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A Middle Jurassic Radiolarite-Clastic Succession from the Medvednica Mt. (NW Croatia)

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Abstract

On the NW part of Medvednica Mt. radiolarites with carbonate olistoliths, shales and siltites, matrix-supported conglomerates and basic volcanic rocks were investigated. This facies association is informally named the Poljanica unit. Major element geochemical data indicate deposition of radiolarites in the vicinity of the middle oceanic ridge, while sedimentological data indicate deposition in an area closer to the continent. Shales and siltites, as well as matrix-supported conglomerates, were deposited in short periods characterised by increased input of terrigenous material. Matrix-supported polymict conglomerates are composed of silicified shales, lithic graywackes, cherts and metabasalts, and were deposited by debris flow mechanisms as a consequence of synsedimentary tectonic activity. Carbonate olistoliths are composed of biomicrosparite, and jointly with deformed radiolarian cherts compose an olistostrome. Basic volcanic rocks represent high-Ti tholeiitic basalts formed in the MORB realm.

Micropalaeontological investigation of radiolarite samples proved the Middle Jurassic (latest Bajocian - early Bathonian to late Bathonian - early Callovian) age of the Poljanica unit. Additionally, a new radiolarian species *Theocapsomma medvednicensis* n.sp. has been described. Conodont analyses from carbonate olistoliths in radiolarites proved their Triassic age.

The investigated radiolarite-clastic succession is the result of subduction processes. Further continuation of this process caused incorporation of these deposits into the accretionary prism, where they were brought in direct contact with Triassic volcanic rocks and radiolarites (in the form of a tectonic mélange).

Based on the lithological similarities with the Middle Jurassic turbidite-olistostrome successions in the Western Carpathians and Northern Calcareous Alps, the study area is considered to be part of the Meliata-Hallstatt Ocean.

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1. INTRODUCTION

In the last few decades, especially after invention of a method for the extraction of radiolarians from radiolarian cherts (DUMITRICĂ, 1970; PESSAGNO & NEWPORT, 1972; DE WEVER, 1982), investigation of radiolarian cherts in the Mediterranean area has intensified. This is the consequence of their stratigraphic importance, bathymetry of their origin, and their common occurrence with ophiolites. All the aforementioned is extremely important for the palaeogeographic reconstruction of this area. From this perspective, in the geological literature dealing with SW part of the Pannonian Basin (i.e. NW Croatia) deposits of this kind were disregarded, and were only mentioned together with magmatic rocks (GORJANOVIĆ-KRAMBERGER, 1908; BABIĆ, 1974; ŠIMUNIĆ & ŠIMUNIĆ, 1979; ŠIKIĆ et al., 1979; BASCH, 1983). The age of the magmatic rocks and associated sedimentary rocks of the northwestern part of the Medvednica Mt. has been, on the basis of their common appearance together with Lower Cretaceous clastic carbonate deposits (which usually overlie them), previously determined as either Lower Cretaceous (ŠIKIĆ et al., 1979; BASCH, 1983; ŠIKIĆ, 1995), or even Upper Cretaceous (CRNKOVIĆ, 1963).

After the discovery of Triassic radiolarites together with basic volcanic rocks from Kalnik and Medvednica Mts. (Middle Carnian to uppermost Carnian - Norian - HALAMIĆ & GORIČAN, 1995; HALAMIĆ, 1998), and Triassic limestones (peperites) in pillow lavas from Medvednica Mt. (upper Anisian - lower Ladinian - HALAMIĆ et al., 1998), it has been determined that part of the magmatic rocks with pelagic sediments on the Medvednica Mt. are of Triassic age, without regard to its present geotectonic position (accretionary complex - HALAMIĆ, 1998). Furthermore, during these studies it has been determined that part of siliceous rocks are of Jurassic age (HALAMIĆ & GORIČAN, 1995; HALAMIĆ et al., 1995), and will be discussed in detail in this paper. Jurassic radiolarites of the Medvednica Mt. alternate with shales, siltites, matrix-supported conglomerates, or represent the matrix of olistostromes, and therefore are very important for the palaeogeographic reconstruction of the SW part of the Pannonian Basin in the Jurassic.

Jurassic mass-flow deposits containing olistoliths of Triassic pelagic rocks are known from Hungary and

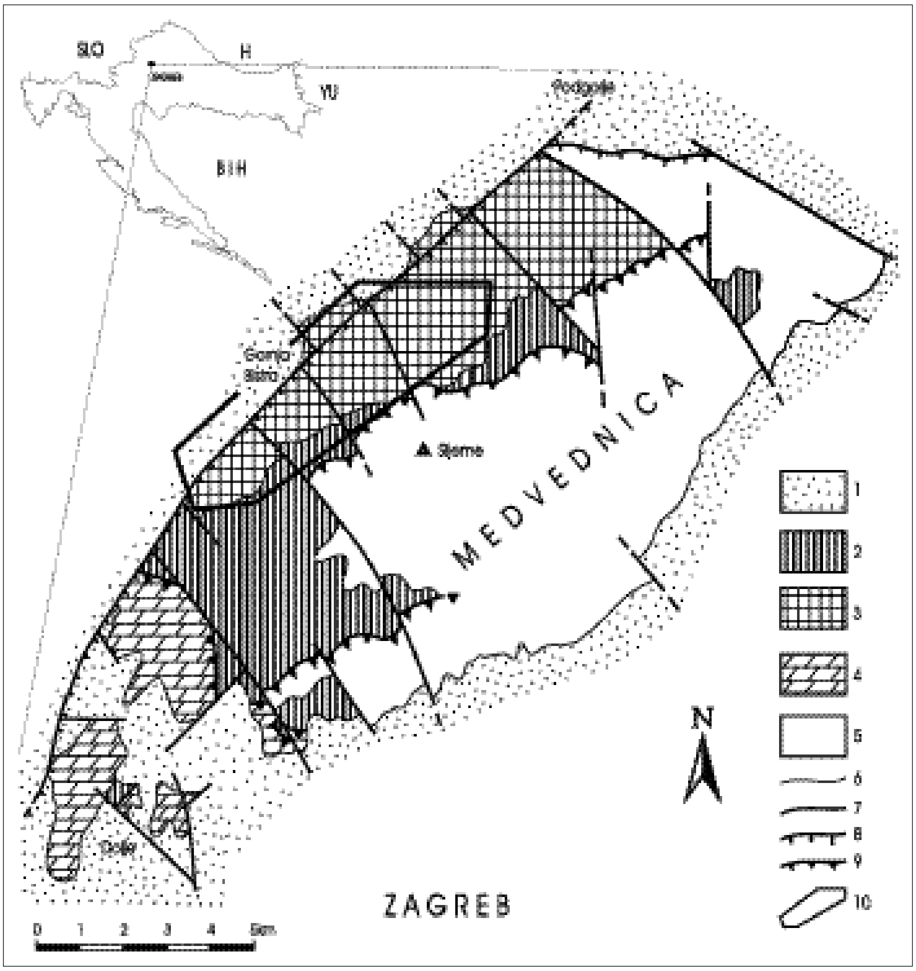

Fig. 1 Location map and geological sketch map of Medvednica Mt. (from HALAMIĆ et al., 1998). Legend: 1) Tertiary sedimentary rocks; 2) Cretaceous-Palaeogene sedimentary rocks; 3) investigated magmatic and sedimentary rocks; 4) Triassic clastic and carbonate rocks of Zakičnica nappe; 5) metamorphic rocks; 6) stratigraphic boundary; 7) fault; 8) reverse fault; 9) thrust fault; 10) investigated area.

Slovakia (KOZUR, 1984, 1991; KOZUR & MOCK, 1985, 1995, 1997; KOZUR et al., 1996), as well as from Austria (MANDL & ONDREJIČKOVÁ, 1991, 1993; KOZUR & MOSTLER, 1992; GAWLICK, 1993).

3. BASIC GEOLOGICAL DATA

Medvednica Mt. is situated in the SW part of the Pannonian Basin, and is incorporated as part of the geodynamic unit Supradinaricum (HERAK, 1986) or Inner Dinarides (HERAK et al., 1990). Tectonically, the Medvednica Mt. belongs to the Mid-Transdanubian Zone (sensu HAAS et al., 1988) or Zagorje-Mid-Transdanubian Zone (as defined by PAMIĆ & TOMLJENOVIĆ, 1998), which is bounded by the Balaton Line in the north and the Zagreb-Zemplen (or Mid-Hungarian) Line in the south.

The core of the Medvednica Mt. is composed mostly of low-grade metamorphic rocks (various metapelites, metapsammites, slate-phyllite, slates, quartzites, marbles, ortho- and paragreenschists of Palaeozoic, and partly Mesozoic age - BELAK et al., 1995), high-pressure metamorphic rocks (blueschists - BELAK & TIBLJAŠ, 1998), magmatic rocks associated with sedimentary rocks (CRNKOVIĆ, 1963; ŠIKIĆ et al., 1979; HALAMIĆ, 1998), and clastic-carbonate deposits of Triassic, Lower Cretaceous and Upper Cretaceous - Palaeogene age (ŠIKIĆ et al., 1979; ŠIKIĆ, 1995). This core is surrounded by younger Tertiary and Quaternary sediments (Fig. 1).

Rocks of the magmatic-sedimentary complex, including those described in this paper, outcrop in the NW part of Medvednica Mt. over an area of approximately 25 km^2. Towards the east they are in reverse tectonic contact with low-grade metamorphic rocks, and towards the NE they are bounded from the low-grade metamorphic rocks by the normal fault. Along their SW margin rocks of this complex are partly surrounded by Lower Cretaceous and Upper Cretaceous - Palaeogene sedimentary rocks, and are partly in contact with Lower Triassic pelites and psammites and Middle and Upper Triassic limestones and dolomites of the Zakičnica nappe (ŠIKIĆ, 1995). Towards the NW, rocks of the magmatic-sedimentary complex are disconformably overlain by sedimentary rocks of the Neogene, which are partly in tectonic contact with them. Magmatic rocks are mainly represented by greenish altered basalts (spilites), with subordinate green-grey massive basalts, pillow lavas, diabases and altered diabases in the form of veins dissecting metabalts, and gabbro and metagab-

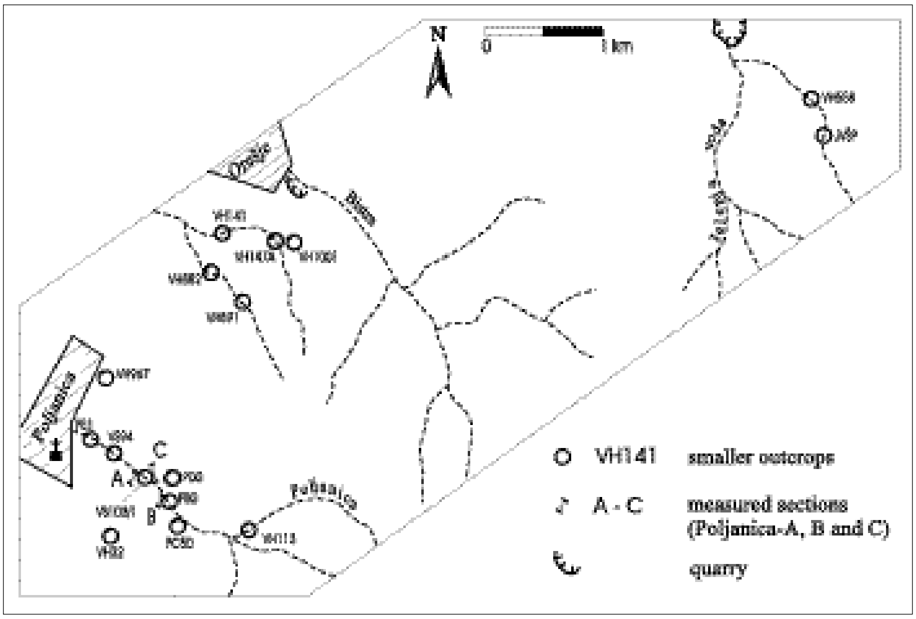

Fig. 2 Location map of analyzed samples and sections.

bro. Among the sedimentary rocks the most frequent are matrix-supported conglomerates, conglomeratic shales and siltites of brown, grey and dark grey colour, composed of pebbles and blocks of sandstones (lithic greywackes, lithic arenites, sublithoarenites), metabasalts and metagabbros. These sediments are most common above the main magmatic body of the NW Medvednica Mt., but are also found as decametre-sized packages within basic volcanic rocks (HALAMIĆ, 1998).

In the SW part of the magmatic-sedimentary complex dark red, grey and green-grey shales, siltites and radiolarian shales are abundant together with dark grey and green-grey radiolarites, which are locally in direct contact to spilites. Some radiolarites and pillow lavas with pelagic limestones are of Triassic age (HALAMIĆ & GORIČAN, 1995; HALAMIĆ et al., 1998), and a part of these siliceous and siliciclastic rocks is of Jurassic age.

3. PETROLOGY

3.1. SEDIMENTARY ROCKS

Siliceous rocks in the Poljanica creek were investigated in detail at three localities, while palaeontological and sedimentary-petrographic studies of outcrops of these rocks south of Poljanica and towards the NE to the Jelenja voda creek were subsequently performed (Fig. 2).

The geological column **Poljanica-A** (Figs. 2 & 3a) represents the sequence on the SW bank of the Poljanica creek, on both sides of the forest road, approximately 600 m E of Poljanica village. The measured deposits are 22.5 m thick.

The lower 12 m of the column is composed of grey and green-grey radiolarites characterised by very thin bedding (1-5 cm thick, rarely to 15 cm), which is laterally persistive. Bedding surfaces are wavy but sharp. Cherts are interbedded with mm- to cm-thick beds of silicified shales and clayey silty cherts. The matrix of the radiolarian cherts is composed of cryptocrystalline quartz, while planparallel oriented white mica flakes (?muscovite) averagely 0.01 mm, rarely up to 0.5 mm in size, as well as silt-sized detrital quartz grains are subordinate. An opâque mineral (?Fe-hydroxide) found in the form of agglomerates up to 0.6 mm in size is an accessory. These cherts are dissected by mm-thick quartz veins and mutually connected mesh-like stylolites. In the lower part, the rocks are characterised by a weakly expressed, parallel laminated structure, while in the upper part the structure is homogenous. Laminae composed of skeletons and relics of radiolarians (up to 0.2 mm in diameter) are less than 2 mm thick. Most of the radiolarian skeletons are recrystallized and filled with microcrystalline quartz, while some are filled with radial chalcedony. Gradation is not visible, both in the laminated and homogenous types of radiolarian cherts.

In the middle part of the column there is a 1.7 m thick bed of dark red and green-red conglomeratic sandy-siltose shale. The deposit is characterised by a slaty structure, and is weathered into cm-sized chips. The rock is matrix-supported, and the matrix is composed of clay minerals and cryptocrystalline quartz, with small subrounded to rounded grains of the same composition, detrital quartz grains (up to 0.1 mm in size) and small rounded grains of quartz siltite. Pebbles larger than 2 mm are irregularly distributed, and composed of silty radiolarian cherts and lithic graywacke of a green-grey colour.

