rm-131, 35 from Rm-135 and 51 from Rm-136. In the early 2000s detailed documentation and sampling were performed by Haas and his co-workers. They revisited the lower part of core Rm-109 when 90 new thin sections were made, the upper part of core Rm-118 complementing the previously made previously made 64 thin sections with 47 new ones, and the upper part of core Rm-63 adding 22 new thin sections to the preserved 225 ones.

Microfacies

The sections were investigated in normal transmitted light on an Olympus-BX51 microscope. The classification of Folk (1959) and Dunham (1962) was applied for description of the texture of the carbonates.

Radiolarians

Samples were collected from Rm-109 borehole (1001.65–1001.75 m) and Mély-völgy by the late Sándor Kovács; these samples contain relatively rich, moderate preserved and diverse radiolarian fauna. Approximately 350–500 g of dice-sized crushed chert from each sample was processed with the dissolution method. Samples were dried and placed in approx. 3–5 % HF (nine parts distilled water and one-part concentrated HF (herewith 48%) following standard laboratory procedures of Pessagno & Newport (1972). The residues were washed through a 63 μm sieve and dried. The laboratory preparation of the samples was carried out at Hungarian Natural History Museum, Budapest. Moderate to poorly preserved but previously unpublished radiolarian fauna of the BüNy-2, Rm-118, Rm-131 and Rm-136 boreholes were collected by the late Lajos Dosztály, and was described by PO. Samples from Csipkés-tető, Bátor and Földszakadás were collected by NDj, SK, LF. These samples were processed in Belgrade by NDj. The most figured radiolarians presented herein were taken on Hitachi S-2600 N-type Scanning Electron Microscope at the Hungarian Natural History Museum, Budapest and a JEOL JSM-T330A SEM at the Research Centre of the Slovenian Academy of Sciences and Art. Smaller part of the illustrated material was obtained from the Dosztály's legacy. The radiolarian specimens are deposited in the Hungarian Natural History Museum in Budapest, Hungary. The Jurassic radiolarian dating is based on the Unitary Association Zones (UAZ) of Baumgartner et al. (1995). Names of genera are updated according to O'Dogherty et al. (2009, 2017).

Nannofossils

Determination of nannofossils requires special technique, which has not applied on the sediments of the Bükk Mountains until this research. Consequently, no nannofossil biostratigraphical data was available. As a try, a total of 6 samples (2 from Rm-136, 2 from Rm-135 and 2 from Rm-131 drilling cores) were investigated – with a Nikon Eclipse 50i POL polarising microscope at 1250x magnification, using oil immersion objective 100x and a 1.25 numerical aperture; only one sample was barren. XPL, PPL and/or gypsum plate (GP) images were captured with a ToupCam digital camera and associated software. All nannofossil smear slides were prepared, investigated and repositored at the Department of Collections, Geological Survey, Supervisory Authority for Regulatory Affairs. The nannofossil biostratigraphy used in this paper is based on the Nannotax website (Young et al., 2017); the preservation categories of Bown (1992) were adopted.

For stratigraphical data the relevant chapters of Geological Time Scale (Gradstein et al., 2020) were used.

Method applied during the construction of cross-sections

During the section construction we dealt with variable levels of information from different boreholes. In case of the key wells (black numbers within rectangles) a great number of thin sections, detailed description of the cores and occasionally the original cores were available. Those marked with black numbers contained only descriptions and a great number of thin sections. When only information from field core descriptions/data repository was available (grey numbers), the classification into lithological units was problematic. We consequently classified the shale lithologies into the Oldalvölgy Shale, while the age of the limestone is uncertain, that is why the possibility of either Triassic or Jurassic classification was allowed.

The general structural style – asymmetric south-to south-east-verging folding – was projected from the Bükk Mts. (Csontos 1988, 1999) and from the outcrops of the Kis-Vár-hegy. The faults were classified into four age groups: Middle Jurassic syn-sedimentary structures, Cretaceous structures connected to the general shortening, Paleogene to Early Miocene structures, which are syn- or early post-tectonic faults with respect to the Recsk Andesite Complex, and Miocene faults.

Results

Our research area is subdivided into 3 sub-areas by two main branches of the Darnó Fault Zone (Fig. 1b, c). The easternmost sub-area is the s.l. Bükk Mts., which has outcrops of the Bánkút Succession, the Mónosbél and the Szarvaskő Complexes. The middle area is within the Darnó Fault Zone and has natural outcrops of the Darnóhegy Mélange. Two different Mesozoic sequences were intersected under it by boreholes Rm-131, -135, 136. The westernmost sub-area is the Recsk, where the basement is covered by several hundred metres of infill of the Pannonian Basin and the Paleogene Recsk Andesite Complex (Arató et al., 2019). Here only core information is available. The presentation of our results starts with a key section from the south-western part of the Bükk Mts., followed up by the Recsk sub-area and finally the Darnó sub-area.

Southwestern margin of the Bükk Mountains

General sedimentological–stratigraphical characteristics

The south-westernmost surface exposures of Mesozoic formations in the Bükk Mts. are located in the Laskó Valley area and on the Vár Hill of Sirok village (Fig. 1b). The Laskó area exposes a duplex-system of few hundred metres thick horses, which are built up by the formations of the Mónosbél Complex (Fig. 3a). The individual thrusts could merge into a roof thrust above which the formerly overlying Szarvaskő Complex could be present before erosion.

The Szarvaskő Complex crops out in small tectonic windows below the basal shear-zone of the SW-verging duplexes (Fig. 3a, Fialowski, 2018). This juxtaposition is of out-of-sequence origin, while the structural order of these two complexes is different in the rest of the Bükk area (Balla, 1987; Csontos, 1999). The lithological content of the horses derived from the Mónosbél Complex show similarities, however, major changes in thickness were observed (Fig. 4).

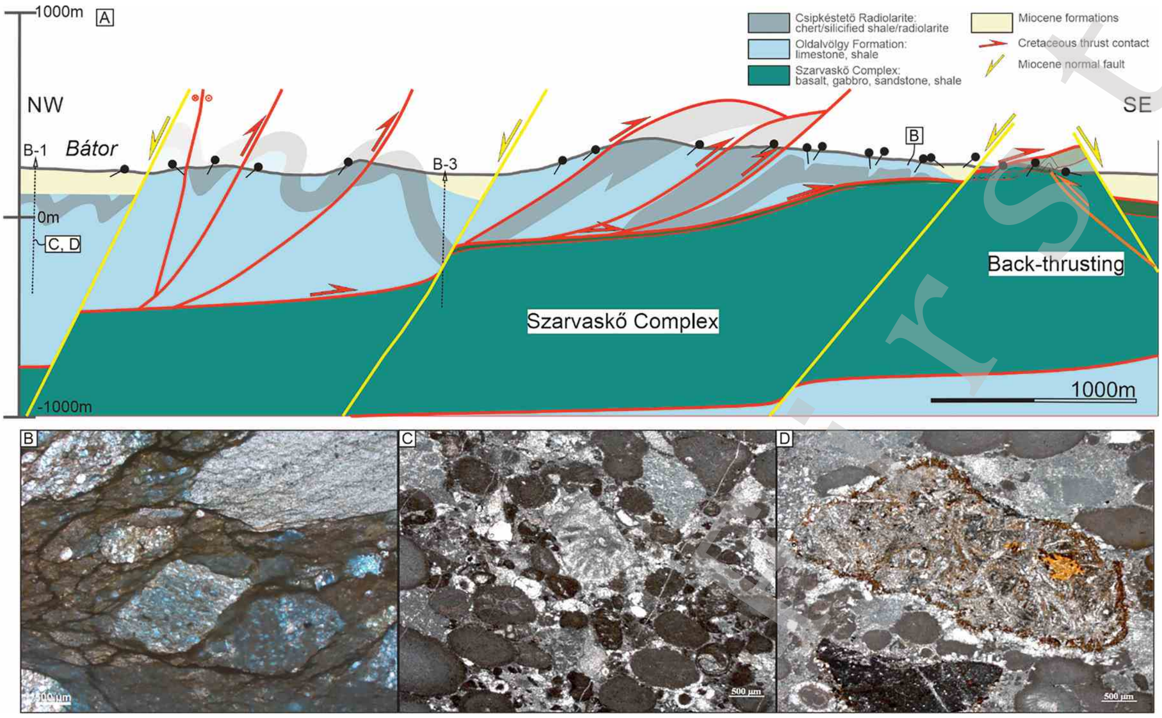


Fig. 3. a) *Simplified cross-section along the Laskó Valley (location is indicated on Fig. 1b).* ***b)*** *Radiolarite breccia whit sigmoidal shaped shear along the clast boundaries.* ***c-d)*** *Partially silicified limestone lithoclast of grainstone fabric with micritized ooid, oncoid, peloid, bioclast and small lithoclast grains*

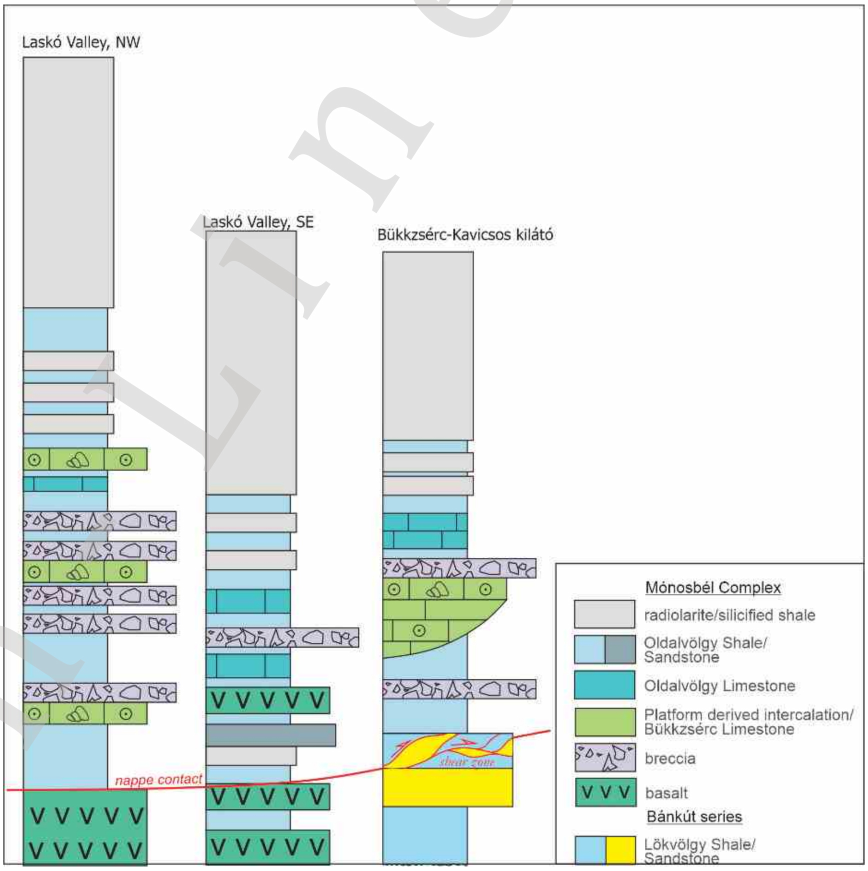


Fig. 4. *Jurassic successions in the south-wastern part of the Bükk Mts. Localities are shown on Fig. 1b.*

In general, the lowermost part of the duplex slices starts with dark grey, partially silicified shale with anastomosing foliation and rare, thin beds of pelagic limestone intercalations (shale lithofacies of the Oldalvölgy Fm.). It contains two types of redeposited sediments: a) carbonate turbidites with platform derived clasts b) breccia/micro-breccia/olistostrome layers. The former one contains single ooid grains, crinoid particles, fragments of calcimicrobes (Fig. 3c, d). The latter one is present in the form of dm to m thick intercalations. They represent typical debris flow deposit (debrite) containing unsorted mm to dm sized litoclasts in a light brownish grey silicified, cherty matrix. The breccia/olistostrome is mainly clast-supported, the clasts are unrounded to sub-rounded. Various lithoclast-types were observed: oolitic wackestone and packstone (the central part of the ooids is commonly dissolved); peloidal, microsparitic wackestone; bioclastic wackestone, sponge spicule wackestone; peloidal grainstone; and radiolarite (Fig. 3b).

A few weathered basalt clasts with limonitic crust were also encountered. Bioclasts, mostly crinoid fragments, foraminifera, and fragments of calcimicrobes, and microbial crusts also occur in the matrix. Some individual carbonate grains (ooids, oncoids and a few grapestones) were also observed. These coarse-grained intercalations get less abundant upwards, while the whole succession becomes more and more silicified. The silicification occurs in large lenses. The silicified part is red or greenish grey chert, however, the original red and grey marl, shale host rock is detectable in some locations. The whole succession can be a few hundred metres thick. However, the total thickness and the number of redeposited layers, the degree of silicification changes from horse to horse. From the upper part of the succession (red radiolarite) very poorly preserved radiolarians, indicating late Bajocian to early Oxfordian age range were found (Haas et al., 2011).

The other Mesozoic locality, the small quarry on the Kis-Vár Hill south-west of village Sirok (Fig. 1c, 11a), exposes a strongly deformed succession made up of alternation of grey micritic, locally cherty limestone, dark grey shale with olistoliths, grey siliceous shale and radiolarite, and light grey oolitic limestone (Kovács et al., 2008). Dosztály's radiolarian studies suggest late Bajocian to early Oxfordian age-assignment (Csontos et al., 1991). According to Bérczi-Makk (1999), the foraminifera fauna indicates Middle Jurassic age.

Radiolarian biostratigraphy

Additional samples were taken from surface outcrops of the Mónosbél Complex to support age data for specific stratigraphic levels. According to our interpretation (Fig. 2, 4) intensive silicification is more pronounced at the upper part of the succession. Sample Csipkés-tető (031015/7-1a) is derived from black radiolarites of an intensively silicified section and yielded poorly preserved and not so diverse radiolarian association (Fig. 5). The assemblage in sample 031015/7-1a is characterized by the presence of *Xitomitra annibill* (Kocher), *Monotrabs goricanae* Beccaro, *Thanarla patricki* gr. (Kocher), *Eoxitus dhimenaensis* (Baumgartner), *Mizukidella hungarica* (Grill & Kozur), *Transhsuum maxwelli* gr. (Pessagno), *Transhsuum* sp. E sensu (Yao), *Archaeospongoprunum elegans* Wu and *Parahsuum* sp. The genus *Xitomitra* ranging from the Middle Bathonian to Early Callovian (O'Dogherty et al., 2017) defines the age of this sample.

Sample Földszakadás (031015/8-2) is about 0.9m thick succession of reddish stratified radiolarites with thin interlayers of siliceous shale. Radiolarians are poorly preserved and their diversity is very low (Fig. 5). A maximum age range between early Bajocian and early Kimmeridgian age (UAZs 3 to 10) can be inferred from *Transhsuum maxwelli* gr. (Pessagno). The genus *Thanarla*, first appearing in the early Bathonian (O'Dogherty et al., 2017), was also found. The species determined as *Parahsuum* sp. and *Williriedellum* sp., are also present in the radiolarian association. Considering these data, the inferred age of this sample is bracketed between Bathonian and early Kimmeridgian.

Samples Bátor, chert tower (021015/5-2 and 021015/5-3) are characterised by a poor and badly preserved radiolarian association and presence of the *Transhsuum* sp. cf. *T. maxwelli* gr. (Pessagno), *Eoxitus* sp. and *Eucyrtidiellum* sp (Additional file 3). A maximum age range between early Bajocian and early Kimmeridgian age (UAZs 3 to 10) can be inferred from *Transhsuum* sp. cf. *T. maxwelli* gr. (Pessagno).

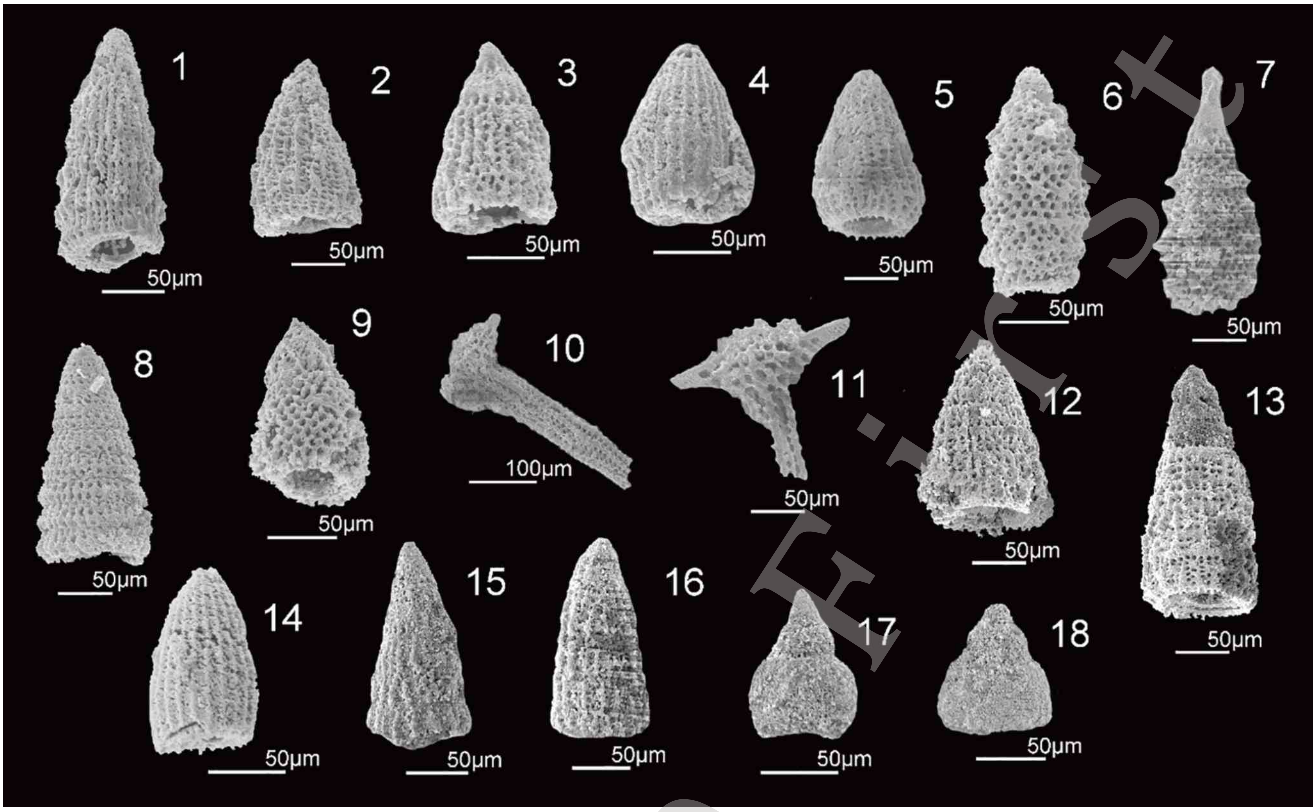


Fig. 5**. Jurassic radiolarians from the Csipkés-tető (1-11; Sample 031015/7-1a), Földszakadás (12-14; Sample 031015/8-2) and Chert tower, Bátor (15, 17; Sample 021015/5-2 and 16, 18; Sample 021015/5-3).* ***1. *Transhsuum maxwelli* gr. (Pessagno)*;* ***2.*** *Transhsuum* sp. *E sensu* (Yao)*;* ***3.*** *Parahsuum* sp.*;* ***4, 5****. Thanarla patricki* gr. (Kocher)*;* ***6.*** *Eoxitus dhimenaensis* (Baumgartner); ***7.*** *Eoxitus* sp.*;* ***8.*** *Mizukidella hungarica* (Grill & Kozur); ***9.*** *Xitomitra annibill* (Kocher); ***10. 11.*** *Monotrabs goricanae* Beccaro*;* ***12.*** *Parahsuum* sp.*;* ***13.*** *Transhsuum maxwelli gr.* (Pessagno)*;* ***14.*** *Thanarla patricki* gr. (Kocher); ***15, 16.*** *Transhsuum* sp. cf. *T. maxwelli* gr. (Pessagno); ***17, 18.*** *Eucyrtidiellum* sp.

The latter two age data, however, should be taken with extreme caution because such a wide age interval is a result of low diversity and poor level of preservation of the analysed radiolarian association.

Recsk area

In the Mesozoic basement of the Recsk area the wells explored predominantly Jurassic pelagic successions, which can be assigned to the Oldalvölgy Formation. This lithostratigraphic unit was defined in the Bükk Mts, where the characteristic shale and cherty limestone lithofacies of this formation alternate. In contrast, in the Recsk area these two lithofacies usually occur as separated units justifying the subdivision the formation into two members: Oldalvölgy Shale and Oldalvölgy Limestone Members. In the following chapters, we will apply this subdivision.

Detailed descriptions of the key boreholes are presented from SW to NE (location of the boreholes are shown on Fig. 1c). At first, core Rm-109 is presented, then Rm-79, followed by the most complete cores in the central area (Rm-63, -62, -34, -87, -61, -58), finally the northernmost Rm-118. After these boreholes cores Rm-XX, XXV and XXIV from the eastern part of this sub-area are described.

Recsk – SW

Rm-109

Well Rm-109 was drilled in the eastern Mátra Mts., north to Mount Kékes, about 5 km SW from Parádfürdő (Fig.1c). After the intersection of Oligocene–Lower Miocene deep marine fine-grained clastic sediments, the well explored Jurassic sedimentary rocks in a thickness of more than 300 m (893.6–1200.0 m). The Jurassic series is made up of two significantly different lithofacies units (Fig. 6).

