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Spatial distribution of geological resources in northwestern Serbia (Jadar block terrane) and its relation to tectonic structures

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Abstract. This work presents new information about the interconnection between diverse geological resources and tectonic structures framing the Jadar block terrane. Deep fault zones are found to have been principal bearers of geothermal, thermomineral and metallic ore resources. Increased bitumen and hydrocarbon concentrations in pre-Tertiary deposits, which may be potential oil/gas zones, are also associated with these areas.

Key words: Boundary deep fault zones, geological resources, northwestern Serbia.

Апстракт. У раду су приказана нова сазнања о међусобној повезаности разноврсног спектра геолошких ресурса и тектонских структура које уоквирују Јадарски блок теран. Констатовано је да су дубинске разломне зоне главни носиоци геотермалног, термоминералног и металичног потенцијала, као и да су за њих у претерцијарним седиментима, везане повећане концентрације битумена и угљоводоника па, у одређеним просторима, могу бити потенцијалне нафтно-гасне зоне.

Кључне речи: граничне дубинске разломне зоне, геолошки ресурси, геотермални и нафтно-гасни потенцијали, северозападна Србија.

Introduction

New geodynamic ideas on the plate tectonics and terranes initiated among national geologists enable fundamentally different interpretations of the spatial distribution of geological resources in northwestern Serbia (Filipović *et al*., 1996). First knowledge about the interconnection of deep boundary fault structures and diverse geological resources was based on a long surface oil-geological study of pre-Tertiary formations in western Serbia (Ašanin *et al*., 1998). Consistent surface sampling and organo-geochemical analyses indicated that pre-Tertiary rocks occur as country rocks only in the zones of deep boundary faults along which different geotectonic units are converging. An illustrative example is the Jadar block terrane. In this paper, its relevant characteristics are described in order to explain the interrelation of different geological resources and boundary tectonic structures with particular reference to potential energy resources in some areas.

Major characteristics of the Jadar block terrane and the boundary tectonic structures

The Jadar tectono-stratigraphic unit has all the relevant characteristics given in the generally accepted definition of a terrane (Keppie & Dallameyer, 1990). It is an exotic block of the Earth's crust which, like the Bükkium terrane in Hungary, is highly correlative with the Dinaride-South Alpine belt.

It differs only in its present geological environment. The major characteristics of the Jadar block terrane, which derived from Gondwana, are the following: 1. Late Variscan molasse with fusulinids; 2. Middle Permian evaporites; 3. Upper Permian limestones bearing Caucasian-Indo-Armenian brachiopods; 4. Extinction of the abundant Upper Permian organic life at the Permian/Triassic boundary; 5. Ooids in the Lower Triassic; and 6. Intracontinental rifting magmatism in the Ladinian.

Marked features of the geotectonic units adjacent to the Jadar block terrane are the following: 1. Cambrian/Ordovician metamorphic rocks: 2. Lower Carboniferous pre-flysch deposits; 3. A long regressive stage in the late Paleozoic; 4. Lower Triassic red continental beds; and 5. Jurassic ophiolite complexes.

The above major characteristics of the Jadar block terrane and the geotectonic units adjacent to the terrane suggest the followings: all formations characterizing the Jadar block terrane are lacking in the surrounding areas, and, *vice versa,* not a single mentioned characteristic of

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the Vardar Zone or the Drina-Ivanjica element is recognized in the Jadar terrane. The boundaries of the Jadar terrane, which were proved in the uncovered profiles to be tectonic, are based on the mentioned pattern model.

2. The southwestern boundary consists of a long, very narrow belt of a ophiolite melange that can be traced from the Boranja granodiorite massif to Jagodnja, to the southwestern slopes of the Sokolska Planina Mt., to Ti-