The overlying interval is 1 m thick, composed of a green-grey massive radiolarite, followed by a 2.6 m thick bed of conglomeratic chert. Its lower boundary is sharp and relatively flat, while the upper boundary is sharp, irregular and uneven. Deformed grey-reddish

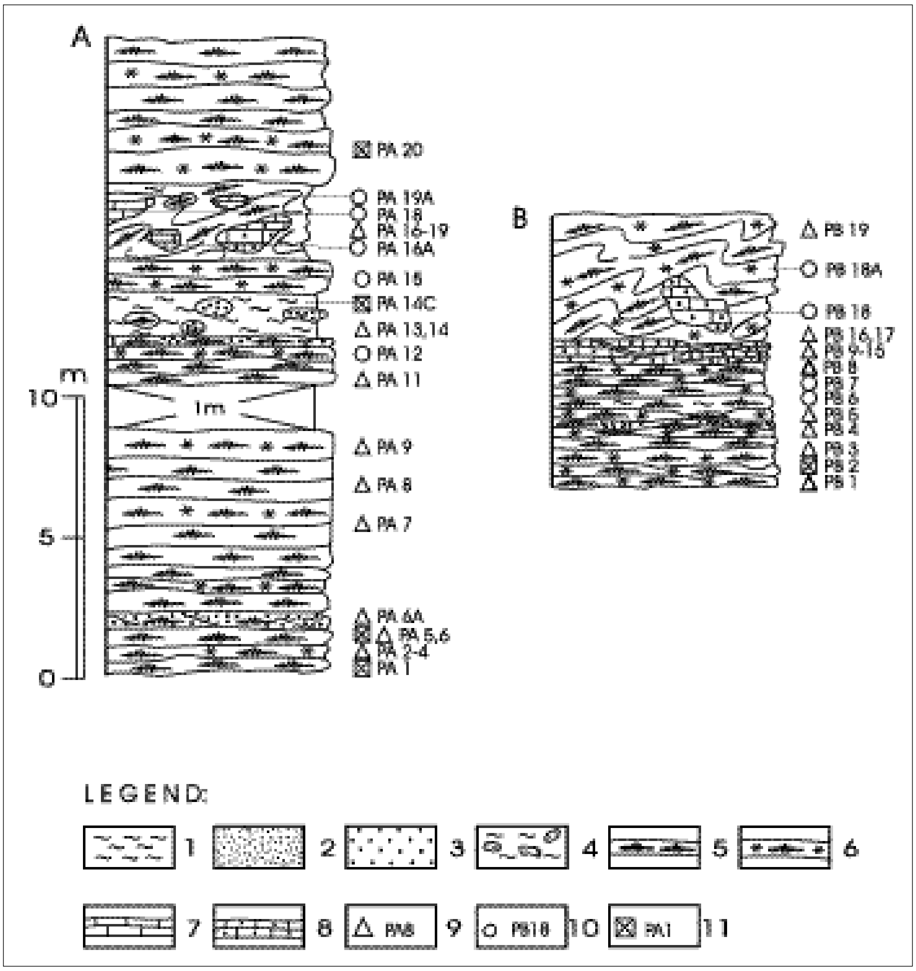

Fig. 3 Geological columns in the Poljanica creek (for location see Fig. 2). Legend: 1) shales; 2) siltites; 3) sandstones; 4) paraconglomerates; 5) cherts; 6) radiolarian cherts; 7) micrites; 8) calcarenites; 9) sedimentary-petrographical analysis; 10) palaeontological analysis; 11) geochemical analysis.

beds of chert have a slaty structure and contain up to 0.3 m large rounded fragments of light-grey carbonates and reddish cherts. Carbonate fragments predominate in the lower part of the bed, and chert fragments in the upper part. Carbonates are represented by sporadically silicified biointrasparrudites containing completely recrystallized mollusc debris; these rocks were sampled for conodont analyses (samples PA 16, PA 18 and PA 19 - Fig. 3).

The upper part of the column is composed of a 5.2 m thick succession of grey, homogeneous and laminated radiolarite. The rock is intensely tectonised and disintegrated. Laminae show no gradation, similar to those in the lower part of the column.

The geological column **Poljanica-B** (Figs. 2 and 3b) of the rocks on the SW bank of the Poljanica creek, east of the Poljanica-A column, in a forest road-cut approximately 900 m E of Poljanica village, comprises a 9.6 m thick succession.

The lower part of the column is composed of 4.2 m of predominantly radiolarian cherts, with subordinate silty radiolarian cherts of a dark red and reddish colour. The rocks are thin-bedded (5-20 cm). Bed surfaces are sharp and wavy. The matrix is composed of cryptocrystalline to microcrystalline quartz, containing radiolarian tests up to 0.15 mm in size, which are partly concentrated in mm-thick laminae and partly distributed irregularly. Tests are mostly filled with chalcedony, and infrequently with microcrystalline quartz. Accesory minerals are white mica and silt-sized detrital quartz grains. An increased content of quartz, in the form of mm-sized elongated lenses is present in silty radiolarian cherts. Rocks are impregnated by Fe-hydroxides in the form of pigments, resulting in the dark red and red colour of the entire rocks. Lamination is the only structural characteristic represented in the sediment.

The middle part of the column is composed of a 0.8 m thick bed composed of lens-shaped fragments (up to 40 cm in diameter) of fine-grained limestones and radiolarian cherts. Limestones are represented by biomicrosparites, biomicrites, fossiliferous micrites and microsparites. Microsparite matrix, which is partially silicified, in some samples contains 10-20% of completely recrystallized 0.1-0.25 mm large grains, probably completely calcitized radiolarian tests. The radiolarian cherts are very similar to those from the lower part of the column. The matrix between carbonate and radiolarian chert fragments is slaty, composed of silicified, dark red shale.

The upper part of the column is composed of an alternation of deformed layers of radiolarian cherts and sandy radiolarian cherts. These deposits also contain a

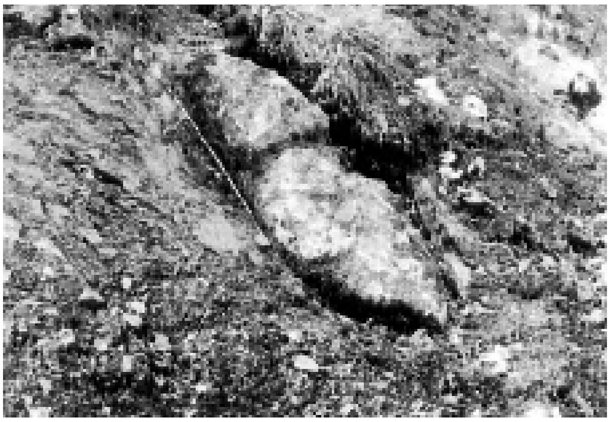

Fig. 4 Metre-sized olistolith of light-grey calcarenitic sandstone in dark-red shale (geological column Poljanica-B). Scale bar = 1 m, sample PB18.

carbonate olistolith, 1.75 m in size (Fig. 4), composed of biocalcarenitic sandstone. The matrix of the radiolarian cherts is composed of microcrystalline quartz with infrequent white mica and quartz grains. The sandy component is composed of quartz grains and mica flakes up to 0.1 mm in size. Micro- and macrofossil detritus, ooid fragments, complete radial ooids and micrite intraclasts, with subordinate quartz, feldspar, microquartzite, microcrystalline quartz and granitoid grains comprise the biocalcarenite. Intergranular spaces are filled with drusy calcite cement, which is sporadically silicified. This level could be, according to its sedimentary-petrographic and sedimentological characteristics, correlated to the upper part of the Poljanica-A column.

The third locality studied is a geological section Poljanica-C (Figs. 2 and 5), located on the N bank of the Poljanica creek, approximately 800 m E of the Poljanica village.

The lower part of the section is composed of matrix-supported conglomerates. The matrix is comprised of brown-grey, slaty, sandy-silty shale. Up to 15 cm sized pebbles are composed of grey and grey-green lithic greywackes. There is no inner organisation of the sediment, which was probably deposited from a mud flow. These conglomerates are followed by a 2 m thick succession of reddish, weakly silty, silicified, radiolarian

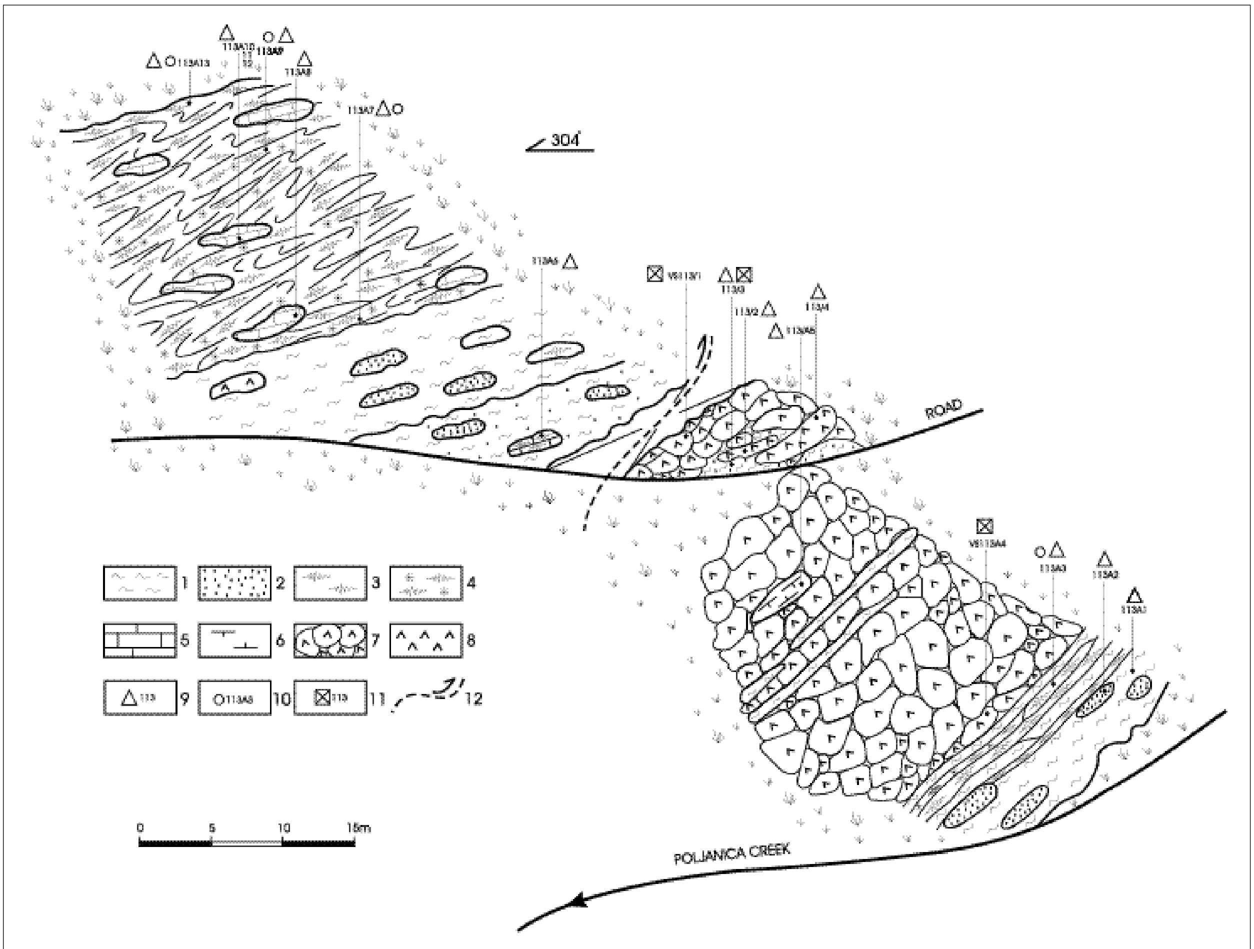

Fig. 5 Geological section Poljanica-C (for location see Fig. 2). Legend: 1) shales; 2) sandstones; 3) cherts; 4) radiolarian cherts; 5) micrites; 6) recrystallized and haematized limestones; 7) pillow lavas; 8) metabasalts; 9) sedimentary-petrographical analysis; 10) palaeontological analysis; 11) chemical analysis; 12) reverse fault. Note: pillow lavas with shale intercalations in the lower part of the section could represent an olistolith.

Fig. 6 Outcrop of pillow lavas in the lower part of the Poljanica-C geological section. Pillows up to 1 m in diameter are well exposed (hammer for scale is 30 cm long).

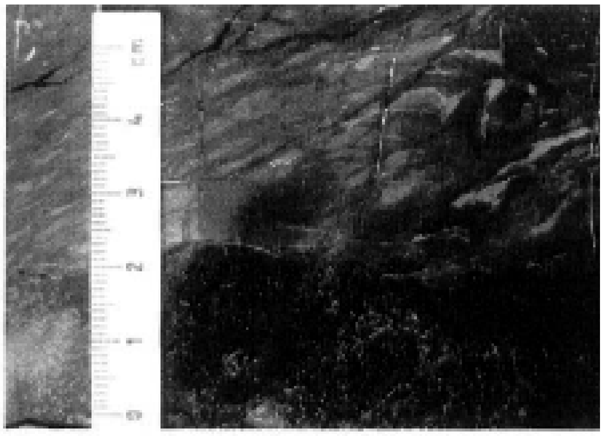

Fig. 7 Contact of haematized shale (up) and metabasalt (below). Note "tongues" of shale filling fractures in metabasalts (Poljanica-C section, below 113/2 sample).

shales, with sharp and wavy lower bedding surfaces. The sediment is thin-bedded (up to 12 cm), and its matrix is composed of clay minerals and subordinate cryptocrystalline quartz, and impregnated with Fe-hydroxides. A silt-sized component is composed of detrital quartz grains and white mica flakes. The matrix comprises up to 5 % of relatively well-preserved radiolarian tests, up to 0.15 mm in size, which are predominantly filled with a greenish mineral from the chlorite group (?seladonite - Dragutin SLOVENEC, unpublished). Infrequent tests are filled either with a ferruginous-clayey substance or radial chalcedony. These radiolarian shales are covered by a 15 m thick succession of pillow lavas. The contact between the sedimentary and volcanic rocks is sheared, as the result of differing competence of the materials. Some pillows are more than 1 m in diameter (Fig. 6). These volcanic rocks will be described in more detail later.

In the middle and upper part of the effusive succession there are a few decimetre thick beds of sediments in contact with volcanic rocks. These are predominantly haematized and silicified shales. Along with the clay minerals, which constitute the rock matrix, there is a silt-sized component composed of quartz grains and planparallely oriented white mica particles, with zircon as an accessory. Millimetre-sized veins filled with quartz, plagioclase and calcite dissect the deposit. At the shale/metabasalt boundary "tongues" of the sediment penetrate into the volcanic rock (Fig. 7), the contact surface is irregular, and joints in the metabasalt are filled by haematized shale and volcanic fragments.

Since this outcrop is very restricted, the possibility that the basalt with shale intercalations represents a megablock within the sedimentary succession cannot be excluded. On the Basic Geological Map (ŠIKIĆ et al., 1977) basalts in the Poljanica creek are presented as small isolated basalt bodies not exceeding 300 m in diameter. This distribution also suggests that the basalt bodies represent allochthonous blocks in a tectono-sedimentary mélange.

