

**THE CONTINUATION OF THE INTERNAL DINARIDIC UNITS IN
THE TRANSITIONAL AREA BETWEEN THE EASTERNMOST PERIADRIATIC LINE
AND NORTHERNMOST SOUTHERN ALPS IN SLOVENIJA**

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In the consideration of the Alps/Dinarides connection, the western parts of the Zagorje-Mid-Transdanubian (or Sava) Zone in Slovenija, positioned between the Apulia and Eurasia, includes disconnected outcrops of the Internal Dinaridic units. The Northern Zone, which is close to the Periadriatic Lineament, is mainly composed of Albian-Cenomanian to Late Cretaceous flysch sequence correlatable to the Sava-Vardar flysch sequence. The outcrops are positioned in frontal parts of the Julian-Savinja Nappe. The Southern Zone included in the Sava Nappe (or the Slovenian Trough), which is thrust onto the northern margin of the Adriatic-Dinaridic carbonate platform, e.g. the External Dinarides, is composed of Aptian to Cenomanian clastics and carbonates disconformably overlain by Late Cretaceous carbonate flysch sequence. It can be correlated with the Bosnian flysch of the Central Dinarides. Both, the Northern and Southern Zone stretch westward up to the frontier with Italy and Austria.

All presented data indicate mutual space connection between the northwesternmost Dinarides and the easternmost Alps during their Late Alpine geodynamic evolution. Their apparent disconnection in the present structure of the Dinarides and Alps is the result of postorogenic indenting of Apulia and related strike-slip faulting.

Key words: The Alps-Dinarides connection, Slovenija, Periadriatic Lineament, Internal Dinaridic units, Zagorje-Mid-Transdanubian Zone.

Introduction

The Alpine tectonostratigraphic units of the Dinarides links up to the north with Alps offering the problem of the Alps/Dinarides connection. However, to date nobody has precisely defined the Dinarides/Alps boundary in a geological sense.

Slovenija is an Alpine country in whose northern area terminates the easternmost part of the Periadriatic Lineament, locally named the Smrekovec Fault (Mioč, 1984).

The aim of this paper is to present basic geological signatures of Mesozoic-Early Paleogene formations of central Slovenija and correlate them with identical formations from the Internal Dinarides.

Internal units of the Dinarides

As distinguished from the Alps, the largest part of the Central Dinarides, despite their complex fold-thrust-imbricate structure, is characterized by a regular zonal pattern in the spatial distribution of characteristic Alpine tectonostratigraphic units which developed during the Alpine evolution of the Dinaridic-Hellenidic part of the Tethys (Pamić 1993). From the southwest to the northeast, i.e. from Adriatic microplate toward the Tisia-Moesia, the following tectonostratigraphic units, originating in different Tethyan environments, can be distinguished (Fig. 1): 1) Adriatic-Dinaridic carbonate platform – External Dinarides; 2) carbonate-clastic formations, in some areas with flysch signatures, of the Tethyan passive continental margin- "flysch bosniaque" (Aubouin et al., 1970); 3) ophiolites associated with genetically related sedimentary formations – Dinaridic Ophiolite Zone (Pamić 1982); 4) sedimentary, igneous and metamorphic units of the Eurasian active continental margin – Sava-Vardar Zone (Pamić 2002); the tectonostratigraphic units 2) to 4) define the Internal Dinarides, also referred to as Supradinaric (Herak 1986); 5) Paleozoic-Triassic nappes which are included into the Internal Dinarides by out of sequence thrusting.

Zagorje-Mid-Transdanubian (or Sava) Zone

The Slovenian territory can be divided into three geotectonic units: 1) the Eastern Alps to the north, 2) the northwesternmost External Dinarides and Southern Alps, respectively to the south, and 3) the middle Slovenian unit which is composed of allochthonous Paleozoic and Mesozoic formations and for that reason, is included in the western parts of the Zagorje-Mid-Transdanubian (or Sava) Zone (ZMTZ) - (Fig. 2).

Most part of the ZMTZ is composed of two large approximately E-W trending nappes: 1) the Sava Nappe which is thrust onto the northeastern margin of the External Dinarides, e.g. the Mesozoic carbonate platform, and 2) the Julian-Savinja Nappe which is thrust onto the Sava Nappe (Mioč 1984).

