Principles of the tectonic subdivision of Slovenia

Osnove tektonske razčlenitve Slovenije

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Abstract

New tectonic subdivision of the junction region between Alps and Dinarides which incorporates Eastern Alps, Southern Alps, Dinarides, Pannonian basin and Adriatic-Apulia foreland is described in this article. The course of the boundary between Southern Alps and Dinarides is updated. Dinarides are subdivided into the Internal and External Dinarides. Internal Dinarides comprise only the areas with deep water sedimentary successions and ophiolites. External Dinarides are composed for the most part of the Adriatic-Dinaric carbonate platform and of transitional area to the Internal Dinarides.

Herak’s subdivision of the External Dinarides into Adriatic, Epiadriatic and Dinaric is not accepted, because he assumes two separate Mesozoic carbonate platforms (Adriatic and Dinaric). In Slovenia, however, existed only one Mesozoic carbonate platform, so it is justified to use the term Adriatic-Dinaric carbonate platform. It started to disintegrate in the Paleocene.

The position of the Adriatic microplate is also included in this subdivision.

Introduction

The present tectonic structure of the Slovenian territory originated during the Tertiary orogeny following the collision of Apulian lithospheric plate (Apulia sensu SCHMID et al., 2004) with Eurasian lithospheric plate on which the Apulian plate was overthrust. The presented subdivision of structure is schematic, and it reposes on second and third order terranes that were formed from Apulia and its marginal regions. In this way in the formal structural sense 1. Adriatic-Apulian foreland, 2. Dinarides, 3. Southern Alps, 4. Eastern Alps, and 5. Pannonian basin are distinguished. Boundaries between units in the tectonic sense or in the sense of regional subdivision are presented by important dislocations: the Periadriatic fault, Labot (Lavanttal) fault, Ljutomer fault, Sava fault, South-Alpine thrust border and the external front of External Dinarides thrust area. The Pannonian basin is determined by the depressions filled with Tertiary sediments of Paratethys.

For the presented tectonic division of Slovenia the following references were used: Basic geologic map of Yugoslavia 1 : 100.000 (1967-1986) the last mapped sheet of which was issued as Basic geologic map of Republic Slovenia and Republic Croatia (1998), in short OGK, Structural-tectonic map of Slovenia (POLJAK, 2007) that summarizes the structural data of OGK, and Geologic map of Slovenia 1 : 250.000 (BUSER, in preparation for print) on which stratigraphic data of all OGK sheets are compiled. The present division repos...
2005) and older attempts (Rakovec, 1956) of tectonic division of Slovenia, and on recent publications that contributed to a contemporary view on the matter (e.g. JeLEN & RIFELJ, 2002).

**Subdivision**

Figure represents the proposed new tectonic division of Slovenia, as modified after Placer (1999b).

1. The Adriatic-Apulian foreland represents a relatively solid core of the Adria microplate. It comprises the larger part of Istria consisting of rocks of the Adriatic segment of the Adriatic-Dinaric Mesozoic carbonate platform, and the flysch rocks resulting from its degradation. The boundary of the foreland is the external limit of the thrust area of the External Dinarides. Actually it became deformed by later separate underthrusting of Istria, the central structural element of it being the Palmanova thrust fault, named in Slovenia the Črn Kal thrust fault. The Adriatic-Apulian foreland represents the foreland of Dinarides, Southern Alps and Apennines. The term Dinaric foreland used by Otoni (2007) is correct, but devoid of the structural unit significance, as it comprises only the northeastern and eastern parts of the Adriatic-Apulian foreland.

2. The Dinarides consist, following the standard structural-paleogeographic model, of the External and Internal Dinarides, and of the transition region between the two that is attributed in the present text to the External Dinarides. The same subdivision is used e.g. also by Grandić et al. (2004). On Slovenia’s territory only the External Dinarides are exposed, comprising also the transition belt. The boundary of Dinarides with Southern Alps is represented by the South-Alpine thrust border which merges further to the east with Marija Reka fault. External Dinarides comprise the prevailing part of Dinaric segment of the Adriatic-Dinaric Mesozoic carbonate platform, and most part of its Adriatic segment. Characteristic for them is the thrust and nappe structure that became accomplished in External Dinarides in the Upper Eocene–Postocene times, whereas the nappe structure of Dinarides started to take shape with the convergence between Apulia and Dacia with Tisia in the Upper Jurassic time. In the External Dinarides on our territory only the Trnovo and Hrushića nappe and also the Snežnik thrust block can be recognized with more certainty. Premru (2005) subdivided in detail the Dinarides east from there, but we consider, however, that there the level of current research is not sufficient to recognize individual units. On the basis of recent data the Sava folds are attributed to Dinarides, since no clear structural boundary to Southern Alps is visible. With respect to their position within the External Dinarides the Sava folds represent a transition zone to the Slovenian basin in