The upper lithofacies unit (893.6–1076.5 m) is made up of dark grey, locally red siliceous shale and radiolarite (Oldalvölgy Shale?), while light grey

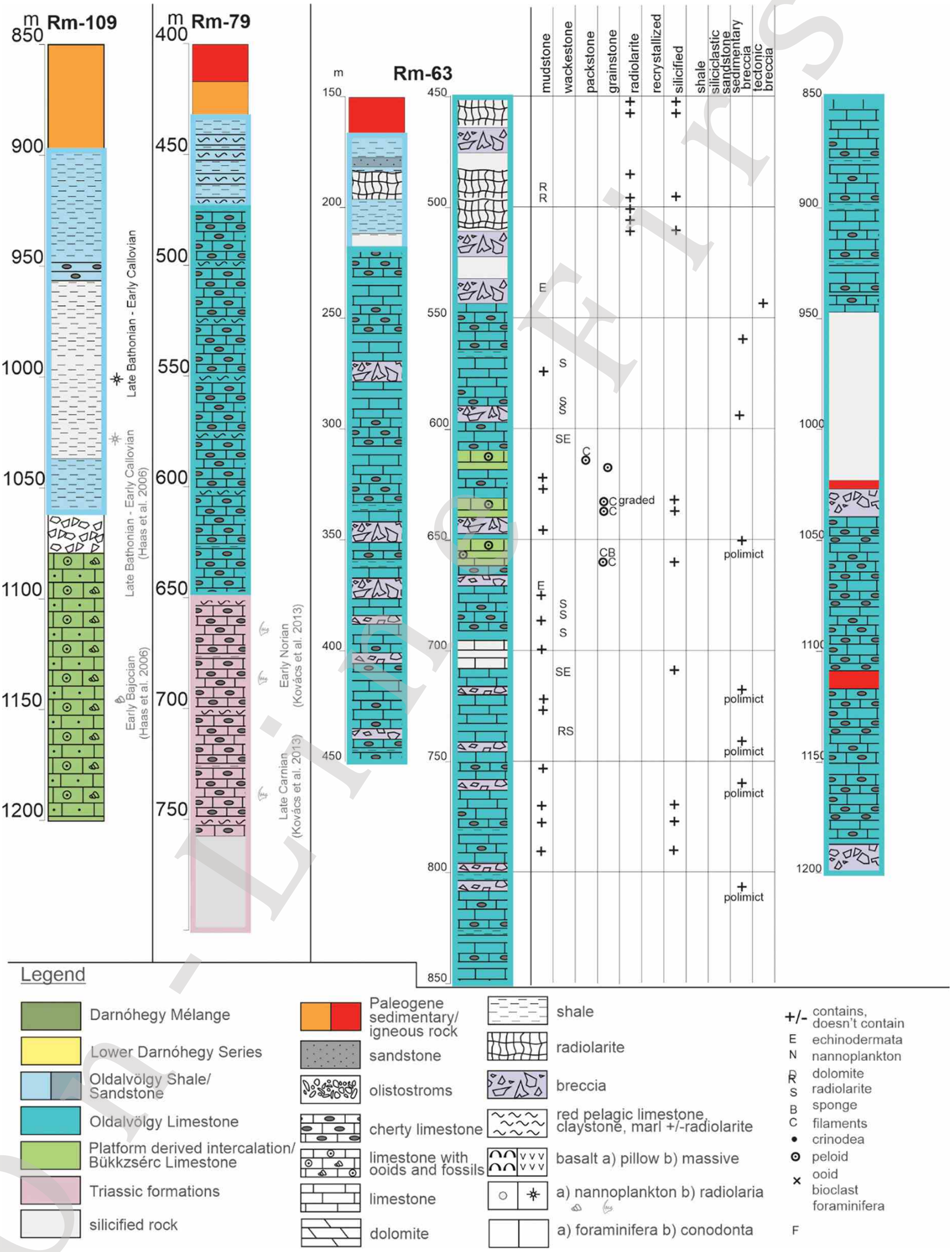


Fig. 6. Mesozoic part of cores Rm-109, -79 and -63: lithologies, microfacies and lithofacies types, fossil content.

chert was intersected between 949.1–955.4 m. From the radiolarite, late Bathonian–early Callovian radiolarians were determined by Ozsvárt (in Haas et al., 2006). A single sample from 1001.65–1001.75 m provided a moderately poor preserved radiolarian assemblage, mainly characterised by nassellarians. The following taxa were identified from this sample: *Cinguloturris carpatica* Dumitrica, *Quarticella magnipora* (Chiari, Marcucci & Prela), *Semihsuum amabile* (Aita), *Praewilliriedellum robustum* (Matsuoka), *Mizukidella kamoensis* (Mizutani & Kido) (Table 1, Fig. 7).

Co-occurrence of these species indicates that this sample can be assigned to UAZ 7 that assumes Callovian age (Table 1), which is in good agreement with the previous age determination of Haas et al. (2006).

The lower unit (1076.5–1200.0 m) consists of grey, brownish grey limestone (Haas et al., 2006). Various microfacies types (oolitic, oncoidal grainstone, peloidal grainstone, intraclastic grainstone, peloidal wackestone) could be distinguished within the macroscopically uniform sequence. Part of carbonate succession was subject to recrystallization and partial dolomitization because of hydrothermal fluids. In some intervals, the intense dolomitization destructed the original sedimentary texture.

The most interesting feature is the variety of grainstones (Figure 8). Fine to medium-sized (0.1–1.0 mm) calcarenite can be classified based on the most characteristic grain types (coated grains, peloids or intraclasts).

Fragments of calcimicrobes and microbial crusts are ubiquitous. In some cases, these cyanobacterial remnants may occur in rock-forming quantities and their size may reach 5 or even 7 mm. Echinoderm, mostly crinoid fragments, and benthic foraminifera are also usually present in every microfacies type. Fragments of corals and calcareous sponges also occur locally, in a small quantity. The wackestone or wackestone–packstone microfacies usually appear in decimetre to metre thick interlayers in the oolitic grainstone or peloidal grainstone facies, however in a single case it was also found in a 6 m thick interval (1105–1111 m).

Based on the foraminifera assemblages, the age of the carbonate succession is early Bajocian (Haas et al., 2006).

Rm-79

Well Rm-79 was drilled south to Parádfürdő relatively far from the central part of the Recsk Ore Field (Fig. 1c). It reached the Mesozoic basement at 435 m (Fig. 6). Shale and marl (Oldalvölgy Shale?) were encountered in the uppermost part of the section (440–475 m). Cherty limestone and locally argillaceous limestone were explored below it (475–765 m). Although the complete core of this well has not been preserved, some samples were still available and made possible the conodont investigations. Interestingly, no conodonts were found in the upper part (475–650 m) of the cherty limestone (9 negative conodont samples) whereas in the lower part (650–765 m) 3 positive samples were encountered which yielded late Carnian – early Norian conodont assemblages (Gecse, 2006; Kovács et al., 2008; Kovács et al., 2013). Below 765 m the original sedimentary fabric was destroyed; the limestones were completely recrystallized and silicified. The recrystallization was explained by the heating effect of the Recsk Andesite Complex, which turned this part of the basement into an exoskarn (Kovács et al., 2013). The only information about the host rock is that at the upper part, close to 765 m marble was drilled, while between 928 and 1013 m quartzite is present.

Recsk, central part W

Rm-63

Well Rm-63 was drilled north to Parádfürdő (Fig. 1c), in 1971. After intersection of the Paleogene andesitic complex the well reached the Mesozoic basement rocks at 172.2 m (Fig. 6). The basic lithological features and the petrographic and microfacies characteristics of the explored Mesozoic section are displayed in Figure 9.

The uppermost part of the Mesozoic succession (172–217 m) consists of dark grey shale with thin radiolarite (Fig. 9i, j) sandstone and limestone interbeds (Oldalvölgy Shale). In the next interval (217–450 m) the dominant lithology is grey cherty limestone, with shale, claystone or marlstone intercalations (cherty limestone lithofacies of the

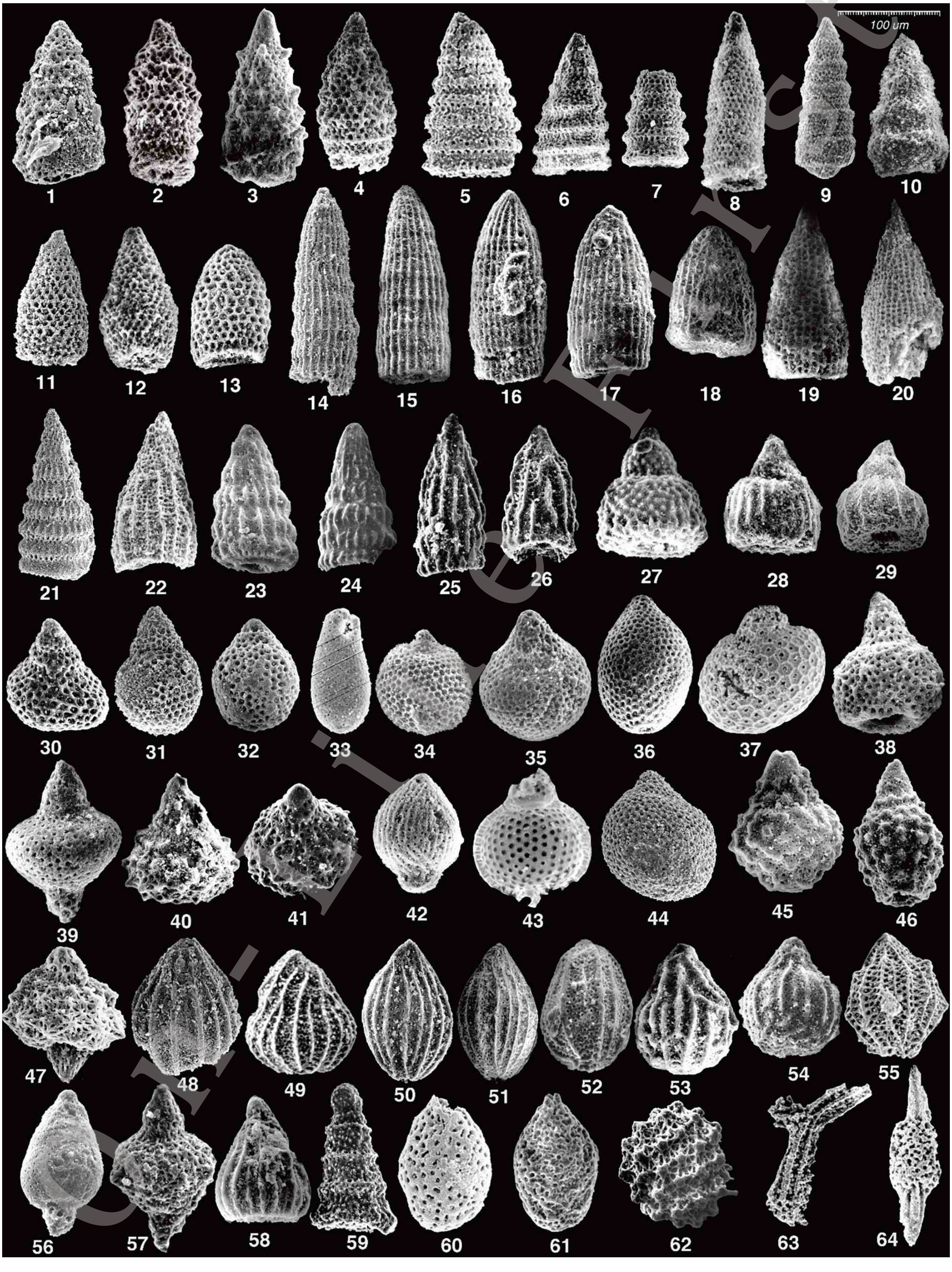
Table 1. *Age assignment of the Jurassic radiolarians.*

Locality	BüNy-2		Rm-109	Rm-118					Rm-131					Rm-136			Mély Valley		
Sample (in m at boreholes)	7590-7725	8145-816	1001.65-1001.75	879.2	845.5	838.7	830.7	827.9	526-525.4	517	511.7	504	322-316.5	59.7	58	55.8	2/07	3/07	UAZ
Alievium? longispineum	+																		
Arcanicapsa funatoensis	+	+			+		+					+							3–11
Archaeodictyomitra cellulata															+				
Archaeodictyomitra exigua	+												+				+		
Archaeodictyomitra primigena															+				
Archaeodictyomitra prisca	+		+																
Archaeodictyomitra rigida			+																
Archaeodictyomitra whalenae	+																		
Archaeodictyomitra sp. A					+											+			
Archaeodictyomitra sp.			+												+				
Archaeospongoprunum elegans	+																		
Archicapsa (?) pachyderma																+			3-4
Campanomitra buekkensis							+												
Campanomitra tuscanica	+																		
?*Campanomitra* sp.			+																
Cinguloturris carpatica	+		+			+													7–11
Cinguloturris latiannulata	+				+	+													
Crococapsa sp. A			+																
Crococapsa sp.												+							
Doliocapsa planata																+			4-7
Emiluvia? sp.			+																
Eoxitus baloghi							+												
Eoxitus dhimenaensis							+					+		+			+		
Eoxitus hungaricus			+									+				+			
Eoxitus mashitaensis												+							8-15
Eoxitus sp.						+													
Eucyrtidiellum nodosum		+																	3-10
Eucyrtidiellum ptyctum	+	+				+										+			5–11
Eucyrtidiellum pyramis																+			12-13
Eucyrtidiellum quinatum								+											
Eucyrtidiellum cf. *unumaense*					+					+		+				+		+	
Eucyrtidiellum sp.									+										
Guexella sakawaensis		+																	
Gongylothorax cf. *favosus*																+			7-8
Hemicryptocapsa buekkensis																			
Hemicryptocapsa yaoi																			
Hsuum matsuokai				+				+											1-5
Hsuum sp.															+				
Laxtorum cf. *hichisoense*				+															1-4
Mizukidella cf. *hungarica* (Grill and Kozur)				+															
Mizukidella kamoensis	+					+										+			3-7
Parahsuum carpathicum	+			+															
Parahsuum sp.				+															
Parvicingula sp. 1				+															
Parvicingula sp. 2						+													
Praeconocaryomma whiteavesi																+			
Praeconocaryomma sp.				+															
Praewilliriedellum convexum			+	+	+	+	+	+											
Praewilliriedellum robustum	+	+			+	+	+	+									+		5–7
Praewilliriedellum sp.									+										
Protunuma turbo			+														+	+	4–7
Protunuma ? lanosus														+					
Protunuma cf. *fusiformis*						+													
Protunuma cf. *ochiensis*																			
Protunuma fusiformis										+	+	+							
Protunuma japonicus	+				+											+			7-12
Protunuma sp.						+													
Protunuma sp.								+											
Protunuma sp.									+										

Table 1. *Continued*

Quarticella magnipora			+																4-7
Saitoum levium																+			4-9
Saitoum pagei																+			4-11
Semihsuum amabile	+					+	+												4-7
"Sethocapsa"? sp.																+			
Stichomitra takanoensis												+				+			3-7
Striatojaponocapsa conexa	+	+																	
Striatojaponocapsa plicarum							+	+											4-5
Striatojaponocapsa sp.	+																		
Thanarla sp.																+			
Transhsuum brevicostatum	+	+	+			+				+	+	+				+			3-11
Transhsuum maxwelli	+	+	+	+		+		+				+			+	+		+	3-10
Transhsuum sp.				+															
Triactoma? sp.				+															
Tricolocapsa ? fusiformis																+			3-5
Tricolocapsa sp.								+											
Tritrabs sp.	+															+			
Unuma gordus					+														4-6
Unuma typicus					+			+								+			3-4
Unuma cf. *echinatus*																+			1-6
Unuma cf. *latusicostatus*					+	+													2-5
Unuma sp. 1																+			
Unuma sp. 2																+			
Williriedellum nodosum								+				+							
Williriedellum sujkowskii																+			
Williriedellum yaoi	+																		
Williriedellum sp.							+												
Yamatoum sp.												+							
Yaocapsa mastoidea																+			3-4
Yaocapsa sp. E					+														5
Zhamoidellum funatoense												+							
Zhamoidellum cf. *ovum*																+			?7-11
Zhamoidellum sp. A			+																
Zhamoidellum sp. B	+						+												
Zhamoidellum? sp.									+										
AGE	Callovian		Callovian	Late Bajocian	*late Bajocian–early Bathonian*				*?Callovian*			*Callovian–early Oxfordian*		*Callovian*			*Late Bajocian–Callovian*		

Oldalvölgy Lst). Polymictic breccia interbeds were encountered in several horizons (Fig. 6). The thickness of these breccia layers varies between 0.1 and 5 metres. The clasts are usually angular. A strongly silicified interval was intersected between 450 to 545 m where due to the pervasive silicification the original microfacies characteristics could not be recognised in many samples, but in other ones, radiolarian packstone (radiolarite) microfacies were found. In three horizons sedimentary breccia and in two horizons mm-sized ghosts of globular grains were observed in the silicified rocks. In between two fault zones (545 m and 551 m) strongly altered argillaceous limestone was found. Below it, in the 551–1200 m interval, light grey argillaceous and/or cherty limestone (Oldalvölgy Limestone) was intersected, although the 920–1035 interval was affected by strong alteration which totally destructed the depositional structure and texture of the rocks. The limestone samples can be characterised predominantly by mudstone or less commonly by wackestone textures. The mudstones are usually free of any grains but in some of them along with unidentifiable silt-sized bioclasts ("biosilt"), fine grained (200–400 μm) echinoderm fragments (plankton crinoids?), sponge spicules, radiolarians, fragments of thin-shelled bivalves ("filaments"), and ostracods rarely occur (Fig. 9a-d). In the wackestones peloidal, peloidal-bioclastic and bioclastic texture types were recognised. Along with unidentifiable silt-sized bioclasts the thin-shelled bivalves, small echinoderm fragments, sponge spicules and radiolarians are the most common biotic components. In three horizons ooidic, crinoidal packstone (Fig. 9e, f) and grainstone (Fig. 9g, h) texture were identified. This lower part of the section also contains several sedimen-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tary breccia layers with unrounded to sub-rounded mm-scale carbonate lithoclasts (Fig. 9k, l).

Clast components of the breccia layers

Microbreccia horizons were identified in several horizons between 270 m and 810 m. These horizons are mainly clast-supported polymict microbreccias with 1 to 30 mm, unrounded to sub-rounded sharp clasts and calcite or silica cement. In the lower horizons the main clast components are limestones of mudstone or filamental wackestone texture, dolomite, chert, shale, silicified shale, siltstone, fine-grained quartz sandstone, radiolarite, silicified, calcified igneous rock, anhydrite?. Above 664m along with the previous clast-types peloidal and ooidal grainstone and wackestone clasts are also present.

According to the identified lithofacies types, the upper part of the Mesozoic succession can be assigned to the Oldalvölgy Shale, while the lower one to the Oldalvölgy Limestone of the Mónosbél Complex.

Rm-62

The well presented in Fig. 10 explored lithofacies types similar to those of the previously described Rm-63 key-section.

The uppermost part of the Mesozoic succession (454–485 m) consists of dark grey shale and fine-grained sandstone (Oldalvölgy Shale). The next interval (485–545 m) is almost completely silicified, however, in some thin sections the original carbonate texture was recognised. Most of the limestones are mudstones with sporadic Echinodermata or sponge spicule remains or dissolved and fragmented nannofossil remnants. In one case crinoidal wackstone texture was described. This silicified limestone section may represent part of the Oldalvölgy Limestone succession. It is followed downward by dark grey limestone, commonly with chert lenses and nodules and thin claystone or marlstone interlayers (Oldalvölgy Limestone). Polymictic breccia interlayers were encountered

Fig. 7. *Radiolarians of the RS and the Darnóhegy Mélange from cores Rm-109, Rm-118, Rm-135, Rm-136, Rm-131, BüNy-2* ***1.*** *Eoxitus hungaricus* Kozur*, Rm-109: 1001.65-1001.75 m;* ***2, 3.*** *Eoxitus dhimenaensis* Baumgartner*, Rm-118: 504.0 m; Rm-136: 55.8 m;* ***4.*** *Eoxitus baloghi* Kozur*, Rm-118: 830.7 m;* ***5–7.*** *Mizukidella kamoensis* (Mizutani & Kido*), Rm-136: 55.8 m; Rm-136: 55.8 m; Rm-118: 838.7 m;* ***8.*** *Mizukidella sp. cf. M. hungarica* (Grill & Kozur) *Rm-118: 879.2 m;* ***9.*** *Cinguloturris carpatica* Dumitrica*, BüNy-2: 759.0-772.5 m;* ***10.*** *Cinguloturris latiannulata* (Grill & Kozur)*, Rm-118: 838.7 m;* ***11.*** *? Campanomitra sp., Rm-109: 1001.65-1001.75 m;* ***12.*** *Campanomitra buekkensis* (Grill & Kozur)*, Rm-118: 830.7 m;* ***13.*** *Campanomitra tuscanica* (Chiari, Marcucci & Prela)*, BüNy-2: 814.5-816;* ***14, 15.*** *Archaeodictyomitra prisca* Kozur & Mostler*, Rm-109: 1001.65-1001.75 m; BüNy-2: 759.0-772.5 m;* ***16.*** *Archaeodictyomitra exigua* Blome*, BüNy-2: 759.0-772.5 m;* ***17.*** *Archaeodictyomitra* sp. *A sensu* O'Dogherty et al. *(2017), Rm-136: 55.8 m; 18. Archaeodictyomitra cellulata O'Dogherty* et al. *(2006), Rm-136: 55.8 m;* ***19, 20.*** *Parahsuum carpathicum* Widz & De Wever*, BüNy-2: 759.0-772.5 m; Rm-118: 879.2 m;* ***21.*** *Transhsuum brevicostatum (*Ožvoldová*), Rm-109: 1001.65-1001.75 m;* ***22.*** *Hsuum matsuokai* (Isozaki & Matsuda)*, Rm-118: 879.2 m;* ***23, 24.*** *Transhsuum brevicostatum* (Ožvoldová)*, Rm-136: 55.8 m; Rm-118: 838.7 m;* ***25., 26.*** *Transhsuum maxwelli* (Pessagno)*, Rm-131: 504.0 m; Rm-131: 504.0 m;* ***27.*** *Eucyrtidiellum nodosum* Wakita*, BüNy-2: 814.5-816 m;* ***28, 29.*** *Eucyrtidiellum ptyctum* (Riedel & Sanfilippo)*, BüNy-2: 759.0-772.5 m; Rm-136: 55.8 m;* ***30.*** *Crococapsa* sp.*, Rm-131: 504.0 m;* ***31.*** *Crococapsa* sp. A sensu O'Dogherty et al*. (2016), Rm-109: 1001.65-1001.75 m;* ***32.*** *Zhamoidellum* sp. cf. *Z. ovum* Dumitrica *Rm-136: 58.0 m;* ***33.*** *Guexella sakawaensis* (Matsuoka)*, BüNy-2: 814.5-816 m;* ***34****. Zhamoidellum* sp.*, Rm-118: 830.7 m;* ***35.*** *Praewilliriedellum convexum* (Yao)*, Rm-118: 830.7 m;* ***36.*** *Praewilliriedellum robustum* (Matsuoka)*, Rm-118: 827.9 m;* ***37.*** *Williriedellum yaoi* (Kozur)*, BüNy-2: 759.0-772.5 m;* ***38.*** *Quarticella magnipora* (Chiari, Marcucci & Prela)*, Rm-136: 55.8 m;* ***39.*** *Yaocapsa* sp.*, Rm-118: 845.5 m;* ***40, 41.*** *Arcanicapsa funatoensis* (Aita)*, Rm-118: 845.5 m; Rm-131: 504.0 m;* ***42.*** *Striatojaponocapsa plicarum* (Yao)*, Rm-118: 827.9 m;* ***43.*** *Striatojaponocapsa* ? sp.*, BüNy-2: 759.0-772.5 m;* ***44.*** *Praewilliriedellum convexum* (Yao)*, Rm-109: 1001.65-1001.75 m;* ***45****. "Sethocapsa "*sp. 1*, Rm-136: 55.8 m;* ***46.*** *"Sethocapsa"* sp. 2*, Rm-136: 55.8 m;* ***47.*** *"Sethocapsa"* sp. 3*, Rm-136: 55.8 m;* ***48.*** *Protunuma* sp.*, Rm-109: 1001.65-1001.75 m;* ***49.*** *Protunuma lanosus* Ožvoldová*, Rm-136: 59.7 m;* ***50, 51.*** *Protunuma japonicus* Matsuoka & Yao*, Rm-136: 55.8 m; Rm-136: 55.8 m;* ***52.*** *Unuma gordus* Hull*, Rm-118: 845.5 m;* ***53, 54.*** *Unuma typicus* Ichikawa & Yao*, Rm-118: 827.9 m; Rm-118: 827.9 m;* ***55.*** *Unuma* sp. cf. *U. echinatus* Ichikawa & Yao*, Rm-136: 55.8 m;* ***56.*** *Yaocapsa mastoidea* (Yao)*, Rm-136: 55.8 m;* ***57.*** *?Yamatoum* sp.*, Rm-131: 504.0 m;* ***58.*** *Semihsuum amabile* (Aita)*, Rm-118: 830.7 m;* ***59.*** *Stichomitra (?) takanoensis* Aita*, Rm-131: 504.0 m;* ***60, 61.*** *Archicapsa (?) pachyderma* (Tan)*, Rm-136: 55.8 m; Rm-118: 827.9 m;* ***62.*** *Praeconocaryomma whiteavesi* Carter*, Rm-136: 55.8 m;* ***63.*** *Tritrabs* sp.*, BüNy-2: 759.0-772.5 m;* ***64.*** *Archaeospongoprunum elegans* Wu*, BüNy-2: 759.0-772.5 m.*