Within the western parts of the ZMTZ, two separate zones with Internal Dinaridic lithologies can be distinguished. 1) The Northern Zone, which is almost continuous, can be

traced in an E-W direction for about 100 km from Celje in the east to southern Julian Alps in the west and Italian-Slovenian frontier in the west. It is positioned along frontal parts of the Julian-Savinja Nappe. 2) The Southern interrupted zone with Internal Dinaridic lithologies, which can be traced along strike for more than 100 km from Slovenia-Croatia frontier in the east to the Tolmin-Gorizia area in the west, is positioned along frontal parts of the Sava Nappe.

Internal Dinaridic units of the ZMTZ

The Northern zone is best exposed in Tolmin area, where internal units have in total thickness of about 900 m. Here, the oldest are Aptian-Albian-Cenomanian shales, marly shales, calcarenites and limestone breccias which disconformably overlie Tithonian-Berriasian micrites with chert nodules. The Lower Cretaceous sediments are conformably (?) overlain by Cenomanian-Turonian marly limestones and limestones with chert nodules which continue into Coniacian. Uppermost parts are represented by Campanian fossiliferous flysch sequence composed of marly shales, calcarenites, sandstones and limestone conglomerates (Buser 1986) – Fig. 3.

These Cretaceous formations can be correlated with the Cretaceous formations of the southerly located Sava-Vardar Zone of the Dinarides (Dimitrijević 1995; Pamić 2002). The lowermost parts of the Sava-Vardar flysch are composed of Lower Cretaceous calcarenites, marly shales and sandstones with non-turbiditic signatures which are disconformably overlain by Late Cretaceous/Early Paleogene flysch sequence which is composed of fossiliferous marly shales, sandstones, calcarenites with subordinate limestone breccias, about 800-900 m thick (Fig. 3).

In this correlation it must be noted that the Sava-Vardar Zone of the Dinarides, beside widespread Cretaceous/Early Paleogene flysch formations, characteristically includes Cretaceous/Early Paleogene tectonized ophiolite mélange whose outcrops to date have been just mentioned in Slovenija (Mioč 1995) but as yet not described. In the Sava-Vardar Zone of the Dinarides, Oligocene post-syn collisional granitoids including tonalites, and andesites are very common (Pamić 2002). The volcanics with tuffs are also abundant in the Northern Zone in the area of the easternmost Periadriatic Lineament in which Oligocene tonalite-granite plutons of Mts. Pohorje and Karavanke are also included. *The Southern Zone* is best exposed in the area of Novo Mesto and Celje (Pleničar and Premru 1977; Buser 1979). Here occur outcrops of the «Slovenian Trough» described in detail by Cousin (1972). In the Celje area, the oldest preserved outcrops are composed of

Aptian-Albian-Cenomanian shales, marly shales, calcarenites with subordinate limestone breccias.

Cousin (1972) has already tentatively correlated the formations of the Slovenian Trough with the Bosnian flysch from the Central Dinarides. Its complete evolution is demonstrated in geological chart in Fig. 3. This correlation shows that the flysch formations of the Southern Zone correspond to the upper parts of the Bosnian flysch, e.g. Ugar subgroup (Hrvatović 1986). The point is that the flysch sequences from both Central Dinarides and the southern ZMTZ are underthrust by the carbonate platform, e.g. External Dinarides.

Discussion

According to the proposed geodynamic model for the Dinarides (Pamić et al. 1998), the Eocene collisional phase was followed by Oligocene transpression, characterized by strong dextral strike-slip faulting (Laubscher 1971, 1983) related to the north-northwestern indenting of Apulia (Coward and Dietrich 1987; Dercourt et al. Eds. 1993; Stampfli and Marchant 1997). It comes out that the main Early Paleogene Sava-Vardar suture Zone was transformed during the Oligocene into strong dextral strike-slip fault system. Reaching this evolutionary stage, the Sava-Vardar Zone obtained the same (similar?) geotectonic setting as the Periadriatic Lineament area. Deep seated effects of these collisional and transpressional processes in the Periadriatic-Dinaridic-Hellenidic region have been recently indicated by seismic tomography (Yoshioka and Wortel 1995).

Alps and the Dinarides with Hellenides developed along the north-northeastern margin of Apulia, and it is quite conceivable that the indentation processes must have peripherally affected the adjacent Dinarides. This is shown by the gradual change of strike from E-W to WNW-ESE in the Alps to NW-SE in Dinarides.