Figure 1. Adrija-Apulia foreland; 2. Sediments resulting from disintegration of the Adria–Dinaric carbonate platform: Eocene flysch; 3. Dinarides; 4. External Dinarides; 5. Sediments resulting from disintegration of the Adria–Dinaric carbonate platform: Upper Cretaceous carbonatic turbidites, Cretaceous–Paleocene and Eocene flysch; 6. Cretaceous–Paleocene scaglia: Trnovo nappe (1 – Goriška Brda, 2 – Banjšiško, Hrushića nappe (3 – Predjama, 4 – Kališče); 5. Kočevje area; 7. Paleozoic (Carboniferous, Permian); 8. T – Trnovo nappe, H – front of the Hrushića nappe, S – front of the Snežnik thrust unit; 9. STW – Strug tectonic window; 10. Transition area between External and Internal Dinarides; 11. Internal Dinarides; 12. Southern Alps; 13. Paleozoic (Devonian, Carboniferous, Permian); 14. STO – Slatna tectonic outlier (»Slatna plate«); PTO – Ponikva tectonic outlier; 15. Slovenian basin; 16. Eastern Alps; 17. Austroalpine nappes: metamorphic rocks; 17. Austroalpine nappes: Perm–Cretaceous overthrust (Gail Alps, Northern Karavanke); 19. Pluton of tonalite/granodiorite (Miocene), Pohorje; 20. Magmatic zone of the Železna Kapla (Eisenkappel): Permo-Triassic intrusives, tonalite (Oligocene); 21. Magmatic zone of the Železna Kapla (Eisenkappel): granite (Triassic); 22. Pannonian basin and marginal basins; 23. Adrija microplate; full lines – Neogene condition, full and interrupted lines – present condition; 24. Faults: PAF – Periadriatic fault; 25. KRF – Kungota – Bač fault; LAF – Lavanttal fault; VEF – Velika pri Celju fault; SOF – Soča-Jalovica thrust; LJJ – Ljutomer thrust; DON – Donji fault; SAF – Sava fault; MRF – Marija Reka fault; ZEF – Želiniške fault; IDF – Idrija fault; RRV – Ravne and Sovodenj fault, BRF – Borovnica and Škavnik fault, PRF – Predjama fault, ZZL – Zagreb–Zemplin lineament; 26. Thrust and overthrust faults in the Dinarides: PNTF – Palmanova thrust fault; 27. Thrust and overthrust faults in Southern Alps: SATB – Southern Alps thrust border; KKT – Kran–Kobla thrust fault; 28. North Karavanke thrust fault in Eastern Alps; 29. Sava folds: MS – Motnik syncline, TA – Trojane anticline, LS – Laško syncline, LA – Litija anticline.
the north that occurs prevailingly in the Southern Alps, and to the Bosnian basin in the east.

3. The Southern Alps are paleogeographically a part of Dinarides, but became separated from them in Miocene. Formally they are situated between the Periadriatic fault, Labot (Lavanttal) fault and Ljutomer fault, which are in the broader sense a part of the Balaton fault zone in the north, and South-Alpine thrust border and Sava fault in the south. Mesozoic rocks of the Slovenian basin and Upper Triassic rocks of the Julian carbonate platform are exposed within them. South of the Periadriatic fault in the Carnian Alps and Southern Karavanke also Paleozoic rocks are exposed (Mioč, 1997). Such conditions are associated with the synform structure of Julian and Kamnik-Savinja Alps in west-east direction and with transpressive extrusion along the Periadriatic fault zone. The South-Alpine thrust border is represented by a thrust faults zone that extends eastward to the Sava fault. Its northern edge represents the Krn-Kobla thrust fault. East of Želimlje fault, the South-Alpine thrust border merges with Marija Reka fault, which is an element of the Sava fault zone. In an earlier interpretation (Placer, 1999b), the Krn-Kobla thrust fault was understood on the basis of OGK data (Grad & Ferjančič, 1974, 1976; Buser, 1986, 1987) as the boundary of the Julian nappe. The new concept is based on data supporting the normal position of Upper Triassic carbonates on Middle Triassic clastics in the Julian Alps (Skaberne et al., 2003), and the equivalent conditions in the
Kamnik–Savinja Alps (Celarc, 2003). Therefore the concept of the Julian nappe should be abandoned, and the Julian Alps should be considered as a thrust block. The nature of the South-Alpine fault border also makes unnecessary the introduction of a Tolmin nappe (Krystyn et al., 1994). The Slatna plate is a tectonic outlier (Seidl, 1929; Jurkovšek, 1987a, 1987b; Celarc & Herlec, 2007) that is probably a remnant of the extreme uplift of northern block of the Julian synform during underthrusting of the External Dinarides.

4. The Eastern Alps are a geologic-orographic term comprising the complex of Precambrian and Old Paleozoic high and low grade metamorphic rocks, and of Permian and Mesozoic sedimentary rocks north of the Periadriatic fault that is called Ljutomer fault in the area east of the Labot fault. In structural sense, the Eastern Alps consist of a system of large nappes called the Austroalpine nappes (in short Austroalpine), that represent compressed and elongated remnants of marginal regions of the intermediate sea that existed between the European (Eurasian) and Apulian lithospheric plates. They originated during Cretaceous and Tertiary orogenies, and are, owing to their close connection with the overthrust Apulian plate, attributed to the latter, Tollmann (1977) distinguished in the Austroalpine nappes the Lower, Middle and Upper Austroalpine nappes, and recent researchers, like Schmid et al. (2004), the Lower Austroalpine nappes, Upper Austroalpine basement nappes, and the Upper Austroalpine nappes. In Slovenia, the Kobansko region, Pohorje, Strojna and North Karavanke belong to Eastern Alps. Mioc (2003), using the older terminology, attributed Pohorje and part of Kobansko region to the Upper Austroalpine, and the other part of Kobansko, Strojna and North Karavanke to the Middle Austroalpine. The latter belongs according to the more recent terminology to Upper Austroalpine basement nappes that comprise also Paleozoic and Mesozoic rocks not affected by metamorphism. In Slovenia, the Northern Karavanke form the characteristic transpressive zone along the Periadriatic fault along which were the highest uplifted the Paleozoic phyllitoid schists in the basement of Permotriassic clastites. Northern Karavanke are attributed in the structural sense to the Southern Alps, but they have a similar lithologic development of basement and of sedimentary Mesozoic cover as the Upper Austroalpine basement nappes south of the Northern Calcareous Alps. Therefore it is reasonable to consider them a part of the Eastern Alps.

An important characteristic of Eastern Alps is, in addition to the nappe structure, the tonalite plutonism that consists of the Periadriatic intrusions, in Slovenia the southern belt of Železna kapla (Eisenkapfel) magmatic zone, and of the Pohorje tonalite/granodiorite pluton with dacitic sills and dykes. According to data by Trajanova et al. (2008), the Periadriatic intrusion is of Oligocene age, around 32 Ma old, and the Pohorje pluton with dacite is Miocene age, between 19 and 18 Ma old; the age of somewhat younger rhyodacitic and lamprophyric dykes is between 17 and 16 Ma. Owing to the difference in age and in position, the Pohorje tonalite is not considered a part of the Periadriatic intrusions.