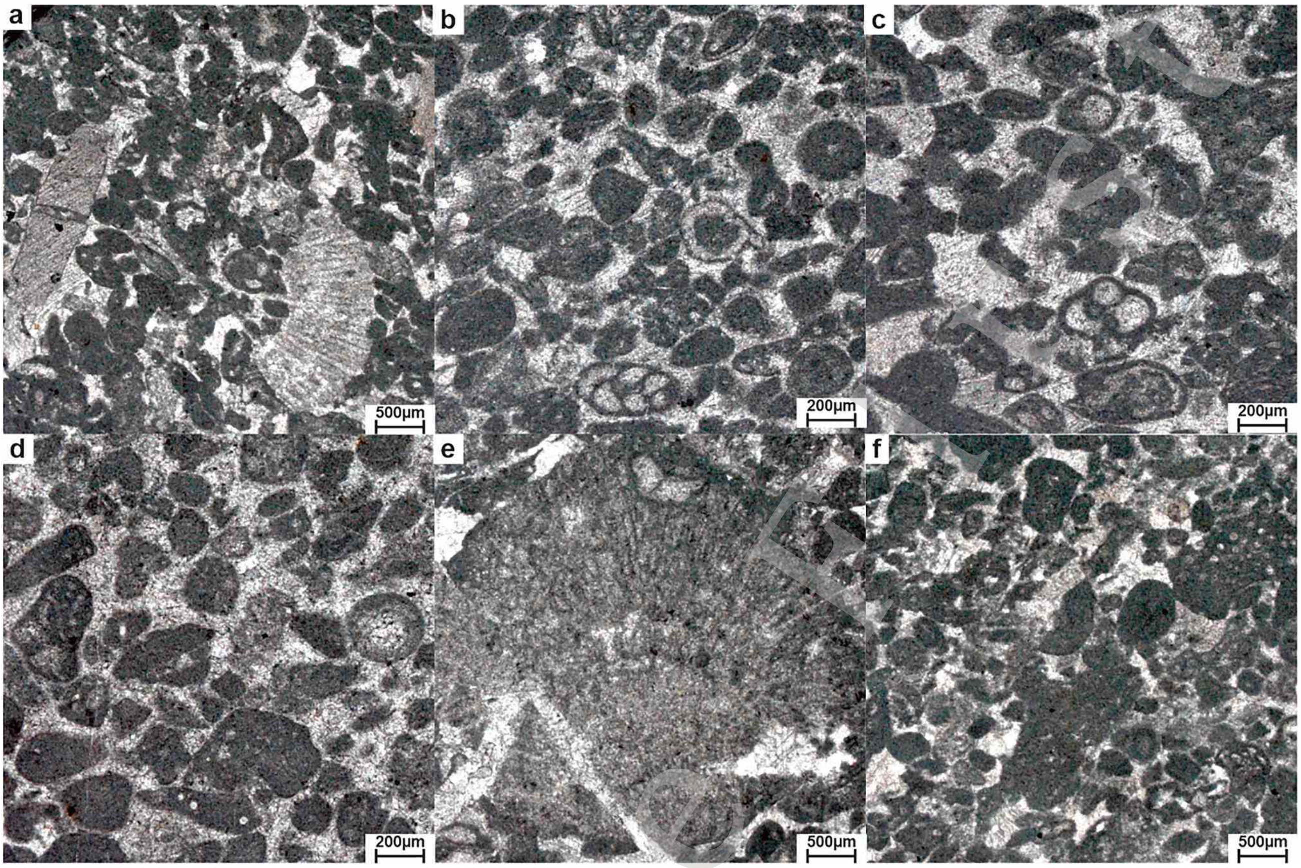

Fig. 8. *Characteristic microfacies of the limestone succession in well Rm-109.* ***a)*** *Peloidal, bioclastic grainstone with fragments of crinoids and calcimicrobes, 1193 m;* ***b)*** *Peloidal grainstone with a few micritized ooids and benthic foraminifera, 1107 m;* ***c)*** *Peloidal grainstone with a micritized ooids, cortoids, grapestones and benthic foraminifera, 1116 m.* ***d)*** *Peloidal grainstone with a micritized ooids and grapestones, 1118 m;* ***e)*** *Peloidal grainstone with a Rivulacean calcimicrobe, 1143 m;* ***f)*** *Peloidal grainstone with micritic lumps and grapestone, 1163 m.*

between 972–983 m and 1000–1005 m, respectively. A strongly silicified interval was intersected between 1050–1087 m and then finely crystalline and locally cherty limestone with thin claystone interlayers was drilled till the bottom of the borehole. In the cherty limestone lithofacies the mudstone and wackestone textures are predominant. They contain bioclasts akin to those in the Rm-63 key-section (Fig. 6a, c, d). Peloidal, ooidic packstone or grainstone with fragments of benthic crinoids were encountered in several horizons (Fig. 11e, f).

Rm-34

Below the Recsk Andesite Complex a thick Mesozoic succession with cross-cutting andesite dykes was penetrated in borehole Rm-34 between 396 and 1251m (Fig. 1c). The upper part of this succession is alternating sericite and chlorite-bearing shale, marl, siltstone and sandstone with some pelagic limestone intercalation. This mainly siliciclastic succession is usually silicified. The main components of the sandstone are quartz, feldspar, muscovite and quartzite lithoclast. This upper part of the Mesozoic succession may correspond to the Oldalvölgy Shale. Below 440 m the limestone intercalations become more frequent, and the succession turns into a partially silicified limestone dominated series with breccia intercalations (478 m, 535 m, 784 m, 857 m) and andesite dykes. The main microfacies types are mudstone and wackstone with radiolarian moulds filled by calcite (max. 100 µm in diameter), sponge spicule

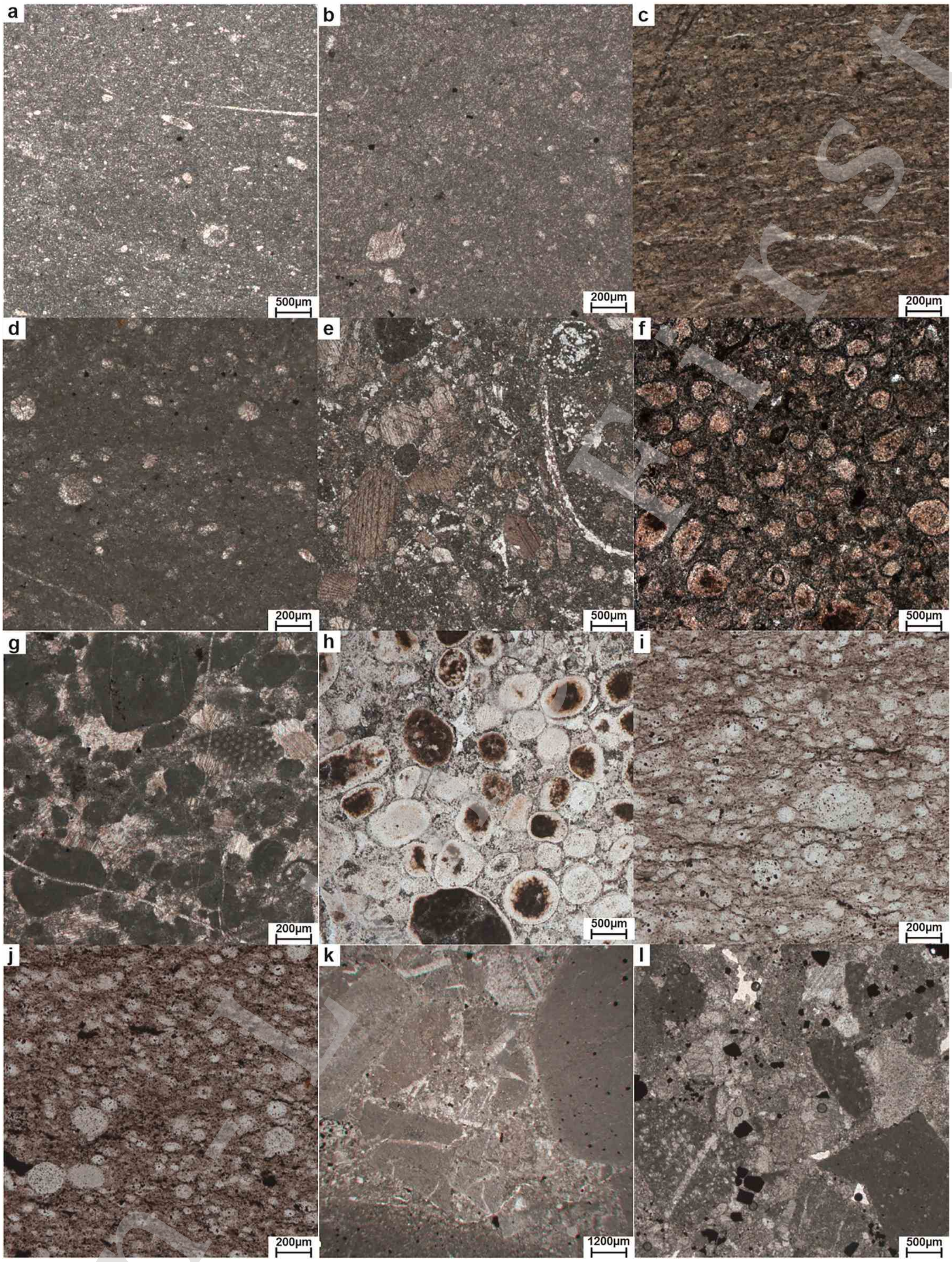

__Fig. 9.__ Microfacies types of Rm-63. __a-b)__ Mudstone types: __a)__ 589 m mudstone with scattered calcisilt and a few calcite-filled moulds of sponge spicules; __b)__ 713 m mudstone with a few calcite-filled radiolarian moulds. __c-d)__ Wackestone types: __c)__ 486 m wackestone with fragments of thin-shelled bivalves („filaments"); __d)__ 699 m packstone with calcite-filled radiolarian moulds. __e-f)__ packstone types: __e)__ 613 m packstone with partially silicified ooids and bivalve fragments and sand-sized crinoid ossicles; __f)__ 673 m packstone with globular coated grains. __g-h)__ Grainstone types: __g)__ 648 m grainstone with peloids, crinoid ossicles, and a calcimicrobe (?) fragment; __h)__ 636 m silicified grainstone with ooids. __i-j)__ radiolarite: __i)__ 189 m; __j)__ 198 m. __k-l)__ polymict sedimentary breccia: __k)__ 742 m; __l)__ 762 m.

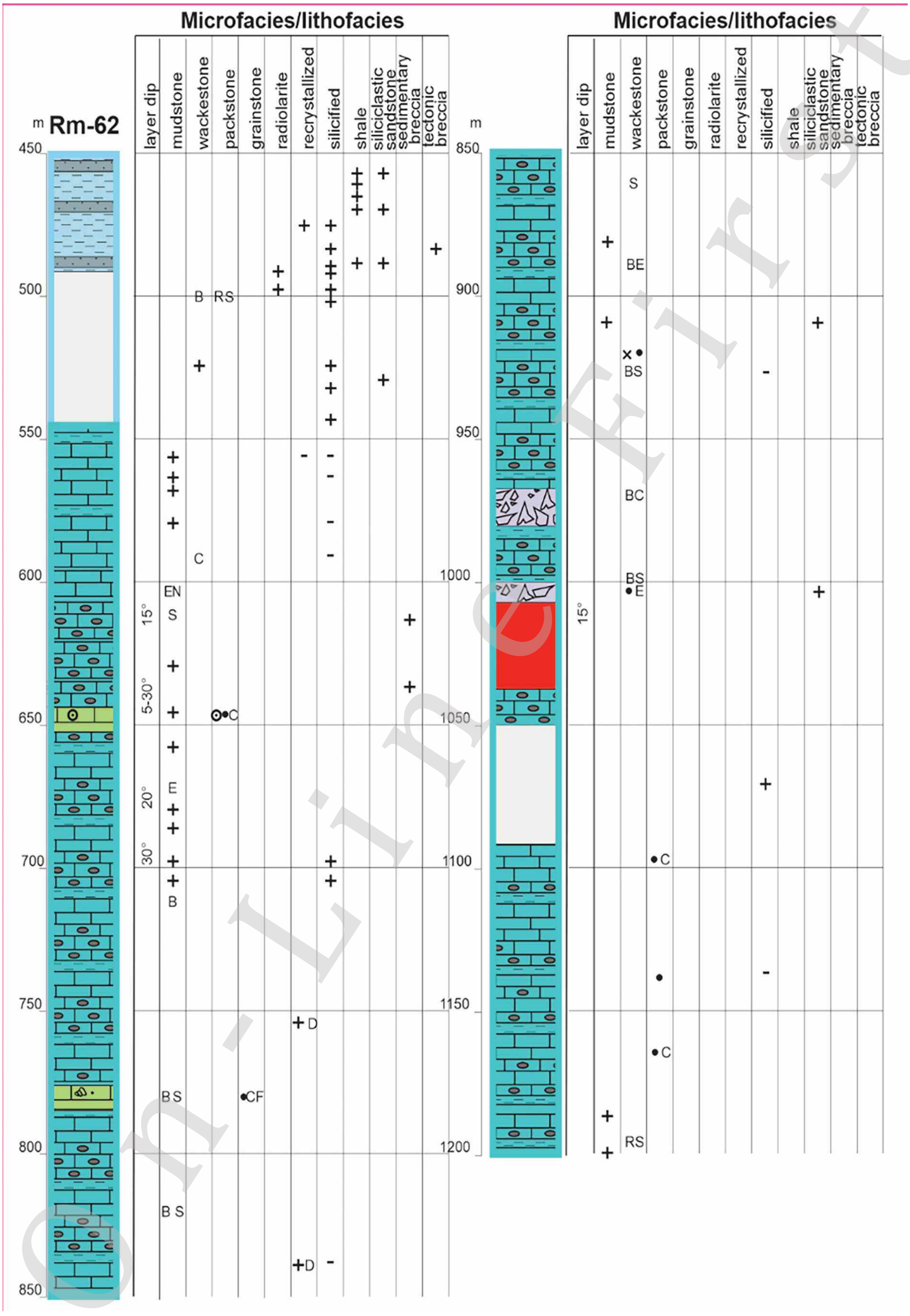

Fig. 10. Mesozoic part of core Rm-62: lithologies, microfacies and lithofacies types, fossil content. For the legend see Fig. 6.

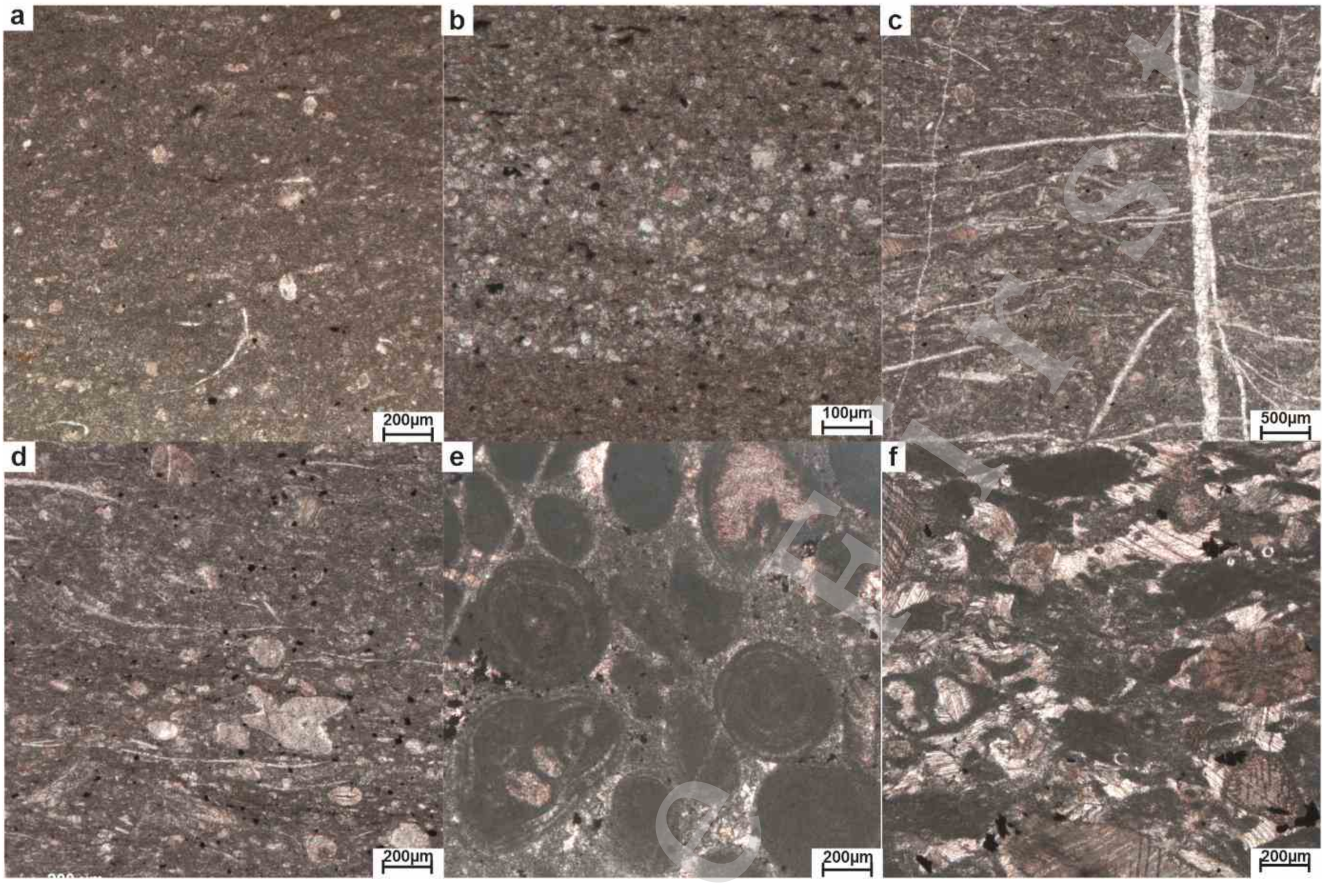

Fig. 11. *Characteristic microfacies of the of the Oldalvölgy Limestone in well Rm-62.* ***a)*** *Bioclastic mudstone–wackestone fragments of thin-shelled bivalves and fine detritus of echinoderms. 686 m;* ***b)*** *mudstone with a wackestone lamina with silt-sized bioclasts. 908 m;* ***c)*** *Bioclastic wackestone rich in fragments of thin-shelled bivalves; few sponge spicules also occur. 888 m;* ***d)*** *Bioclastic, peloidal wackestone with fragments of crinoids and thin-shelled bivalves and silt-sized bioclasts. 888 m;* ***e)*** *Oolitic packstone–grainstone containing micritized oolite, cortoid and grapestone grains 645 m;* ***f)*** *Bioclastic grainstone with fragments of cinoids, bivalves and foraminifera. 781 m.*

mudstone, radiolarian wackestone, Echinodermata and ostracoda-bearing wackstone, wackstone with filaments. The limestone is frequently recrystallized.

This limestone rich part of the Mesozoic succession is most probably Jurassic in age and may correlate with the Oldalvölgy Limestone.

Rm-87

In well Rm-87 (Figs. 1c, 12) shale, sandstone with breccia intercalation (Oldalvölgy Shale) was intersected in the uppermost part of the Mesozoic series (514–585 m). In the breccia layer penetrated at 568.5 m the matrix is siltstone to medium-sized sandstone, the lithoclasts are made up of claystone and coarse-grained sandstone. Below the siliciclastic series, limestone with thin clayey interbeds was drilled (585–720 m) which is characterised by mudstone/wackestone lithofacies with sponge spicules and radiolarians (Fig. 13a, b) A thick cherty limestone interval was intersected downward (720–1010 m). Ooidic grainstone, peloidal grainstone with fragments of benthic crinoids was encountered in four horizons (735 m, 752 m, 875 m, 985-988m; Fig. 13 c-f, j) within the predominantly mudstone/wackestone texture types abundant in thin-shelled bivalves, locally (Fig. 13g, h, i).