After a 15 m thick covered interval the section is continued with matrix-supported conglomerates, which in the lower part are brownish-red, and in the upper part dark red and greenish, partly silicified and partly covered by Mn or haematite-limonite crusts. In the lower part the matrix is composed of sandy-silty shale, and pebbles are represented by lithic greywackes and almost completely calcitized cherts. Pebbles in the upper part of paraconglomerates are represented by brownish-green metabasalts, greenish lithic greywacke, greenish vitreous and grainy chert and dark red siltite. A further part of the section is composed of very thin- and thin-bedded, deformed dark red radiolarian cherts. Radiolarian tests in these radiolarites are, as in the lower part of the section, filled by a green, chloritic substance (?seladonite). Within the radiolarites irregularly distributed pebbles, cobbles and smaller blocks (olistoliths) of light grey limestones can be found (Fig. 8). These carbonates are composed of recrystallized, and sporadically dolomitized biomicrosparites and intrabiomicrosparites.

Beside the aforementioned columns we have investigated several other localities. At the Pijesak locality south of the Poljanica creek (sample VH 32 on Fig. 2) there is an alternation of centimetre-decimetre thick

Fig. 8 Decimetre-sized carbonate olistoliths within radiolarian cherts in the upper part of the Poljanica-C section (objective cap is 55 mm in diameter).

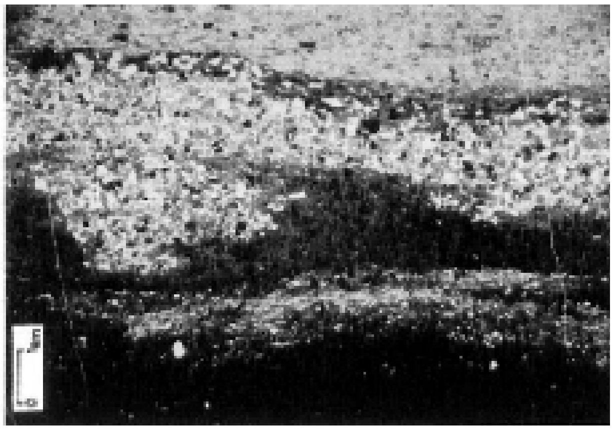

Fig. 9 Quartz arenite bed within radiolarite (outcrop VH32, sample VH32/4).

beds of reddish radiolarian cherts, greenish cherts and dark red fine-grained quartz arenites.

The radiolarian cherts are characterised by the same composition as in the aforementioned successions. The chert is composed of a cryptocrystalline quartz matrix, and 0.03 mm long planparallel oriented sericite particles. Detrital, subrounded quartz grains from 0.04-0.22 mm in size, which compose submillimetre-thick laminae, are subordinate, as well as rare radiolarian tests. The chert is characterized by stylolitized bedding surfaces, stylolites being filled by a ferruginous substance. Quartz arenites are characterized by a psammitic texture and homogenous structure. They are composed of poorly sorted subrounded detrital grains of quartz, up to 0.5 mm in size, most of them exhibiting undulatory extinction. Subordinate muscovite particles up to 0.5 mm in size (longer grains are trapped between quartz grains and fragmented) occur with rock fragments (chert and quartzite) and amphibole. Zircon and garnet, as well as opâque minerals are accessory, and a haematite-limonite component fills interstices, causing the reddish colour of the rock. The rock matrix is composed of cryptocrystalline quartz and sericite (Fig. 9).

At the VH 891 locality (Fig. 2) interbedded matrix-supported conglomerates were discovered, which are greenish-grey in colour, and characterized by a slaty structure. A greenish-grey silty shale matrix is composed of clay minerals and cryptocrystalline quartz. Subordinate silt-sized, rarely sand-sized detrital quartz grains and white mica also occur. Zircon and opâque minerals are accessory. Poorly-sorted fragments, 2-50 mm in size are found in the matrix, rarely exhibiting orientation of the longer axis subparallel to the schistosity. The matrix around fragments and pebbles show no signs of their subsequent rotation, indicating that their orientation originated during the flow of the mud mass. Fragments are angular to subangular, partly rounded, composed predominantly of dark grey, grey, grey-green and yellow-green silicified shale. Some fragments are covered by Mn and limonite crusts (Fig. 10). At this locality radiolarian chert does not crop out; therefore, these rocks are not dated (see Table 1).

The VH 967 locality is situated on the slope NE of the Poljanica village (Fig. 2), and the eastern part of the outcrop is composed of a breccia, which is towards the west followed by grey radiolarites. The breccia matrix is composed of calcarenite consisting predominantly of radial ooids with silicified margins and partly visible agglomeration, as well as fragments of recrystallized fossiliferous micrites, cherts and scarce metabasalts in recrystallized microsparite. Centimetre sized fragments in the breccia are predominantly composed of grey and light-grey, partly laminated radiolarian cherts. Subordinate fragments include biomicritic limestones and metabasalts. Radiolarites found in the western part of the outcrop represent typical ribbon radiolarites composed of chert beds ranging in thickness from a few to ten centimetres.

The outcrop at the PE 1 locality is composed exclusively of dark red radiolarite, which is tectonically deformed and folded, and the contact with neighbouring rocks is not visible.

Fig. 10 Matrix-supported conglomerate. Pebbles are composed of cherts and silicified and manganised shales (outcrop VH891).

The PD 0 locality is situated in a small abandoned quarry, where an olistolith composed of grey, recrystallized and weakly silicified pelmicrite was found within dark red and grey radiolarites. In the pelmicrite pellets and small circular forms, up to 0.03 mm in diameter, which could represent calcitized radiolarians were found.

The PC 50 locality is situated approximately 400 m up-stream of the Poljanica-B column (Fig. 2). The lower part of the outcrop is composed of grey, fractured radiolarian chert covered by matrix-supported conglomerates.

An outcrop of grey to light grey radiolarian cherts at the VH 113 locality (Fig. 2) lies toward the E, bounded by a several metre wide tectonic zone of Upper Cretaceous(?) carbonate-clastic deposits, while towards the W, the outcrops are covered by Quaternary deluvial deposits.

Sample VH 882 (Fig. 2) was taken from a several metre-sized outcrop of intensely folded dark red, massive, clayey radiolarian chert. The rock is at places intensely manganized.

Samples VH 141 and VH 147A (Fig. 2) were collected from grey and dark red radiolarian cherts. The associated rocks are radiolarites, polymict and monomict matrix-supported conglomerates and metabasalts in the form of pillow lavas. Towards the W these deposits are covered by delluvium, while towards the E they are in tectonic contact with Cretaceous calcisiltites and calcarenites.

Samples VH 558 and JVŠP (Fig. 2) were taken from grey, greenish and red radiolarites, associated with matrix-supported conglomerates and metadiabase and metabasalt blocks.

Rocks from these localities represent part of the Poljanica lithostratigraphic unit, which is composed of radiolarites, siltites and shales with limestone olistoliths, ?blocks of basic volcanic rocks and matrix-supported conglomerates. The footwall of this unit is not defined, while the hanging-wall is composed of debrites of the Markov travnik unit, which are in disconformable contact with the Poljanica unit. Deposits of these units are allochthonous to neighbouring rocks, and represent parts of the accretionary complex (HALAMIĆ, 1998).

3.2. VOLCANIC ROCKS

In the eastern part of the Poljanica-C section (Fig. 5) basic volcanic rocks are present in the form of pillow lavas. These rocks are green (in the lower part) to red (upper part), characterised by irregular fracturing. There are several textural varieties of metabasalts.

Metabasalt texture is predominantly microcrystalline, ophitic and porphyric-ophitic, and in the upper part of the section towards the contact with shale also divergent-radial. The structure in the lower part is amygdaloidal, while towards the upper part it becomes massive. Vesicles are monomineralic, composed either of calcite, chlorite or fine-grained quartz (up to 0.7 mm in diameter). On the basis of textural and structural characteristics the following varieties of metabasalts were separated: ophitic, porphyric-ophitic and divergent-radial. These varieties contain the mineral association of albite ± altered clinopyroxene ± secondary minerals.

Albite in the groundmass has a twig-like habit, commonly ranging 0.1-0.9 mm in size, and rarely occurs in the form of phenocrysts up to 1.6 mm in length. Grains are mostly inhomogenous because of small inclusions of chlorite, calcite and minerals from the zoisite-epidote group. Albite originated from the alteration of basic plagioclases, by the albitization process under the hydrothermal influence during the postmagmatic phase.

Clinopyroxenes were found exclusively in the upper part of this sequence as small skeletal relics of yellow augite. In other parts of the succession, albite interstices are filled with completely weathered contours or aggregates of former pyroxenes, which were postmagmatically hydrothermally altered into an aggregate of chlorite and blurred cryptocrystalline mass of ?clinozoisite-epidote.

Interstices in the upper part of the sequence, near the contact with shale, contain finely dispersed haematite, and on the surface (weathering crust) also limonite, and sporadically radial prehnite, formed by alteration of basic plagioclases. Besides chlorite, which is the most abundant alteration product, there is secondary, fine-grained calcite which substitute other constituents of the rock, forming irregular aggregates or filling numerous veins. Opâque minerals, finely dispersed magnetite and skeletal ilmenite are accessory.

Besides the Poljanica-C section, basic volcanic rocks in the contact with red shales and cherts were investigated at two other localities. Locality VS 94 is situated in the Poljanica creek valley, 350 m E of Poljanica village, and locality VH 1001/1 is located on the NE bank of the nameless creek, in the area called Popovčica, approximately 500 m south of Orešje village (Fig. 2). These rocks are green, and according to their microphysiographic properties they are identical to the aforementioned rocks from the Poljanica-C section. Due to their ophitic texture and massive structure they were determined as ophitic metabasalts. Main rock-forming minerals, especially pyroxenes, are completely altered, predominantly into chlorite and calcite. Associated sedimentary rocks from these localities were not dated.

4. STRATIGRAPHY

4.1. RADIOLARIAN DATING

Twenty samples of red and green chert were examined for radiolarians. They were prepared using standard HF methods. The location of all samples is shown on the map (Fig. 2), the stratigraphic position of the samples from the Poljanica-C (samples 113A), Poljanica-A (samples PA), and Poljanica-B (samples PB) sections is shown in Figs. 3 and 5.

Small nassellarians predominate in all samples, spumellarians are represented by rare *Bernoullius* and *Emiluvia* in addition to some indeterminable fragments (spines, rays). Planktonic foraminifera were found in sample PD 0.

The radiolarian dating (Table 1) is based on the zonation of BAUMGARTNER et al. (1995b). Eight samples correspond to the UAZ 5 and two to the UAZ 7. The assemblages in the other samples do not contain species or pairs of species characteristic of one zone and allow only a broader age assignment corresponding mainly to UAZs 5 to 7. The minimum range of the Poljanica unit is thus latest Bajocian - early Bathonian (UAZ 5) to late Bathonian - early Callovian (UAZ 7).

Theocapsomma cucurbiformis was found in the sample VH 882/1, which is assigned to the UAZ 5 based on the co-occurrence of *Guexella nudata* and *Theocapsomma cordis* with *Unuma latusicostatus*. This association suggests that the range of *T. cucurbiformis* (UAZ 6 to 7) should be extended. *T. cucurbiformis* is therefore not considered indicative of UAZ 6 and UAZ 7 in the other samples. Another example is *Xitus magnus*, supposed to make its first appearance in the UAZ 8 but already occurring in the UAZ 7 (see sample VH 967) in association with *Dictyomitrella* ? *kamoensis*, *Stichocapsa naradaniensis* and *Tricolocapsa conexa*. The shortened ranges of *T. cucurbiformis* and *X. magnus* in the zonation of BAUMGARTNER et al. (1995b) are due to a small number of records for these two species in their database.

Tricolocapsa plicarum s.l. ranges from UAZ 3 to UAZ 8 while both subspecies *T. plicarum plicarum* and *T. plicarum* ssp. A, range only from UAZ 4 to UAZ 5. This discrepancy exists because in the oldest and youngest samples containing *T. plicarum*, this species was not introduced at subspecific level in the database of BAUMGARTNER et al. (1995b). The proposed ranges of *T. plicarum plicarum* and *T. plicarum* ssp. A are therefore not considered reliable and were not used for age determination.

The sample PA 15 comes from a deformed, brecciated chert bed. In addition to *Cyrtocapsa* aff. *mastoidea, Stichocapsa robusta* and *Tricolocapsa tetragona*, which first appear in the UAZ 5, it also contains *Cyrtocapsa mastoidea*, which is restricted to UAZs 3 and 4 and seems to be reworked. The UAZ 5 or younger age of this sample is also evidenced by its stratigraphic position above the UAZ 5 (sample PA12).

4.1.1. Systematics of radiolarians

Basic synonymy is provided for the species which are not included in the catalogue of BAUMGARTNER et al. (1995a). *Theocapsomma medvednicensis* n.sp. is introduced; a short description is given for the species in open nomenclature.

We retained the generic names (see species list in Table 1) commonly used in the literature on Jurassic radiolarians, although some of these names are not in agreement with ICZN rules. Two examples of incorrect generic assignment have recently been discussed by KOZUR et al. (1996). Most of these taxonomic problems are not satisfactorily solved yet and would need a more thorough revision, which is beyond the scope of this paper.

***Canoptum* sp. A**
(Pl. III, Figs. 18-22)

1985 *Canoptum* sp. - YAMAMOTO et al., p. 34, pl. 3, fig. 10.

Description: Test multicyrtid, conical, with well pronounced constrictions. Surface rough, covered with small irregularly arranged nodes. Minute pores present on circumferential ridges. A thin spongy meshwork is developed on some specimens (Pl. III, Fig. 18) suggesting that *Canoptum* is closely related to *Spongocapsula* PESSAGNO. The pitted surface of the circumferential ridges on some specimens resembles that of *Cinguloturris carpatica* DUMITRICĂ. It seems that *Spongocapsula* and *Cinguloturris* evolved from *Canoptum*.

***Cyrtocapsa* aff. *mastoidea* YAO**
(Pl. I, Fig. 24)

1994 *Cyrtocapsa* aff. *mastoidea* YAO - GORIČAN, p. 65, pl. 9, fig. 20.

1995a *Stichocapsa* sp. E - BAUMGARTNER et al., p. 524, pl. 4042.

***Obesacapsula magniglobosa* AITA**
(Pl. III, Figs. 6, 7 a-b)

1987 *Obesacapsula magniglobosa* n. sp. - AITA, p. 71, pl. 2, figs. 4a-b; pl. 9, figs. 10-11.

***Parvicingula* ? *cappa* CORTESE**
(Pl. III, Figs. 8-9)

1993 *Parvicingula cappa* n. sp. - CORTESE, p. 176, pl. 4, figs. 1-4.

***Protunuma fusiformis* ICHIKAWA & YAO**
(Pl. II, Figs. 14-16)

1976 *Protunuma fusiformis* n. sp. - ICHIKAWA & YAO, p. 116, pl. 2, figs. 1-4.

***Protunuma* ? *lanosus* OŽVOLDOVÁ**
(Pl. II, Figs. 20-22)

1996 ?*Protunuma lanosus* OŽVOLDOVÁ n. sp. - SYKORA & OŽVOLDOVÁ, p. 23, pl. 2, fig. 13; pl. 3, figs. 1-6.

Genus: *Theocapsomma* HAECKEL, emend. FOREMAN

***Theocapsomma medvednicensis* GORIČAN n. sp.**
(Pl. I, Figs. 12a-b, 13, 14a-b, 15-16)

1997 *Theocapsomma* sp. A - ARAKAWA, pl. 6, fig. 17.