5. The Pannonian basin, Pannonian basins system respectively, consists of individual depressions that originated during Paleogene and Neogene. They are filled with sediments of the Paratethys deposited on subsided continuations of the Eastern and Southern Alps and Dinarides. The region of the Pannonian basin started its distinct structural evolution at the beginning of Miocene with the post-collision tectonic escape of the Eastern Alps whose southern border was the Periadriatic fault zone (Ratschbacher et al., 1991). According to surmise of Podor et al. (2002), we suppose that escape in the starting stage could have taken place along the Ljutomer fault. The lateral extrusion affected also the region of Dinarides north of the Zagreb lineament (Haas & Kovacs, 2001; Jelen et al., 2001). Development of the basin was polyphase due to the interchanging of extensional and compressional regimes. The result of these processes is the actual structure characterized in northeast Slovenia by subbasins derived from the Lower Miocene Mura-Zala and Styrian basins, e.g. the Haloze-Ljutomer subbasin, and in the western rim the isolated basins in Eastern and Southern Alps and Dinarides. Of more importance are the Smrekovec, Celje, Tunnjice-Motnik, Laško, Planina, Senovo and Krško basins. Situated the farthest west is the Bohinj basin (Jelen et al., 2008).

Problems of tectonic division

In updating the scheme of tectonic subdivision of Slovenia, two important questions must be considered, both not appropriately solved yet: firstly, the course of the boundary between Southern Alps and Dinarides, associated with the question of extension of the Trnovo nappe, and secondly, the question of internal subdivision of the Dinarides. The boundary between Southern and Eastern Alps passes formally along the Periadriatic and Balaton fault zones. The question of genesis of the Pannonian basin and of isolated basins along its western rim in Eastern and Southern Alps and Dinarides has been the object of numerous studies in the last two decades.

Boundary between Southern Alps and Dinarides. Data of OGK mapping supported the opinion that Blegoš is a part of External Dinarides (Grad & Ferjančič, 1974, 1976; Premru, 1980). This was confirmed by kinematic analysis of evolution of the Blegoš structure (Placer & Car, 1997) from which it follows that the Blegoš structure emerged first because of the thrusting in Dinaric direction (from northeast toward southwest), and afterwards, because of underthrusting of External Dinarides under Southern Alps (south-southeast toward north-northwest). Therefore it is possible
to determine in the Blegoš area the unequivocal structural boundary, which is a thrust plane, between the External Dinarides and Southern Alps. Its continuation west of Blegoš to the Idrija fault is relatively clear, as on the northern side deeper sea originated rocks of the Slovenian basin crop out, and on the southern side carbonate rocks of the Trnovo nappe are exposed. At the Idrija fault, the boundary is displaced toward northwest for a few kilometers. A special role in defining its character has the Ponikve tectonic klippe, situated east of the Idrija fault, which is an isolated part of the overthrust of the Slovenian basin onto the Trnovo nappe. The considered boundary can be traced east of Blegoš as far as to the Ljubljana depression and along its western rim.

In discussing the passage of boundary between Southern Alps and External Dinarides east of the Ljubljana depression it is useful to compare the development of rocks of the Slovenian basin east of Ljubljana depression in the frame of Southern Alps, with its development east of Ljubljana depression in the western part of the Sava folds, and verify the existence of Dinaric nappe structures in the Sava folds. For the rocks of the Slovenian basin west of Ljubljana depression, Mesozoic deeper sea sediments are characteristic, whereas in the eastern borders of Ljubljana depression the aforementioned sediments exist only in the northern belt of the Sava folds north of Trojane anticline. In central and southern parts of Sava folds, Triassic-Jurassic platform carbonates prevail on which the Upper Cretaceous flysch is deposited (Premru, 1980, 1983a, 1983b, 2005). Such development is found also in certain isolated hills in the Ljubljana field. In association with the nappe structure we recognized that in Sava folds the Mesozoic rocks form one or several large nappe units that became overthrust before the deposition of Middle to Upper Oligocene beds (Placer, 1999a), as deduced from details of mapping the Basic Geologic Map, sheets Celje (Buser, 1978) and Novo mesto (Plenčar & Premru, 1976). The nappe units of Sava folds can be chronologically compared only with the Dinaric nappes of southwest Slovenia; consequently, the cycle of overthrusting was mostly achieved at the end of Eocene or in the beginning of Oligocene time, which allows the conclusion about the Dinaric provenience of the Sava folds nappes. The central and southern part of Sava folds belongs in the facial sense to rocks of the border belt of the Adriatic-Dinaric carbonate platform and the Slovenian basin. The Dinaric provenience is supported also by internal structure of the nappe units. Their boundaries pass east of Ljubljana depression in the west–east direction, which can be formally compared with the Alpine W-E direction. This direction is of multiphase origin under various dynamic conditions.

The Sava folds consist of nappe overthrusts of Dinaric provenience that are folded in the Alpine W-E direction. A part of this system is also the Kum thrust which was considered in the former interpretation (Placer, 1999b) owing to morphological reasons as a continuation of the South-Alpine thrust front east of the Ljubljana depression. The former argument for attribution to the Southern Alps was supported also by similar conditions west of the Julian Alps (Doglioni & Boselli, 1987; Doglioni & Storløkken, 1990).

In Sava folds, the structural boundary between the Southern Alps and Dinarides can be positioned only along northern boundary of the Trojane anticline where are, according to the Geological map of Slovenia 1: 250.000 (Buser, in press), deeper water successions of the Slovenian basin thrust toward south. In the macrotectonic subdivision of Slovenia (Placer, 1999b, fig. 8, variant a), this variant was characterized as possible, but considered as less probable due to a different stratigraphical attribution of lithological units. The South-Alpine thrust front merges to the east with Marija Reka fault (Grad, 1969) considered as an element within the Sava fault zone (Vrabec, 2001). Such a solution makes sense, since the Kamnik–Savinja Alps are a cut off part of the Julian Alps displaced along the Sava fault.

