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SUBDUCTION RELATED JURASSIC GRAVITY DEPOSITS IN BÜKK-DARNÓ AREA, NORTHEAST HUNGARY

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Abstract: Jurassic sedimentary sequences of pelagic basin facies and slope-related gravity deposits occur in several places in North Hungary (Bükk Mountains, Darnó area, Rudabánya Hills). The aim of the paper is to characterise the Jurassic formations of the study area with special regard to the redeposited sedimentary rocks in order to get information on the provenance of the clasts, and the mode and time of their redeposition. In the Bükk Mts., the Mónosbél Group contains various redeposited sediments showing an upward coarsening trend. They were deposited in Bathonian in subduction-related basins formed in the course of subduction of the Neotethys Ocean. The lower part of the complex is typified by pelagic carbonates, shales and radiolarites with andesitic volcaniclast intercalations. The higher part is characterised by polymict olistostromes. Large olistoliths that are predominantly blocks of Bajocian shallow marine limestones (Bükkzsérc Limestone) appear in the upper part of the sequence. Evolutionary phases of the sedimentry basins were defined from an early extensional stage of the subduction, through island-arc formation, to the compressional stages when onset of nappe stacking gave rise to formation of polymict olistostromes and then redeposition of large blocks derived from out-of-sequence nappes of the previous platform foreland. Remarkable differences between the composition of the redeposited clasts in the olistostromes of the Bükk and Darnó area indicate deposition in different subduction-related subbasins.

Keywords: Bükk Mountains, Jurassic, facies analysis, gravity deposits, subduction-related basins.

1. Introduction

In the Bükk Mountains presence of Jurassic sedimentary and volcanic formations was recognised only at the beginning of the 1980-ies (Bérczi-Makk and Pelikán, 1984). Studies performed in the latest decade led to the conclusions that Jurassic formations akin to those in the Bükk Mts. occur also in the Darnó area, in western foreland of the Bükk Mts. and in the pre-Tertiary basement of the Mátra Mts. (Kovács et al., 2008). The Jurassic formations were interpreted as elements of an accretionary complex formed during closure of the Neotethys Ocean and their close genetic relationships with the ophiolite mélange complex of the Dinarides were suggested (Pamić, 1997, 2003; Haas and Kovács, 2001, Dimitrijević et al., 2003) (Fig. 1). Striking similarity of the Upper Paleozoic and Triassic formations with the corresponding formations of the Dinarides has been known for a long time (Schréter, 1959; Balogh, 1964; Filipović et al., 2003). These considerations inspired the concept that the Bükk together with other terranes in North Hungary derived from the Dinaridic realm and got into its present-day setting via large-scale tectonic displacements in the Tertiary (Csontos and Nagymarosy, 1988).

2. Methods

Interpretation of history of basin evolution and paleo-environmental conditions controlled the accumulation of gravity deposits were based on sedimentological investigations, petrographical analysis of the components of the clastic rocks and biostratigraphic studies of the matrix and the clastic components to get age data.

3. Results

In the area of the Bükk Mts. extensional tectonics led to formation of platforms and basins, that was accompanied by intense andesitic and then basaltic volcanism during the Mid-Triassic. Both platform and basin facies are overlain by red radiolarian chert yielded poorly preserved radiolarians indicating a wide Early Bajocian – Kimmeridgian age range (Bányahegy Radiolarite). Above it, dark grey to black shale occurs, containing sandstone, siltstone and claystone layers deposited via turbidity currents (Lökvölgy Formation). In some places, the Triassic formations are directly overlain by siliciclastic sandstones (Vaskapu Sandstone) in other places similar sandstones occur within or above the Lökvölgy Formation (Pelikán et al., 2005).

In the western part of the Bükk Mts. Jurassic basic magmatic rocks i.e. hyaloclastic lava flows and pillow lavas occur. Relation of the magmatic suits with the sedimentary formations is not perfectly clear. In some places the igneous rocks have thermal contact with the Lökvölgy Formation (Pelikán et al., 2005)

Above the siliciclastic series calcareous and siliceous basin and redeposited slope facies occur, referred as the Mónosbél Group (Pelikán et al., 2005). Within the group several lithofacies can be distinguished. In many cases they show interfingering or transitional features and some of them may appear as redeposited clasts, blocks. Among them the Oldalvölgy Formation is typically made up of alternating dark grey cherty limestone and black shale (silty claystone, sandstone) layers.