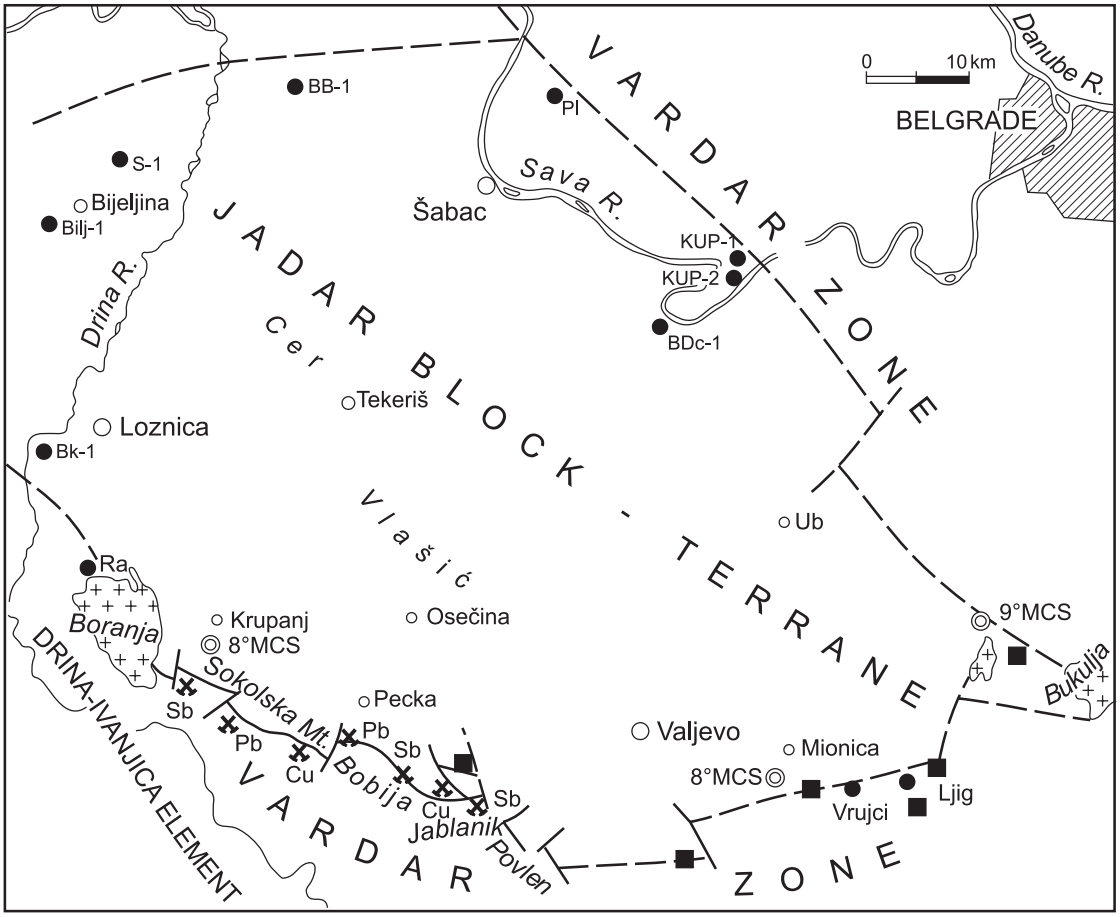

Fig. 1. Map of the Jadar block terrane. Legend: ● = Geothermal or thermomineral spring; ✱ = Sb, Pb-Zn, Cu, Au, deposits or occurrence; ■ = Country oil-source rocks; ◎ = Epicenter of a registered earthquake.

The Jadar terrane is bounded by deep fault zones and tectonic melanges with which diverse geological resources are associated: geothermal and thermomineral waters, metallic ores (Pb-Zn, As, Au, Cu, Sb), country rocks having oil-bearing properties and epicenters of registered earthquakes (Fig. 1). Tectonic structures - deep seated faults and tectonic melanges – are geologically well marked and exposed for direct observation in the southern half of the Jadar tectono-stratigraphic unit. Unlike these, the boundary faults are covered by thick Neogene deposits in the northern half of the unit, as inferred from drilling data. Thus, the drilled Triassic limestone aquifers belong to the Jadar terrane, and the drilled ophiolite, north of the Sava, to the Vardar Zone. The major characteristics of the boundary structures are the following:

1. The western boundary of the Jadar block terrane is marked by the thermomineral springs of Banja Koviljača and Radaljska Banja. Further to the SSE, the Boranja granodiorite intrusion and contact-metamorphic aureoles are obviously associated with the boundary fault zone.

sovik and Bobija. This repeatedly reduced ophiolite complex is at present a typical tectonic melange which was produced during the Jadar block sliding. According to ĆIRIĆ (1996), it is the large fault zone of Azbukovica which "could have been formed by faulting and differential block movements, including rock crushing and mixing over the entire fault zone". The western part of the Azbukovica Zone is described by RADOIČIĆ (1977) as "a chaotic formation of Rujevac and Veliki Majdan" in which rocks of diverse geological ages were "mechanically" mixed (Paleozoic, Triassic, Jurassic, and epochs of the Cretaceous from the Malm/Neocomian conclusive with the Lower Senonian). The most instructive profiles of the melange were formed in the Rujevac area, which show the crushed groundmass of dominantly basic rocks that include clasts and blocks of various sizes, diverse lithology and stratigraphy. Associated with the tectonic melange of Azbukovica are the deposits of Rujevac (Sb-Pb-Zn-As), Postenje and Tisovik (Pb), Erići and Skakavci (Cu), and Crvena Stena (Sb).