The Trnovo nappe sensu Mlakar (1969) and Placer (1998b) is structurally the highest nappe element of the External Dinarides of western Slovenia. The Carboniferous–Permian clastites in the northeastern root part of nappe west of Ljubljana depression undoubtedly lie on Mesozoic carbonate beds of the lower nappe unit. On the contrary, however, the Carboniferous–Permian clastites of the Litija anticline east of Ljubljana depression occur consistently below the Mesozoic beds, and there is no direct or indirect argument to prove the contrary (Placer, 1998b). The Carboniferous–Permian clastites of the Trnovo nappe and Litija anticline come then in contact in the area of Ljubljana depression, although they belong to different structural units. This problem, seen from a different angle, has been solved from various aspects by a number of geologists (Kosmat, 1913; Winkler, 1923; Rakovec, 1956; Buser, 1978, 1979; Mlakar, 1987; Placer, 1999b; Mioč, 1976, 1981, 2003; Premru, 1980, 1983a, 1983b, 2005).

Important for interpretation of continuation of the Trnovo nappe east of Ljubljana depression, and of different development of Mesozoic beds in eastern and western rim of the Ljubljana depression, and in northern and eastern border of the Ljubljana moor, is the existence of the vast Miocene wrenching zone (Tari, 2002) that is supposed to pass from the Ljubljana depression to Imotski in Herzegovina, and farther. Let us call it, for easier communication, the Ljubljana–Imotski fault zone. It has a special position among the longitudinal faults of Dinarides. The most important in the array of faults of this zone is in Slovenia the Želimlje fault that passes over the central part of the External Dinarides along the eastern rim of Ljubljana moor and western rim of Ljubljana depression, where it joins the Sava fault. From the incompatibility of western and eastern rims of Ljubljana depression and of Ljubljana moor, we conclude that the boundary of the Trnovo nappe continues to the Želimlje fault. Its position in the
The Zelimirje fault separates two distinct zones of tectonized rocks on the southern side of the South-Alpine border. In the west, the tectonized zone is narrow and more pronounced and in the east it consists of a broad, multiphase transformed folded zone with subordinate symmetrically arranged thrust faults.

Significant displacement of the Trnovo nappe boundary and insignificant displacement of the South-Alpine thrust boundary are connected with pre-Middle Oligocene age of the Trnovo nappe, which is older than the fault zone Ljubljanina-Imotski, and Miocene and post-Miocene underthrusting of the Dinarides under Southern Alps. The last mentioned event is younger than the peak movements along Zelimirje fault. According to differences in the tectonic structure of the Ljubljana moor and Ljubljana depression, it is assumed that in these zones the movement is still active. Ljubljana moor occupies a transverse position between Zelimirje fault and an array of faults on its SW edge. These faults are part of the fault series from Ravne fault to the Sovodenj fault (Mlakar & Placer, 2000) and Borovnica fault to Ravnik fault (Buser, 1976). The latter is connected with the Zelimirje fault near Ribnica. On figure, the Ravne and Sovodenj fault are marked RVF, and the Borovnica fault zone and Ravnik fault are marked BRF. These faults, together with the Zelimirje fault, form a laterally pushed wedge whose dynamics has not been investigated yet. According to the regional conditions, the wedge could be in the extensional regime, but in the case that Julian Alps prevented its movement and the South Alpine thrust border between aforementioned faults is not active, then the wedge is in the compressional regime.

The question of division of Dinarides is many-sided, and several models have been proposed. They are based on the existence of either one, or of two Mesozoic carbonate platforms which influenced the subsequent structural development, and also the division. A single platform is advocated e.g. by Vlahović et al. (2005) (Adriatic carbonate platform), for which certain authors use the term Adriatic-Dinaric carbonate platform (Pamić & Hrvatović, 2003). According to the classical model based on a single Mesozoic carbonate platform the Dinarides consist in the structural sense of Internal and External Dinarides, but the extents of units and concepts of their kinematic evolution have changed in the historical periods. However, the region of Mesozoic carbonate rocks has been attributed to the external part of Dinarides by all, e.g. V. Petković, 1931 and K. Petković, 1957, and by some among them decidedly to the External Dinarides, e.g. B. Ćirić, 1960; J. Aubouin, 1974 and M. Andelković, 1978 (Andelković, 1978). The Dinarides are built of nappe units that were thrust southwestward, that had a paleogeographic origin, and that were formed in the time from Upper Jurassic to Upper Eocene, and even to Lower Oligocene. External Dinarides comprise the larger part of the Adriatic-Dinaric carbonate platform with the exception of its southwestern part, which belongs to the Adriatic-Apulian foreland and the marginal basins. The Inner Dinarides comprise parts of the oceanic crust. Boundary between the External Dinarides and the Adriatic-Apulian foreland is structural, and it passes along the external border of Adriatic islands and across the northeastern part of Istria. The boundary to Internal Dinarides is a wide transition area with marginal deeper water basins.

Based on model of two Mesozoic carbonate platforms, Adriatic and Dinaric, interesting interpretations of the Dinarides were proposed among others by Herak (1986, 1989, 1991, 1999) and Tari (2002). Herak's interpretation assumes large intersequence nappe thrusts. He distinguished the Adriatic comprising the Adriatic carbonate platform, the Epiadriatic encompassing the intermediate basin, the Dinaric comprising the Dinaric carbonate platform, and the Supradinaric consisting of rocks of the transition region. Mioč (2003) used Herak's model in his tectonic division of Slovenia. Tari's interpretation distinguishes Adria in the sense of Adria microplate which comprises Adriatic Mesozoic carbonate platform and Dinarides, with Dinaric Mesozoic carbonate platform as their constitutive part. Dinarides are overthrust on the Adria. Adria consists of a relatively weakly tectonized core in which participate a part of the Adriatic carbonate platform (Istria), Adriatic basin and a part of the Apulian carbonate platform, and the imbricated borderland to which belong in eastern part of Adriatic Sea the islands and the Ravni Kotari area. The Dinarides comprise the entire Dinaric Mesozoic carbonate platform with marginal basins (Western thrust belt) and the overthrust oceanic crust (Eastern thrust belt). The sediments of the Budva basin are covered with the overthrust Dinarides. In Slovenia, the imbricated belt of Čičarija is attributed to the Adria imbricated zone by Tari, and Čičarija itself with the Kras plateau to the Dinarides. Vrabec & Fodor (2006) attributed to the Adria imbricated belt also the belt between Čičarija and Mt. Snežnik thrust. Herak and Tari supposed in Slovenia the existence of large nappe structures.