Argillaceous limestone of peloidal, bioclastic wackestone fabric (Fig. 13k) was explored in the lowest part of the well (1010–1230 m). A peloidal, bioclastic grainstone intercalation was found also in this interval (1030 m) (Fig.13 l). This lower lime-

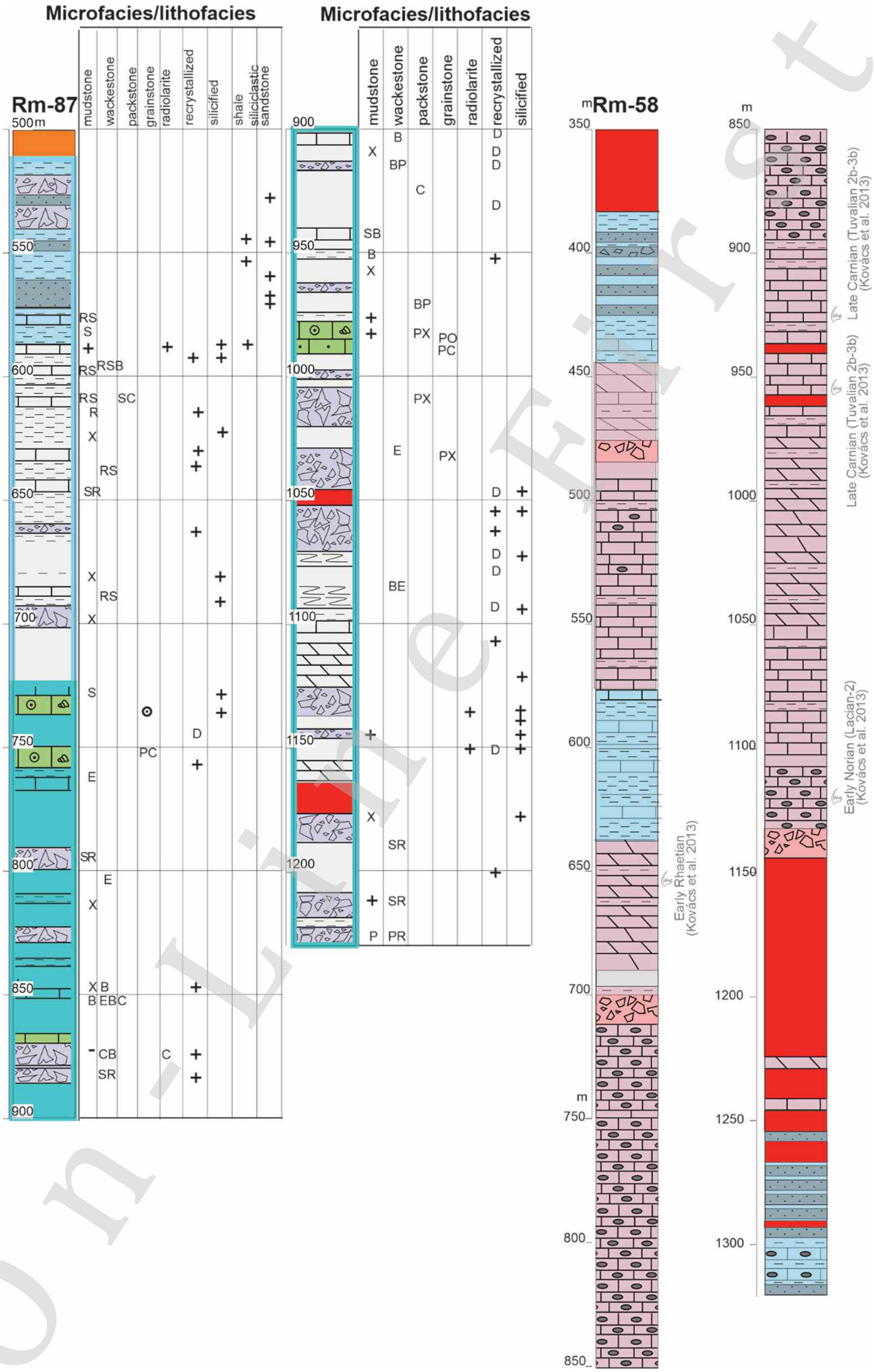

Fig. 12. Mesozoic part of core Rm-87 and Rm-58: lithologies, microfacies and lithofacies types, fossil content. For the legend see Fig. 6.

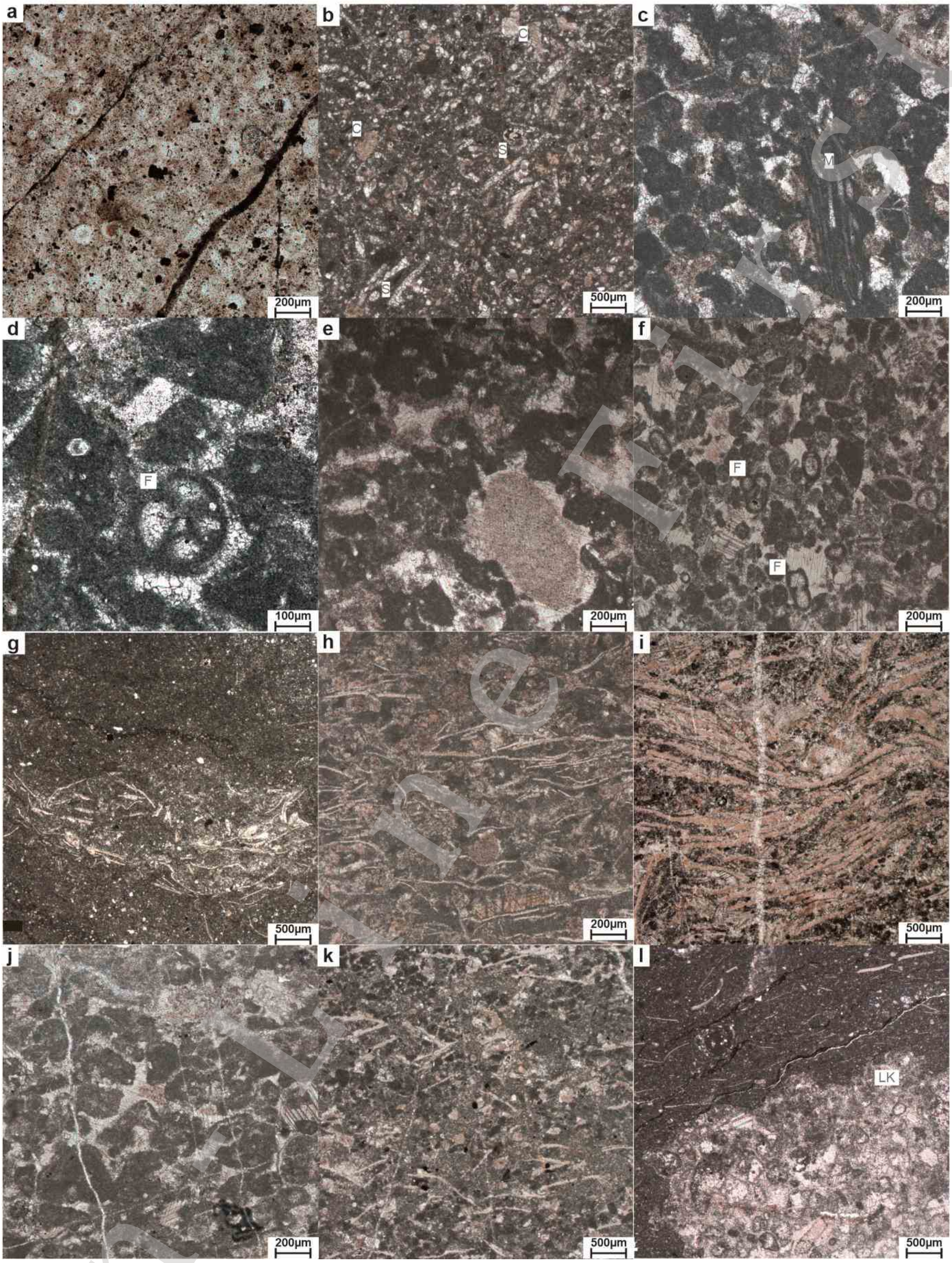

Fig. 13. *Characteristic microfacies of the Oldalvölgy Limestone in well Rm-87.* ***a)*** *Radiolarian chert, 587 m;* ***b)*** *Wackestone–packstone with sponge spicules (calcite-filled moulds – S) and fragments of crinoids (C), 608 m;* ***c)*** *Peloidal grainstone with a fragment of calcimicrobe (M), 752 m;* ***d)*** *Peloidal grainstone with a foraminifera (F) 752 m;* ***e)*** *Peloidal grainstone with fragments of crinoids 752 m;* ***f)*** *Peloidal grainstone with foraminifers (F), 764 m;* ***g)*** *Bioclastic wackestone with lens-shape accumulation of thin-shelled bivalve detritus, 873 m;* ***h)*** *Bioclastic, peloidal wackestone with fragments of thin-shelled bivalves ("filaments"), 913 m;* ***i)*** *Thin-shelled bivalve coquina, 971 m;* ***j)*** *Peloidal, bioclastic grainstone, 988 m;* ***k)*** *Peloidal, bioclastic wackestone with fragments of thin-shelled bivalves, 1010 m;* ***l)*** *Peloiodal bioclastic grainstone lithoclast (LK) in bioclastic wackestone, 1084 m.*

stone lithofacies part of the core is rich in sedimentary breccia layers. The clasts are angular to subrounded lithoclasts. Slump folds were also observed in some horizons. The lowermost 150 m of the core is throughoutly recrystallized, the limestone is usually dolomitized, locally also silicified.

Rm-61

In well Rm-61 (Fig. 1c) below the Cenozoic formations the cherty limestone lithofacies of the Oldalvölgy Limestone was explored (450–1200 m). Ooidic, peloidal bioclastic grainstone were encountered in three horizons (704 m, 746 m, 756 m).

Rm-55

In well Rm-55 (Fig. 1c) below the Cenozoic formations the cherty limestone lithofacies of the Oldalvölgy Limestone was explored (634–1230 m). Ooidic, peloidal, bioclastic grainstone was encountered in only one horizon, at 814 m.

Rm-51

In well Rm-51 (Fig. 1c) below the Cenozoic formations variable micritic limestones were explored (463–1230 m). The main microfacies types are mudstone, bioclastic wackstone with radiolarian moulds, sponge spicules, fragments of echinoderms, gastropods, and a whole ophiuroidea at 780. The radiolarian moulds are relatively small, with a max diameter of 100 µm. At 1018 m a dark grey, crinoidal limestone was penetrated with crinoidal, brachiopodal packstone texture. The size of the crinoids is between 1 and 5 mm. Till 780 m the Mesozoic succession is most probably Jurassic in age and may correlate with the Oldalvölgy Limestone. The lower part can either be Jurassic or Triassic in age.

Rm-58

The succession intersected in well Rm-58 (Figs. 1c, 12) significantly differs from those explored in the previously discussed ones. Directly below Cenozoic sedimentary formations and andesite dark grey shale, sandstone with limestone and marl intercalations were intersected between 386–445 m (Oldalvölgy Shale). Below it, a series of alternating light grey dolomite, limestone, rarely cherty limestone and dark grey claystone was intersected (445–700 m). A 10 m thick tectonic breccia interval is present at 475-485 m, and at the bottom of this dolomite rich interval (700–710 m). Cherty limestone was drilled in the next segment (700–894 m) which was followed by an interval of alternating limestone, dolomite and dark grey marl, claystone (894–1100 m). After 33 m of cherty limestone (1100–1133 m) andesite dykes of the Paleogene Recsk Complex are present. Between the dykes the Mesozoic host rock (limestone, dolomite and sandstone) was explored. Below the dykes alternating claystone and sandstone with limestone intercalations were penetrated till the bottom.

Triassic conodonts were found in 4 samples in the intersected more than 500 m thick limestone rich interval (Kovács et al., 2013); early Rhaetian fauna was determined in the upper part (657 m), late Carnian in the middle part (927 m, and 953 m) and early Norian in the lower part (1125 m). Based on its lithologic features and the conodont biostratigraphic data this carbonate unit may probably correlate with the Felsőtárkány Limestone Formation of the Bánkút Succession (Fig. 2). The mainly siliciclastic series in the upper part and lowermost part of the borehole may correspond to the Oldalvölgy Shale.

Recsk, central part E

Rm-20

In well Rm-20 (Fig. 1c) the cherty limestone lithofacies of the OldalvölgyLimestone was intersected with totally silicified segments in ~450 m total thickness. Sponge spicule and radiolarian mudstone and wackestone microfacies are dominant. Ooidic, peloidal and bioclastic grainstone interbeds were found in a few samples (946 m, 950 m, 965 m, 983 m).

Rm-25

In well Rm-25 (Figs. 1c, 14) a thick series of strongly silicified shale and red radiolarian marl with a considerable number of breccia interbeds

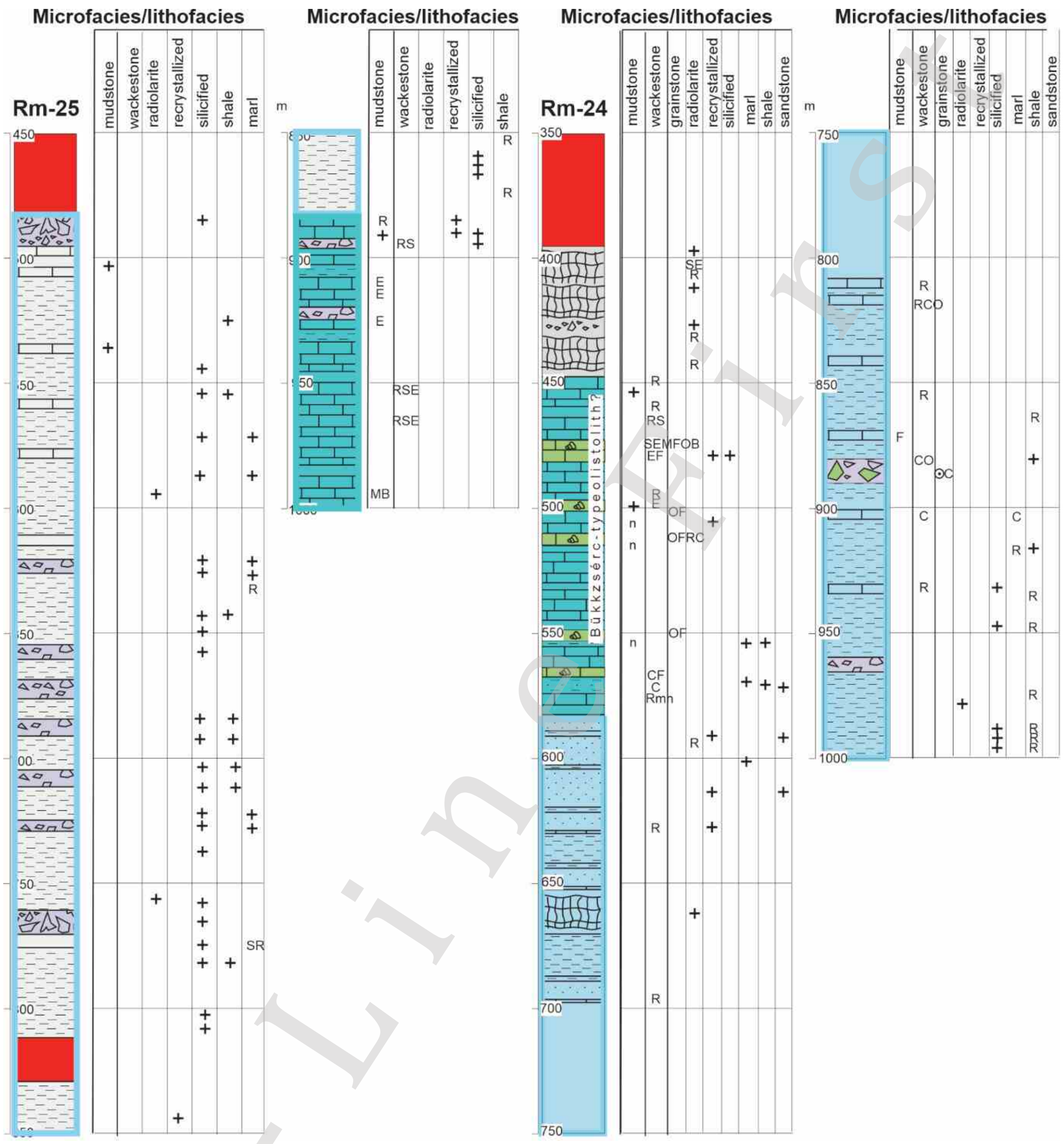

Fig. 14. Mesozoic part of core Rm-25 and Rm-24: lithologies, microfacies and lithofacies types, fossil content. For the legend see Fig. 6.

(Oldalvölgy Shale) were penetrated in the upper part of the Mesozoic succession (480–900 m). Limestone typically exhibiting mudstone or wackestone texture with small-sized crinoid detritus, sponge spicules and ostracods were found below it (900–1000 m). This limestone part of the core (Oldalvölgy Limestone) also contains breccia intercalations.

Rm-24

In well Rm-24 (Figs. 1c, 14) a 600 m thick Mesozoic succession was penetrated below the Recsk Andesite Complex. The uppermost part of it is a ~50 m thick radiolarite with well-preserved radiolarians, locally with sponge spicules and Echinodermata detritus The next lithological unit is a more than 100 m thick pelagic limestone succession with mainly nannoplankton-bearing mudstone and radiolarian wackestone texture. Echinodermata particles are also present within the bioclasts of the wackestones. Platform-derived redeposited layers are present in 5 horizons. The main components are crinoidea fragments, forams and ooids within the packstone to grainstone textures. Below 580 m, the rest of the core is built up by a partly silicified siliciclastic series with shale, radiolarite, sandstone and a few pelagic limestone intercalations (Oldalvölgy Shale). Radiolarians were frequently detected, while a platform-derived lithoclast with ooids and crinoids was also encountered at 879 m.

Northeastern margin of the Recsk Ore Field (well Rm-118, BüNy-2)

Rm-118

Well Rm-118 was drilled in the north-eastern part of the Recsk Ore Field (Figs. 1c, 15.). Under Cenozoic formations, between 389–610 m the well intersected silicified limestone, marl and claystone beds with intercalations of thick mud-supported sedimentary breccia and conglomerate intervals (Fig.16a–f).

The breccia horizons of the upper part of the core (389–520m) were investigated in detail (Fig. 17).

The matrix of the breccia is radiolarian wackestone or packstone. The amount of the clasts is usually between 50 and 80%, the clast size is 0.1 mm to a few cm-s. Most of the clasts are sub-rounded to angular. The predominant microfacies of the clasts are radiolarian packstone and radiolarian wackestone with the presence of sponge spicule wackestone, shale, dolosparite, mudstone, quartz grain, claystone. In the more than 40 thin sections only two were found with a minor amount of peloidal wackestone clasts. Grains of shallow marine origin were not found except for two with redeposited ooids and oncoids and peloidal wackestone.

Slump folds are common in certain horizons (Fig. 16a). Importantly, clasts commonly exhibit features of the plastic deformation like isoclinal folding (Fig. 16 a), bending and dissection of the micro-layers without discrete fault planes (Fig. 16 a) and thus can be interpreted as intraclasts. Incipient wavy or anastomosing foliation is present (Fig. 16c-e). The main mechanism was pressure solution (wet diffusion), which is especially expressed at clast contacts, or along sharp clast edges (Fig. 16d-f). The foliation is usually bent around larger, more rigid clasts (Fig. 16c, d, f).

Completely silicified rocks occur between 610–780 m, although ghosts of radiolarians are rarely recognizable in them. Olistostromes made up mostly of limestone clasts were encountered in the interval 780–880 m. Late Bajocian to early Bathonian radiolarians were found in a clast of the olistostrome (829–831 m); late Bathonian to early Callovian fauna was encountered in a greenish grey siliceous shale bed (838.7 m); a Bajocian–Bathonian assemblage in red radiolarite (845.5 m) and Aalenian to early Bathonian in a deeper red claystone bed (879.2 m) (Dosztály, 1994; Ozsvárt in Haas et al., 2011). Under this interval, smaller and larger limestone clasts in clayey and siliceous matrix and a large red nodular limestone (Hallstatt Limestone) olistolith were encountered (937–957 m). Carnian and middle Norian conodonts were determined from the olistolith (Kovács et al., 2013). Completely silicified rocks and sedimentary breccia were explored in the lowermost part of the well (970–1100 m).

The previous radiolarian investigations were complemented by the study of ten new samples (Fig. 7, Table 1). From the deepest sample at 879.2 m the following stratigraphically important radiolarian species have been obtained: *Hsuum matsuokai* (Isozaki & Matsuda), *Laxtorum* sp. cf. *L. hichisoense* (Isozaki & Matsuda) and *Parahsuum carpathicum* Widz & De Wever. Based on these species, it can be stated that this horizon can belong to UAZ 1–4 biozones (Baumgartner et al., 1995). Since the samples appearing shortly above it (from 845.5 m) are already verifiably dominated by species of UAZ 5, the age of the lowermost sample is most probably late Bajocian (UAZ 4). The four samples above this horizon (845.5 m, 838.7 m, 830.7 m and 827.9 m) contain the following biostratigraphically important species: *Eucyrtidiellum ptyctum* (Riedel & Sanfilippo), *Hsuum matsuokai* Isozaki & Matsuda, *Mizukidella kamoensis* (Mizutani & Kido), *Praewilliriedellum robustum* (Mat-

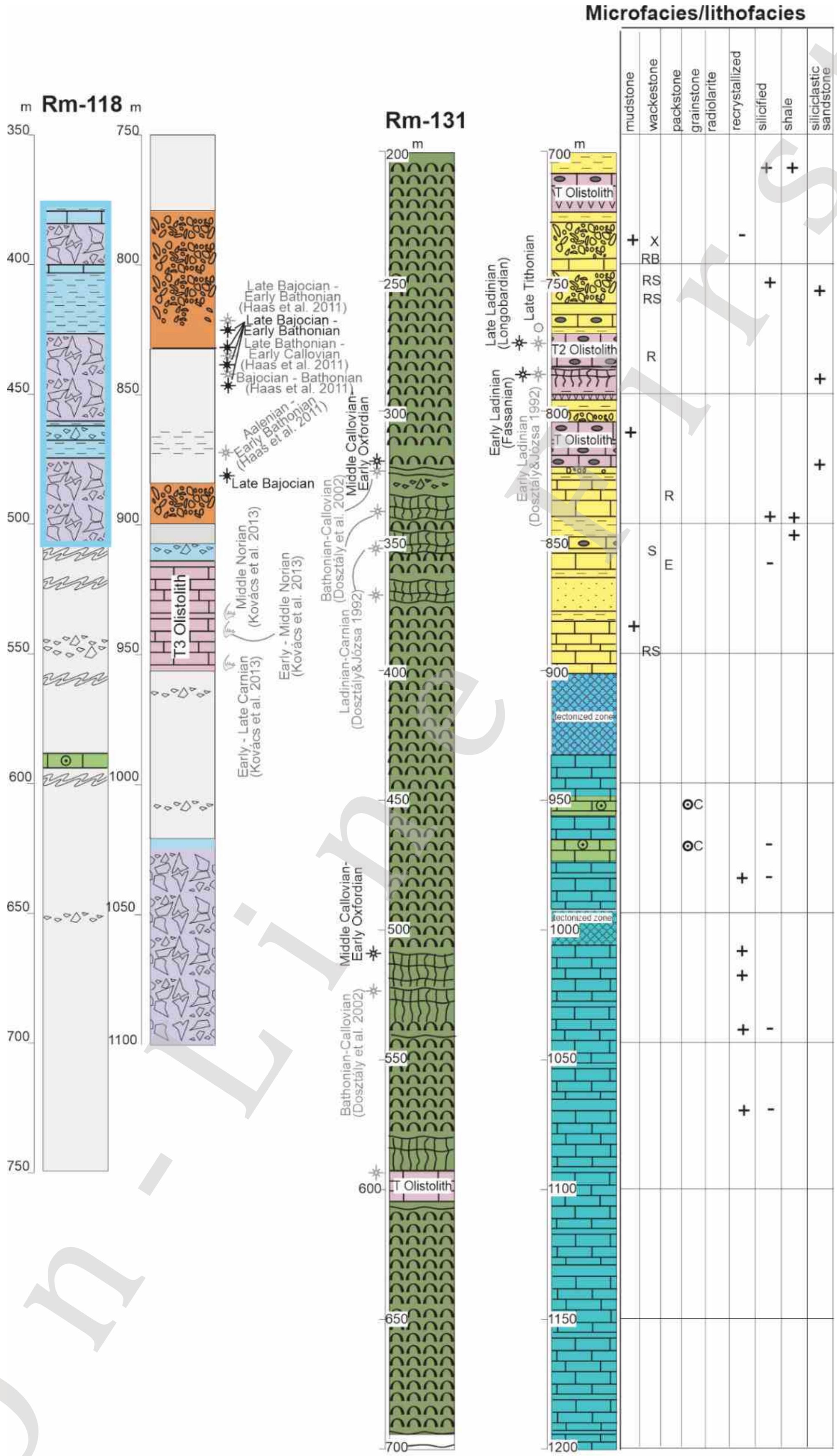

Fig. 15. *Mesozoic part of core Rm-118 and Rm-131: lithologies, microfacies and lithofacies types, fossil content. For the legend see Fig. 6.*