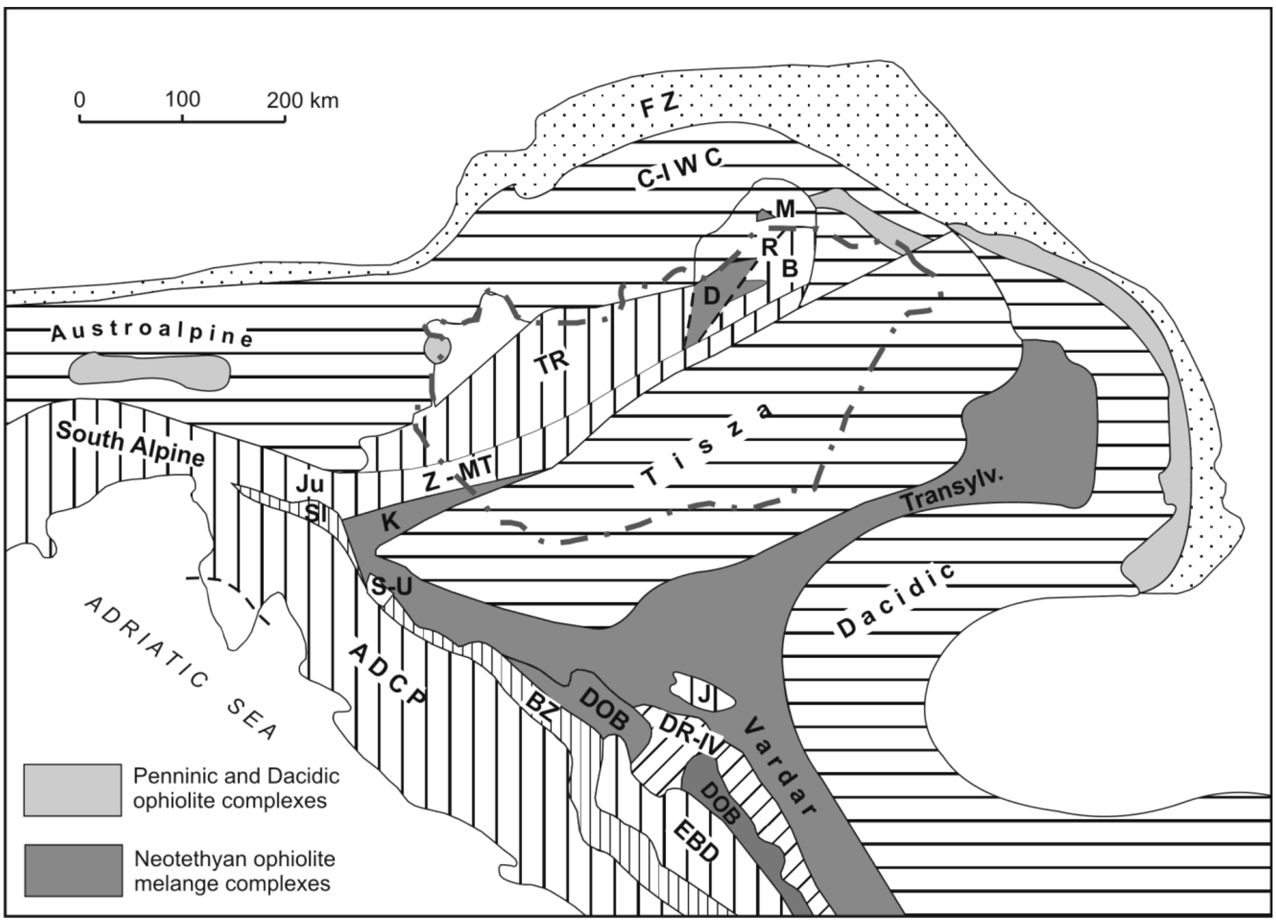

Fig. 1 Geographical and geological setting of the Bükk Unit within the Circum-Pannonian region. Abbreviations: ADCP – Adriatic–Dinaridic Carbonate Platform; B – Bükk Unit; BZ – Bosnian Zone; C-I WC – Central and Inner West Carpathians; D – Darnó Unit; DOB – Dinaridic Ophiolite Belt; DR-IV – Drina–Ivanica Unit; EBD – East Bosnian–Durmitor Unit; FZ – Helvetic and Outer Carpathian Flysch Zone; J – Jadar block; Ju – Julian Alps; K – Kalnik Unit; M – Meliata Unit; R – Rudabánya; Sl – Slovenian Trough; S-U – Sana–Una Unit; TR – Transdanubian Range Unit; Z-MT – Zagorje–Mid-Transdanubian Unit.