Drbne & Ogorelec (2008) describe in the northeastern border of Vipava and Brkini flysch syncline elements of deeper water development and Paleocene scaglia, which allowed them to assume the existence of Adriatic in Istria, Čičarija and on Kras plateau, and of Epiadriatic in the northeastern borders of Vipava and Brkini flysch syncline. The Epidinaric unit is believed to be covered by the Dinaric overthrust (sensu Herak, 1999). In this connection they used the model of the struc-
cultural map of Italy (Bigi et al., 1990–1992), where
the Snejnik thrust fault as well as the Hrushiča
and Trnovo nappe faults are merged into a single
nappe thrust plane. By doing so they did not open
the question of existence of a Mesozoic basin be-
tween the two platforms, which is an essential el-
ment of Herak's model.

On the basis of results of structural mapping
of southwestern Slovenia (Placer, 2002, 2005,
2007; Placer et al., 2004), investigations in Friuli
(PeRuzzA et al., 2002; Caruli, 2006), the explicit
out-of-sequence position of the Snejnik thrust
fault, and of Hrushiča and Trnovo overthrust fault,
sufficiently precise analysis of the Trnovo nappe
displacement (Placer, 1973, 1981), and results
of drilling within the Trnovo nappe (Placer et al.,
2000) it is possible to assume in the north-
western part of Dinarides a deepening between
the Adriatic and Dinaric segments of Mesozoic
carbonate platform only from the Paleocene on.
Therefore it is justified to consider the Adriatic-
Dinaric carbonate platform with shallower in-
traplatform trenches in the sense of VLahovic et
al. (2005). Such a conclusion is meaningful also
because the Paleocene scaglia occurs also on
Sabotin and Banjšečice in the Trnovo nappe, on
Kalše in the Hrushiča nappe, and in the Kočejev
region, which all can be interpreted as shallower
deepenings. The area of outcropping scaglia on
Banjšečice is separated from the older basin sedi-
mentary beds of Trnovski gozd by the Predjama
fault that covers a stronger thrust fault within the
Trnovo nappe. This interpretation of the territory
has been proposed by Bigi et al. (1989–2000) and
PREMru (2005), and is confirmed also by the new
geologic map of Friuli–Venezia Giulia (Carulli,
2006). Such a structure confirns the out-of-
sequence passage of thrust planes of this part of
Dinarides, and with it the justification of a uni-
form concept of the Adriatic-Dinaric carbonate
platform. Conditions in the central and southeast
parts of Dinarides are different.

It follows from the partly published fragmen-
tary materials on structure of the border belt be-
tween the Adriatic–Apulian foreland and the re-
igion in its hinterland – Kras edge (Placer, 2002,
2005, 2007; Placer et al., 2004) that the Trnovo
and Hrushiča nappe, Snejnik overthrust and the
very origin of the Kras edge were formed in the
overthrusting phase of the External Dinarides at
the end of Eocene and at beginning of Oligocene,
whereas the underthrusting of Adria microplate
(Tarì, 2002) and separately, of Istria, took place in
Middle Miocene and later. At that time only deve-
loped the actual underthrusting belt in Istria with
its central element, the Črni Kal thrust fault, re-
spectively the Palmanova thrust fault. Therefore
the formal boundary of the External Dinarides is
represented by the border of the external front of
the thrust area.

Figure shows also the Adriatic microplate.
There is an important question concerning the
course of its northeastern border. In the middle
and southeastern parts of the External Dinarides
it separates the Adriatic and Dinaric segments

Osnove tektonske razželenitve Slovenije

Uvod

Današnja tektonska zgradba ozemlja, na kate-
rem leži Slovenija, je nastala med terciarno oro
genozo po koliziji Apulijanske litosferske plošč
(Apulija sensu SchMiD et al., 2004) in Evrozijske
litosferske plošče, na katero se je Apulijanska
narina. Predstavljena razželenitev je shematska in sloni na
teranih drugega in tretjega reda, ki so se izobil-
kovali iz Apulije in njenih marginalnih območj.
Tako ločimo v formalno-strukturnem smislu: 1.
Jadransko-Apulijansko predgorje, 2. Dinaride, 3.
Južne Alpe, 4. Vzhodne Alpe in 5. Panonski ba-
zen. Meje med enotami so v tektonskej kategorii ali
v smislu rajonizacije pomembni prelomi: Peri-
adiatski prelom, Labotski prelom, Ljutomerski
prelom, Savski prelom, Južnoalpska narina meja
in zunanja mej narinjskega območja Zunanjih Di-
naridov. Panonski bazen določajo depresije, za-
polnjené s terciarni sedimenti Paratetide.

Za predstavljeno tektonske razželenitev Slo-
venije so bile uporabljene naslednje podlage:
Osnovna geološka karta Jugoslavije 1 : 100.000
(1967–1986), katere zadnji list je izšel kot Os-
novna geološka karta Republike Slovenije in Re-
publike Hrvaške (1998), skrajšano OGK, Struk-
turno-tektonska karta Slovenije (POLJAK, 2007), ki
povzema strukturne podatke iz OGK in Geološka
karta Slovenije 1 : 250.000 (BuSER, v pripravi za
tisk), na kateri so usklajeni stratigrafski podat-
ki z OGK. Sedanja razželenitev sloni na novešjih
(PLACER,1999b; MOJc, 2003; PREMU, 2005) in
starešjih (RAKovec, 1956) poizkusi tektonske
razželenitve Slovenije ter novešjih objavah, ki so
prispevala k sodobnem pogledu na to vprašanje
(npr. JEnEJ & RifELJ, 2002).

Razželenitev

Na sliki je podan predlog nove tektonske raz-
želenitve Slovenije, ki je dopolnjena po PLACERU
(1999b).