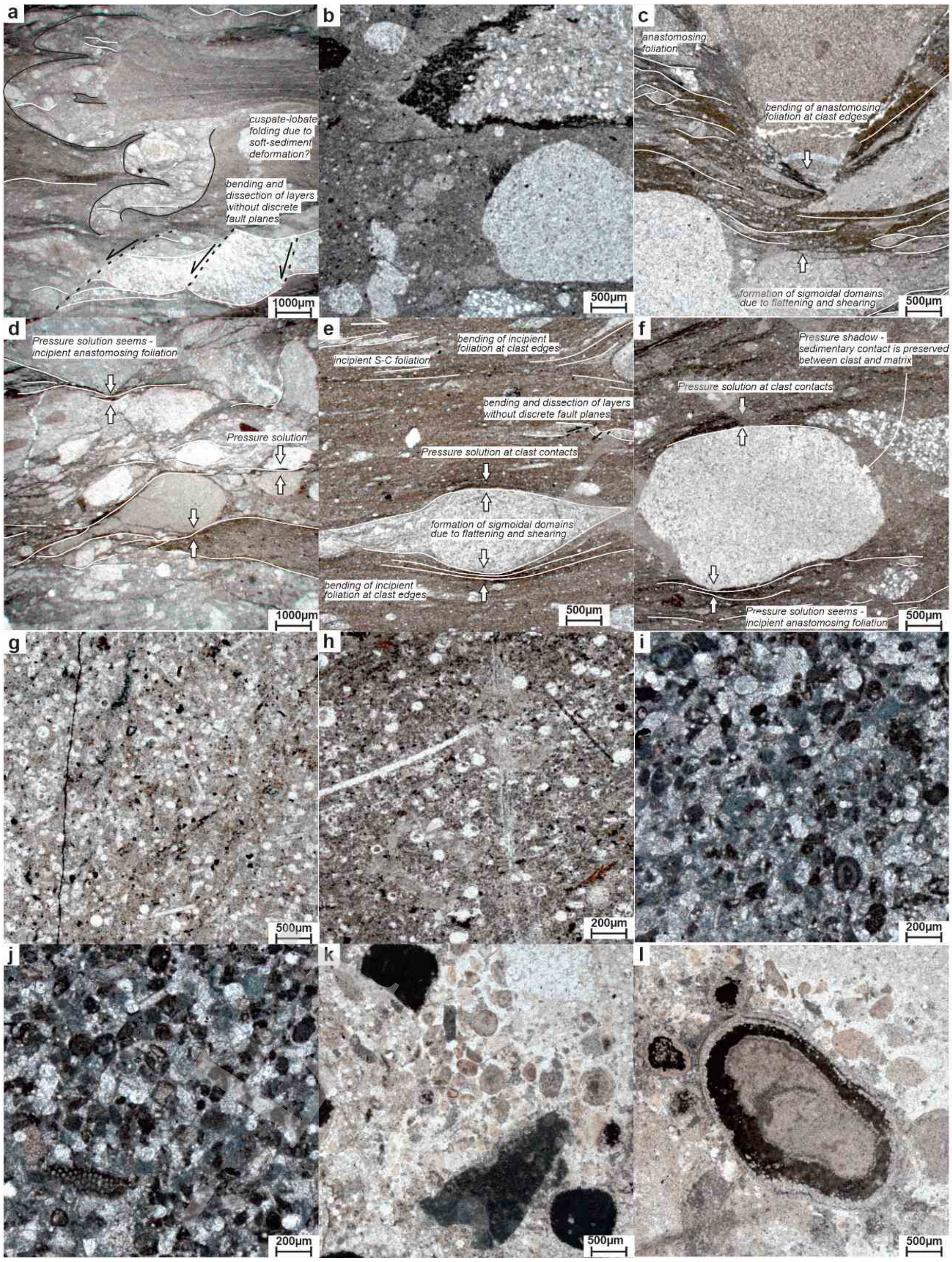

Fig. 16. Fabric types and deformation of lithoclasts (microbreccia) in well Rm-118. ***a)*** *Mudstone and radololarian packstone (radiolarite) clasts in mudstone/wackestone matrix. Signs of soft-sediment deformation: isoclinal cuspate-lobate folding, dissection of siltstone layer without discrete fault plane. 464 m.* ***b)*** *radolarian packstone (radiolarite) lithoclasts in mudstone/wackestone matrix, 465 m.* ***c)*** *The matrix shows anastomosing foliation and bending of foliation at rigid clast edges due to flattening and shearing. 440 m.* ***d)*** *Pressure solution seams at larger clast edges due to flattening. 437 m.* ***e)*** *Incipient S-C foliation within the matrix due to shearing. 404 m.* ***f)*** *Pressure solution seams along clast contacts. Not pressure shadows at perpendicular directions. 399 m. Characteristic microfacies of the breccia clasts:* ***g)*** *Partially silicified radiolarian – sponge spicule packstone– wackestone. 400 m.* ***h)*** *Partially silicified radiolarian – sponge spicule wackestone. 569 m.* ***i, j)*** *Limestone; peloidal, bioclastic grainstone rich in calcisphares. 406 m.* ***k, l)*** *silicified limestone; grainstone with intraclasts and microbially coated grains. 594 m.*

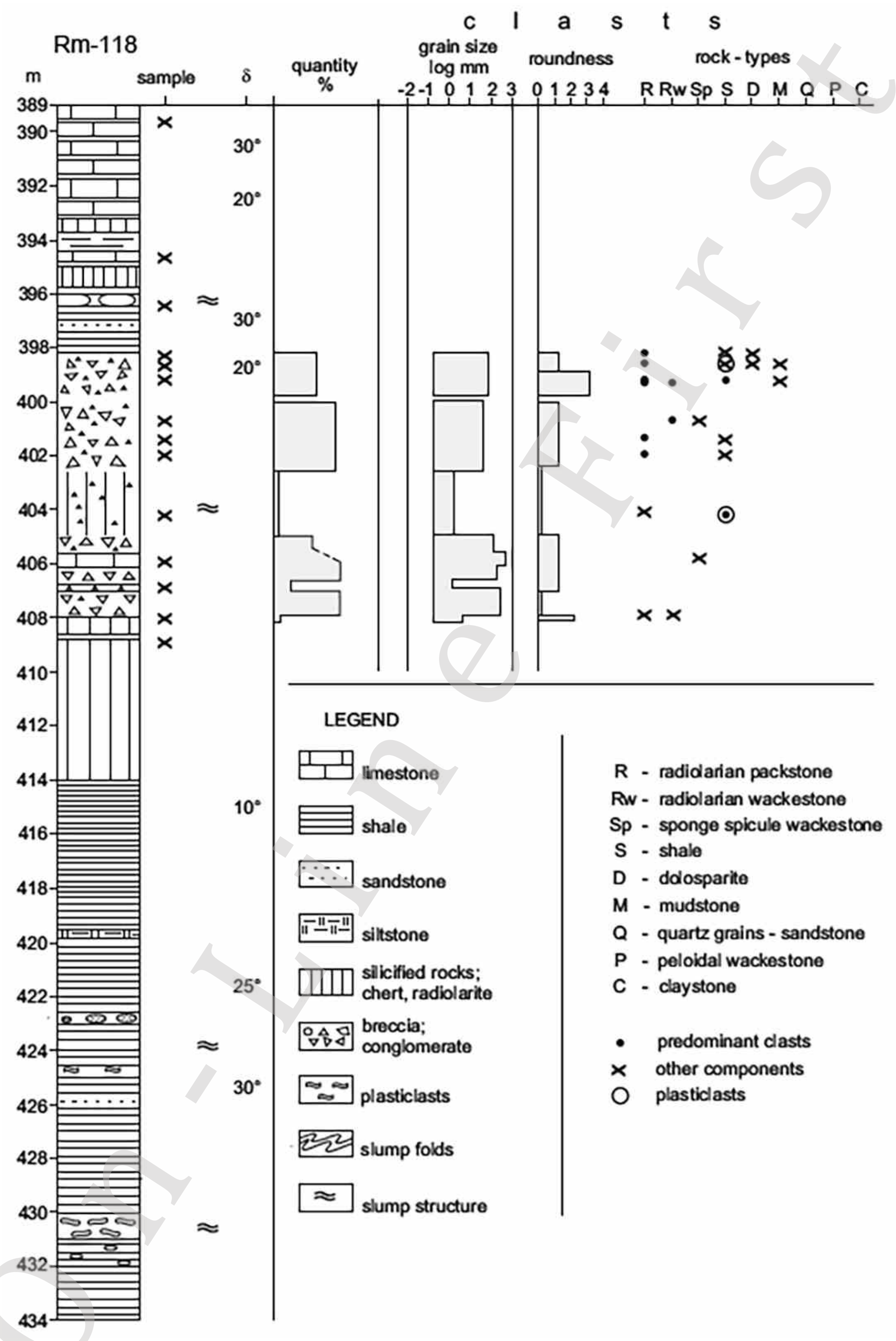

Fig. 17. *Results of detailed clast analysis performed in the upper part of core Rm-118.*

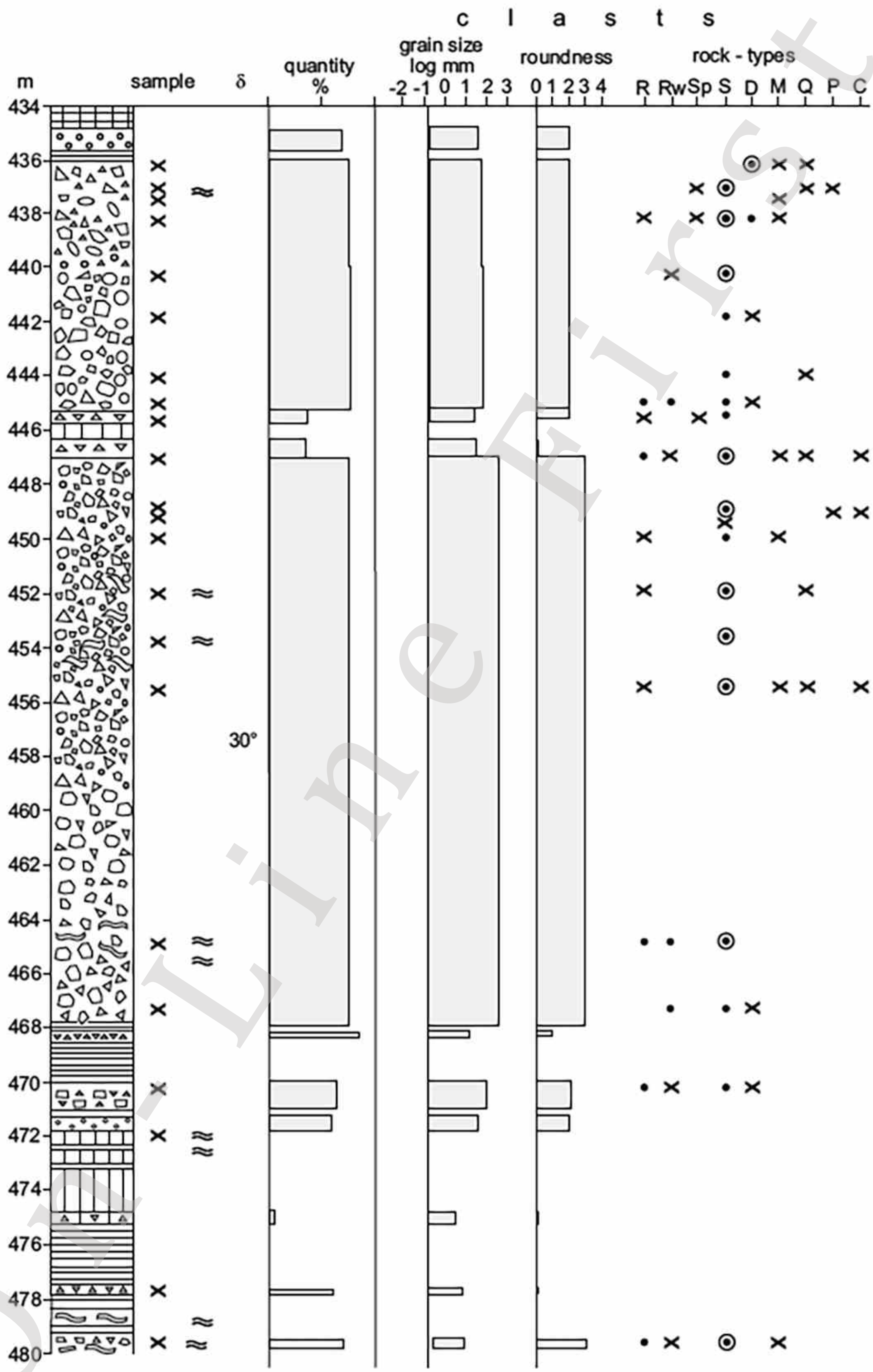

Fig. 17. *Second part.*

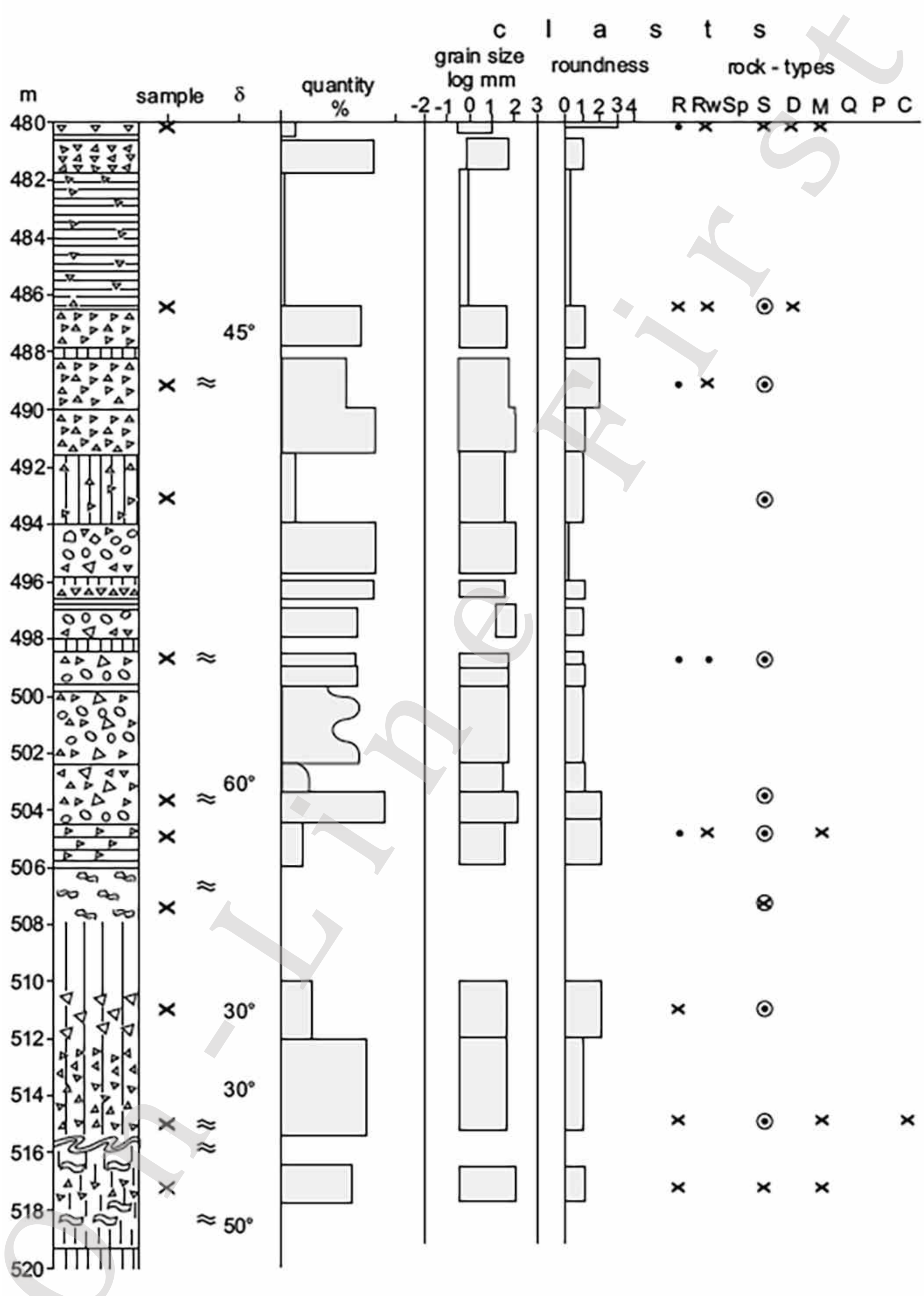

Fig. 17. Third part.

suoka), *Yaocapsa* sp. E sensu (Baumgartner) *Semihsuum amabile* (Aita), *Striatojaponocapsa plicarum* (Yao), *Unuma gordus* Hull, *Unuma typicus* Ichikawa & Yao and *Unuma* sp. cf. *U. latusicostatus* (Aita). Based on these species, the interval between 845.5 and 827.9 m is most likely in UAZ 5, so its age is late Bajocian – early Bathonian (Table 1).

Based on its lithological characteristics and age data, most of the intersected Mesozoic succession can belong to a breccia-rich version of the Oldalvölgy Shale, while the part containing the Triassic olistolith to the Laskóvölgy Olistostrome.

BüNy2

Two samples taken from the Oldalvölgy Shale of the north-easternmost BüNy-2 borehole (Fig. 1c) (759.0–772.5m and 814.5–816 m) have provided a moderately poor preserved radiolarian assemblage (Fig. 7, Table 1). The following stratigraphically important radiolarian species are in both samples: *Cinguloturris carpatica* Dumitrica, *Eucyrtidiellum ptyctum* (Riedel & Sanfilippo), *Mizukidella kamoensis* (Mizutani & Kido), *Praewilliriedellum robustum* (Matsuoka), *Protunuma japonicus* Matsuoka & Yao and *Semihsuum amabile* (Aita). The co-occurrence of these species suggests that the samples are Callovian age (UAZ 7 by Baumgartner et al., 1995) (Table 1).

East from the Darnó Fault, Darnó Hill (wells Rm-131, -135, -136)

Upper parts of boreholes – Darnóhegy Mélange

The Darnóhegy Mélange was penetrated by wells Rm-131, -135, -136 drilled in the vicinity of the Darnó Hill (Fig. 1c). In well Rm-135, along with the pillow basalt lava rocks, intrusive rocks (gabbro, microgabbro) were explored in more than 300 m virtual thickness. K-Ar dating yielded 175–165 Ma ages for the gabbro samples (Józsa, 1999), which are considered as the magmatic ages. Below the gabbro, silicified shale alternates with red pelagic limestone and radiolarite and occasionally metre to tens of metres sized basalt blocks. However, in wells Rm-131 and Rm-136 several metres to tens of metres thick shale, bluish grey siliceous shale, red radiolarite or debrite intervals were intersected between basalt intervals (Kovács et al., 2008). From some of the red radiolarites, both Ladinian–Carnian radiolarians and Bathonian–Callovian assemblages were found (Dosztály, 1994). On the other hand, the dark grey siliceous shales yielded exclusively Callovian radiolarian fauna (Dosztály, 1994; Kovács et al., 2008). These observations imply that the massive and the pillow basalt lava rocks, the Triassic red ribbon radiolarites, and probably also the red Jurassic radiolarites are present in the form of olistoliths (slide blocks) in late Middle Jurassic bluish grey siliceous shale and radiolarite matrix.

Radiolarian biostratigraphy

Mély-völgy quarry

Samples 02/07 and 03/07 (Mély-völgy quarry) (Fig. 1c) were taken from radiolarites, which directly overlies basalt, turned to be late Bajocian to Callovian (UAZ 5-7, Baumgartner et al., 1995) due to the co-occurrence of *Praewilliriedellum robustum* (Matsuoka) and *Protunuma turbo* Matsuoka (Fig. 7, Table 1). The sample 04/07 comes from a red radiolarite intercalation in a basalt block. This sample yielded numerous unidentifiable spongy shells and some poorly preserved radiolarian species: "*Entactinosphaera*'' sp. cf. *E. triassica* Kozur & Mostler, *Pseudostylosphaera longispinosa* Kozur & Mostler, *Spongopallium* sp., *Parasepsagon* sp. The occurrence of *Pseudostylosphaera longispinosa* Kozur & Mostler in Buchenstein Limestone of Recoaro (Vicentinian Alps, Northern Italy) is late Illyrian to early Fassanian (Kozur & Mostler, 1981, 1994) (Table 2). In addition, Goričan & Buser (1990) mentioned from late Illyrian to late Fassanian (?)–Longobardian of the Julian Alps (Vršič section, Slovenia). Consequently, this sample could be assigned to late Anisian to Ladinian (late Illyrian to Longobardian) age.

Rm-131

In the zone between 525.4 m and 511.7 m no biostratigraphically unambiguously precise fauna has been found, the extracted radiolarians (e. g. *Transhsuum brevicostatum* (Ožvoldová) indicate that it belongs to UAZ 3–11. The samples from 504 m and 322-316.5 m contains relatively rich radiolarian fauna (*Eoxitus hungaricus* Kozur, *E. dhimenaensis* (Baumgartner), *E. mashitaensis* (Mizutani) and *Mizukidella kamoensis* (Mizutani & Kido) that indicates these samples can be assigned to UAZ 7-8: Callovian–early Oxfordian (Fig. 7, Table 1).

Several horizons in the Rm-131 borehole contain Triassic radiolarians (Table 2). Their preservation is very poor, and it is difficult to identify on species level in most cases. The sample from 602.7 m contains *Muelleritortis cochleata* Kozur & Mostler, which suggests late Ladinian (Longobardian) age, while the sample from 594.8 m contains *Capnuchosphaera* sp. that indicates Carnian age.

Rm-136

Three samples were investigated from red radiolarite, which directly overlies basalt from core Rm-136 (59.7m, 58 m and 55.8 m). However, only sample 55.8 has been provided a biostratigraphically valuable radiolarian fauna: *Archicapsa* (?) *pachyderma* (Tan), *Yaocapsa mastoidea* (Yao), *Eucyrtidiellum ptyctum* (Riedel & Sanfilippo), *Gongylothorax* sp. cf. *G. favosus* Dumitrica, *Mizukidella kamoensis* (Mizutani & Kido), *Protunuma japonicus* Matsuoka & Yao, *Saitoum levium* De Wever, *Saitoum pagei* Pessagno, *Stichomitra* (?) *takanoensis* Aita (Fig. 7). The co-occurrence of these species suggests that these samples are Callovian (UAZ 7 by Baumgartner et al., 1995) (Table 1).

Five horizons contain Triassic radiolarians in the Rm-136 borehole, but only the sample comes from 124.8 m can be assumed with high probability to be of Carnian age (Table 2).

Formations below the Darnóhegy Mélange

Rm-136

In well Rm-136 shale, siliceous shale and sandstone with debris flow intercalations (olistostromes) and large olistoliths was explored under the Darnóhegy Mélange (below 335 m) (Figs. 18, 19).