Most of the limestone layers have mudstone or peloidal wackestone texture but ooids and shallow marine bioclasts could also be recognised locally. Radiolarian and/or sponge spicule wackestones are also typical textures of the formation. These beds gradually progress into the Csipkéstető Radiolarite. Lateral and vertical transition between the Oldalvölgy Limestone and Csipkéstető Radiolarite are common. Volcaniclastic interbeds were encountered in these formations locally (Fig. 2). Andesite clasts are prevailing in the deepest and thickest bed whereas in the higher beds the basalt clasts are also present.

Polymict olistostrome beds typify the upper part of the series that was assigned to the Mónosbél Formation (Pelikán et al., 2005) (Fig. 2). Along with clasts of siliclastic rocks various volcanites and metamorphic rocks, oolitic carbonates are also common. The volcanic material is extremely variable in these beds including clasts of andesite, dacite, rhyolite and rarely basalt. In the majority of the studied occurrences the carbonate clasts are predominant. Based on their microfacies characteristics and in some cases their microfossil content, the limestone clasts derived from the previously deposited and consolidated Jurassic succession, rarely from carbonate platform and mostly from toe-of-slope (e.g. redeposited oolitic packstone, peloidal grainstone) and basin (“filament” wackestone, sponge spicule wackestone, radiolaria wackestone) facies. The radiolarite clasts are probably derived also from Jurassic basin facies. Limestone clasts containing shallow marine Triassic foraminifera were also encountered. Clasts derived from siliciclastic formations (silty claystone, siltstone, fine to medium grained quartz sandstone) are also common. These clasts probably derived also from the Jurassic succession (Vaskapu Sandstone). Clasts of fillite and micaschist must have been subject to metamorphism prior to the redeposition also occur, rarely.

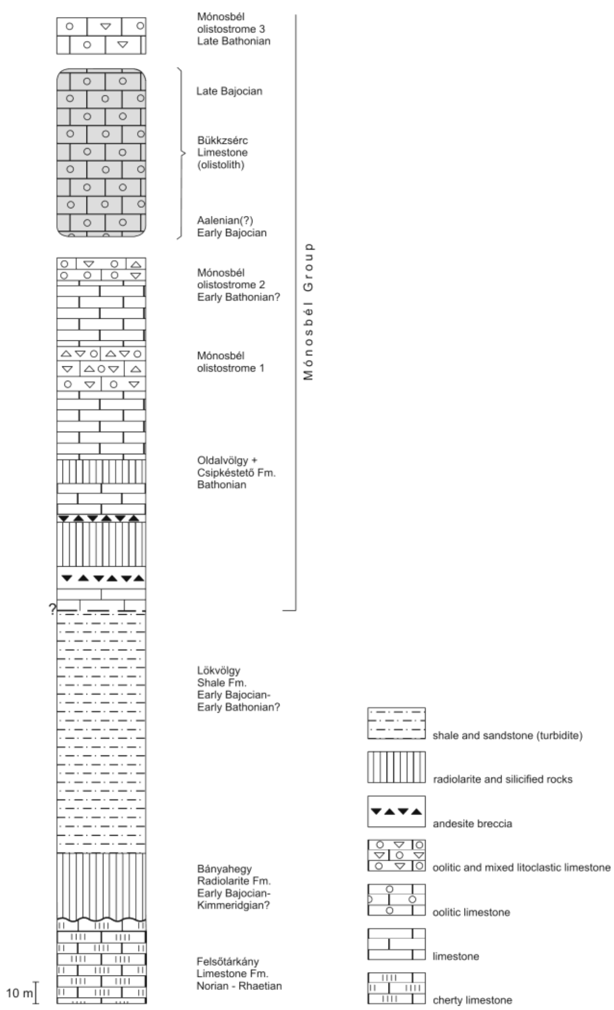

Fig. 2. General lithostratigraphic succession of the study area with indication of age data based on biostratigraphic results of the present study.