SPECIES	UAZ95	113 A3	113 A7	113 A9	113 A13	PA 12	PA 16	PH 6	PH 7	PH 19A	PC 50	PIJ 0	PP 1	VH 32	VH 113	VH 141	VH 147A	VH 858/5	VH 882/1	VH 987	JM/1P
										SAMPLES											
Archaeodictyomitra (?) *amabilis*	4-7	x			x	x	x	x		x	x	x					x		x		x
Bernoullius cristatus BAUMGARTNER	6-8																				x
Canoptum sp. A						x				x	x	x									
Cinguloturris carpatica DUMITRICĂ	7-11																	x		x	
Cyrtocapsa mastoidea YAO	3-4						x														
Cyrtocapsa aff. *mastoidea* YAO	5-6						x		x												
Dictyomitrella? kamoensis MIZUTANI & KIDO	3-7	x	x	x	x	x	x	x	x	x	x	x			x	x	x		x	x	x
Eucyrtidiellum nodosum WAKITA	3-10																			x	
Eucyrtidiellum unumaense pustulatum BAUMGARTNER	6-8	x		x	x	x						x	x				x				x
Eucyrtidiellum ptyctum (RIEDEL & SANFILIPPO)	5-11																	x		x	
Guexella nudata (KOCHER)	6-8			x		x				x		x		x	x				x		x
Obesacapsula magniglobosa AITA										x	x	x									
Parvicingula dhimenaensis BAUMGARTNER s.l.	3-11	x	x	x	x	x	x	x	x	x	x	x			x		x		x	x	x
Parvicingula? cappa CORTESE					x					x											
Protunuma? ochiensis MATSUOKA	5-14				x	x											x				
Protunuma fusiformis ICHIKAWA & YAO							x											x		x	
Protunuma? lanosus OŽVOLDOVA						x		x				x									
Protunuma turbo MATSUOKA	4-7	x							x												x
Ristola procera (PESSAGNO)	8-9																			x	
Ristola? turpicula PESSAGNO & WHALEN	5-6					x															
Stichocapsa himedaruma AITA						x						x									
Stichocapsa naradaniensis MATSUOKA	6-7																			x	
Stichocapsa robusta MATSUOKA	6-7			x	x	x	x			x		x									x
Stichomitra? takanoensis AITA gr.	3-7					x	x	x	x										x		
Stylocapsa oblongula KOCHER	6-8												x					x		x	
Theocapsomma cordis KOCHER	6-8							x									x		x	x	x
Theocapsomma cucurbiformis BAUMGARTNER	6-7						x										x		x		
Theocapsomma medvednicensis GORIČAN n.sp.			x	x	x	x	x			x		x									
Transhsuum brevicostatum (OŽVOLDOVA) gr.	3-11					x										x	x		x	x	
Tricolocapsa? fusiformis YAO	3-6						x														
Tricolocapsa? aff. *fusiformis* YAO	4-6						x					x							x		
Tricolocapsa conexa MATSUOKA	4-7		x	x	x	x	x	x		x			x				x	x	x	x	x
Tricolocapsa plicarum plicarum YAO	4-6						x														
Tricolocapsa plicarum ssp. A sensu BAUMGARTNER et al.	4-6				x		x	x		x	x	x				x					
Tricolocapsa tetragona MATSUOKA	6-8			x		x	x	x		x	x	x									
Tricolocapsa sp. A sensu YAMAMOTO et al.						x	x	x		x				x			x		x		
Tricolocapsa sp. A						x															
Unuma darnoensis KOZUR		x																			
Unuma latusicostatus (AITA)	2-8					x	x			x	x	x							x		
Williriedellum marcucciae CORTESE	4-8				x	x	x	x			x	x					x	x	x	x	
Xitus magnus BAUMGARTNER	8-11																			x	
Xitus sp. A					x	x				x	x	x					x				
AGE (UA Zones 95)		5-7	4-7	6	5-7	6	6?	6	6	6	6	6	5-7	6-8	5-7	5-7	5-7	7	6	7	6-7

Holotype: Pl. I, Fig. 12a-b; sample PA 12.

Etymology: The species is named after its type locality, Medvednica Mountain, northern Croatia.

Description: Test composed of three segments. Cephalis small, hemispherical. Thorax and abdomen much larger, hemispherical; abdomen distally constricted, having a circular aperture. The lumbar stricture well marked. Thorax and abdomen bear small circular pores. Thorax and lumbar stricture covered with vertical ridges, the distal part of the abdomen is nodose.

Remarks: Theocapsomma medvednicensis n.sp. differs from *T. cordis* KOCHER (KOCHER, 1981, p. 100, pl. 17, figs. 2-4) by having ridges on the thorax and at the lumbar stricture. It differs from *T. cucurbiformis* BAUMGARTNER (BAUMGARTNER et al., 1995a, p. 574, pl. 3047) and *T. bicornis* BAUMGARTNER (BAUMGARTNER et al., 1995a, p. 572, pl. 3276) by having no horn.

Measurements (in µm, based on 13 specimens): total height - holotype: 90, minimum: 75, maximum: 115, average: 91; width of thorax - holotype: 50, minimum: 45, maximum: 60, average: 52; width of abdomen: holotype: 63, minimum: 55, maximum: 75, average: 64.

***Tricolocapsa* sp. A sensu YAMAMOTO et al.**
(Pl. II, Figs. 5-6)

1985 *Tricolocapsa* sp. A - YAMAMOTO et al., p. 39, pl. 8, figs. 6a-c.

1991 *Striatojaponocapsa* sp. - KOZUR, pl. 3, fig. 3.

1997 *Protunuma* (?) sp. A - ARAKAWA, pl. 5, fig. 7.

***Tricolocapsa* sp. A**
(Pl. II, Figs. 10-12)

1993 *Tricolocapsa* sp. - MAATÉ et al., fig. 3/14, 15.

Description: Test composed of three segments. Cephalis and thorax small, partly encased in the abdomen. Abdomen subspherical, inflated. Thorax and abdomen perforate, and covered by longitudinal plicae. On the thorax, the plicae are connected with transverse ridges. Several rows of small circular pores present between adjacent plicae and transverse ridges.

***Unuma darnoensis* KOZUR**
(Pl. II, Fig. 13)

1991 *Unuma darnoensis* n.sp. - KOZUR, pl. 2, fig. 2.

1994 *Unuma darnoensis* KOZUR - GORIČAN, p. 95, pl. 10, figs. 7-8, 9a-b.

***Williriedellum marcucciae* CORTESE**
(Pl. I, Figs. 26-28)

1993 *Williriedellum* (?)*marcuccii* n.sp. - CORTESE, p. 180, pl. 7, figs. 6-7.

1995a *Williriedellum* sp. A sensu MATSUOKA - BAUMGARTNER et al., p. 628, pl. 4060, and synonymy therein.

***Xitus* sp. A.**
(Pl. III, Figs. 1-4)

1993 *Xitus* (?) sp. A - CORTESE, p. 181, pl. 7, fig. 8.

1997 *Xitus* sp. - MATSUOKA & BAUMGARTNER, pl. 3, fig. 16.

Description: Test short, conical. Cephalis smooth, poreless, bearing a stout apical horn. Thorax and the following segments with pores. Prominent tubercles are developed on the post-thoracic segments.

4.2. CONODONT DATING

4.2.1. Material and methods

Seven samples between 0.5 to 1.5 kg were collected and processed for conodonts by dissolving them in 15% acetic acid following standard conodont techniques. After laboratory treatment only four samples proved to contain conodont elements. The frequency of conodonts is low, mostly of fragmentary preservation.

The fossil material is stored at the Geological Survey of Slovenia, catalogue numbers IGGG 3139-3141. The figured conodont specimens were photographed on an EM GEOL by Dr. K. DRAŠLAR (Institute of Biology, University of Ljubljana). The location of investigated samples is shown in Figs. 2 and 3.

4.2.2. Conodont fauna

Sample PA 16A (IGGG 3128)

The sample yields a microfauna that includes foraminifera (*Toplypammina discoidea* TRIFONOVA), ostracods (*Polycope* sp.), echinoderm ossicles as well as conodont elements *Norigondolella steinbergensis* (MOSHER) (Pl. IV, Fig. 2) and *Epigondolella* ex gr. *postera* (KOZUR & MOSTLER) (Pl. IV, Fig. 1).

Age: Middle - Upper Norian. In Slovenia, diagnostic Norian elements *Epigondolella postera* and *Norigondolella steinbergensis* have been recognized in the *postera*-A.Z. (Alaunian) and *bidentata*-R.Z. (Sevatian) (KOLAR-JURKOVŠEK, 1991).

Remarks: The elements which are characterized by a narrow platform, about half of the total unit length and denticles arranged on the anterior part of the plat-

Table 1 Occurrence of radiolarian species in the samples studied. The first column gives zonal ranges of species according to BAUMGARTNER et al. (1995b), the age of the samples is shown in the bottom row. The radiolarian dating indicates that the Poljanica unit spans at least from the latest Bajocian - early Bathonian (UAZ 5) to the late Bathonian - early Callovian (UAZ 7). Note that the sample PA 15 contains a mixed radiolarian assemblage.

form are here assigned to *Epigondolella* ex gr. *postera* (KOZUR & MOSTLER). Similar elements were separated from the *E. postera* population of Canada (ORCHARD, 1983) and described as *E. elongata* ORCHARD where it is a name-bearer of the Middle Norian *elongata* zone (ORCHARD, 1991b).

Sample PA 18 (IGGG 3130)

The sample produced a small microfauna including ramiform conodont elements and rare but diagnostic platform conodont elements of *Paragondolella foliata* BUDUROV.

Age: The species is characteristic of Upper Langobardian - uppermost Julian (KOVÁCS, 1983) and has been reported from the Tethyan realm except for the West Mediterranean province (KOZUR, 1973; KOVÁCS, 1983).

Sample PA 19A (IGGG 3131)

The microfauna contains numerous ramiform and platform conodont elements, however mainly of fragmentary preservation. The elements of *Neocavitella* sp. and *Paragondolella tadpole* (HAYASHI) (Pl. IV, Fig. 3) are recognized.

Age: Stratigraphic range of *Paragondolella tadpole* (HAYASHI) is the Cordevolian - Lower Tuvalian interval (KOVÁCS & KOZUR, 1980; KOVÁCS, 1983).

Sample PB 18 (IGGG 3134)

A small microfauna is represented by rare foraminifera and a single conodont element referred to *Norigondolella navicula* (HUCKRIEDE).

Age: Stratigraphic range of *Norigondolella navicula* is confined to the Norian stage (KOVÁCS & KOZUR, 1980; KOZUR, 1990) and it is regarded as definitive of the basal Norian (ORCHARD, 1991a).

4.2.3. Summary of the conodont dating

Triassic conodont faunas are recorded from Mt. Medvednica, Croatia. Element *P. foliata* is recognized in the sample PA 18. It is an index species of the *foliata*-R.Z. that in Slovenia encompasses Upper Langobardian and Lower Cordevolian (KOLAR-JURKOVŠEK, 1991). The sample PA 19A is characterized by the Carnian species *P. tadpole*. The presence of the Ladinian-Carnian and Carnian conodont elements has been hitherto proved in several locations of Mt. Medvednica (ĐURĐANOVIĆ, 1973; BELAK et al., 1995). Norian conodonts were collected in two outcrops. The element *N. navicula* was recovered from the sample PB 18 thus proving a Norian age. A diverse fauna of the sample PA 16A contains *E.* ex gr. *postera* and *N. steinbergensis*. In Slovenia, *E. postera* is recorded in the Middle and Upper Norian (KOLAR-JURKOVŠEK, 1991).

5. GEOCHEMISTRY

5.1. RADIOLARITES

Geochemical analyses were undertaken on the radiolarian cherts from the radiolarite succession, which were dated as Jurassic on the basis of radiolarians. Additionally, shale samples were collected for correlational purposes. The position of samples in columns and sections, as well as in the field, is presented in Figs. 2, 3 and 5.

Major elements in sedimentary rocks were determined by standard wet chemical analyses. The Ca, Fe_2O_3, Mg and Al contents were analysed complexometrically by EDTA with corresponding indicators; Ti, Mn and P were analysed spectrophotometrically from the same solution. The K and Na contents were determined by flame photometry, while the Fe^{2+} and Si contents were determined gravimetrically. Volatiles were measured by loss of ignition at 1150 °C.

Trace elements were done by the ICP-AES method at ACME Analytical Laboratories Ltd. (Vancouver). Rock samples were milled into powder and homogenized in an agate mill. A sample of 0.25 gr. was digested with 10 ml $HClO_4$-HNO_3-HCl-HF at 200 °C to fuming and diluted to 10 ml with diluted aqua regia. This leach is partial for magnetite, chromite, barite, oxides of Al, Zr and Mn and massive sulphide samples.

Recalculated contents of major elements on 100 % without volatiles, trace elements contents, as well as various ratios between major- and trace elements are presented in Table 2. In addition, the table contains average values of major- and trace element contents of the Triassic radiolarian cherts and shales (HALAMIĆ & GORIČAN, 1995; HALAMIĆ, 1998).

Chemical elements can be divided into three groups according to their origin in siliceous deposits. The first group comprise biogenic silica, originating from siliceous tests, spicules and other skeletal detritus. The second group is of terrigenous origin, comprising elements which are predominately related to clay minerals: SiO_2, TiO_2, Al_2O_3, FeO*, MgO, Na_2O, K_2O, Cr, Rb and Zr. The third group of so-called hydrogenous elements (Fe_2O_3, MnO, Cu, Ni, V and Zn) comprise elements which are predominantly precipitated directly from marine water (MATSUMOTO & IJIMA, 1983).