A slide block/olistolith of Triassic reddish–whitish limestone with red chert and reddish amygdaloidal basalt was intersected at 350–375 m (Kovács et al., 2008). The limestone has mudstone and wackestone texture with various amounts of radiolarians and fragments of thin-shelled bivalves. Under the big olistolith an olistostrome layer was intersected with carbonate clasts exhibiting microfacies akin to that of the olistolith. After a few metres of tectonized zone sandstone and shale alternates between 415 and 665 m. Pelagic mudstone textured limestone intercalation is also present at 580–600 m. The next part of the core (to 1000 m) consists of olistostrome beds and olistoliths in a predominantly shale matrix. The olistoliths are various both in age and lithology. At 860 m a limestone block was penetrated, while in another large slide block Middle Permian green claystone and evaporites (Szentlélek Fm) and Upper Permian fossiliferous limestone (Nagyvisnyó Fm.) were identified (Józsa et al., 1996; Kovács et al., 2008). Below 1000 m subvertical shale beds with olistoliths were penetrated. The whole section below the Darnóhegy Mélange can be interpreted as a sedimentary succession of mixed siliciclastic and carbonatic beds with redeposited layers/blocks, where the clasts are not basalts, but different sedimentary rocks. The name Tarna Olistostrome will be used for it in the following chapters.

Rm-135

In well Rm-135, under the gabbro and basalt (between 670–770 m) red radiolarite–mudstone and siliceous shale were explored (Figs. 1c, 18). Middle Jurassic radiolarians were found in this interval (Dosztály, 1994; Kovács et al., 2008). Below it large basalt olistoliths, and smaller radiolarite clasts occur in shale and siliceous shale matrix (770–880 m) (Fig. 20).

While this interval still contains basalt blocks, we preferably classify this segment also to the Darnóhegy Mélange. Sandstone, shale, limestone and debris flow deposits prevail in the next segment (880–960 m). This mixed lithology shows similarities to an olistostrome/breccia-bearing Oldalvölgy Shale and to the Tarna Olistostrome. After a strongly fractured, brecciated interval (960–1100 m) a series of alternating limestone and shale with thin debrite interbeds was explored (1100–1200 m). The lower

Table 2. *Age assignment of the Triassic radiolarians from the Darnóhegy Mélange (borehole and surface outcrops)*

Locality	**Rm-131**								**Rm-136**					**Mély Valley**
Sample	781.4	780	771.7	767.22	602,7	594,8	346.4	342.9	374.5	354,8	196,4	124.8	114.8	4/07
Archaeocenospaera sp.	+		+	+		+								
Astrocentrus sp.		+												
Baumgartneria cf. *retrospina*		+							+					
Capnuchosphaera sp.						+						+		
Cryptostephanidium sp.		+												
"Entactinosphaera" cf. *triassica*														+
Muelleritortis cochleata				+	+									
Nassellaria gen. et sp. indet														+
Oertlispongus inaequispinosus		+												
Oertlispongus sp.										+	+			
Parasepsagon sp.														+
Paroertlispongus sp		+												
Plafkerium sp.								+						
Pseudostylosphaera cf. *coccostyla*	+													
Pseudostylosphaera goestlingensis						+								
Pseudostylosphaera longispinosa														+
Pseudostylosphaera sp.		+	+	+			+	+					+	
Sarla sp.						+								
Spongopallium sp.														+
Spumellaria gen. et sp. indet														+
Triassocampe cf. *scalaris*						+								
Triassocampe sp.				+				+		+			+	
Triassocampe sp. A sensu Gorican and Buser 1990		+												
Triassocampe spp.		+												
Tritortis kretaensis				+										
Age		*Anisian*		*Ladinian (Longobardian)*		*Carnian*						*Carnian*		*Middle Triassic*

part of the limestone succession is partly silicified. The main microfacies type is wackestone, while ooidal, crinoidal packstone is present in 3 horizons (Fig. 18). This lowermost part of the succession may correspond to the Oldalvölgy Limestone.

Rm-131

In well Rm-131 below the Darnóhegy Mélange, Triassic red cherty limestone olistoliths and blocks containing Triassic limestone and basalt occur in

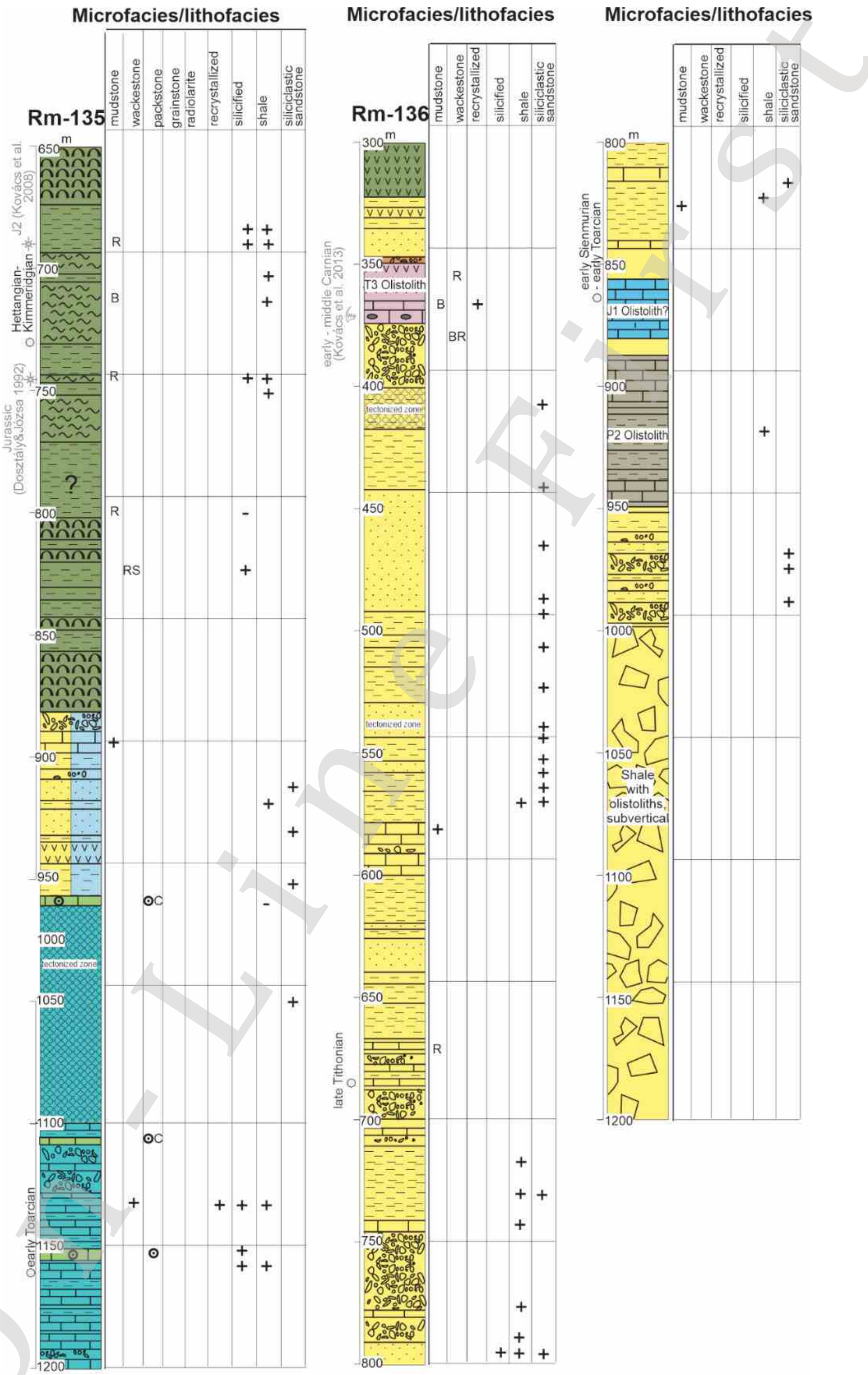

Fig. 18. *Mesozoic part of core Rm-135 and Rm-136: lithologies, microfacies and lithofacies types, fossil content. For the legend see Fig. 6.*

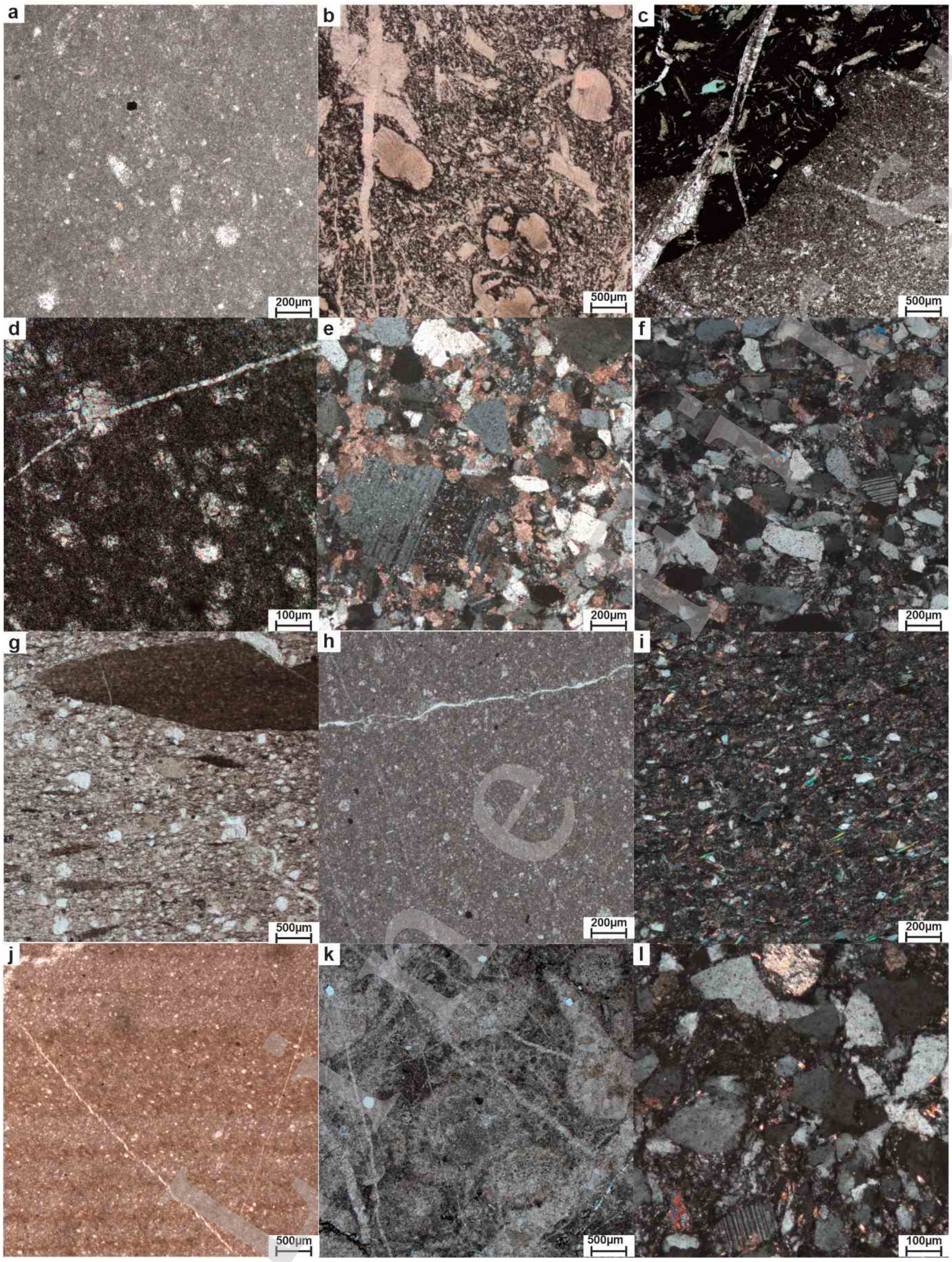

Fig. 19. *Characteristic microfacies types of the well Rm-136.* ***a)*** *Limestone; bioclastic wackestone with calcite occluded moulds of radiolarians and fragments of thin-shelled molluscs. 252.3 m;* ***b)*** *amygdaloidal basalt 367.7 m;* ***c)*** *sharp contact between limestone (bioclastic, peloidal wackestone) and basalt. 369 m;* ***d)*** *Limestone; bioclastic wackestone with calcite filled mould of radionarians. 380.6 m;* ***e)*** *Fine to coarse grained sandstone; it is made up predominantly of unrounded quartz (magmatic origin) with a few plagioclase grains; the intergranular pores are occluded by calcite cement (crossed polars). 466 m;* ***f)*** *Fine to medium grained sandstone; it is made up of unrounded quartz (magmatic origin) and plagioclase grains; the intergranular pores are occluded by quartz and calcite cement (crossed polars). 525.4 m;* ***g)*** *Sandy, clayey siltstone (shale) with claystone clasts which were subject of flattening and shearing and subsequent faulting. 576 m;* ***h)*** *673 m Limestone, mudstone with scattered calcite occluded moulds of radiolarians and sponge spicules;* ***i)*** *Sandy, clayey siltstone (shale). Along with quartz and mica there are a great number of claystone clasts in the fine sand to silt size grain fraction. 795.1 m;* ***j)*** *Limestone of mudstone fabric; micrite and microsparite microlayers alternate. Calcite filled moulds of radiolarians occur. 833.2 m;* ***k)*** *Limestone; bioclastic packstone. It is rich in fragments of green algae Mizzia velebitana and foraminifera and ostracods also occur (Upper Permian) 899.8 m;* ***l)*** *Fine to medium grained sandstone; it is made up mostly of unrounded quartz, and quartzite with small amount of plagioclase and mica; the intergranular pores are occluded by quartz and calcite cement (crossed polars). 982 m.*

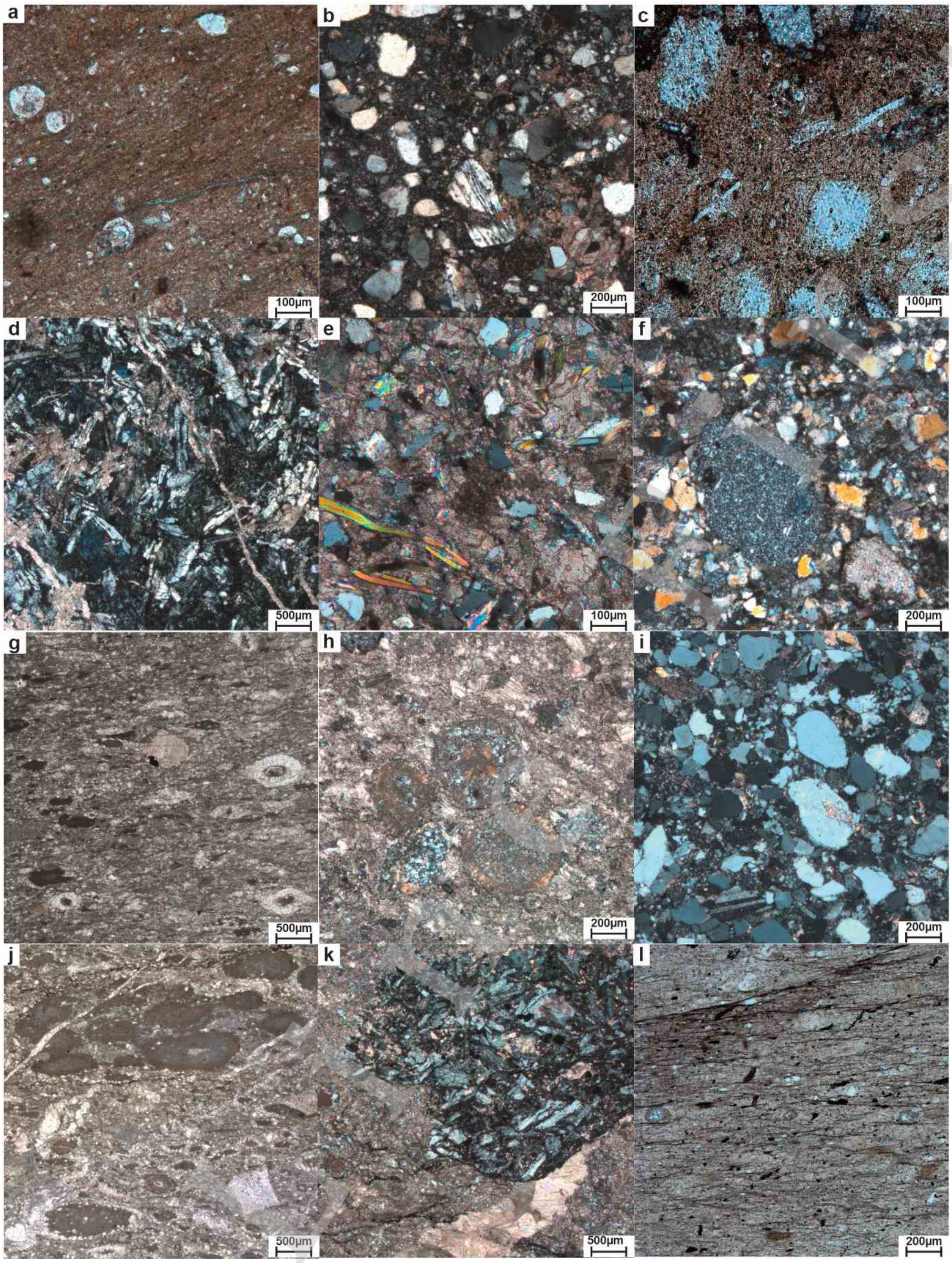

Fig. 20. Characteristic microfacies types of the well Rm-135. ***a)*** *Red sitly claystone/marl with tests and quartz occluded moulds of radiolarians (Jurassic?) 740 m;* ***b)*** *Silty sandstone; it is made up predominantly of unrounded/subrounded quartz grains, but a few recrystallized calcite grains also occur (crossed polars). 817 m;* ***c)*** *Silicified rock with quartz occluded moulds of radiolarians and sponge spicules. 818.2 m;* ***d)*** *Pillow basalt, 845 m;* ***e)*** *Sand-size siliciclastic grains occur in recrystallized carbonate matrix/cement. Unrounded quartz grains (magmatic origin) are dominant, but mica grains are also common (crossed polars). 915 m;* ***f)*** *Fine to medium grained sandstone; it is made up predominantly of unrounded quartz grains and a few larger rounded carbonate ? clasts (crossed polars) 960 m;* ***g)*** *Partially silicified limestone of peloidial–ooidal wackestone fabric. The originally globular peloids, ooids and also a crinoid ossicle exhibit layer-parallel flattening. 964.7 m (sample A);* ***h)*** *Partial selective silicification in some ooid grains (crossed polars) 964.7 m (sample B—perpendicular to sample A);* ***i)*** *Fine to medium grained sandstone; it is made up predominantly of unrounded to subrounded quartz (magmatic origin) with a few plagioclase and carbonate grains (crossed polars) 977 m;* ***j)*** *Limestone of oncoidal, ooidic packstone fabric. In microsparite matrix along with individual oncoids and ooids, intraclasts containing similar coated grains also occur. The grains exhibit parallel flattening.1114.9 m;* ***k)*** *Basalt clast in limestone 1153.8 m;* ***l)*** *Totally silicified radiolarian slate; ghosts of radiolarian tests are locally visible. 1160 m.*

shale and siliceous shale matrix (690–820 m) (Figs. 15, 21).

In the red cherty limestone olistolith Middle Triassic radiolarians were encountered (Dosztály et al., 2002). Middle Jurassic radiolarian fauna was found in black shale between two Triassic olistoliths (Dosztály, 1994; Dosztály & Józsa, 1992; Kovács et al., 2008). Sandstone, marl, shale and micritic argilla-

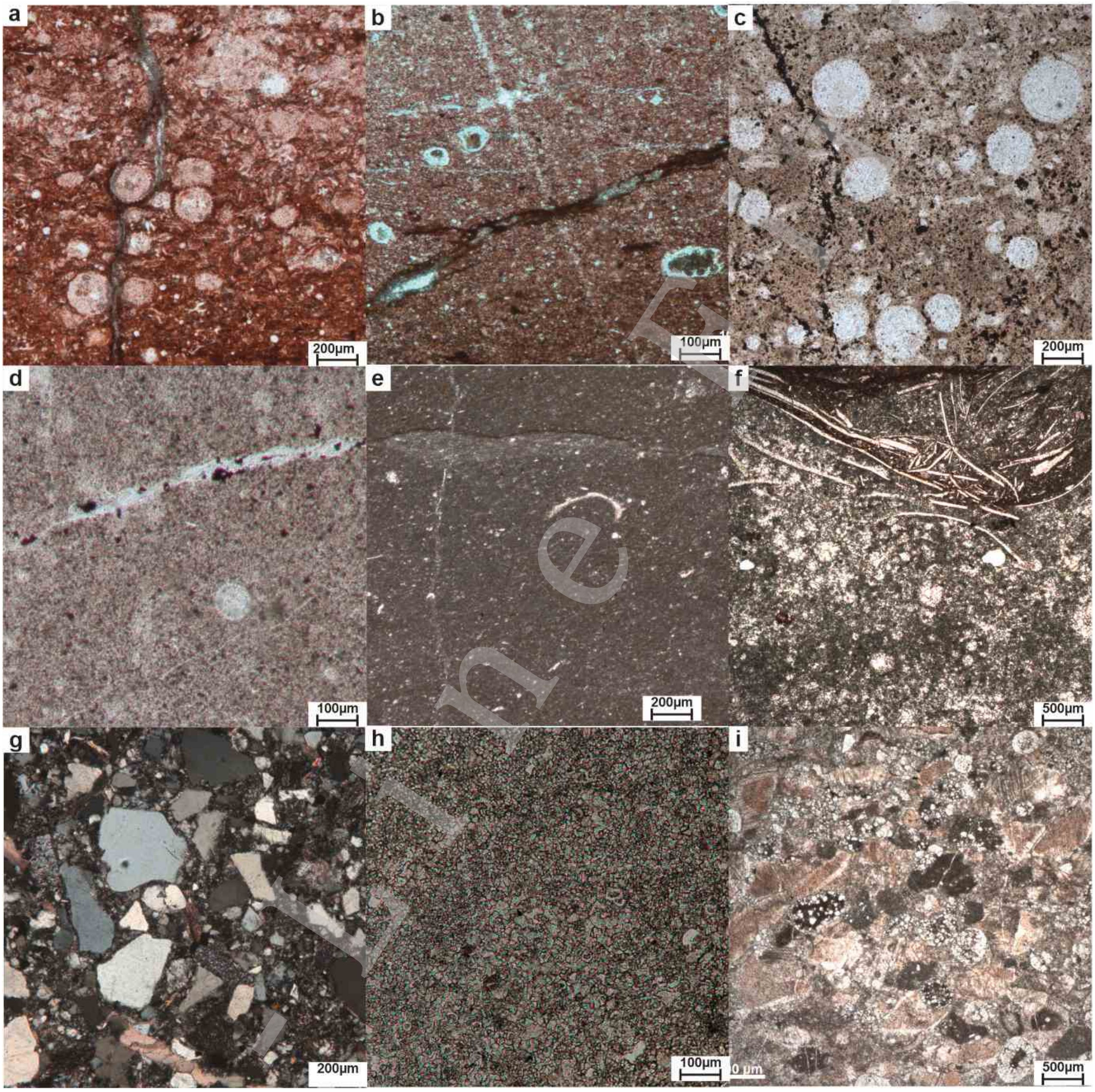

Fig. 21. *Characteristic microfacies types of the well Rm-131.* ***a)*** *Red silicified radiolarian-sponge spicule wackestone (Triassic) 347.5 m;* ***b)*** *Red silicified claystone with scattered tests of radiolarians (Jurassic?) 510.7 m;* ***c)*** *Chert with radiolarians and sponge spicules (Triassic) 603.5 m;* ***d)*** *Chert with ghost of radiolarians (Jurassic?) 693 m;* ***e)*** *Limestone of mudstone fabric with peloids and scattered fragments of thin-shelled bivalves and ostracods 736 m;* ***f)*** *Limestone of bioclastic wackestone fabric with radiolarians and fragments of thin-shelled bivalves (Triassic?). 741 m;* ***g)*** *Medium to coarse grained sandstone; it is made up predominantly of unrounded quartz (magmatic origin) and a few plagioclases, muscovite, chert and opac grains in siliceous cement/matrix (crossed polars). 820.5 m;* ***h)*** *Limestone; it is made up mostly of calcisphares (20–30 µm in size) and peloids in a microsparitic matrix. 951.8 m (sample A);* ***i)*** *Crinoidal limestone with micrite intraclasts and moulds if globular grains (probably dissolved ooids) The crinoid ossicles are surrounded by syntaxial sparry calcite rims. The globular grains are usually occluded by quartz. 951.8 m (sample B).*

ceous limestone were intersected in the next interval (820–900 m). This 690–900m part of the core can be assigned to the Tarna Olistostrome, however, the exact upper boundary towards the mélange cannot be defined unambiguously. Below it, pelagic limestone and argillaceous limestone typically with bioclastic mudstone and wackestone textures (Oldalvölgy Limestone) were explored in the lower part of the well (900–1200 m). Within this interval, crinoidal, ooidic, intraclastic grainstone was found in a few samples (951 and 971 m).