The Bükkzsérc Limestone is made up mostly of oolitic grainstone, and peloidal grainstone with intercalations of peloidal-filament wackestone and radiolarian wackestone and packstone representing platform foreslope and toe-of-slope facies (Haas et al., 2006). According to our new biostratigraphic (foraminifera) data this is the oldest unit of the Mónosbél Group. However, this lithofacies occur in the higher part of the Mónosbél Group (above or within the Oldalvölgy–Csipkéstető Formation) usually in smaller or larger redeposited blocks (olistolithes). Although in a lot of cases the geometry of the large blocks could not be unambiguously determined; the anomalous stratigraphic setting of the oolitic limestones suggests their redeposition in the form of olistolithes (Fig. 2).

Interpretation of the lithostratigraphic and biostratigraphic data and construction of a coherent chronostratigraphic scheme is not easy. There are uncertainties in the structural model which influence the assumed relations of the lithostratigraphic units and there are uncertainties in the radiolarian and foraminifera biostratigraphy as well. Evaluation of the new radiolarian data allowed a very wide time-range for the Bányahegy Radiolarite from the Early Bajocian to the Early Kimmeridgian. If the younger age date (younger than Bajocian) is valid, we have to find tectonic solution as it was done by Csontos (2000). However, if the Bányahegy Radiolarite is Early Bajocian, a continuous succession from the Bányahegy Radiolarite through the Lökvölgy Formation to the Mónosbél Group cannot be excluded either. We have a few foraminifera data from the upper part of the Lökvölgy Formation suggesting Early Bajocian – Early Bathonian age. According to the foraminifera fauna the Oldalvölgy–Csipkéstető Formation can be assigned to the Early Bajocian – Early Bathonian as well. Based on the radiolarian biostratigraphy this interval can be assigned to the Bathonian. Taking into account all of these data, the age of the Oldalvölgy–Csipkéstető Formation is Bathonian, probably Early Bathonian (Fig. 2).

Based on foraminifera Age-range of the Bükkzsérc Limestone encompasses the (Aalenian?) Early Bajocian to Late Bajocian interval. According to the foraminifera fauna the deposition of the lithoclastic beds (Mónosbél Formation) continued at least until the Late Bathonian.

Two, Middle-Late Jurassic sedimentary complex can be found farther to the North, in the Rudabánya Hills. One of them is built up by Bajocian–Callovian black shales, sandstone turbidites and olistostrome beds, and deposited by gravity mass flows. The clasts of the olistostrome are predominantly Middle to Upper Triassic pelagic limestones, rhyolite and basalt (Grill, 1988; Kövér et al., 2009). The other series consists of carbonate turbidite beds containing Jurassic platform derived clasts (ooids, peloids, foraminifera) and olistostrome horizons with Middle–Upper Triassic limestone clasts of red Hallstatt facies. The foraminifera assemblage is similar to that found in the Bükkzsérc Limestone (Kövér et al., 2009).

From Medvednica Mts., Croatia Triassic carbonate olistoliths and matrix-supported polymict conglomerates containing clasts of Triassic radiolarian chert, Jurassic silicified shale and sandstone, basalt and ultramafic rocks were reported. Radiolarians found in the radiolarite matrix proved latest Bajocian–Early Bathonian to Late Bathonian–Early Callovian age of the mélange complex (Halamić et al., 2005). This lithofacies is very similar to those of the Mónosbél Formation in the Bükk as far as both the matrix and the components of the olistostromes are concerned; moreover their ages are also similar.

The Mónosbél Group extends over the limits of the study area in the Bükk Mountains and continues in the Darnó area (Fig. 1). It was also recognised in ore exploratory wells at Recsk, Mátra Mts. (Haas et al., 2006; Kovács et al., 2008). Dark grey shale, siliceous shale, pelagic limestone, radiolarite, carbonate turbidites, debrites containing predominantly siliciclastic sandstone clasts and oligomict olistostomes are the typical lithofacies. Olistoliths of marine Upper Permian and Upper Triassic Hallstatt Limestone were encountered here within Bajocian to Callovian shale and radiolarite. The clasts of olistostromes are mostly radiolaria-bearing silicified rock-types. In a borehole drilled in the central part of Mátra Mts. Bajocian platform derived redeposited carbonates, more proximal than the Bükkzsérc Limestone in the Bükk Mountains, were encountered in a remarkable thickness (Haas et al., 2006).