1. Jadransko-Apulijansko predgorje predstavlj
relativno trdno jedro Jadranške mikroplóšče. Pri-
pada mu večji del Istre, ki je zgrajen iz kamnin
Jadransko-Dinarske mezozojske karbonatne platforme in lisni kamnin, nastalih pri njejadi gradaciji. Meja predgorja je zunanja meja naluskane pasu Zunanjih Dinaridov. Danes je deformirana s poznejšim separatnim podriva

jem Istre, katerega osrednji strukturni element je Palmanovski narivni prelom, pri nas imoven Črnokalski narivni prelom.

Jadransko-Apulijsko predgorje leži v vznjožu Dinaridov, Južnih Alp in Apeninov. Zato je termin Dinarsko predgorje, ki ga je uporabil OTONIČAR (2007) pravilen, vendar nima poma v strukturne enote, saj označuje le severovzhodni in vzhodni del Jadransko-Apulijskega predgorja.

2. Dinaridi so razdeljeni po standardnem struktturno-paleogeografskem modelu na Zunanje in Notranje Dinaride ter prehodno območje med njima, ki ga v prispevku pristevamo k Zunanjem Dinaridom. Enako razčlenitev uporabljajo tudi GRANDI in sodelavci (2004). Na našem ozemlju izdajajo v Zunanji Dinaridi pretežni del dinarskega protaevropskega segmenta. Zunanji Dinaridi zajemajo pretežni del dinarskega protaevropskega segmenta in medtem ko je v zunanjem Dinaridi zgrajena oblač območje med Periadriatskim a v zgornjejurskem obdobju. V Zunanji Dinaridi zajemajo pretežni del dinarskega protaevropskega segmenta.

3. Južne Alpe so paleogeografsko del Dinaridov, vendar so se od njih ločile v moico. Formalno ležijo v Periadriatskim, Labotskim in Ljutomerskim prelomom, ki je v širšem smislu del Bala-

nem metamerizirene kamnine Jurljske karbonatne platforme. Južno od Periadriatskega preloma v Karmaljskih Alpah se venj nato

jen Alpam poteka po Južnoalpski narivni meji, ki se proti vzhodu naslanja na Marijareški prelom. Meja Dinaridov nasproti Južnih Alp vsebuje zunanjo narivno mejo in Savskim prelomom na jugu. V prejšnji interpretaciji (PLAC-

ER, 1999b) je bil Krnsko-Koblanski narivni prelom na podlagi podatkov OCG (GRAD & FERJANČIČ 1974, 1976; BUSER, 1986, 1987) interpreteran kot meja Julijskega pokrova. Novi sklep izhaja iz podatkov o normalni legi zgornjetriasnih karbonatov na srednjetriasnih klastitih v Julijskih Alpah (SKABERN et al., 2003) in enakih razmerih v Kamniško-Savinjskih Alpah (CELAR, 2003). Zaradi tega moramo opustiti idejo o Julijskem pokrovu in obravnavati Julijske Alpe kot narivno grudo. Iz narave Južnoalpske narivne meje je nepotreben tudi uvojovan Tolminskega pokrova (KRSTIČ et al., 1994). Slatenska plošča je tektónska ktpa (SEIDL, 1929; JURKOVŠEK, 1987a, 1987b; CELAR & HERLEC, 2007), ki je verjetno ostanek ekstremnega dviga severnega krala Julijske sinformne pri podpiranju Zunanjih Dinaridov.

4. Vzhodne Alpe so geološko-orografski termin, ki zajema kompleks predkambrijskih in staroapulijskih metamorforiziranih kamnin ter permskih in mezozojskih sedimentnih kamnin v severno od Periadriatskega preloma, ki se vzhodno od Labotskega preloma izdaja v Ljutomerski prelom. V strukturnem smislu so Vzhodne Alpe zgrajena iz sistema obsežnih pokrovov, imenovanih Avstroalpinski pokrovi, skrajano Avstroalpin, ki predstavljajo stisnjene in razpotegnjene ostanke marginalnih območij vmesnega morja med Evropsko (Evrazijsko) in Apulijsko litosfersko ploščo. Ti pokrovi so nastali v teku kredne in prednjetriasne orogeneze in jih zaradi tvega povzajem in s narinjeno Apulijsko ploščo pristevamo k slednji. TOLLMAN (1977) je Avstroalpinske pokrove razdelil na spodnji, srednji in zgornji Avstroalpin, mlajši raziskovalec Schmid in sodelavci (1995) pa v spodnji, srednji in zgornji Avstroalpin. Pri nas pripadajo Vzhodnim Alpam Kobansko, Pohorje, Strojno in Severne Karavanke. MOČ (2003) je uporabil Tollmanovo razčlenitev ter Pohorje in del Kobanskega ustvaril v zgornji Avstroalpin, del Kobansko, Strojno in Severne Karavanke pa v srednji Avstroalpin. Ta po neneviji teravniologiji pripada spodnjemu delu zgornjega Avstroalpina, ki vključuje tudi nematomorforizirane paleozojske in mezozojske kamnine, na nas Severne Karavanke. Te teravniologije značilno izravno transgresivno strukturo ob Periadriatskih pokrilni koni, ob katerih so najvišje dvignjeni paleozojski filitoidni skrilavci v podlagi permutriasnih klastitov. Severne Karavanke uvrščajo v strukturnem smislu v Južne Alpe, vendar imajo podoben litološki razvoj podlage in sedimentnega mezozojskega pokrova kot spodnji del zgornjega Avstroalpina južno od Severnoapnenških Alp. Zato je smiselno, da jih obravnavamo kot del Vzhodnih Alp.

Poleg krovnih zgrajbo je pomembna značilnost Vzhodnih Alp tonalitni plutonizem, ki ga de-
limo na periadiratske intruzije (pri nas južni pas Železnokapelske magmatske cone) in na pluton tonalita/granodiorita na Pohorju s sili in dakji dacita. Po podatkih Tranič et al. (2008) je periadiratska intruzija oligocenska, stara okoli 32 Ma, pohorski pluton skupaj z dacitom in miocenski, star med 19 in 18 Ma. Nekoliko mlajši so dakji riodacita in lamporfirja, med 17 in 16 Ma. Zaradi razlike v starosti in drugačne lege pohorskega tonalita ne uvrščamo med Periadiratske intruzije.