Calcareous nannofossil and radiolarian biostratigraphy

According to the categories of Bown (1992), the overall preservation of the nannofossils is poor to moderate. Diagenetic effects may have affected the assemblage due to the deep burial of the host rocks. Moreover, nannofossils are extremely rare in the samples, sometimes recrystallized, dissolved, overgrown and etched. Recorded taxa are shown on Fig. 22.

Rm-136

From a sample of 865.5m depth, a ?*Calcivascularis jansae* Wiegand (1984) is documented (Fig. 22.), which occurs from NJT2b to NJ6 nannozones. This indicates an interval between the early Sinemurian to early Toarcian age (199.5–180.5 Ma). Above, from a sample of 679.2 m depth, a *Conusphaera mexicana* subsp. *minor* Bown & Cooper (1989) (Fig 22) is observed and captured, which indicates NJ15a to NJ18 nannofossil subzones of the late Tithonian (149.2–145Ma).

Rm-135

From a sample of 731m depth, a specimen of *Schizosphaerella punctulata* Deflandre & Dangeard (1938) is documented (Fig. 22), which occurs between NJT1 and NJ16 nannozones. This indicates a long interval between the lowermost Hettangian to latest Kimmeridgian age (201.4–149.2Ma), however, it is most commonly found in Lower and Middle Jurassic deposits. This is a very resistant species to diagenesis, probably due to its robust structure and rather big size. Below, from a sample of 1165.3m, a *?Sollasites arctus* (Noël, 1973) Bown, 1987 (Fig. 22) is observed and captured, which indicates early Toarcian age of top NJ5 to lower NJ7 nannofossil zones (199.5–180.5Ma).

Rm-131

From a sample of 761m depth, a single specimen of *Conusphaera mexicana* subsp. *mexicana* Trejo (1969) is documented (Fig. 22), which indicates an age of NJ15b to NJ18 nannozones. This points towards the late Tithonian age (approx. 147.5Ma–145Ma) of the sample.

The radiolarian sample from 780.0 m contain *Oertlispongus inaequispinosus* Dumitrica et al. that indicates the upper subzone of the *Spongosilicarmiger italicus* Radiolarian zone (*Oertlispongus inaequispinosus* subzone) by Kozur & Mostler (1994), which belonged to the upper part of the Anisian, although recent radiolarian biostratigraphic results suggest that this zone may belong to the lower part of the *Eoprotrachyceras curionii* Ammonite Zone (Ozsvárt et al., 2023), thus it is probably Lower Ladinian age. The sample from 767.2 m contains *Muelleritortis cochleata* Kozur & Mostler, which suggests Ladinian (late Fassanian?–Longobardian) age.

In summary, newly encountered microfossil ages let us define the age of the Tarna Olistostrome as Tithonian, with some new clast ages like an early Sinemurian to early Toarcian limestone and Ladinian (cherty limestone clasts).

Discussion

General characteristics of the successions and their depositional environment

Recsk Succession: Triassic – lower Callovian passive margin succession

In the Recsk area upper Carnian–lower Norian, grey cherty limestone with marl interlayers (Felsőtárkány Limestone Fm.) is the oldest penetrated formation. The same lithology continues upwards for ~150m with lack of conodonts, which

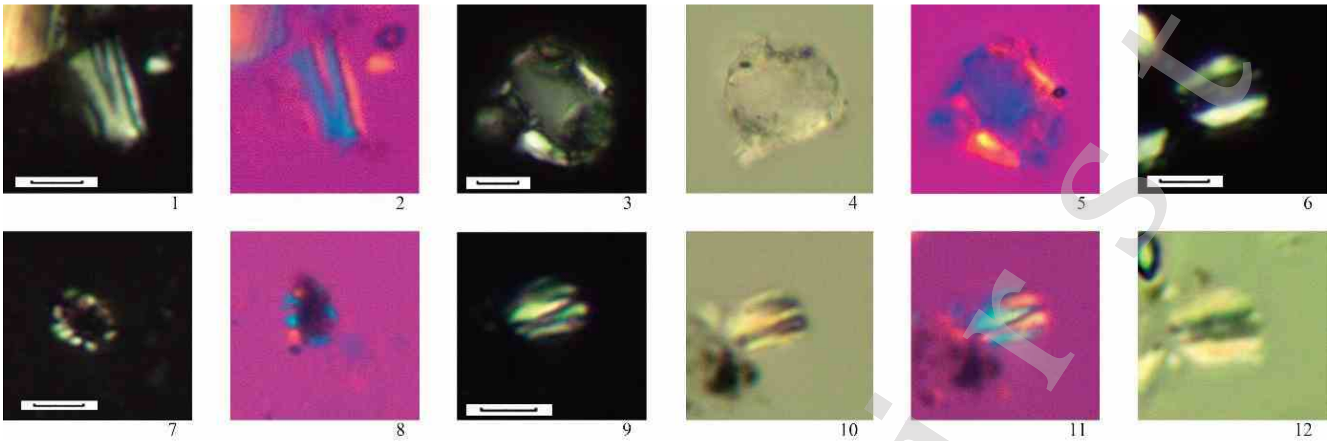

Fig. 22. *Nannofossils of the Rm-131, Rm-135 and Rm-136 drilling cores.* ***1, 2.*** *Conusphaera mexicana subsp. mexicana Trejo, 1969; Rm-131, 761 m; upper Tithonian.* ***3, 4, 5.*** *Schizosphaerella punctulata* Deflandre & Dangeard, 1938; *Rm-135, 731 m, lowermost Hettangian – uppermost Kimmeridgian.* ***7, 8.*** *Sollasites arctus* (Noël, 1973) Bown, 1987; *Rm-135, 1165 m, lower Toarcian.* ***9, 10, 11.*** *Conusphaera mexicana subsp. minor* Bown & Cooper, 1989; *Rm-136, 679.2 m, upper Tithonian.* ***6, 12.*** *Calcivascularis jansae Wiegand, 1984; Rm-136, 865.5 m, lower Sinemurian-lower Toarcian. Scale bar represents 5µ.*

may refer to early Jurassic age (Kovács et al., 2013). In some successions lower Norian grey, cherty dolomite (i.e. pervasively dolomitized pelagic carbonate) was encountered.

Both types of Upper Triassic–Lower Jurassic(?) succession is overlain by grey, occasionally cherty limestone, with claystone and marl intercalations (Oldalvölgy Limestone, Fig. 23). Observed microfacies types are indicative for pelagic depositional environments. The Oldalvölgy Limestone is a widespread lithology and was intersected by almost all of the examined boreholes. Its thickness changes across the area between 180 m to 1000 m (Fig. 23). Despite its widespread nature, due to scarcity of age-diagnostic fossils, chronostratigraphic assignment of the Oldalvölgy Limestone is particularly difficult. The core Rm-79 suggests post-Triassic, probably Early Jurassic age. In several cores calcite spheres of 10–20 µm diameter were observed in some cases in rock-forming quantities that can be assigned to the nannofossil group *Schizosphaerella.* This group has a long range from the Early to the Late Jurassic. Our new nannofossil data proved the Early Jurassic (early Sinemurian–early Toarcian) minimum age of the formation. Considering the overlying Oldalvölgy Shale lithofacies unit, the age can be assigned to early Sinemurian–Bathonian.

There is a gradual lithological transition from the Oldalvölgy Limestone to the Oldalvölgy Shale; the grey micritic limestone progresses to grey marl and shale, which pass upward to grey shale with sandstone intercalations. Red radiolarian marl was also encountered in one of the boreholes (Rm-25). Breccia layers also occur with radiolarite, claystone/shale and sandstone lithoclasts. The sandstone intercalations are fine- to coarse-grained; the dominant minerals are quartz, muscovite, plagioclase and chlorite. The age of this lithofacies unit was determined to be late Bathonian–early Callovian thus the cessation of carbonate deposition, and gradual change into the siliciclastic sedimentation may have taken place during the Bathonian. This lithofacies unit is the uppermost element within the detected passive margin sequence, which will be referred to as Recsk Succession.

Intensive silicification of both the limestone and shale is quite common, especially at the upper part of the succession, where radiolarite also occurs locally.

A unique succession was explored in borehole Rm-109 in the south-westernmost part of the area (Figs. 1c, 6, 23c). Here, in contrast with all the other boreholes, a platform carbonate succession was found directly below the Oldalvölgy Shale of late

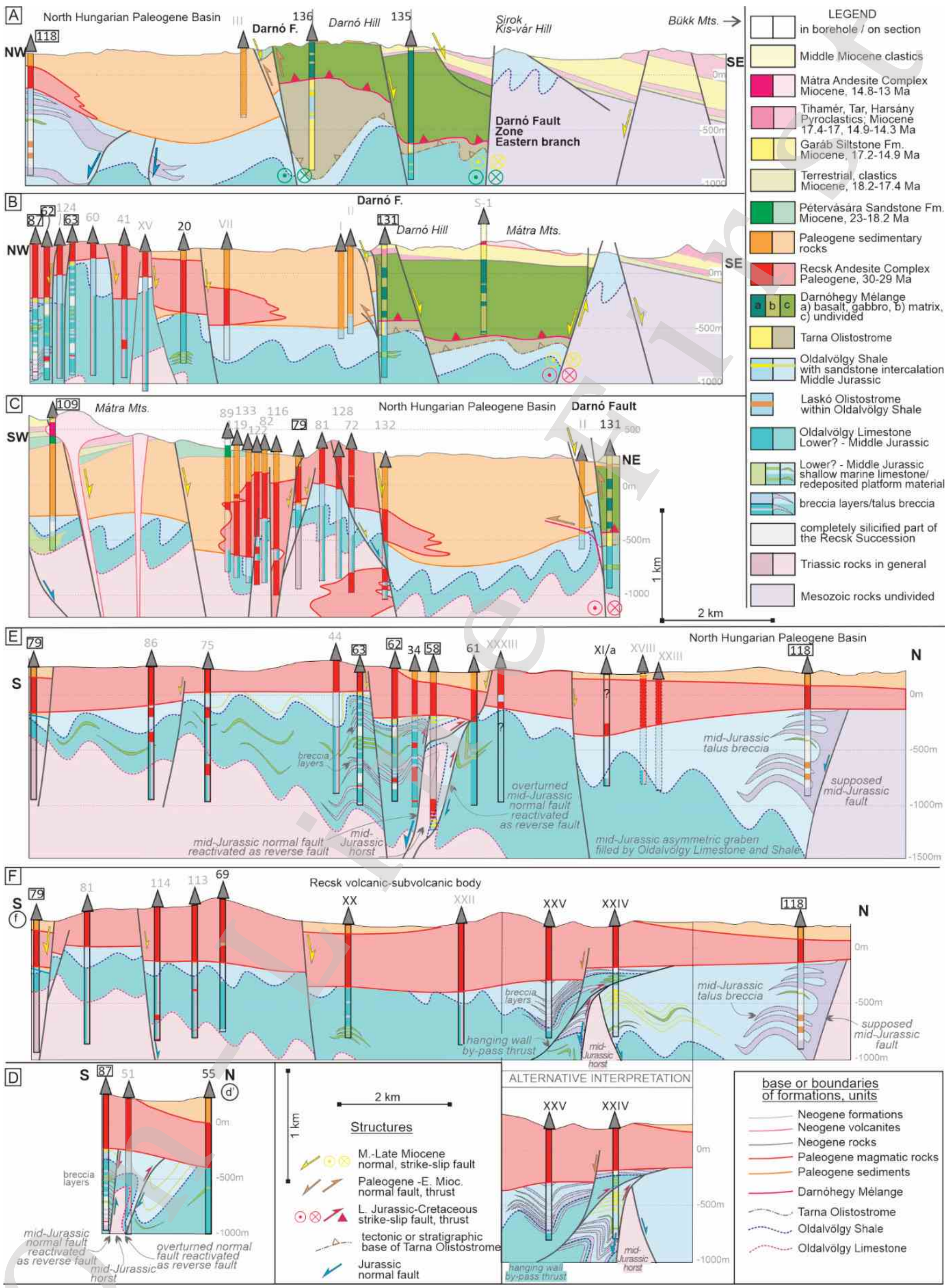

Fig. 23. *Geological cross-section of the Recsk and Darnó area. The locations of the sections are indicated on Fig. 3. Note 2X vertical exaggeration.*

Bathonian to early Callovian age. (Haas et al., 2006). The microfossil assemblage and microfacies analysis suggest platform margin as site of deposition (Fig. 8). The age of the succession is early Bajocian, which is coeval with the formation of the more distal pelagic Oldalvölgy Limestone. We classify all these rock types as part of a passive margin Recsk Succession although the depositional environment of the rocks of Rm-109 was more proximal. In the Recsk area, the Oldalvölgy Shale is the uppermost known Mesozoic lithofacies unit. In the boreholes it is capped by an erosional surface followed either by Paleogene sedimentary rocks or the volcanic–sub-volcanic build-up of the Recsk Andesite Complex (Figs 1c, 23).

The limestone- to shale-dominated transition in the Bathonian may represent either the cessation of pelagic carbonate source or deepening of the depositional area. While this change equally occurs in the westernmost bore, where the change in depositional depth seems to be more important, we attribute the lithological change to a Bathonian deepening of the basin. Despite the subsidence, the occurrence of gravity mass flow deposits continued and partly sourced on the Adriatic Carbonate Platform. This source of clasts, and the platform-related development of the Rm-109 borehole suggest that the RS was deposited from the Neotethayn intra-oceanic subduction and can not be considered as a tectonic mélange.

Tarna Olistostrome (TarO): Late Jurassic sedimentary complex

East of the Darnó Fault Zone, in the Darnó Hill area above the Oldalvölgy Limestone and Shale two other stratigraphic units are preserved (Dimitrijević et al., 2003; Kovács et al., 2008). The lower unit (Tarna Olistostrome) that is intersected by Rm-131, Rm-135(?) and Rm-136 in a remarkable thickness (200m to 900m, respectively), comprises dark grey shale, siliceous shale, sandstone, red claystone, radiolarite, pelagic, occasionally cherty limestone, with olistostromes and large blocks (olistoliths) of Upper Permian, Triassic and Jurassic limestones and red and grey Triassic and Jurassic radiolarites are also present.

Our new early Sinemurian–early Toarcian age data from a grey, pelagic limestone block gives important additional information on the Early Jurassic stratigraphy of the source area, while the newly detected Tithonian age for the time of deposition has great importance. A deep marine basin may have been the depositional environment, where carbonates and fine siliciclastic mud were deposited as “background” sediments and were also supplied by mass flows at least from two sources: 1) siliciclastic source for the sandstone turbidite layers; 2) exposed older carbonate and radiolarite-bearing succession for the olistostrome and olistoliths. The upper part of the series is truncated by the basal thrust of the overriding Darnóhegy Mélange nappe, and also the lower contact is most probably of tectonic origin, thus fining or coarsening trends cannot be deduced.

Darnóhegy Mélange: Callovian – Oxfordian sub-ophiolitic mélange

The uppermost unit of the cores Rm-131, -135, and -136 (Figs. 1c, 15, 18, 23) can be classed to the Darnóhegy Mélange, which is a block-in-matrix style complex composed mainly of massive and pillow basalt blocks with red claystone, red and black radiolarite and cherty/silicified limestone intercalations and/or matrix layers (Kovács et al., 2008; Kiss et al. 2012, 2023). In many cases determination of the boundaries of the different blocks were not easy, while the shale and radiolarite can either represent the matrix, individual block or the original sedimentary cover of basaltic blocks. In line with the previous concepts, we interpret the Triassic basalt and distal margin sediments as upper crustal fragments crapped off the undergoing plate, while the Middle Jurassic basalts and radiolarites as blocks deriving from the overriding upper plate ophiolite nappe. Radiolarites with uncertain position can be either matrix, or upper plate-derived blocks. Re-evaluation of the radiolarian fauna from the boreholes resulted in the extension of the previously assumed depositional age interval to a longer Callovian to Oxfordian range. Based on its lithology, both lower and upper plate origin of the clasts and its age, we agree with the previous concept, that the Darnóhegy Mélange is a real sub-ophiolitic mélange that was formed during the early-stage emplacement of the upper-plate Western Vardar Ophiolite (Kovács et al. 2008, 2011a, b; Schmid et al. 2008, 2020). The Miocene conglomerate and sandstone of the surroundings of the Darnó Hill contains pebbles and sand-sized clasts of the mélange (Sztanó & Józsa 1996) but also metaultrabasics (mainly serpentinites, Józsa 2024) which could represent the now-eroded uppermost ophiolitic nappe.

Connections towards the Bükk Mountains

The Recsk Succession (RS) resembles the Mónosbél Complex (MC) (Fig. 2, 24) of the Bükk Mts. in several aspects. Both units contain pelagic limestones, shales, sandstones, olistostromes and breccias with angular radiolarite clasts (Csontos, 1999; Haas et al., 2013; Scherman, 2018; Fialowski, 2018).

However, the MC has no preserved Triassic part, and the fine-grained pelagic limestones do not form a continuous part of the succession (Fig. 2), but occur within shales, which contrasts with boreholes in the Recsk area. On the other hand, the MC olistostromes contain more variable clast composition than in the RC, e.g, Triassic acidic to neutral magmatites (Csontos, 1988; Kövér et al., 2018b), low-grade metamorphic clasts (Pelikán et al., 2005). In the MC the lateral lithological changes are frequent and complex, albeit this could be due to bias derived from observation types: outcrops instead of boreholes. Despite the lithological similarities, temporarily we keep these two successions separate; a potential future unification is not excluded but needs further studies.

There are significant differences between the Recsk and Bánkút Successions (BS) in their Upper Triassic and Jurassic formations. While the previous one contains a more or less continuous succession from the pelagic Upper Triassic to the Bathonian, the BS is characterised by a long period of non-deposition/submarine erosion from the uppermost Triassic till the Bajocian (Haas et al., 2012) or the Callovian (Csontos et al., 1991; Dosztály 1994) (Fig. 2). This very reduced succession may refer to the elevated position (submarine high/horst) of the whole Bánkút Succession area (Fig. 24). Thus, both the BS and the surroundings of borehole Rm-109 represents elevated

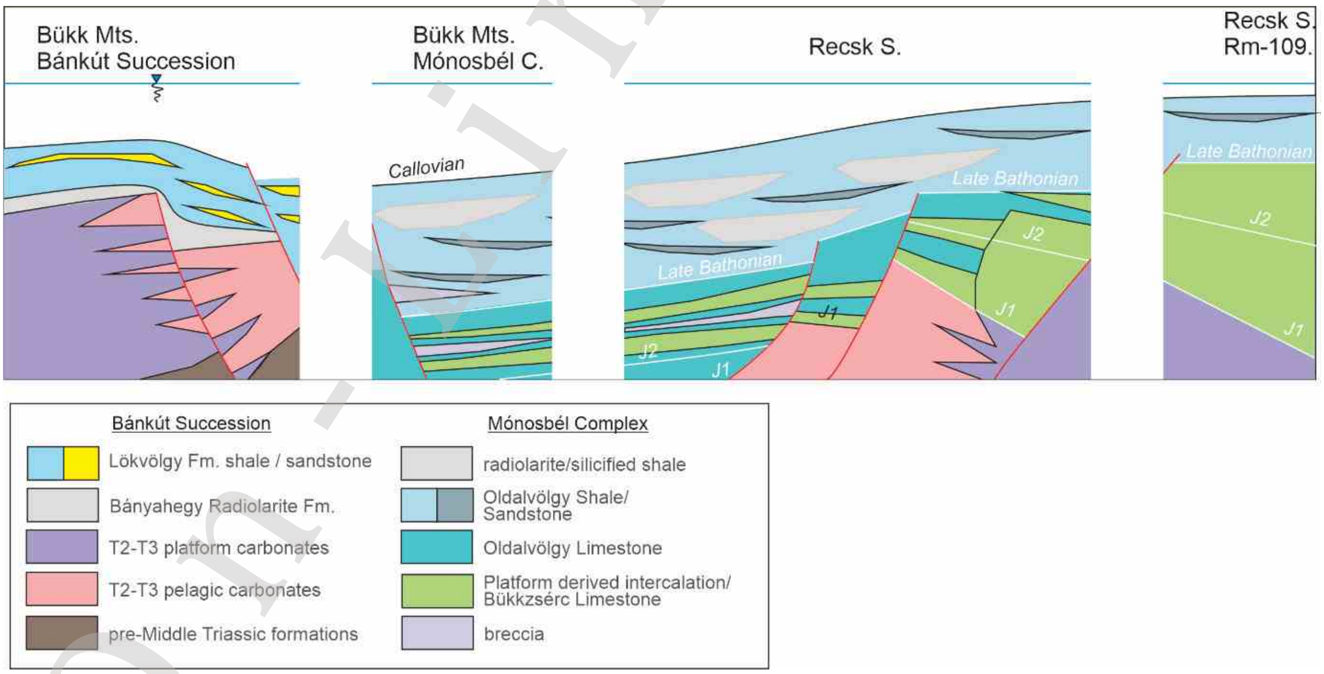

Fig. 24. Possible paleogeographic connections in the Middle Jurassic between the Bánkút Succession, the Mónosbél Complex of the Bükk Mts. and the Recsk Succession of the Recsk area. Note, that the four separate segments do not necessarily were positioned along one strait section.

areas, however, the latter one has continuous carbonate platform develepement from the Late Triassic till the Bajocian. The rest of the RS and the MC represents deeper areas, grabens with sediment transport from the elevated horsts (Fig. 24). All these observations support the location of the original depositional area of both the MC and RS to be distinct from the Bánkút Succession. This conclusion is not surprising from the postulated nappe position of the MC over the BS (Csontos, 1999, 2000).