Due to this NNW directed indenting of Apulia, the Alpine tectonostratigraphic units of the Internal Dinarides become narrower and gradually wedge out toward the NW.

In conclusion, presented data on the Internal Dinaridic units in the eastern parts of the ZMTZ document the mutual space connection between the northwestern Dinarides and easternmost Alps during the late Alpine geodynamic evolution. Their apparent disconnection in the present structure of the Dinarides and Alps is the result of postorogenic indenting of Apulia and related strike-slip faulting.

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Fig. 1. Major tectonic units of the Dinarides.

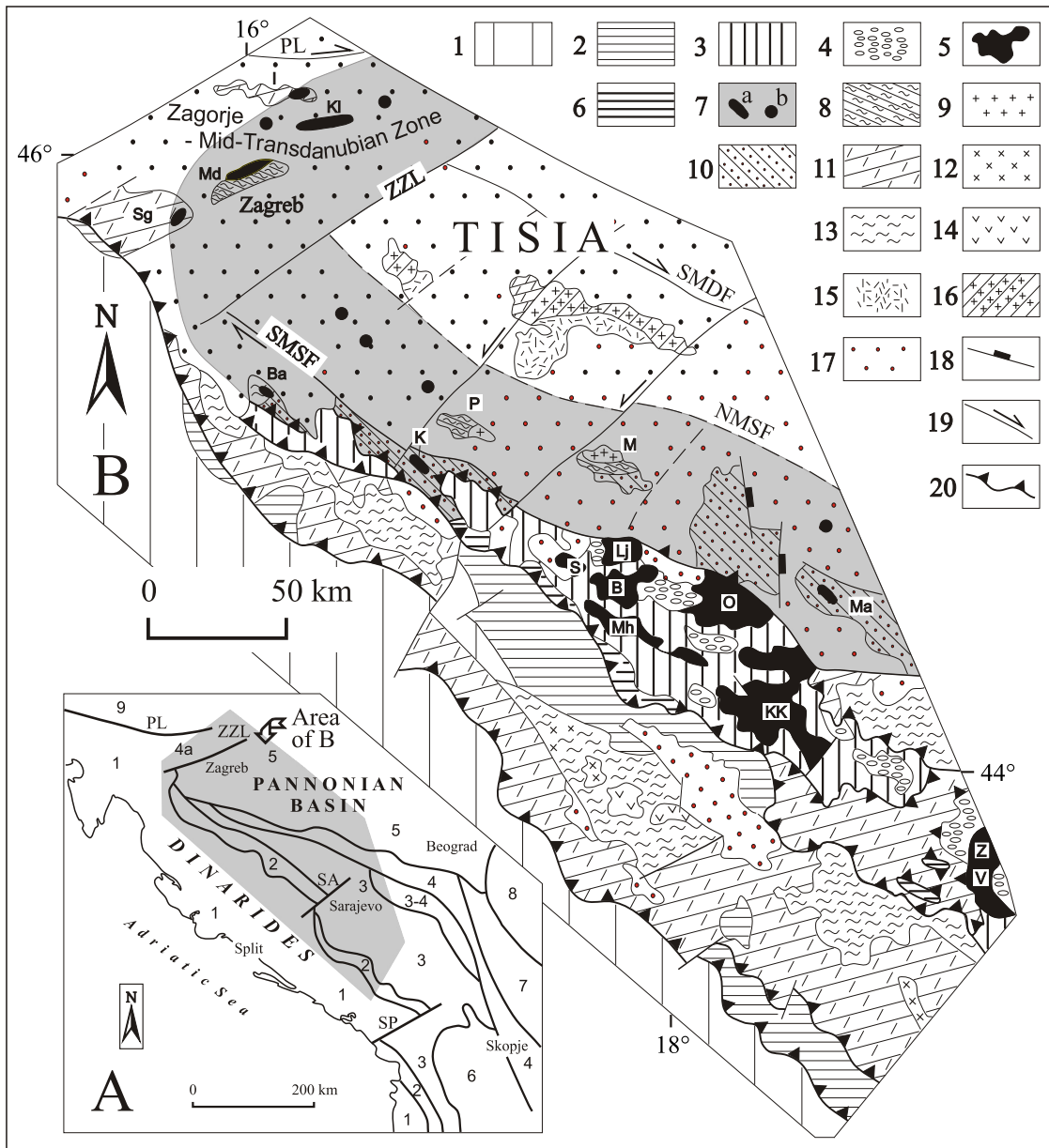
A. Index map showing major tectonic units of the Dinarides and surrounding regions (simplified after Aubouin, 1974). Legend: 1 External Dinarides and Southern Alps; 2 Carbonate platform margin formations; 3 Dinaride Ophiolite and Mirdita Zones; 3-4 Golija Zone; 4 Vardar Zone; 4a Zagorje - Mid-Transdanubian Zone; 5 Pannonian Basin; 6 Pelagonide; 7 Serbo-Macedonian Massif; 8 Carpathians and Balkan; 9 Eastern Alps; Major faults: PL Periadriatic Lineament; ZZL Zagreb-Zemplin Line; SA Sarajevo Line; SP Scutari-Peć Line.