5. Panonski bazen, oziroma sistem bazenov, se stavlja posamezne depresije, ki so nastajale in se spremnjale tekom paleogenja in neogenja. Izpolnjene so s sedimenti Paratetide, ki so odloženi na pogrebnjenih vzhodnih podaljških Vzhodnih Alp, Južnih Alp in Dinaridov. Prostor Panonskega baza- se na je pričel dejavnje strukturno oblikovati z postkolizijijsko tektonskim pobegom Vzhodnih Alp proti vzhodu v zacitku miocena, katerega južna meja je bila Periadiratska prelomna cona (Ratschbacher et al., 1991). Po podatkih Fodor- ja in sodelavcev (2002) v ologi Ljutomerskega preloma, domnevamo, da bi se pobeg v zacetnem stadiju lahko dogajal ob Ljutomerskem prelomu. Lateralna ekstruzija je zajela tudi območje Dinaridov severno od Zagrebskega lineamenta (Haas & Kovács, 2001; Jelen et al., 2001). Razvoj bazena je bil ob menjavanju ekstenzijskih in kompresijskih pogojev večstopenski. Rezultat teh procesov je današnja zgradba kjer v severovzhodni Sloveniji nastopajo podbazi, ki so nastali iz spodnjemiocenskega Mura–Zala in Stajerskega bazena, npr. Haloško–Ljutomerski podbazen, na zahodnem obrobju pa izolirani bazeni v Vzhodnih in Južnih Alpin ter Dinaridih. Pomembnejši so Smrekovski, Celjski, Tunjiško–Motniški, Laški, Planinski, Senovski in Krški bazeni. Najdlje na zahodu je Bohinjski bazen (Jelen et al., 2008).

Problematika tektonske razčlenitve

Pri posodobitvi sheme tektonske razčlenitve Slovenije je potrebno izpostaviti dve pomembni vprašanji, ki se še vedno intenzivno raziskujeta: Prvič, potek meje med Južnimi Alpinami in Dinaridii skupaj z vprašanjem razprostranjenosti Trnovskega pokrova in drugič, vprašanje razčlenitve Dinaridov. Meja med Južnimi in Vzhodnimi Alpinami poteka formalno po Periadiratski in Balatonski prelomni coni, vprašanje geneze Panonskega bazena in izoliranih bazenov ob njegovem zahodnem obrobu v Vzhodnih in Južnih Alpin ter Dinaridih je rezultat številnih raziskav zadnjih dveh desetletij.

Meja med Južnimi Alpinami in Dinaridi

Podatki kartiranja za OGK so utrdili mnenje, da je Blegoš del Zunanjih Dinaridov (Grad & Ferjančič, 1974, 1976; Premru, 1980). To je bilo potrjeno s kinematisko analizo geneze blegoške strukturske (Placer & Čar, 1997), iz katere je razvidno, da je zgradba Blegoša nastala najprej zaradi dinarsko usmerjenega narivanja od severovzhoda proti jugozahodu in nato zaradi podiravanja Zunanjih Dinari-
dov pod Južne Alpe od juga do jugovzhoda proti severu do severozahoda. Na območju Blegoša je zato mogoče nedvoumno določiti strukturno mejo med Zunanjimi Dinaridi in Južnimi Alpami, ki je narivna ploskev. Njen potek zahodno od Blegoša je do Idrijskega preloma sorazmerno jasen, saj se na severni strani nahajajo globljemorske kamnine Slovenskega bazena, na južni strani pa karbonatne kamnine Trnovskega pokrova. Ob Idrijskem prelomu je mejastarkazznajena proti severozahodu za nekaj kilometrov. Poseben pomen pri doka-

zovanju njenega značaja ima vzhodno od Idrijskega preloma ležeča Ponikvanska tektonska krpa, ki predstavlja ostanek nariva kamnin Slovenskega bazena na Trnovski pokrov. Obravnavano mejo je mogoče vzhodno od Blegoša slediti do Ljubljanske kotline in ob njenem zahodnem robu.

Pri razpravi o poteku meje med Južnimi Alpami in Zunanji Dinaridi vzhodno od Ljubljanske kotline je pomemben primerjati razvoj kamnin Slovenskega bazena zahodno od Ljubljanske kotline v okviru Južnih Alp z razvojem vzhodno od Ljubljanske kotline v zahodnem delu Posavskih gub in ugotoviti, če obstajajo v Posavskih gubah dinarske krovne strukture. Za kamnine Slovenskega bazena zahodno od Ljubljanske kotline so značilni globljemorski jurorski in kredni sedimenti, medtem ko na vzhodnem obrobju Ljubljanske kotline nastopajo ti le v severnem pasu Posavskih gub severno od jedra Trojanske antikline. V osrednjem in južnem delu Posavskih gub pa prevladujejo plitvodovne trasno-jurske karbonatne kamnine, na katerih je odložen zgornjekreden fliš (Premru, 1980, 1983a, 1983b, 2005). Tak razvoj najdemo tudi na nekaterih osamelcih Ljubljanskega polja. V zvezi z narivno zgradbo je pomembno, da tvorijo v Posavskih gubah mezoizotopske kamnine eno ali več obsežnih krovnih enot, ki so bile narinjene pred odložitvijo srednje do zgornjeoligocen-
skih plasti (Placer, 1999a), kar je razvidno iz de-
tajlov kartiranja za OGK, lista Celje (Busar, 1978) in Novo mesto (Plemenic & Premru, 1976). Krovne enote Posavskih gub lahko časovno vzporejamo le z dinarskimi pokrovi v jugozahodni Sloveniji, torej se je ciklus narivanja zaključil konec eocenske ali na začetku oligocenske dobe, iz česar sklepamo, da so pokrovi Posavskih gub dinarske provenience. Osrednji in južni del Posavskih gub pripada v facielnem smislu kaminin mejnega pasu Jadranko-Dinarske karbonatne platforme in kaminin Slovenskega bazena.