Alternation of radiolarian cherts and shale beds in radiolarites results from the mutual influence of several processes. It has been undoubtedly proven that during diagenesis there is a segregation of silica from siliceous mud into nodules, lenses and beds (TADA, 1991; MURRAY et al., 1992a, b, c; DE WEVER, 1994; MURRAY, 1994 and cited literature). However, beside diagenetic processes, during the deposition of mud there is an alternation of periods characterised by increased bioproductivity (e.g. radiolarians) with the constant sedimentation rate of clastic detritus, or increased input of clastic detritus with constant bioproduction (DECKER, 1991; DE WEVER, 1994). Furthermore,

	RADIOLARIAN CHERTS									SILICEOUS SILTY SHALES								
	VH 558/4	PA1	PA5	PA20	PB2	VH 882	x	SD	X* n=5	VH 558/2	VS 94[1)]	VS 103/1[1)]	113/3	PA 14C	PB 0[1)]	x	SD	X* n=5
SiO_2	89.37	91.70	88.42	91.45	95.40	91.00	**91.22**	2.41	**91.27**	78.38	70.11	62.72	64.27	79.09	87.15	**73.62**	9.53	**79.97**
TiO_2	0.21	0.20	0.24	0.28	0.12	0.24	**0.22**	0.05	**0.18**	0.44	0.61	0.73	0.30	1.44	0.22	**0.62**	0.44	**0.42**
Al_2O_3	0.40	1.80	2.57	2.90	1.55	0.94	**1.69**	0.95	**2.93**	9.22	12.38	13.27	5.69	3.96	5.47	**8.33**	3.89	**7.03**
Fe_2O_3	6.40	4.13	6.86	3.03	2.03	4.98	**4.57**	1.89	**2.87**	5.97	7.09	9.71	10.67	6.42	3.31	**7.20**	2.67	**5.33**
MnO	0.36	0.05	0.13	0.10	0.05	0.05	**0.12**	0.12	**0.13**	0.03	0.12	0.09	0.37	0.20	0.15	**0.16**	0.12	**0.12**
MgO	1.07	0.59	0.49	0.59	0.28	0.37	**0.57**	0.28	**0.78**	0.92	1.45	1.73	16.33	0.62	0.57	**3.60**	6.25	**1.58**
CaO	1.72	0.32	0.69	0.37	0.20	0.23	**0.59**	0.58	**0.79**	0.73	1.41	0.93	1.87	2.81	0.97	**1.45**	0.78	**1.68**
Na_2O	0.13	0.15	0.15	0.12	0.08	1.23	**0.31**	0.45	**0.35**	0.45	1.25	5.41	0.98	0.86	0.31	**1.54**	1.93	**0.87**
K_2O	0.68	1.21	0.70	1.29	0.41	1.19	**0.91**	0.36	**0.80**	4.05	5.68	5.53	1.20	4.87	1.94	**3.88**	1.89	**3.10**
P_2O_5	0.02	0.01	0.01	0.02	0.01	0.01	**0.01**	0.01	**0.00**	0.01	0.01	0.02	0.00	0.02	0.01	**0.01**	0.01	**0.01**
$CaCO_3$	2.92	0.46	1.06	0.49	0.27	0.34	**0.92**	1.02	**1.23**	0.77	1.77	0.92	2.81	4.50	1.41	**2.03**	1.41	**2.50**
Al_2O_3/TiO_2	1.91	9.00	10.71	10.36	12.92	3.92	**8.14**	4.28	**16.28**	20.95	20.30	18.18	18.97	2.75	24.86	**17.67**	7.67	**16.74**
Fe_2O_3/TiO_2	30.48	20.65	28.58	10.82	16.92	20.75	**21.37**	7.31	**15.94**	13.57	11.62	13.30	35.57	4.46	15.05	**15.60**	10.47	**12.69**
$100x\ Fe_2O_3/SiO_2$	7.16	4.50	7.76	3.31	2.13	5.47	**5.06**	**2.18**	**3.14**	7.62	10.11	15.48	16.60	8.12	3.80	**10.29**	4.91	**6.66**
$100x\ Al_2O_3/SiO_2$	0.45	1.96	2.91	3.17	1.62	1.03	**1.86**	1.05	**3.21**	11.76	17.66	21.16	8.85	5.01	6.28	**11.79**	6.44	**8.79**
$Fe_2O_3/100\text{-}SiO_2$	0.60	0.50	0.59	0.35	0.44	0.55	**0.51**	0.09	**0.33**	0.28	0.24	0.26	0.30	0.31	0.26	**0.28**	0.03	**0.27**
$Al_2O_3/100\text{-}SiO_2$	0.04	0.22	0.22	0.34	0.34	0.10	**0.21**	0.12	**0.34**	0.43	0.41	0.36	0.16	0.19	0.43	**0.33**	0.12	**0.35**
$Al_2O_3/Al_2O_3+Fe_2O_3$	0.06	0.30	0.27	0.49	0.43	0.16	**0.29**	0.16	**0.51**	0.61	0.64	0.58	0.35	0.38	0.62	**0.53**	0.13	**0.57**
Si/Si+Al+Fe+Ca	0.88	0.91	0.86	0.92	0.95	0.91	**0.91**	0.03	**0.91**	0.79	0.72	0.67	0.72	0.81	0.87	**0.76**	0.07	**0.81**
Al/Al+Fe+Mn	0.04	0.25	0.22	0.41	0.36	0.12	**0.23**	0.14	**0.43**	0.54	0.56	0.51	0.28	0.31	0.54	**0.46**	0.13	**0.47**
Ba	51	104	98	92	71	85	**84**	20	**130**	206	239	276	35	229	100	**181**	93	**297**
Th	2	2	3	3	< 2	3	**2**	1	**2**	7	9	11	5	10	3	**8**	3	**7**
Nb	2	5	4	4	2	2	**3**	1	**3**	6	8	7	3	10	4	**6**	3	**7**
Sr	37	35	37	58	14	25	**34**	15	**24**	49	49	60	16	38	32	**41**	16	**45**
Y	9	6	6	10	2	6	**7**	3	**4**	10	14	25	11	18	12	**15**	6	**10**
Zr	7	23	21	22	6	15	**16**	8	**13**	21	39	58	23	53	20	**36**	17	**38**
Sc	4	5	6	7	2	6	**5**	2	**4**	13	19	23	7	17	7	**14**	7	**12**
Cr	15	18	25	26	9	20	**19**	6	**16**	60	73	97	42	85	30	**65**	26	**37**
Ni	48	23	26	32	10	44	**31**	14	**20**	45	56	116	200	86	32	**89**	62	**54**
Cu	35	41	55	59	25	47	**44**	13	**51**	20	68	81	9	113	65	**59**	39	**88**
Pb	27	< 5	< 5	7	< 5	6	**9**	9	**7**	11	20	29	< 5	< 5	7	**13**	10	**15**
Zn	67	32	44	20	11	55	**38**	21	**33**	52	48	118	46	117	33	**69**	38	**72**
Co	25	7	6	23	5	26	**15**	10	**8**	13	7	31	21	28	12	**19**	10	**15**
V	25	31	34	45	15	35	**31**	10	**21**	93	115	159	107	142	47	**111**	39	**50**
La	6	9	13	13	3	10	**9**	4	**7**	23	30	36	11	31	13	**24**	10	**18**
Th/Sc	0.50	0.40	0.50	0.43	0.50	0.50	**0.47**	0.04	**0.50**	0.54	0.47	0.48	0.71	0.59	0.43	**0.54**	0.10	**0.58**

Table 2 Major element content (%), recalculated on 100% without volatiles and some trace elements (mg/kg) in radiolarian cherts and radiolarian shales. Major element analysis were performed by classical silicate-chemical method at the Institute of Geology, Zagreb; analyst: Vlasta JURIŠIĆ-MITROVIĆ. Trace elements were measured by ICP-AES at ACME Laboratories, Vancouver, Canada. Legend: x) average value; SD) standard deviation; X*) average values of Triassic sediments (after HALAMIĆ & GORIČAN, 1995). [1)] Shale samples are not dated because of the lack of fossil material; however, they are attributed to the Poljanica unit since they contact dated cherts.

partial redeposition of sedimented material by contour currents or low-density turbidite currents is indicated by the sedimentary structures preserved in radiolarian cherts, like gradation, horizontal and wavy lamination and load casts on lower bedding surfaces (NISBET & PRICE, 1974; FOLK & McBRIDE, 1978; VECSEI et al., 1989; HALAMIĆ & GORIČAN, 1995).

Investigations of recent and ancient oceanic siliceous deposits have shown, that during diagenesis, fractionation and migration of some elements occur, which partly result in the formation of radiolarian chert/shale alternation. During these processes important mobilization of biogenic SiO_2 takes place, which migrates into beds enriched in silica, and from these beds Mn, Ca, Mg, P, Sr and Ba are remobilized and removed (MURRAY, 1994). Manganese is especially subject to these processes, and its migration is further enhanced during subductional-accretional processes involving pelagic sediments. During diagenesis moderately migrative elements entering into chert beds are K, Na, Ge, Co and B, while V migrates out. On the basis of these facts MURRAY (1994) proposed that only Al, Ti, Fe and rare earth elements should be used as the most reliable for determination of the geotectonic position of radiolarites and radiolarian chert origin with discrimination diagrams (GIRTY et al., 1996).

As a result of the important migration of SiO_2 during the diagenetic processes, radiolarian tests within shale beds should be weakly preserved (MURRAY et al., 1992a). However, microscopic examination of thin-sections prepared from samples of silicified shale beds of Jurassic radiolarites of Medvednica Mt. and similar rocks of Triassic age from Kalnik and Medvednica Mts., has shown that radiolarian tests in these rocks are best preserved (HALAMIĆ & GORIČAN, 1995; HALAMIĆ, 1998). Therefore, for estimation of the biogenic silica contents in radiolarites we used a value of the Si/Si+Al+Fe+Ca ratio (RANGIN et al., 1981; RUITZ-ORTIZ et al., 1989), while for calculation of $CaCO_3$ we used a method after BALTUCK (1982).

Examination of the major element contents in the analysed samples (Table 2) revealed that some of the shale samples are characterised by significantly increased SiO_2 contents, and therefore could be determined as siliceous shales. Furthermore, shales have much higher values of all major elements than the cherts (except SiO_2, FeO and MnO contents), which is the result of the quantity and variability of terrigenous material composing the shales. The Fe content of shales is generally significantly higher than that of the cherts.

Results of trace element analysis of shales show generally higher values of all trace elements in respect to cherts, which is caused by the higher clay minerals content of shales.

The Si/Si+Al+Fe+Ca ratio presents information on the content of biogenic silica with respect to aluminosilicates and ferrugenous and calcic minerals (RANGIN et al., 1981; RUITZ-ORTIZ et al., 1989). Rocks rich in biogenic silica have ratio values between 0.8 - 0.9. Investigated radiolarian cherts have an average ratio value on the upper boundary of this range (0.9 - see Table 2), indicating that the major part of silica in cherts originates from siliceous tests and biogenic siliceous detritus. The principal portion of silica in shales is also of biogenic origin (high values of the ratio - 0.76), which is further indicated by well preserved radiolarian skeletons in shales.

Calculated values of the Fe_2O_3/TiO_2, $Al_2O_3/(Al_2O_3+Fe_2O_3)$, $100xFe_2O_3/SiO_2$, $100xAl_2O_3/SiO_2$, $Fe_2O_3/100-SiO_2$ and $Al_2O_3/100-SiO_2$ ratios (Table 2) were inserted into discrimination diagrams after MURRAY (1994). This author suggested the aforementioned major element ratios as the most reliable for the determination of depositional environments for siliceous rocks. His chemical sedimentary model distinguished three areas on these diagrams: a) spreading ridge - proximal or near ridge, b) pelagic (including parts of the sedimentary area closer to the continent, but topographically protected from more important terrigenous input) and c) conti-

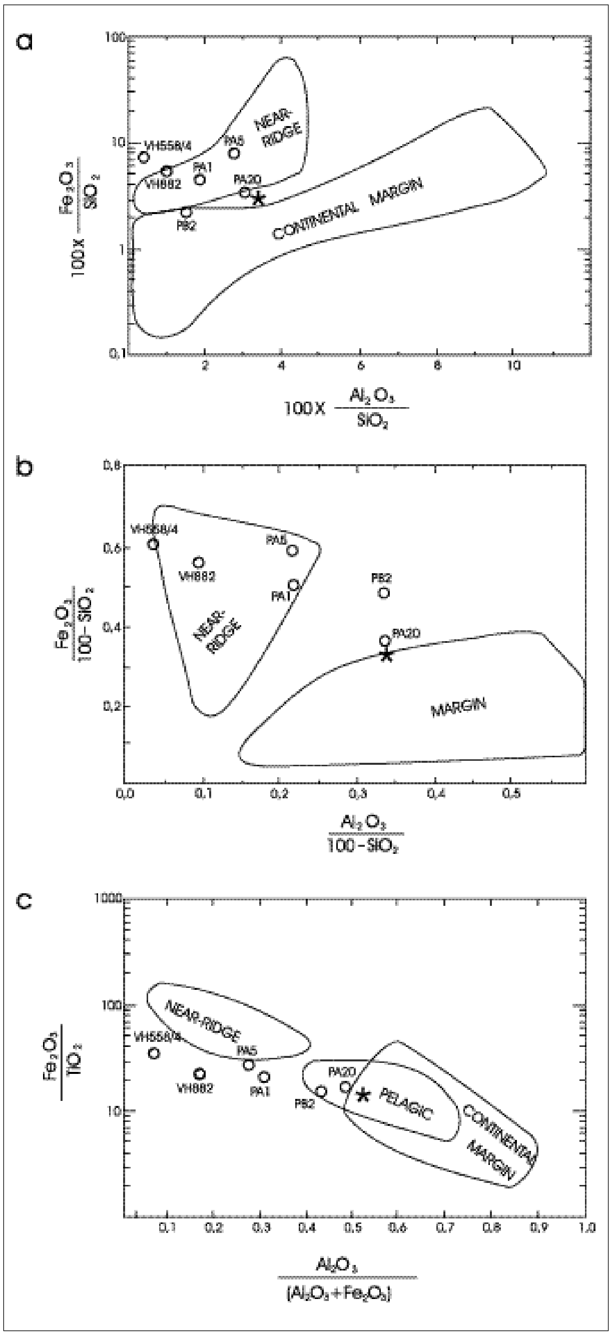

Fig. 11 a) Diagram of Fe_2O_3/Al_2O_3 ratio normalized on SiO_2. Points representing analyzed samples bundle in the field indicating vicinity of the mid-oceanic ridge; b) Diagram representing Fe_2O_3/Al_2O_3 ratio normalized on $100-SiO_2$. The analyzed samples also bundle in the field indicating vicinity of the mid-oceanic ridge; c) Diagram showing bundling of Jurassic radiolarite samples near the field indicating vicinity of the mid-oceanic ridge, but are below it because of the increased Ti values. To a lesser extent samples fall within the field of pelagic environment. *) average value for Triassic cherts (n=5; after HALAMIĆ & GORIČAN, 1995).

Sample	VH 1001	VS 94	VS 113/1	VS 113A4	VH 1001[1)]	VS 94[1)]	VS 113/1[1)]	VS 113A4[1)]	Average *MORB
SiO_2	46.90	37.00	48.10	44.30	51.01	42.08	52.25	49.25	49.10 ± 1.50
TiO_2	2.13	1.44	0.93	1.11	2.31	1.64	1.03	1.23	1.17 ± 0.05
Al_2O_3	13.10	16.60	14.00	15.40	14.25	18.88	15.50	17.12	15.60 ± 1.60
Fe_2O_3	3.63	2.94	2.43	2.61	3.95	3.34	2.69	2.90	2.60 ± 1.40
FeO	9.51	9.77	2.95	6.27	10.34	11.11	3.27	6.97	6.70 ± 1.70
MnO	0.29	1.60	0.29	0.83	0.32	1.82	0.32	0.92	0.16 ± 0.03
MgO	7.90	9.39	5.68	11.10	8.59	10.68	6.29	12.34	8.20 ± 2.30
CaO	5.06	5.81	12.00	4.67	5.50	6.61	13.28	5.19	11.80 ± 1.40
Na_2O	3.03	3.06	3.55	3.47	3.29	3.49	3.93	3.86	2.40 ± 0.50
K_2O	0.17	0.03	0.26	0.06	0.18	0.03	0.29	0.06	0.20 ± 0.19
P_2O_5	0.23	0.29	0.14	0.12	0.25	0.33	0.15	0.13	0.12 ± 0.05
LOI	6.35	11.20	8.20	9.50					
Total	**99.40**	**100.30**	**99.00**	**100.30**					
Ba	213	298	189	124					
Cr	<50	312	364	780					
Nb	8	18	12	8					
Sr	116	52	169	73					
V	458	168	238	213					
Y	51	34	24	25					
Zr	151	106	75	81					

Table 3 Chemical composition of metabasalts (wt. %) and some trace elements (mg/kg). [1]) Recalculated on 100 % without volatiles. *MORB) middle-oceanic ridge basalt (WEDEPOHL, 1988).

nental margin (back-arc basins, marginal seas, epicontinental seas and open continental shelves) (MURRAY, 1994, p. 218).