Magmatites prevail above the Mónosbél Group. These are amygdaloidal basalts with red calcareous inclusions and inter-pillow void fillings, Triassic in age, and greenish usually pillow basalts, probably of Jurassic age. Deep-sea sediments, red radiolarite and dark grey siliceous shale also occur among the magmatic rocks (Kovács et al., 2008). The red radiolarite yielded either Ladinian-Carnian or Bathonian-Callovian radiolarians (Dosztály and Józsa, 1992). The magmatite bodies are probably olistolites in pelagic shale and radiolarite matrix.

The Triassic basalt olistoliths in the Jurassic mélange complex of Kalnik Mts., Croatia show definite genetic relationships with the Triassic volcanite bodies known in the Darnó area (Kiss et al., 2008).

In the Dinarides ophiolite mélange complexes comparable to those in the Bükk area occur in the Dinaridic Ophiolite Belt (Dimitrijević et al., 2003). The ophiolite mélange contains fragments of obducted ophiolites (lherzolite), Triassic and Jurassic limestone olistoplaka, and polymict olistostromes. Carnian to Upper Jurassic radiolarian chert, greywacke, basalt, gabbro, ultramafic rocks, granite and Triassic and Jurassic limestones are typical clastic components of the olistostromes (Robertson et al., 2009).

4. Geodynamic evolution and related sediment deposition

Terranes made up the pre-Tertiary basement of North Hungary approached its present-day setting only during the Tertiary (Late Paleogene to Early Miocene) as a result of multiple large-scale tectonic movements (Csontos and Nagymarosy, 1998). Prior to the large displacements they were located probably somewhere between the South Alpine and Dinaridic domain.

Neotethys rifting in the Late Anisian to Early Ladinian led to segmentation of the former ramp; isolated platforms and grabens were formed. In the Carnian some of these grabens filled up by siliciclasts or platform derived carbonates. In contrast, in the Slovenian Trough the pelagic basin setting preserved during the entire Late Triassic – Jurassic interval (Buser, 1989; Rožič et al., 2009). These tectonic processes led to separation of the Adriatic-Dinaridic Carbonate Platform from the Julian Carbonate Platform. Dismembering of other blocks inclusively the Bükk may have taken place similarly.

In the area of the Bükk Mts., drowning of the carbonate platforms took place by the end of the Triassic. In the Early Jurassic the former platforms transformed to submarine highs. In the Middle Jurassic the deepening continued and a radiolarite veneer formed covering both the previous platform and basin deposits. Than course to fine-grained siliciclastics (Vaskapu Sandstone), and distal siliciclastic turbidites (Lökvölgy Formation) were deposited in a deep-sea basin developed above the attenuated continental crust. The siliciclastic series were intruded by back-arc basalt.

Composition of the Mónosbél Group is complex, reflecting its multi-stage depoisitional history. The oldest biostratigraphically dated element of the Mónosbél Group is the (Aalenian?) Early to Late Bajocian Bükkzsérc Limestone, although these rocks are usually present as smaller or larger redeposited fragments. The large blocks should have slid down from the neighbourhood into the deep depositional basin in the late Middle Jurassic most probably in the Late Bathonian. However, beds containing fine redeposited shallow marine carbonate grains (ooids, cortoids, peloids, bioclasts) are also present in the hemipelagic Oldalvölgy Formation and in some olistostrome beds of the Mónosbél Formation. These facts imply continuing shallow marine input during the Middle Jurassic at least until the Late Bathonian.

The grains of the Bükkzsérc Limestone were formed on a carbonate platform; the redeposited particles were accumulated in the foreland of a platform foreslope. Considering that in the Middle Jurassic the Adriatic-Dinaridic Carbonate Platform (ADCP) remained the only large active platform in the wider region, we suppose that this was the provenance of the Bükkzsérc Limestone. In the Middle Jurassic mostly oolitic sediments were formed in the NE part of the ADCP (Dragičević and Velić, 2002). In several places, coeval slope and toe-of-slope facies of ADCP were also preserved. Textural features and microbiofacies (e.g. foraminifera fauna) of these formations are very similar to that of the Bükkzsérc Limestone (Haas et al., 2006).