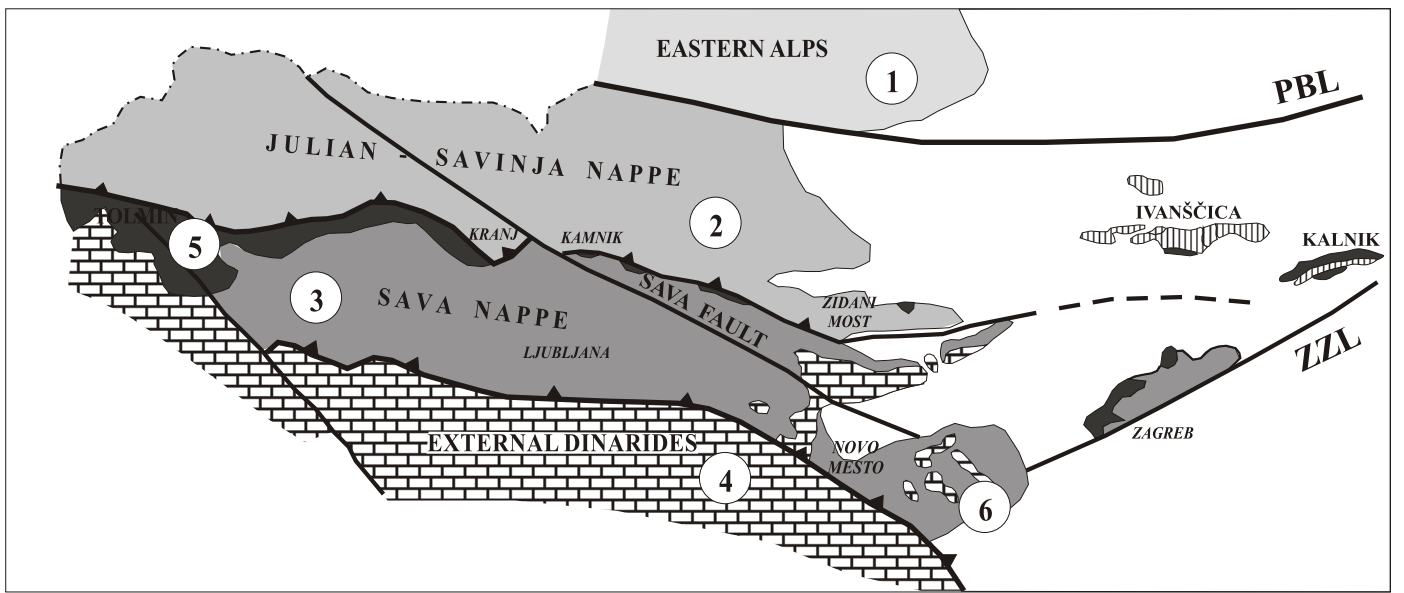
B. Geological map of the central and northwestern Dinarides (modified after Pamić et al., 1998) Legend: 1 Adriatic-Dinaridic carbonate platform; 2 Jurassic-Cretaceous passive continental margin sequences ("flysch bosniaque" and "zone prekarstique"; Aubouin et al. (1970)); 3 Dinaride Ophiolite Zone; 4 Late Jurassic-Cretaceous sequences unconformably overlying ophiolites; 5 large ultramafic massifs; 6 Radiolarite Formation; 7 Vardar Zone with ophiolites exposed on surface (a) and in deep wells (b); 8 Late Paleogene synkinematic metamorphic rocks; 9 Late Paleogene synkinematic granitoids; 10 Late Cretaceous-Early Paleogene flysch; Paleozoic-Triassic Nappes: 11 allochthonous Triassic sequences; 12 Triassic igneous rocks; 13 allochthonous Paleozoic sequences; 14 Paleozoic volcanics; Tisia: 15 Hercynian progressively metamorphosed sequences; 16 Hercynian granitoids and migmatites; 17 Neogene overstep sequences; 18 fault with downthrown block; 19 strike-slip fault; 20 major thrust;. Large faults: PL Periadriatic Lineament; ZZL Zagreb-Zemplin Line; SMDF Southern marginal Drava fault; NMSF Northern marginal Sava fault; SMSF Southern marginal Sava fault. Mountains: B Borje, Ba Banovina, I Ivanščica, K Kozara, Kl Kalnik, KK Krivaja-Konjuh, Lj Ljubić, M Motajica, Ma Majevisa, Md Medvednica, Mh Mahnjača, O Ozren, P Prosara, S Skatavica, Sg Samoborsko gorje, V Varda, Z Zlatibor.