On the basis of calculation of the aforementioned major element ratios, investigated Jurassic radiolarites fall within the fields of the area near the mid-oceanic ridge (Fig. 11a and b). Figure 11c shows a certain dissipation of a minor part of the data into the pelagic area, while the major part is grouped in the area which corresponds to the vicinity of the mid-oceanic ridge.

Since they are connected with aluminosilicates, Al and Ti are good indicators of a terrigenous influence. The Al_2O_3/TiO_2 ratio for the analysed cherts ranges from 1.91-12.92 (average value 8.14 - see Table 2), indicating that detrital material in cherts may have originated from an undifferentiated magmatic arc characterised by a predominance of basic magmatic rocks over acid varieties (Al_2O_3/TiO_2 ratio values for these areas are ≤14 - GIRTY et al., 1996). However, the possibility of a detrital origin from the accretionary prism comprising parts of the MORB cannot be excluded. Values of the Th/Sc ratio for Jurassic cherts (Table 2) also indicates an origin of the material from a magmatic arc, but also a possible origin from oceanic island arcs.

Despite the fact that manganese is very mobile during diagenetic and later processes (as previously discussed), we took values of the Al/Al+Fe+Mn ratio for evaluation of the hydrothermal influence on the origin of the siliceous sediments (BALTUCK, 1982; ADACHI et al., 1986), i.e. for estimation of the contribution of continental material in respect to the oceanic material (RUITZ-ORTIZ at al., 1989). Removal of manganese from this calculation would not significantly change values of this ratio (because of its small contents in the rocks - from 0.05-0.36%, average 0.12%), while in this case it would not be possible to compare our results with published data. The value of this ratio for typical continental material is 0.619 (average value for shale), for marine biogenic material 0.391, for basaltic material of the Eastern Pacific rift 0.00815 (BALTUCK, 1982), and for pelagic clays 0.54 (WEDEPOHL, 1969). The studied Jurassic cherts exhibit much lower average values (0.23) than for continental material, which indicate a large distance from the continental mass to the sedimentary area, i.e. weaker terrigenous influence. In contrast, debris flow beds and siltite and shales indicate a more important input of terrigenous material.

Increased values of Al/Al+Fe+Mn ratio in shales in respect to cherts represent a consequence of the higher contents of clay minerals.

5.2. VOLCANIC ROCKS

Geochemical analysis were performed on 4 samples of magmatic rocks (Figs. 2 and 5). Samples VS113/1 and VS113A4 were collected on the Poljanica-C geological section (Fig. 5). Samples VS94 and VH1001 from separate localities (Fig. 2) are taken from rocks which are in contact with dark red haematized shales without any fossil remains, and therefore they were not stratigraphically determined; however, on the basis of geological relationships they are attributed to the Poljanica unit.

Major element and some trace element (Rb, Sr, Y, Nb and Ba) analyses were performed by the XRF method at XRAL Laboratories (Canada). Other trace elements were analysed by the ICP-AES method in ACME Analytical Laboratories (Canada). Results of these analyses are presented in Table 3, and the CIPW normative composition and petrochemical indices in Table 4.

Sample	CIPW norms VH 1001	VS 94	VS 113/1	VS 113A4	Petrochemical indices	VH 1001	VS 94	VS 113/1	VS 113A4
qz	2.01	-	-	-	AI	5.3	1.0	6.8	1.7
c	-	1.89	-	1.58	FI	38.7	34.7	24.1	43.0
or	1.09	0.20	1.70	0.39	MI	62.5	57.5	48.7	44.4
ab	27.88	21.48	33.25	32.64	SI	33.1	37.7	38.8	47.7
an	23.53	30.63	23.80	24.89	DI	31.0	26.0	34.9	33.0
ne	-	4.32	-	-	VSM	Th	Th	CA	CA
diwo	0.89	-	17.16	-	VSIB	B	PB	B	B
dien	0.53	-	13.12	-					
difs	0.31	-	2.24	-	CA - calc-alk.				
hyen	20.86	-	1.20	11.55	Th - tholeiite				
hyfs	12.18	-	0.21	3.79	B - basalt				
olfo	-	18.64	0.94	13.45	PB - picrite basalt				
olfa	-	14.15	0.18	4.86					
mt	5.72	4.58	3.90	4.21					
hm	-	-	-	-					
il	4.40	3.11	1.95	2.34					
ap	0.58	0.76	0.36	0.31					
norm Pl. (%an)	46	52	42	43					

Table 4 CIPW normative composition and petrochemical indices.

According to their SiO_2 contents on the TAS diagram (Le BAS et al., 1986) samples VH1001 and VS113A4 represent basic rocks, sample VS94 ultrabasic, while sample VS113/1 falls within the field of neutral rocks, but very close to the border with basic rocks (Fig. 12). On the same diagram two analyzed samples fell within the basalt field, and sample VS113/1 in the field of basaltic andesite, as a consequence of increased SiO_2 contents resulting from the presence of quartz vesicles. Sample VS94, which represents the most altered rock, falls within the field of basanite and tephrite because of the low SiO_2 contents, which is a consequence of the presence of a large quantity of chlorite, pumpellyite(?), and less prehnite, the formation of which caused migration of the surplus silica from the rock.

According to the normative CIPW composition (Table 4), most of the samples contain normative hypersthene, except sample VS94 which contains normative nepheline and belong to the alkali basalts. Furthermore, normative olivine is present in most samples, and is especially high in sample VS94, where it is stated instead of chlorite. High values of normative nepheline and olivine in sample VS94 are caused by high Na contents, which is introduced in the rock by hydrothermal solutions with insufficient Si. In normative anor-

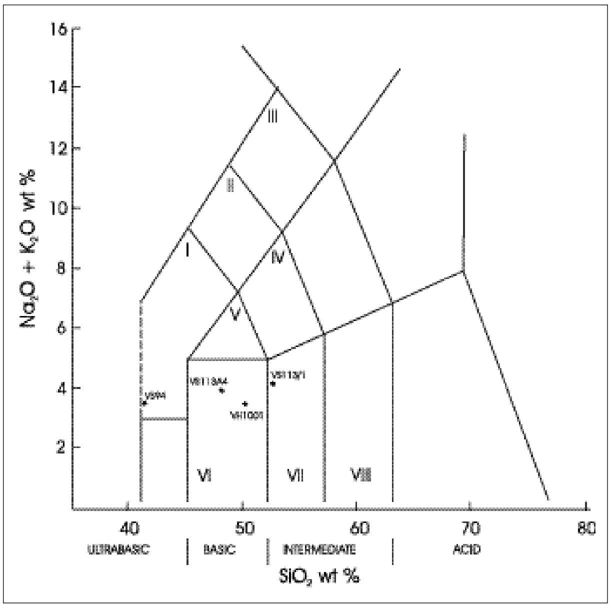

Fig. 12 TAS diagram (Le BAS et al., 1986). Legend: 1) basanite and tephrite; II) phonotephrite; III) tephriphonolite; IV) basaltic trachyandesite; V) trachybasalts; VI) basalts; VII) basaltic andesite; VIII) andesite.

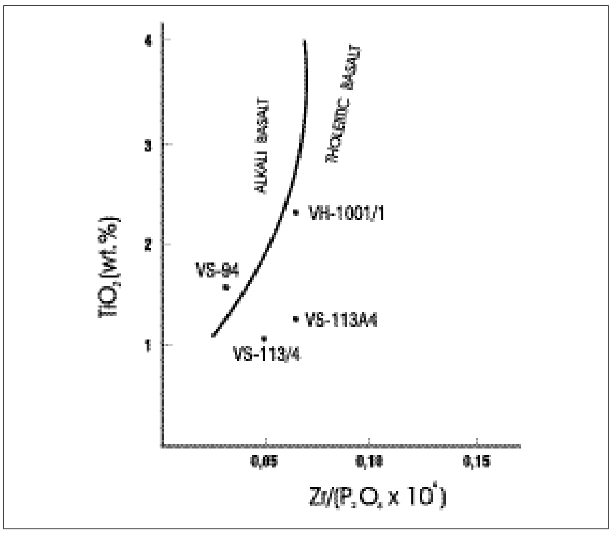

Fig. 13 TiO_2 vs. Zr/P_2O_5 diagram (WINCHESTER & FLOYD, 1976).

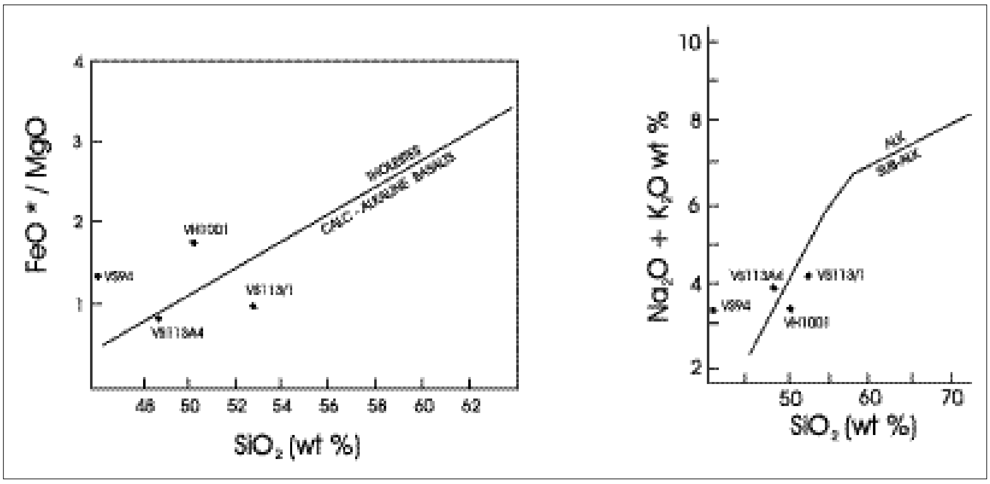

Fig. 14 Variation diagram FeO*/MgO vs. SiO_2 and TAS diagram (MIYASHIRO, 1974).

thite part of the calcium from the zoisite-epidote group, as well as prehnite and rarely augite is included; these minerals are very common, and therefore increase the anorthite contents.

By comparison of some major elements contents with the average major element contents in oceanic tholeiites of mid-oceanic ridges (MORB; Table 3) increased Na_2O contents (as a consequence of postconsolidational changes) and decreased K_2O contents may be noted. In sample VH1001 TiO_2 is increased, in sample VS94 MnO is increased, while in sample VS113/1 the Fe^{2+} content is significantly decreased. Contents of other major elements are within the range of average values for MORB.

On the TiO_2 vs. Zr/P_2O_5 diagram (WINCHESTER & FLOYD, 1976) all samples fall within the field of tholeiite, except sample VS-94 which belongs to the

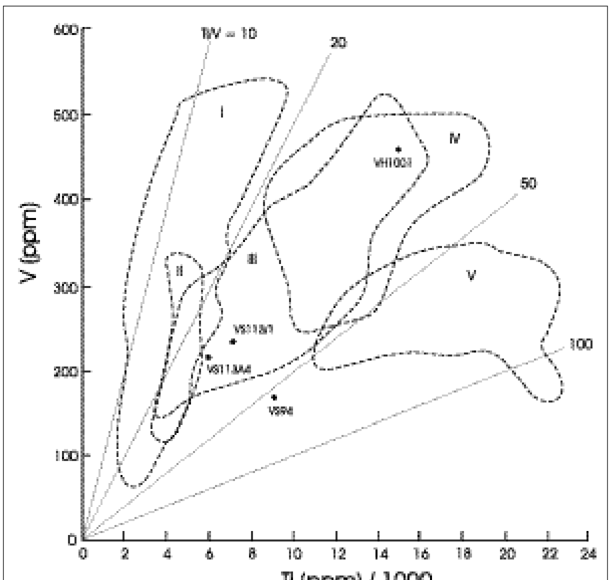

Fig. 15 Ti-V discrimination diagram (SHERVAIS, 1982). Legend: I) arc tholeiite; II) calc-alkali basalts; III) MORB and BAB; IV) continental flood basalts; V) ocean-island and alkali basalts.

alkali basalts (Fig. 13). On the basis of SiO_2 vs. (Na_2O+K_2O) ratio (MIYASHIRO, 1974) it is visible that samples VH1001 and VS113/1 fall within the field of subalkalic basalts, and samples VS94 and VS113A4 within the field of alkali basalts (Fig. 14). However, on the SiO_2 vs. FeO*/MgO diagram (MIYASHIRO, 1974) samples VS113/1 and VS113A4 fall within the field of calc-alkali basalts, sample VH1001 in the field of the tholeiitic series, and sample VS94 in the same field, although outside the diagram (because of decreased SiO_2 contents).

Contents of some typical trace elements were used for the interpretation of geotectonic regime in which basic magmas were produced. On the Ti-V diagram (SHERVAIS, 1982) all rocks belong to high-titanium basalts formed in the MORB realm (Ti/V ratio >20), except sample VS94, which, due to decreased value of V, falls outside the area (Fig. 15). A similar situation is present on the Zr:Ti/100:Yx3 diagram (PEARCE & CANN, 1973), where all analyzed rocks are concentrated within the MORB field (Fig. 16). On the Zr/4:2Nb:Y diagram (MESCHEDE, 1986) analyzed samples mostly fall within the E-MORB type field, except for one sample which falls within the N-MORB field (Fig. 17).

Due to the small number of samples, processes of hydrothermal alteration, spilitization and low-grade metamorphism, together with the enhanced mobility of some major elements, the analyzed rocks concerning the magma character show two different results: they belong to alkalic, but also to tholeiitic rock series. Fresh rocks belong to the tholeiitic series, which suggests their primary tholeiitic character.

In the geotectonic sense analyzed metabasalts belong to the tholeiitic basalts of the MOR.

6. DISCUSSION

Radiolarian cherts in radiolarites show no sedimentary structures except lamination. A lack of other structures indicates the "normal" deposition, i.e. alternation of periods with increased bioproduction or periods with

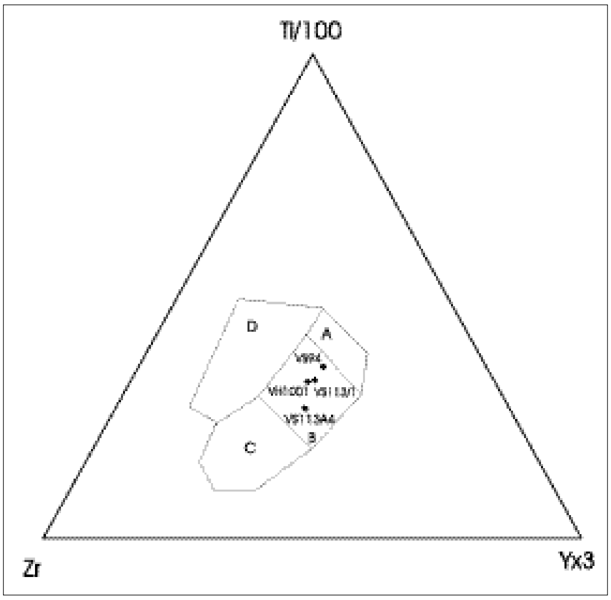

Fig. 16 Zr:Ti/100:Yx3 diagram (PEARCE & CANN, 1973). Legend: A) island-arc tholeiites; B) MORB; C) calc-alkali basalts; D) within-plate basalts.