Deposition of the Bükkzsérc Limestone and the coeval basin facies represents the passive margin evolutionary stage of the Adriatic (Apulian) margin of the western Neotethys during the Bajocian (Fig. 3). Dismembered and drowned blocks of the former platforms were already deep pelagic basins at that time far from the still existing platform.

Occurrence of the predominantly andesitic coarse clastic beds in the lower part of the Oldalvölgy–Csipkéstető Formation indicates the development of a magmatic island arc formed on continental crust in connection with the subduction of the Neotethys. As a consequence of the island arc development, the distal toe-of-slope and the connected pelagic basin transformed to an arc-related (inter-arc/backarc) basin. This event can be considered as the second evolutionary stage that may have taken place in the Early(?) Bathonian (Fig. 3).

In the Late Bathonian appearance of the polymict gravity deposits (turbidites and debrites – olistostromes) and later on large slided blocks (olistoliths) suggests the onset of the intense orogenic movements in the third stage of the evolution (Fig. 3). The compressive tectonic movements led to imbrication, nappe stacking and accordingly uplifting and disruption of the previously deposited and already lithified peri-platform carbonate deposits and also the island-arc and back-arc volcanites. In the course of the overthrusting movements, also the older basement rocks may have been exposed and subject to erosion.

The Dinaridic (-Hellenidic) ophiolites are interpreted as mostly supra-subduction zone (SSZ) ophiolites which were crystallized at 171 Ma and emplaced by 169 Ma i.e. during the Bajocian (Smith, 2006). This is roughly coeval with the basic change in the evolution of the area studied, a change from the passive carbonate platform evolution when mostly uncemented carbonate grains accumulated in the foreground of a carbonate platform to the accumulation of volcaniclasts and polymict gravity deposits which clearly indicate the onset of the active subduction period. It was followed by obduction probably in the latest Jurassic to earliest Cretaceous (Balla, 1987; Csontos, 2000) and development of a subduction–collision-related