Conclusion

The examined core material in the south-eastern part of ALCAPA, between the Austroalpine related Transdanubian Range and the Bükk Mts. of Dinaric affinity resulted in the following conclusions. The pre-Cenozoic basement of the area is characterised by three juxtaposed units: the lowermost Recsk Succession (RS), the Tarna Olistostrome (TarO) and the topmost Darnóhegy Mélange nappe (DM). The lowermost penetrated part of the RS is built up by upper Carnian–lower Norian, grey cherty limestone with marl interlayers or its dolomitized version (Felsőtárkány Fm.). It is overlain by grey pelagic limestone with occasional chert nodules of Early to early Middle Jurassic age, prior to the late Bathonian (Oldalvölgy Limestone). The predominantly carbonate sedimentation changed gradually into siliciclast-dominated one, during the late Bathonian to the early Callovian (Oldalvölgy Shale). In the Bajocianto early Callovian interval the Recsk area was located at the toe of a coeval carbonate platform, which was penetrated by core Rm-109. The external margin of thisplatform was active till the late Bathonian, when it drowned and covered by the pelagic Oldalvölgy Shale. The RS is juxtaposed by the Tarna Olistostrome. The transition between the two units is suggested to be of tectonic origin, however, it cannot be excluded that the TarO represents the original sedimentary cover of the underlying RS. The TarO is built up by a Tithonian pelagic mixed carbonatic and siliciclastic succession with breccia/olistostrome horizons and tens-of-metres scale olistolites. The clasts derived from the Upper Permian–Lower Jurassic succession of a distal Adriatic margin. The DM is a typical sub-ophiolitic mélang nappe overriding the TarO. It is built up by scrapped off blocks and slices from the lower plate and gravitationally redeposited blocks from the overriding ophiolite nappe, namely Middle Triassic and Middle Jurassic basalt and gabbro blocks with their sedimentary cover and radiolarite and shales both as blocks and matrix. The age of the mélange is Callovian–Oxfordian.

Acknowledgements

The Bükk National Park, and particularly S. Holló facilitated the field work and assisted at discussions. Field work of B. Scherman during his MSc work contributed to the knowledge on the Mónosbél Complex. The authors thank P. Gál for the usage of his unpublished uncovered geological map of the Sirok area. B. Beke and A. Petrik assisted at field work around the Darnó Fault Zone. The research was supported by the National Research, Development and Innovation Office of Hungary, project 134873 (LF). This study was supported by the National Research, Development and Innovation Office (project no.: K135309). The present study is HUN-REN-MTM-ELTE paleo contribution No. 414 (PO). N. Djerić acknowledges the Ministry of Science, Technological Development and Innovation of the Republic of Serbia (Contract no. 451-03-65/2024-03/200126) and Science Fund of the Republic of Serbia (Grant no. TF C1389-YF/Project no. 7461). Careful reviews of Milan Sudar (Belgrade) and Nikita Bragin (Moscow) and their suggestions are gratefully acknowledged.

References

Aigner-Torres, M. & Koller, F. 1999. Nature of the magma source of the Szarvaskö Complex (NE-Hungary): petrological and geochemical constraints. *Ofioliti*, 24 (1a): 1-12.

Arató, R., Dunkl, I., Takács, Á., Szebényi, G., Gerdes, A. & von Eynatten, H. 2019. Thermal evolution in the exhumed basement of a stratovolcano: case study of the Miocene Mátra Volcano, Pannonian Basin. *Journal of the Geological Society of London,* 175 (5): 820–835.

Árkai, P. 1983. Very low- and low-grade Alpine regional metamorphism of the Paleozoic and Mesosoic formations of the Bükkium, NE Hungary. *Acta Geologica Hungarica,* 26(1-2): 83-101.

Árkai P., Balogh, K. & Dunkl, I. 1995. Timing of the low-temperature metamorphism and cooling of the Paleozoic and Mesozoic formations of the Bükkium, innermost West Carpathians, Hungary. *Geologische Rundschau,* 84: 334-344.

Árváné Sós, E., Balogh, K., Ravaszné Baranyai, L. & Ravasz, Cs. 1985. Mezozóos magmás kőzetek K/Ar kora Magyarország egyes területein [Mesozoic igneous rocks, K/Ar age, in some areas of Hungary - in Hungarian]. *Annual Report of the Hungarian Geological Institute,* 1987: 295-307.

Balla, Z. 1983. A szarvaskői szinform rétegsora és tektonikája [Stratigraphy and tectonics of the Szarvaskö synform - in Hungarian]. *Annual Report of the Eötvös Lóránd Geophysical Institute from 1982*, 42–65.

Balla, Z. 1987. Tectonics of the Bükkian (North Hungary) Mesozoic and relation to the West Carpathians and Dinarides. *Acta Geologica Hungarica 30*(3-4), 257-287.

Balogh, K. 1964. Die geologischen Bildungen des Bükk-Gebirges. *Annals of the Geological Institute of* Hungary, 48 (2): 245-719.

Baumgartner, P.O., Bartolini, A., Carter, E.S., Conti, M., Cortese, G., Danelian, T., De Wever, P., Dumitrica, P., Dumitrica-Jud, R., Goričan, Š., Guex, J., Hull, D., Kito, N., Marcucci, M., Matsuoka, A., Murchey, B., O'Dogherty, L., Savary, J., Vishnevskaya, V., Widz, D. & Yao, A. 1995. Middle Jurassic to Early Cretaceous radiolarian biochronology of Tethys based on Unitary Associations. In: Baumgartner, P.O., O'Dogherty, L., Goričan, Š., Urquhart, E., Pillevuit, A. & De Wever, P. (Eds.). *Middle Jurassic to lower Cretaceous radiolaria of Tethys: Occurrences, Systematics, Biochronology*. Mémories de Géologie, 23: 1013–1048.

Bérczi-Makk, A. 1999. Foraminiferal stratigraphy of Jurassic beds in Bükkzsérc, N-Hungary. *Földtani Közlöny*, 129 (3): 363-392.

Bown, P.R. 1992. New calcareous nannofossil taxa from the Jurassic/Cretaceous boundary interval of sites 765 and 261, Argo Abyssal Plain. *In*: Gradstein, F.M., Ludden, J.N., et al. (Eds.). *Proceedings of the Ocean Drilling Program, Scientific Results, College Station, TX (Ocean Drilling Program)*, 123: 369-379

Csontos, L. 1988. *Étude géologique d'une portion des Carpathes internes: le massif du Bükk (Nord-est de la Hongrie).* PhD Thesis, Université Lille Flandres-Artois, n° 250, 327 pp. Lille, France.

Csontos, L. 1999. Structural outline of the Bükk Mts. (N. Hungary). *Földtani Közlöny,* 129 (4): 611-651.

Csontos, L. 2000. Stratigraphic re-evaluation of the Bükk Mts., Hungary. *Földtani Közlöny,* 130 (1): 95-131.

Csontos, L. & Nagymarosy, A. 1998. The Mid-Hungarian line: a zone of repeated tectonic inversion. *Tectonophysics,* 297*:* 51–72.

Csontos, L., Dosztály, L. & Pelikán, P. 1991. Radiolarians from the Bükk Mts. *Annual Report of the Geological Institute of Hungary from 1985*, 357-409.

De Wever, P. 1984. Triassic radiolarians from the Darnó area (Hungary). *Acta Geologica Hungarica,* 27 (3-4): 295-306.

Dimitrijević, M.N., Dimitrijević, M.D., Karamata, S., Sudar, M., Gerzina, N., Kovács, S., Dosztály, L., Gulácsi, Z., Less, Gy. & Pelikán, P. 2003. Olistostrome/mélanges – an overview of the problematics and preliminary comparison of such formations in Yugoslavia and NE Hungary. *Slovak Geological Magazine*, 9 (1): 3-21.

Dosztály, L. 1989. Triassic radiolarians from Dallapuszta (Mount Darnó, N Hungary). *Annual Report of the Geological Institute of Hungary from 1988*, 193-201.

Dosztály, L. 1994. Mesozoic radiolarian investigations in Northern Hungary. Unpublished PhD Thesis, 108 pp. (in Hungarian)

Dosztály, L. & Józsa, S. 1992. Geochronological avaluation of Mesozoic formations of Darnó Hill at Recsk on the basis of radiolarians and K-Ar age data. *Acta Geologica Hungarica,* 35 (4): 371-393.

Dosztály, L., Józsa, S., Kovács, S., Less, Gy., Pelikán, P. & Péró, Cs. 2002. North-East Hungary – post congress excursion guide. In: Vozár, J., Vojtko, R. & Sliva, L. (Eds.). Guide to geological excursions, XVIIth Congress of Carpathian – Balkan Geological Association, Bratislava, 104–117.

Dunham, R.J. 1962. *Classification of carbonate rocks according to depositional texture*.

Fodor, L., Jelen, B., Márton, E., Skaberne, D., Čar, J. & Vrabec, M. 1998. Miocene-Pliocene tectonic evolution of the Slovenian Periadriatic Line and surrounding area – implication for Alpine-Carpathian extrusion models. *Tectonics*, 17: 690–709.

Földessy-Járányi, K. 1975. Deep-seated sedimentary rocks of the basement at Recsk. *Földtani Közlöny,* 105: 598–611.

Folk, R.L 1959. Practical petrographic classification of limestones. *AAPG Bull*., 43: 1–38.

Gál, P., Pecsmány, P., Petrik, A., Lukács, R., Fodor, L., Kövér, Sz. & Harangi, Sz. 2021. A Sirok környéki miocén rétegsor földtani és geomorfológiai reambulálása [*Geological and geomorphological reambulation of the Miocene strata around Sirok* – in Hungarian]. In: Füri, J. & Király, E. (Eds.). Átalakulások, 11. Kőzettani és Geokémiai Vándorgyűlés, Sopron, 2021. September 02-04., Geological Society of Hungary, 23.

Gecse, Zs. 2006. A Darnó-hegy mezozoós képződményei és környékének triász conodontái [Triassic conodonts of the Mesozoic formations of Darnó-hegy and its surroundings – in Hungarian]. MSc Thesis, Department of Geography, Eszterházy College, Eger, 58 pp.

Gradstein, F.M., Ogg, J.G., Schmitz, M.D. & Ogg, G.M. 2020. *Geologic time scale 2020.* Amsterdam: Elsevier.

Gyalog, L. & Síkhegyi, F. 2005. *Geological map of Hungary, 1:100 000*. Geological Institute of Hungary, Budapest.

Haas, J. & Kovács, S. 2001. The Dinaridic-Alpine connection – as seen from Hungary. *Acta Geologica Hungarica,* 44 (2-3): 345-362.

Haas, J., Görög, Á., Kovács S., Ozsvárt, P., Matyók I. & Pelikán, P. 2006. Displaced Jurassic foreslope and basin deposits of Dinaridic origin in Northeast Hungary. *Acta Geologica Hungarica*, 49 (2-3): 345-362.

Haas, J., Budai, T., Csontos, L., Fodor, L. & Konrád, Gy. 2010. *Pre-Cenozoc geological map of Hungary, 1:500000.* Geologoical Institute of Hungary.

Haas, J., Kovács, S., Gawlick, H.J., Grădinaru, E., Karamata, S., Sudar, M., Péró, Cs., Mello, J., Polák, M., Ogorelec, B. & Buser, S. 2011. Jurassic evolution of the tectonostratigraphic units in the Circum-Pannonian region. *Jahrbuch der Geologischen Bundesanstalt,* 151 (2): 125-163.

Haas, J., Kovács, S., Pelikán, P., Kövér Sz., Görög, Á., Ozsvárt, P. Józsa, S. & Németh, N. 2012. Remnants of the accretionary complex of the Neotethys Ocean in Northern Hungary. *Földtani Közlöny*, 141 (2): 167-196.

Haas, J., Pelikán, P., Görög, Á., Józsa, S. & Ozsvárt, P. 2013. Stratigraphy, facies and geodynamic settings of Jurasic formations in the Bükk Mountains, North Hungary: its relations with the other areas of the Neotethyan realm. *Geological Magazine*, 150: 18-49.

Harangi, Sz., Szabó, Cs., Józsa, S., Szoldán, Zs., Árváné Sós, E., Balla, M. & Kubovics, I. 1996. Mesozoic igneous suits in Hungary: implications for genesis and tectonic setting in the northwestern Tethys. *International Geological Revue,* 38: 336-360.

Józsa, S. 1999. *Petrography and geochemistry of ocean floor magmatic rocks of Darnó Hill, HE Hungary.* PhD thesis. Eötvös Loránd University, Budapest, 137pp.

Józsa, S., Dosztály, L., Gulácsi, Z. & Kovács, S. 1996. Ophiolites of Szarvaskő, Darnó Hill and Bódva Valley. *Excursion guide IGCP-369. Workshop of rift magmatism*, Budapest, 16.

Józsa, S. 2024. Petrography of Ophiolitic Detritus from a Miocene Conglomerate Formation on Darnó Hill, SW Bükk Mts (N Hungary): A Unique Tool to Trace Covered Ophiolitic Sequences. *Minerals*, 14: 983.

Kiss, G., Molnár, F., Koller, F. & Péntek, A. 2011. Triassic advanced rifting related and Jurassic ophiolite-like magmatic rocks in the Bükk Unit, NE-Hungary – an overview. *Mitt. Österr. Miner. Ges.*, 157.

Kiss, G., Molnár, F., Pálinkás, L., Kovács, S. & Horvatovic, H. 2012. Correlation of Triassic advanced rifting-related Neotethyan submarine basaltic volcanism of the Darnó Unit (NE-Hungary) with some Dinaridic and Hellenidic occurrences on the basis of volcanological, fluid–rock interaction, and geochemical characteristics. *International Journal of Earth Sciences,* 101: 1503-1521.

Kovács, S., Haas J., Szebényi G., Gulácsi, Z., Józsa, S., Pelikán, P., Bagoly-Árgyelán G., Görög, Á., Ozsvárt, P. Gecse, Zs. & Szabó, I. 2008. Permo-Mesozoic formations of the Recsk-Darnó Hill area: stratigraphy, and structure of the Pre-Tertiary basement of the Paleogene Recsk Ore Field. *Communication of the University of Miskolc, I. Mining,* 73: 33-56.

Kovács, S., Sudar, M., Grădinaru, E., Karamata, S., Gawlick, H.J., Haas, J., Péró, Cs., Gaetani, M., Mello, J., Polák, M., Aljinićić, D., Ogorelec, B., Kollar-Jurkovšek, T., Jurkovšek, B. & Buser, S. 2011a. Triassic evolution of the tectonostratigraphic units in the Circum-Pannonian region. *Jahrbuch der Geologischen Bundesanstalt*, 151 (3–4): 199–280.

Kovács, S., Haas, J., Ozsvárt, P., Palinkaš, L.A., Kiss, G., Molnár F., Józsa, S. & Kövér, Sz. 2011b. Re-evaluation of the Mesozoic complexes of Darnó Hill (NE Hungary) and comparisons with Neotethyan accretionary complexes of the Dinarides and Hellenides – preliminary data. *Central European Geology,* 53 (2-3): 205-231.

Kovács, S., Gecse, Zs., Pelikán, P., Zelenka., T., Szebényi, G. & Szabó, I. 2013. Upper Triassic conodonts from deep boreholes of the Recsk—Darnó area: new data on the geology of its pre-Cenozoic basement. *Földtani Közlöny,* 141 (1): 29-46.

Kövér, S., Fodor, L. & Haas, J. 2018a. Tectonic overview map of the Carpathian-Pannonian area. In: Kocsis, K., Gercsák, G., Horváth, G., Keresztesi, Z. & Nemerkényi, Zs (Eds.). *National atlas of Hungary: volume 2. Natural environment* Budapest, Magyarország : Geographical Institute, Research Centre for Astronomy and Earth Sciences.

Kövér, S., Fodor, L., Kovács, Z., Klötzli, U., Haas, J., Zajzon, N. & Szabó, C. 2018b. Late Triassic acidic volcanic clasts in different Neotethyan sedimentary mélanges: paleogeographic and geodynamic implications *International Journal of Earth Sciences*, 107 (8): 2975-2998.

Kozur, H. 1984. New radiolarian taxa from the Triassic and Jurassic. *Geol. Paläont. Mitt.,* 13 (2): 49-88.

Kozur, H. 1991. The evolution of the Meliata-Hallstatt ocean and its significance for the early evolution of the Eastern Alps and Western Carpathians. *Palaeography, Palaeoclimatology Palaeoecology,* 87: 109–135.

Kozur, H. & Krahl, J. 1984. Erster Nachweiss triassischer Radiolaria in der Phyllit-Gruppe auf der Insel Kreta. *N. Jb. Geol. Paläont.*, 77: 400-404.

Kozur, H. & Mostler, H. 1981. Beitrage zur Erforschung der mesozoischen Radiolarien. *Geologisch-Paläontologische Mitteilungen Innsbruck*, 1: 208.

Kozur, H. & Mostler, H. 1994. Anisian to Middle Carnian radiolarian zonation and description of some stratigraphically important radiolarians. *Geologisch-Paläontologische Mitteilungen Innsbruck. Sonderband*, 3: 39–255.

Less, Gy. & Mello, J. 2004. *Geological map of the Gemer-Bükk area, 1:100.000*. MÁFI, Budapest, and GÚDS, Bratislava.

O'Dogherty, L., Carter, E.S., Dumitrica, P., Goričan, Š., De Wever, P., Bandini, A.N., Baumgartner, P.O. & Matsuoka, A. 2009. Catalogue of Mesozoic radiolarian genera. Part 2: Jurassic-Cretaceous. *Geodiversitas,* 31: 271–356.

O'Dogherty, L., Goričan, Š. & Gawlick, H.J. 2017. Middle and Late Jurassic radiolarians from the Neotethys suture in the Eastern Alps. *Journal of Paleontology,* 91: 25–72.

Oravecz, J. 1971. Report on petrographic investigations of ore exploratory boreholes Rm-14, -44, -51, -55, -58, -59, -60, and studies performed on the Darnó Hill, and Kis Várhegy, Nagy Várhegy at Sirok. Unpublished report (in Hungarian), Repository of the Eötvös Loránd University.

Ozsvárt, P., Rieber, H. & Brack, P. 2023. Middle Triassic radiolarians from the Dolomites, Southern Alps, Italy. *Geo.Alp*, 20: 5-100.

Pelikán, P. 2012. Oldalvölgyi Formáció [Side Valley Formation – in Hungarian]. In: Főzy, I. (Ed.). *Magyarország litosztratigráfiai alapegységei - jura* [*Lithostratigraphic Units of Hungary – Jurassic* - in Hungarian]. Geological Society of Hungary, 118-120.

Pelikán, P., Less, Gy., Kovács, S., Pentelényi, L. & Sásdi, L. 2005. *Geology of the Bükk Mountains. Explanatory Book to the Geological Map of the Bükk Mountains, 1:50.000.* Geological Institute of Hungary, 284 pp.

Pessagno, E.A. & Newport, R.L. 1972. A technique for extracting Radiolaria from radiolarian cherts. *Micropaleontology,* 18: 231-234.

Schréter, Z. 1952. Levés réambulatifs dans la partie méridionale de la Montagne de Bükk. *Annual Report of the Hungarian Geological Institute for 1944*, 45–48.

Schmid, S.M., Bernoulli, D., Fügenschuh, B., Matenco, L., Schefer, S., Schuster, R., Tischler, M. & Ustaszewski, K. 2008. The alpine-carpathian-dinaridic orogenic system: correlation and evolution of tectonic units. *Swiss Journal of Geosciences,* 101 (1): 139–183.

Schmid, S.M., Fügenschuh, B., Kounov, A., Maţenco, L., Nievergelt, P., Oberhänsli, R., Pleuger, J., Schefer, S., Schuster, R., Tomljenović, B., Ustaszewski, K. & van Hinsbergen, D.J.J. 2020. Tectonic units of the Alpine collision zone between Eastern Alps and western Turkey. *Gondwana Research,* 78: 308–374.

Sztanó, O. & Józsa, S. 1996. Interaction of basin-margin faults and tidal currents on nearshore sedimentary architecture and composition: a case study from the Early Miocene of northern Hungary. *Tectonophysics*, 266: 319–341.

Velledits, F. 2000. Evolution of the area from the Berva Valley to the Hór Valley in the Middle-Late Triassic. *Földtani Közlöny,* 130 (1): 47-93.

Young, J.R., Bown, P.R. & Lees, J.A. 2017. Nannotax3 website. International Nannoplankton Association, 20. Jan 2017. http://www.mikrotax.org/Nannotax318 Microfossils: Calcareous Nannoplankton (Nannofossils).

Резиме

Средње до горње јурски пелашки седименти и депонати гравитационог масеног тока измештене маргине Неотетиса: микрофацијална и биостратиграфска истраживања у североисточној Мађарској

Микрофације, време и средине депоновања две јурске сукцесије, таложене на јадранској микроконтиненталној маргини океана Неотетис, приказане су у овом раду. Истраживања су вршена углавном на језгрима избушеним у мезозојској основи источног дела планине Mátra (подручје Recsk) и најзападнијег дела планине Bükk, СИ Мађарска. Ово подручје представља наставак система навлака Унутрашњих Динарида, које су измештене дуж средњемађарске зоне смицања током касног олигоцена до раног миоцена. Пре-кенозојска подина овог подручја представљена је следећим сукцесивним јединицама: најнижом Recsk сукцесијом, потом Tarna олистотром и највишом јединицом - меланж Darnóhegy. Recsk сукцесија изграђена је од горњотријаских пелашких фација представљених карбонатима са рожнацима, преко којих леже доње јурски до најстарије средње јурски пелашки кречњаци. Током горње батског до доње келовејског ката карбонатна седиментација је постепено замењена седиментацијом глиновитих седимената. У периоду бајски кат–келовеј, област Recsk се налазила на падини, у близини карбонатне платформе, која је омогућавала гравитационе масене токове који су доспевали у истраживано подручје. Спољна маргина ове платформе је постепено тонула током горњег дела бајеског ката и била прекривена пелашким финозрним силицијским седиментом. Олистостром Tarna је изграђен од титонских пелашких седимената, представљених сменом карбонатне и силикокластичне сукцесије са хоризонтима брече/олистострома. Класти су пореклом из горњопермских до доњојурских сукцесија дисталне маргине Адрије. Меланж Darnóhegy представља типичан суб-офиолитски меланж који се састоји од откинутих блокова и фрагмената доње плоче и гравитационо унешених или тектонски инкорпорираних блокова офиолитске навлаке. Старост меланжа је келовеј–оксфордска. Ови подаци могу послужити као основа за нове геодинамичке интерпретације истраживаног региона.

Manuscript received October 10, 2024
Revised manuscript accepted November 04, 2024