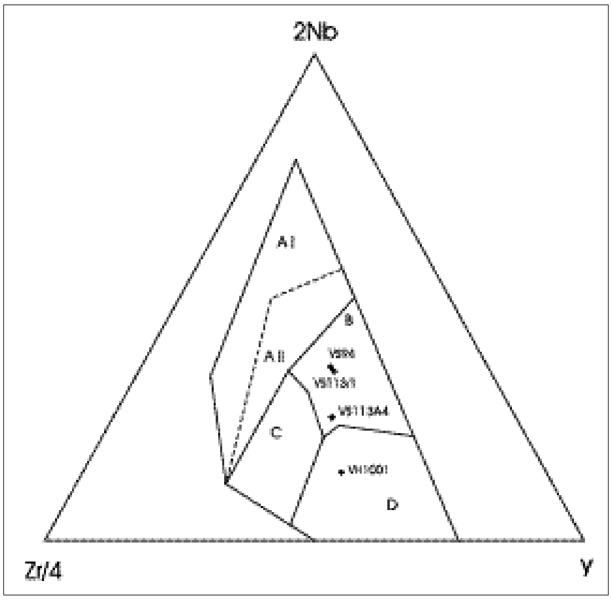

Fig. 17 Zr/4:2Nb:Y diagram (MESCHEDE, 1986). Legend: AI) within-plate alkali basalts; AII) within-plate alkali basalts and within-plate tholeiite; B) E-type MORB; C) within-plate tholeiite and volcanic-arc basalts; D) N-type MORB and volcanic-arc basalts.

increased input of terrigenous material. The difference in silica contents in different layers is further increased by diagenetic processes (TADA, 1991; MURRAY et al., 1992a; MURRAY, 1994).

Centimetre-thick layers of quartz arenite within radiolarite are the consequence of rapid deposition by gravity flows, while the angularity of grains indicates relatively short transport. On the basis of mineral composition (predominantly undulatory quartz, microquartzite, garnet and mica, and only subordinate magmatogenic quartz) it may be concluded that the continental source area was composed mostly of metamorphic rocks, and subordinately of acid magmatic rocks.

Metre-thick layers of matrix-supported conglomerates within the radiolarites described from the VH891 locality (Fig. 2), as well as from other localities, are the consequence of tectonic activity within the depositional area or on its margin, which resulted in debris flows of unconsolidated sediments.

In the study area radiolarites s. str. are subordinate to shales and siltites, and are found as metre-decametre thick packages within pelitic sediments. This indicates that: a) periods with increased input of terrigenous material were much longer than those with increased bioproductivity, or b) that significantly increased input of terrigenous material took place in a short period. Debris flow layers support the latter assumption. Geochemically analyzed radiolarite samples fall within the diagrammatic fields suggesting the vicinity of the ridge (Fig. 11a-c). This might be related to some sediment input from the oceanic crust or accretionary wedge as also suggested by metabasalt clasts in conglomerates.

On the basis of the appearance of decimetre-metre sized carbonate olistoliths of Triassic age in radiolarites, it may be concluded that parts of the Triassic carbonate platform were, during the Middle Jurassic, located close to the sedimentary realm where siliceous rocks were deposited. Carbonate rocks formed the relatively steep slopes of the sedimentary basin, and their parts disintegrated and fell into unconsolidated siliceous mud. Additionally, these tectonically uplifted parts represented a barrier to a greater input of terrigenous material into the sedimentary basin. This described arrangement of elevated areas and a deeper-water sedimentary basin is a consequence of subduction processes which were already active in this area (HALAMIĆ, 1998).

Further subduction caused more severe disintegration of the described deposits and resulted in formation of a tectonic mélange, which also incorporated parts of the Triassic oceanic crust (basic magmatic rocks) as well as parts of the Triassic siliceous rocks.

Similar Middle Jurassic successions composed of chert, shale, sandstone and olistostromes with clasts of Triassic rocks were described from the Western Carpathians (KOZUR & MOCK, 1985, 1995, 1997; KOZUR, 1991; KOZUR et al., 1996) and from the Northern Calcareous Alps (MANDL & ONDREJIČKOVÁ, 1991, 1993; KOZUR & MOSTLER, 1992). These facies associations are considered the most characteristic lower Mesozoic tectofacies of the Meliaticum (KOZUR & MOCK, 1997). HALAMIĆ & GORIČAN (1995) correlated the Triassic radiolarites overlying basic volcanic rocks in the study area, with those of the Meliata Unit. The presence of a Middle Jurassic (uppermost Bajocian - lower Bathonian to upper Bathonian - lower Callovian) radiolarite-clastic succession further supports the idea that the study area was part of the Meliata-Hallstatt Ocean. HALAMIĆ & GORIČAN (1995) pointed out that the Triassic basalts are younger in the Medvednica - Kalnik area (Middle Carnian to uppermost Carnian - Norian than in the Meliata Unit (Ladinian to Lower Carnian). More recently, HALAMIĆ et al. (1998) proved that some pillow lavas of MORB type in Medvednica Mt. are as old as upper Anisian to lower Ladinian. The age difference between the basalts in the Meliata Unit and the Medvednica-Kalnik area is thus minor and does not contradict the assignment of the studied Mesozoic succession to the Meliata-Hallstatt Ocean.

HALAMIĆ & GORIČAN (1995) correlated the Medvednica - Kalnik area also with the Vardar Zone in Serbia, based on the occurrence of Carnian - Norian basic volcanics in both areas. The ophiolite-bearing clastic succession (ophiolitic mélange) of the Vardar Zone is assignable to the Middle and Upper Jurassic as evidenced by its stratigraphic position (DIMITRIJEVIĆ, 1995). Due to the lack of more precise biostratigraphic data for the Jurassic successions of the Vardar Zone, a reliable correlation with the Poljanica unit is still not possible.

7. CONCLUSIONS

Siliceous and siliciclastic deposits from the area between the Poljanica and Jelenja voda creeks in NW Medvednica Mt. consist of radiolarites s. str., shales and siltites, radiolarian cherts with carbonate olistoliths and matrix-supported conglomerates. These rocks were attributed to the Poljanica informal lithostratigraphic unit.

On the basis of radiolarians it is concluded that the analyzed radiolarites were deposited from the latest Bajocian - early Bathonian (UAZ 5) to late Bathonian - early Callovian (UAZ 7). Furthermore, study of conodonts from the carbonate olistoliths proved their late Ladinian - Carnian, Carnian and Norian age.

Geochemical scatter diagrams of major elements indicate that the radiolarites were deposited in the area close to the mid-oceanic ridge. However, sedimentological characteristics indicate significant input of terrigenous detritus (matrix-supported conglomerates, siltites and shales), which suggests proximity to the continent. For comparison, diagrams include data for Triassic cherts from the same area (HALAMIĆ & GORIČAN, 1995), which were, according to geochemical data, also deposited in marginal areas, i.e. in the area closer to the continental mass.

Several textural varieties of metabasalts associated with siliceous rocks were analyzed petrographically. Geochemical analysis of these rocks indicated that these high-titanium tholeiitic basalts were generated in the area of the mid-oceanic ridge. It should be noted that the age of these metabasalts has not been proven. It is possible that they represent large olistoliths or off-scraped blocks in the mélange and could thus be Middle to Late Triassic in age.

Investigated Middle Jurassic radiolarites with Triassic carbonate olistoliths, shales and siltites, matrix-supported conglomerates and basic volcanic rocks were incorporated in an accretionary prism, where they were brought in direct contact with Triassic volcanic rocks and radiolarites (tectonic mélange).

Based on the lithological similarities with Middle Jurassic turbidite - olistostrome successions in the Western Carpathians and in the Northern Calcareous Alps, the study area is considered to have been part of the Meliata - Hallstatt Ocean. This palaeogeographic location is also suggested by previously documented Triassic basic volcanics (HALAMIĆ & GORIČAN, 1995; HALAMIĆ et al., 1998).

Acknowledgements

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PLATE I

Radiolarians

For each illustration the sample number, SEM-negative number, and magnification are indicated. The scanning electron micrographs were taken on a JEOL JSM-330A at the Institute of Palaeontology, Scientific Research Centre of the Slovenian Academy of Sciences and Arts. Rock samples, residues and SEM negatives are stored in the collection of the second author.

1-2 *Eucyrtidiellum ptyctum* (RIEDEL & SANFILIPPO), 1: VH 558/5, 961022; 2: VH 967, 971905; 200x.

3 *Eucyrtidiellum nodosum* WAKITA, VH 967, 971906, 200x.

4 *Eucyrtidiellum unumaense pustulatum* BAUMGARTNER, 113 A13, 962111, 200x.

5 *Bernoullius cristatus* BAUMGARTNER, JVŠP, 971006, 200x.

6-7 *Guexella nudata* (KOCHER), 6: PA 12, 960716; 7: JVŠP, 971026; 200x.

8-9 *Stylocapsa oblongula* KOCHER, 8: PE 1, 960113; 9: VH 967, 971934; 200x.

10-11 *Theocapsomma cucurbiformis* BAUMGARTNER, 10: PA 15, 961603; 11: VH 882/1, 961733; 200x.

12-16 *Theocapsomma medvednicensis* GORIČAN n. sp., 12 (holotype): PA 12, a: 960718, b: antapical view, 980101; 13: PB 18A, 960332; 14: PB 18A, a: 960326, b: antapical view, 980115; 15: PA 12, 960527; 16: PD 0, 961101; 300x.

17-19 *Theocapsomma cordis* KOCHER, 17: JVŠP, 971005; 18: VH882/1, 961735; 19: VH 967, 971914; 300x.

20 *Stichocapsa himedaruma* AITA, PD 0, 961035, 300x.

21 *Tricolocapsa*? *fusiformis* YAO, PA 15, 961614, 300x.

22 *Tricolocapsa*? aff. *fusiformis* YAO, PD 0, 961207, 300x.

23 *Cyrtocapsa mastoidea* YAO, PA 15, 961534, 200x.

24 *Cyrtocapsa* aff. *mastoidea* YAO, PA 15, 961535, 200x.

25a, b *Stichocapsa robusta* MATSUOKA, PB 18A, 25a: 960321; 25b: antapical view, 960320; 200x.

26-28 *Williriedellum marcucciae* CORTESE, 26: VH 882/1, 961722; 27: PA 12, 960611; 28: PA 12, 960609; 200x.

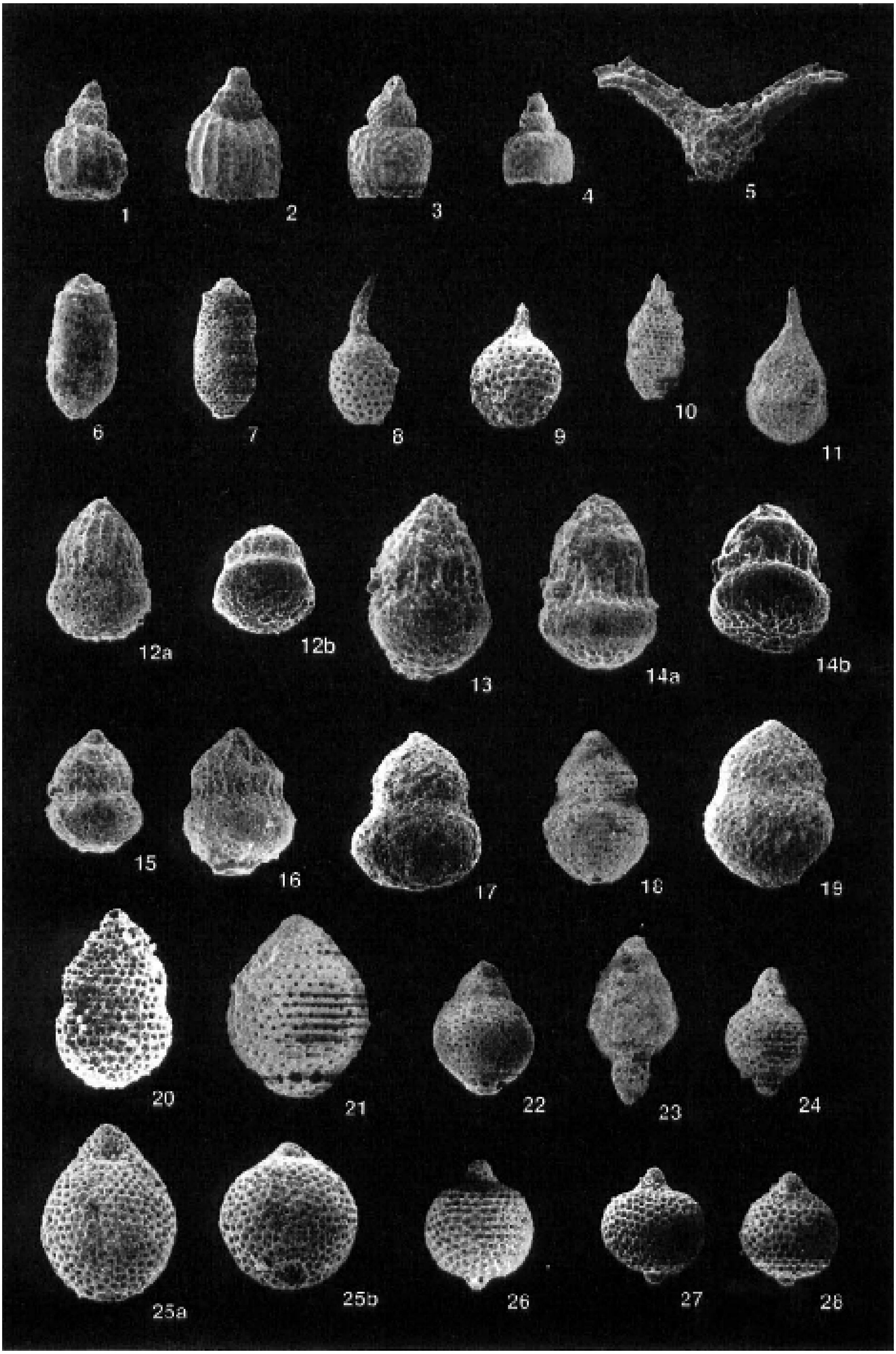
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PLATE II

Radiolarians

For each illustration the sample number, SEM-negative number, and magnification are indicated. The scanning electron micrographs were taken on a JEOL JSM-330A at the Institute of Palaeontology, Scientific Research Centre of the Slovenian Academy of Sciences and Arts. Rock samples, residues and SEM negatives are stored in the collection of the second author.

1 *Tricolocapsa plicarum plicarum* YAO, PA 15, 961608, 200x.

2 a, b *Tricolocapsa plicarum* ssp. A sensu BAUMGARTNER et al., PD 0, 2a: 961116; 2b: antapical view, 961115; 200x.

3-4 *Tricolocapsa conexa* MATSUOKA, 3: PA 12, 960510, 4: PB 18A, 960317; 200x.

5-6 *Tricolocapsa* sp. A sensu YAMAMOTO et al., 5: PA 12, 960532; 6: VH 882/1, 961727; 300x.

7-8 *Tricolocapsa tetragona* MATSUOKA, 7: PD 0, 961129; 8: PB 18A, 960310; 200x.