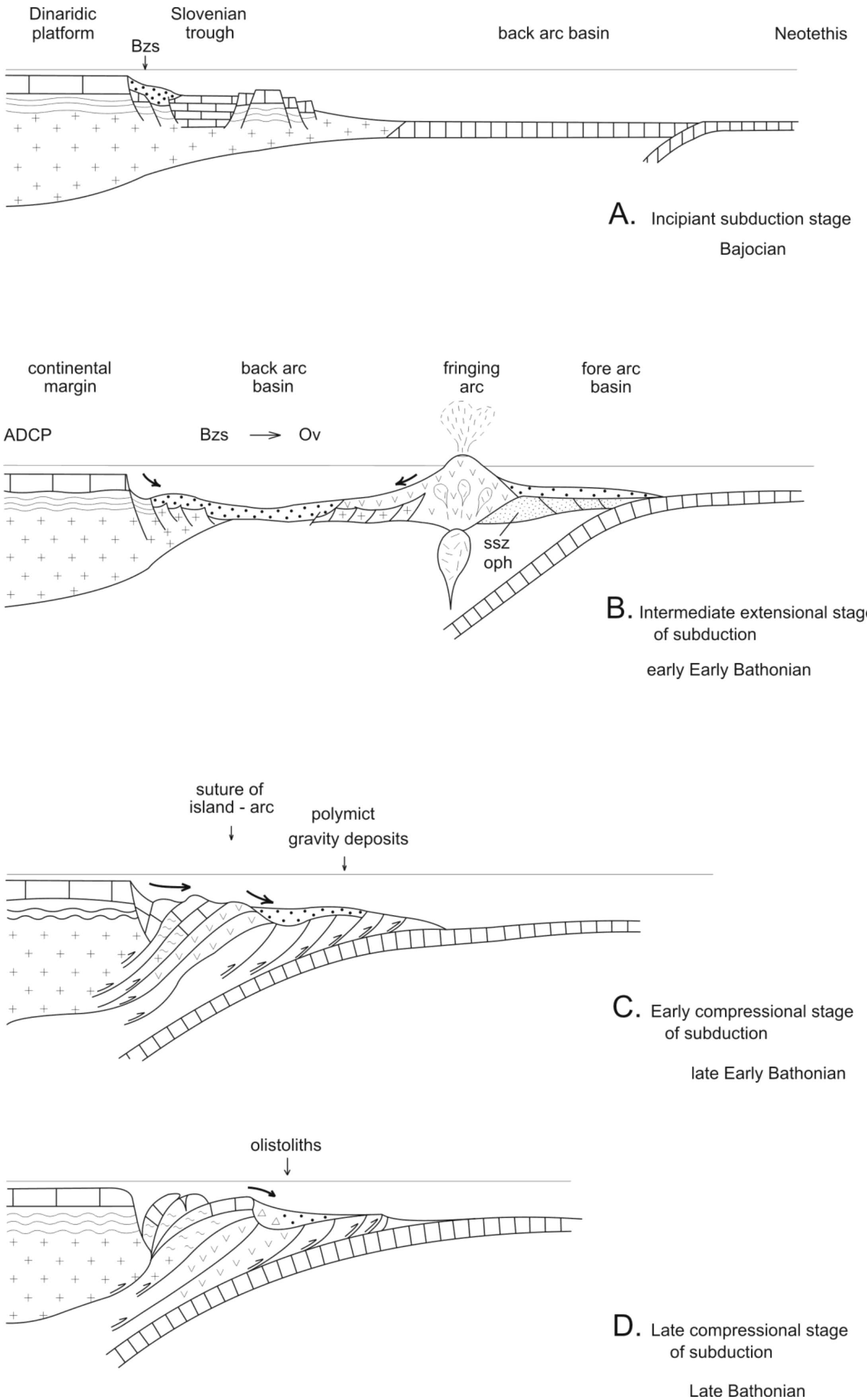

Fig. 3 Conceptual geodynamic and sedimentation model for the Middle Jurassic evolution of the region studied.

mélange complex containing blocks of ophiolites and fragments of the Adriatic continental margin. Further compression resulted in the overthrust of the mélange complex onto the blocks dismembered earlier from the Adriatic margin i.e. the Bükk Parautochthonous, leading to regional metamorphism of the Late Paleozoic to Late Jurassic formations in the late Early Cretaceous (110–120 Ma) and in the Late Cretaceous (90 Ma) (Árkai et al., 1995). The nappe emplacements and the related tectono-metamorphic events took place prior to the Tertiary long-distance displacement of the Bükk Unit.

5. Conclusions

Displaced elements of the Neotethys ophiolite mélange complex occur in the Bükk Mts. and Darnó–Mátra area, in Northeast Hungary. Study of the depositional facies, age determination of the subduction-related sedimentary formations on one hand and detailed petrographic analysis, facies interpretation and age determination of the clastic components of the mélange on the other, provided important data to detect the origin of the clastic material and reconstruction of the complex closure history of the western Neotethys Ocean.

The Bükkzsérc Limestone represents the passive evolutionary stage of a carbonate platform system. It is made up of redeposited platform-derived grains which were deposited in a toe-of-platform foreslope and peri-platform basin setting in the Aalenian(?) Early to Late Bajocian interval.

Based on radiolarians and foraminifera in the matrix of olistostrome interbeds, the Mónosbél Group deposited most probably during the Bathonian. The lower part of the complex is typified by predominance of pelagic carbonates, shales and radiolarites with andesitic volcaniclast intercalations. Intercalations of the andesitic volcaniclasts suggest an island arc provenance and accordingly development of an arc-related basin.

The higher part of the succession is characterised by polymict olistostromes. Large olistoliths that are predominantly blocks of shallow marine "Bükkzsérc-type" limestones appear in the upper part of the sequence.

Appearance of the polymict olistostromes with shallow and deep marine carbonate, siliciclasts, basic to acidic volcaniclasts and metamorphic components implies imbrications, incipient nappe development in a compressional regime probably in the Late Bajocian. This stage is followed by input of large slided blocks mostly of the Bükkzsérc Limestone suggesting disruption and thrusting of the previous passive margin.

Significant difference between the composition of the redeposited clasts in the olistostromes of the Bükk and Darnó area indicate deposition in different subbasins formed along the subducted margin of the Neotethys.

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