Dinarski izvor potrjuje tudi notranja zgradba krovnih enot. Meje le teh potekajo vzhodno od Ljubljanske kotline v smeri zahod–vzhod, ki jo formalno vzporejamo z alpsko smerjo. Ta je na-

stala v več fazah pri različnih dinamskih pogojih.

Posavsko gube so zgrajene iz krovnih narivov dinarskega izvora, ki so nagubani v alpski smeri. V ta sistem spada tudi Kumski nariv, ki je bil v prejšnji interpretaciji (Placer, 1999b, sl. 8, varianta b) zaradi morfološke izrazitosti obravnavan kot Južnoalpsko narivno mejo. Tedano odločitev izuvrstitev V-južne Alpe so podpirale tudi podobne razmere zahodno od Julijških Alp (Doglioni & Bosellini, 1987; Doglioni & Siropaes, 1990).
V Posavskih gubah lahko potegnemo ozko strukturno mejo med Južnimi Alpami in Dinaridi le ob severnem robu Trojanske antikilinale, kjer so po podatkih Geološke karte Slovenije 1:250.000 (BUSER, v tisku) globljevodne plasti Slovenskega bazena narivnje proti jugu. V makrotektonski razčlenitvi Slovenije (PLACER, 1999b, sl. 8, varianta a) je bila ta varianta omenjena kot možna, vendar obravnavana kot manj verjetna zaradi drugačnih stratigrafskih razvrstitv kamnin tega območja. Južnoalpska narivna meja se proti vzhodu nasproti proračuna proti jugu. V makrotektonski strukturni meji med Južnimi Alpami in Dinaridi na Marijareški prelom (Grad, 1969), ki ga obravnavamo kot element znotraj cone Slovenskega preloma (VRABEC, 2001). Tako rešitev je smiselna, kar je bila ta varianta omenjena kot možna, vendar (BUSER, v tisku) globljevodne plasti Slovenskega bazena oziroma južne Mežo, ki so Savinjske Alpe ob Savskem prelomu odpri preloma (Vrabec, 2001). Taka rešitev je smiselna, obravnavana kot manj verjetna zaradi drugačne razloge označenih proti jugozahodu, ki ležijo strukturno nad Trnovskim pokrovom. Karbonskopermske plasti Posavskih gubah izhajajo izravne ali v zunanji del Julijske Alpe. Karbonskopermske plasti za katero nekateri uporabljajo termin Jadran-Dinarska karbonatna platforma, so Dinaridi v strukturnem smislu razdeljeni na Notranje in Zunanje Dinaride, pri čemer pa se je obseg enot in predstava o njihovem kinematskem razvoju v zgodovinskih razdobjih spreminjala. Vendar so območje mezoozaksih karbonatnih kamnin višja v Zunanje Dinaride, npr. V. Petkovič, 1957, nekateri določajo, da je južnoalpska narivna meja med obravnavanimi prelomoma neaktivna.
Po modelu dveh mezozojskih karbonatnih platform, Jadranske in Dinarske, sta med drugimi nizmi interpretacije Dinaridov predložil Herak (1986, 1989, 1991, 1999) in Tarjiva (2002). Herak zagovarja velike krovne medsečvene narive. Ločil je Adriatik, ki obsega Jadransko karbonatno platformo, nanj narinjeni Epiadriatik, ki zajema vmesni bazen, na Epiadriatik narinjeni Dinari, ki zajema Dinarsko karbonatno platformo in Dinaride, ki zajemajo Dinaridsko mezozojsko karbonatno platformo. Dinaridi so narinjeni na Adrio. Adrio se sestavlja, saj sorazmeroma šibko tekonizirano jedro, kamor sodi del Jadranske karbonatne platforme (Istra), Jadranski bazen in del Apulijanske karbonatne platforme ter naluksano obrobje, kamor spadajo jadranski otoki in Ravniki Kotari. Dinaridi zajema celotno Dinaridsko karbonatno platformo z marginalnimi bazeni (Zahodni narivni pas) in nanje narinjeno oseansko skorjo (Vzhodni narivni pas). Narinjeni Dinaridi prekrivajo sedimente Budvanskega bazena. V Sloveniji je v nalukani rob Adrie Tarjiva ustvrdila naluksani pas Čičarje, samo Čičarji in Kraško planoto pa v Dinaride. VRABEC in Fodor (2006) sta v nalukani pas Adrie ustvrdila tudi pas med Čičarji in Smešniškim narivom. Herak in Tarjiva (2006, 2007) uporabljajo formalno mejo Zunanjih Dinaridov meja zunanjega naluskanega pasu. Prav tako je karbonatna in sedimentska kukovina, na njem narušena na sliki, označena tudi Jadranska mikroplišča. Pomemben problem predstavlja kazalnost tega ozemlja Bigi et al. (1989-2000) izdankov scaglie v označenem je nasproti starejših bazenskih plitvejših intraplatformskih jarkih v smislu Vlahovica in sodelavcev (2003). Tekst zaključek je smiselno tudi zato, ker uporabljena struktura poteka mejnega pasu med Jadranjsko-Adrijanskim predgorjem in jugovzhodnim delom Dinaridov so drugačne.

Po sicer delno objavljenih fragmentih o zgradbi mejnega pasu med Jadranjsko-Adrijanskim predgorjem in jugovzhodnim delom Dinaridov so drugačne.

Na sliki je označena tudi Jadranska mikroplišča. Pomemben problem predstavlja vprašanje poteka njene severovzhodne meje. Ta v srednjem in jugovzhodnem delu Zunanjih Dinaridov ločuje jadranski in dinarski segment Jadranjsko-Dinarske mezozojske karbonatne platforme, na severovzhodnem delu Jadranjsko-Dinarske mezozojske karbonatne platforme, saj so različne sosednje in pozneje. Odbijarjev polegadi zahodni pas v Istri, katerega osrednji element je Črnikov narivni prelom, oziroma Palmanovski narivni prelom. Zato predstavlja formalno mejno Dinaridovalca v slovenjskem pasu.

Za krožnost in osrednjem i jugovzhodnem delu Dinaridov so drugačne.

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