9 *Stichocapsa naradaniensis* MATSUOKA, VH 967, 971912, 300x.

10-12 *Tricolocapsa* sp. A, PA 12; 10: 960518; 11: 960713; 12: 960520; 200x.

13 *Unuma darnoensis* KOZUR, 113 A3, 961913, 200x.

14-16 *Protunuma fusiformis* ICHIKAWA & YAO, 14: VH 967, 971908; 15: PA 15, 961612; 16: PA 15, 961613; 200x.

17-18 *Unuma latusicostatus* (AITA), 17: PA 12, 960524; 18: PD 0, 961219; 200x.

19 *Protunuma turbo* MATSUOKA, PB 7, 961504, 200x.

20-22 *Protunuma*? *lanosus* OŽVOLDOVÁ, 20: PD 0, 961208; 21: PA 12, 960515; 22: PB 6, 961409; 300x.

23-24 *Protunuma*? *ochiensis* MATSUOKA, PA 12, 23: 960615; 24: 960721; 200x.

25-27 *Archaeodictyomitra*? *amabilis* AITA, 25: PD 0, 961114; 26: PD 0, 961212; 27: PA 12, 960604; 200x.

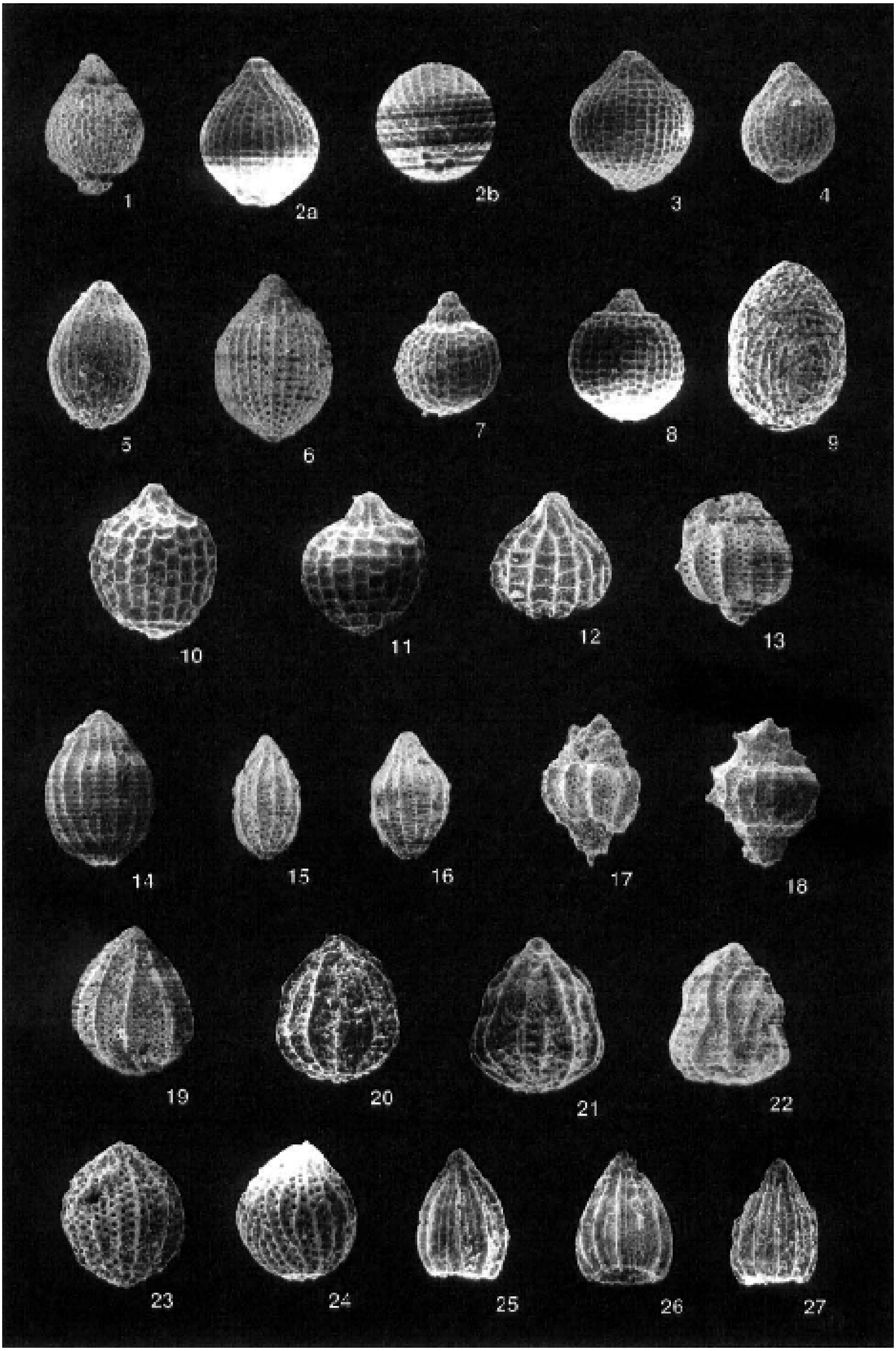
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PLATE III

Radiolarians

For each illustration the sample number, SEM-negative number, and magnification are indicated. The scanning electron micrographs were taken on a JEOL JSM-330A at the Institute of Palaeontology, Scientific Research Centre of the Slovenian Academy of Sciences and Arts. Rock samples, residues and SEM negatives are stored in the collection of the second author.

1-4 *Xitus* sp. A, 1: PD 0, 961125; 2: PD 0, 961102; 3: PC 50, 962228; 4: VH 147A, 960229; 200x.

5 *Xitus magnus* BAUMGARTNER, VH 967, 971928, 150x.

6-7a, b *Obesacapsula magniglobosa* AITA, 6: PB 18A, 960413; 7: PD 0, a: 961033; b: antapical view, 961034; 200x.

8-9 *Parvicingula*? *cappa* CORTESE, 8: 113 A13, 962030; 9: PB 18A, 960334; 300x.

10-11 *Parvicingula dhimenaensis* BAUMGARTNER s.l., 10: PA 12, 960635; 11: PA 12, 960631; 200x.

12 *Ristola procera* (PESSAGNO), VH 967, 971921, 200x.

13-16 *Dictyomitrella*? *kamoensis* MIZUTANI & KIDO, 13: PA 12, 960621; 14: PA 18A, 960427; 15: PA 18A, 960428; 16: PD 0, 961209; 200x.

17 *Ristola*? *turpicula* PESSAGNO & WHALEN, PA 12, 960720, 200x.

18-22 *Canoptum* sp. A, 18: PB 18A, 960403; 19: PB 18A, 960410; 20: PA 12, 960727; 21: PD 0, 961221; 22: PB 18A, 960415; 200x.

23-24 *Stichomitra*? *takanoensis* AITA gr., 23: PB 7, 961503; 24: PA 12, 960728; 200x.

25-26 *Cinguloturris carpatica* DUMITRICĂ, 25: VH 967, 971923; 26: VH 967, 971926; 200x.

27 *Transhsuum brevicostatum* (OŽVOLDOVÁ) gr., VH 141, 962233, 200x.

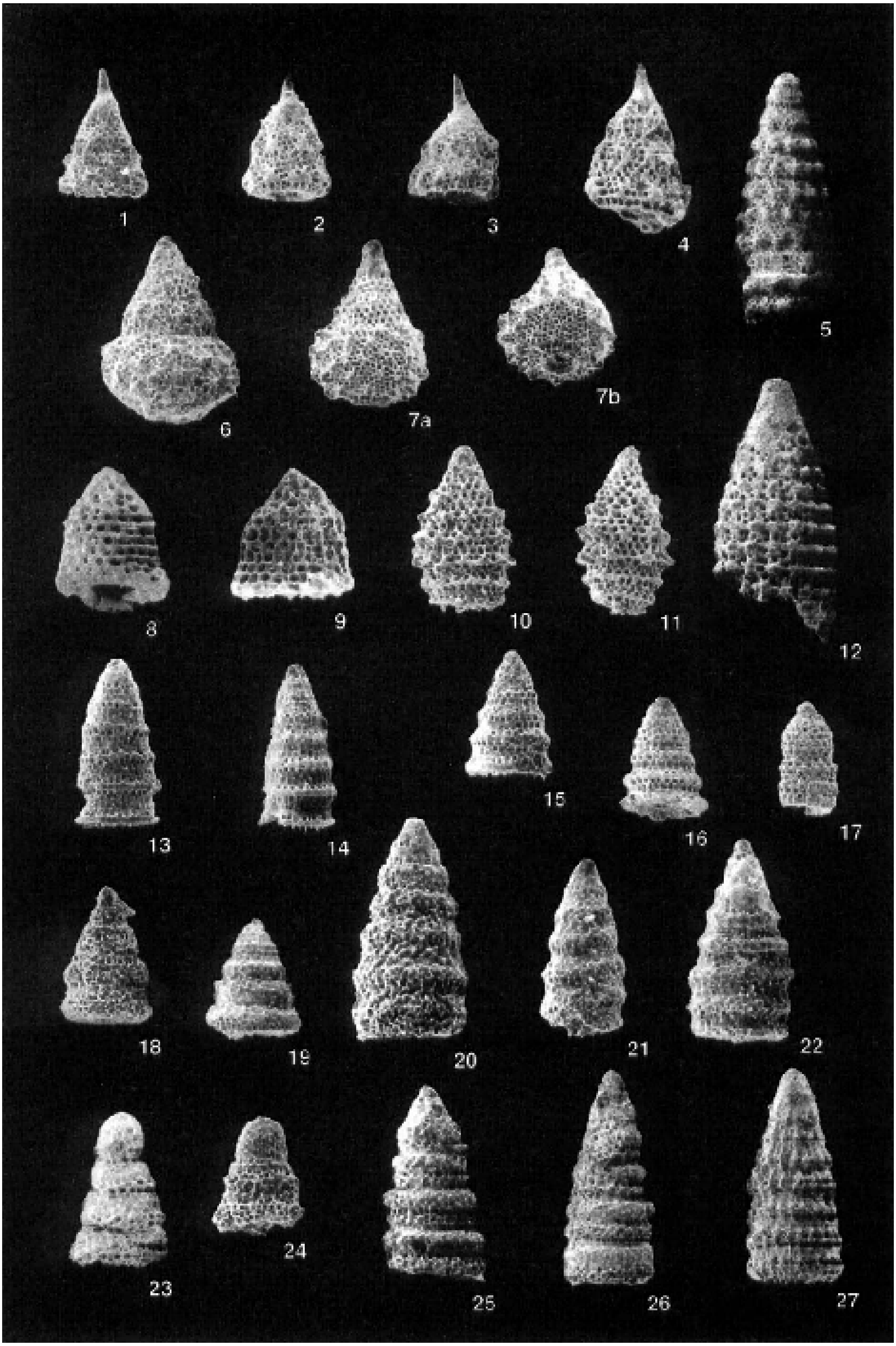
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PLATE IV

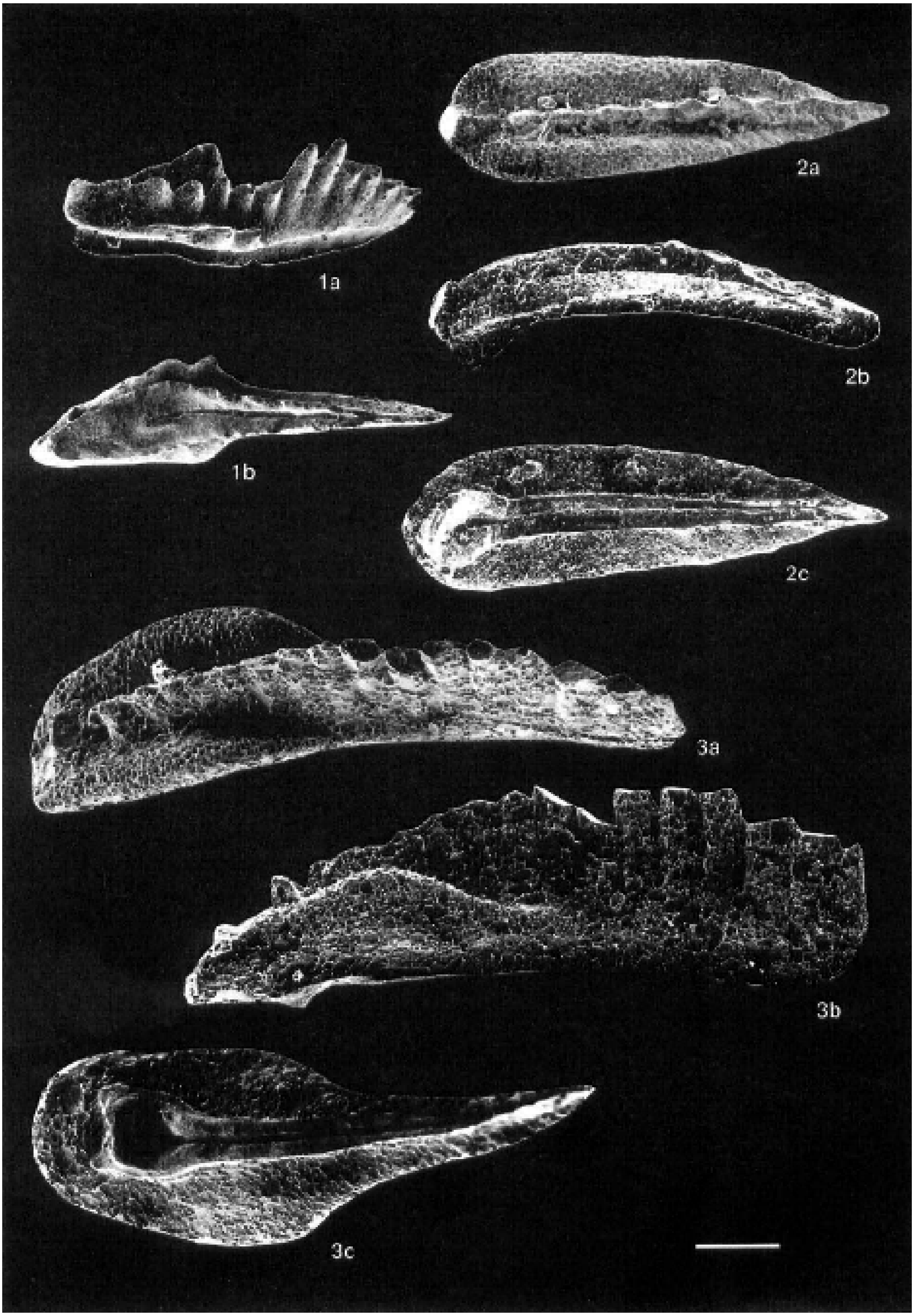
Conodonts

Scale bar = 100 μm.

1 *Epigondolella* ex gr. *postera* (KOZUR & MOSTLER), sample PA 16A (IGGG 3128), 1a: oblique oral view, 1b: aboral view.

2 *Norigondolella steinbergensis* (MOSHER), sample PA 16A (IGGG 3128), 2a: oral view, 2b: lateral view, 2c: aboral view.

3 *Paragondolella tadpole* (HAYASHI), sample PA 19A (IGGG 3131), 3a: oblique oral view, 3b: lateral view, 3c: aboral view (anteriormost platform broken off).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1b
2a
2b
2c
3a
3b
3c