Figure 2. Sketch map of Hrvatsko Zagorje and Central Slovenija areas.

1 Eastern Alps; 2 Julian Savinja Nappe; 3 Sava Nappe; 4 External Dinarides; 5 Northern Zone; 6 Southern Zone.

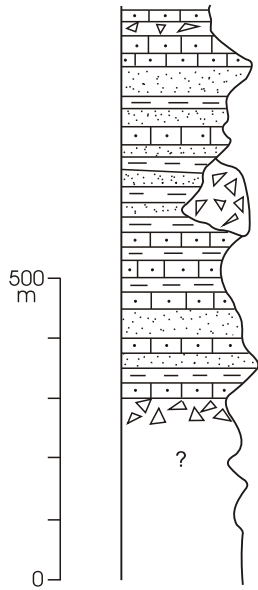
Figure 3. Geological columns for the Northern and Southern zones within the Internal Dinaridic units.



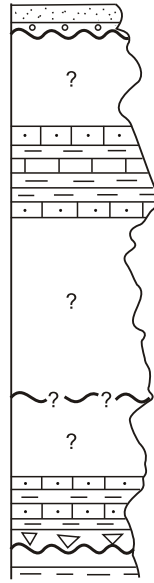


SOUTHERN ZONE

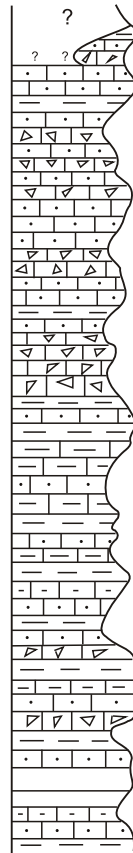
NOVO MESTO



CELJE

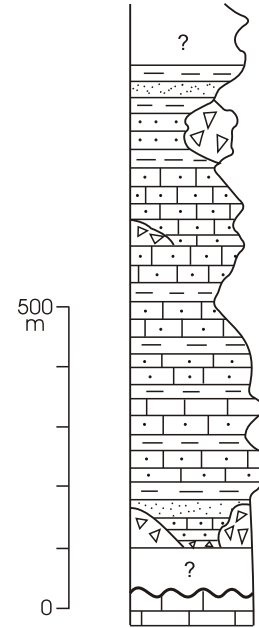


BOSNIAN FLYSCH

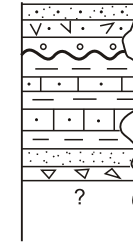


NORTHERN ZONE

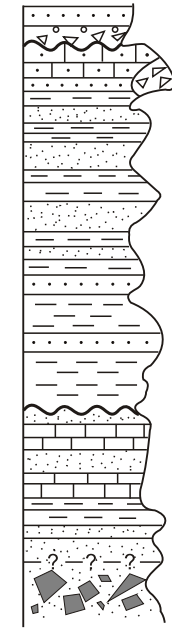
TOLMIN



LJUBLJANA



SAVA-VARDAR ZONE



- 1 2 3 4
- 5 6 7 8

1 breccia; 2 sandstone; 3 marly shale;
 4 pyroclastics; 5 limestone;
 6 calcarenite; 7 marly limestone; 8 limestone
 breccia-arenite