3. The southern boundary runs along the northern slopes of the Medvednik, Jablanik and Povlen Mts., the Zabava, Krčmarska and Paštrić valleys to Vrujci spa. This boundary is marked also by an ophiolite melange, with which the Rebelj and Krstić copper deposits, the Vujinovača and Brezovica antimony deposits, the Vrujci thermomineral springs, and country rock near Poćuta and Podbukovo are associated. The ophiolite complex is much wider than the Azbukovica belt, and is characterized by the presence of a tectonic melange only in the contact zone with the Jadar block, which refutes the statement that the melange is of sedimentary derivation (DIMITRIJEVIĆ & DIMITRIJEVIĆ, 1973). The information of particular importance concerning the tectonic melange is (1) A Lower Permian dkm/size block containing fusulinids at Podbukovo and (2) the epicenter of a recent earthquake in the Krmčar-Paštrić area. Further eastwards, the boundary fault trace is indicated by the thermomineral springs of Ljig and by numerous occurrences of oil-source country rock. The extreme eastern boundary is marked by Bukulja granitoid, and the northwestern by antimony minerals at Trbušnica and Devonian/Carboniferous rocks of oil-bearing properties in Kruševica.

4. The deep seated boundary faults in the northern half of the terrane are marked by thermal springs at Posavo-Tamnava, Mačva, and Semberija in the Jadar block, near the boundary faults which separate this tectono-stratigraphic unit from the Vardar Zone.

Discussion

The purpose of this work was is to develop a model of the geological resource distribution pattern of NW Serbia. The model is based on the following relevant information:

1. The Jadar block terrane is a segment of the Earth's crust which is highly correlative with the Dinaride-South Alpine belt, and extremely different from the adjacent geotectonic units.

2. The tectonic structures bounding the Jadar block are deep fault zones which allowed migration and formation of diverse geological resources.

3. Surface geological explorations for petroleum in western Serbia revealed that rocks of oil-bearing properties occur only in the boundary fault zones. In the tectonic structures bounding the Jadar block terrane these rocks are found in Devonian/Carboniferous clastics, Upper Permian limestones, and Cretaceous/Paleogene flysch.

4. There are many examples in the literature of the spatial interconnection of thermomineral aquifers, ore deposits, and oil fields, particularly among recent seismogenetic faults. Some of the examples are locations on the southern and eastern margins of the Jadar tectono-stratigraphic unit, where the mentioned geological resources were found or were epicenters of registered earthquakes (8° MCS, Krupanj, 1905; 8° MCS, Mionica, 1998; 9° MCS, Lazarevac, 1992).

Conclusion

Based on this new research data, it can be concluded that most of the geological resources of northwestern Serbia are associated with the faults bounding the Jadar block terrane, which explains the distribution pattern of the geological resources (thermal and thermomineral waters and metallic ores) and oil-bearing rocks. It also enables the location of new deposits.

Economic concentrations of hydrocarbons may be expected only in deep depressions under impermeable rocks, bounded by fluid-permeable deep-seated faults. Resources of this kind can be expected to be found in the Kačer depression and in the Neogene valleys of the Kolubara, Mačva, and Semberija.

The hydrothermal resources in Mačva and Posavo-Tamnava are the largest in the southern part of the Pannonian basin. According to this model, the existing reserves may increase toward the boundary faults. Moreover, thermomineral water may also be expected, and even oil deposits, in some tectonic structures.

References

AŠANIN, P., FILIPOVIĆ, I., JOVANOVIĆ, D., JOVANČIĆEVIĆ, D. & VITOROVIĆ, D., 1998. Results of geological and organic – geochemical investigations of western Serbia, Šumadija and Kosmet. *Vesnik Zavoda za geološka i geofizička istraživanja*, Serija A, 48: 277–295.

ĆIRIĆ, B., 1966. *Geology of Serbia: Composition and development of the Earth's crust*. "Geokarta", 1–273, Beograd (in Serbian).

DIMITRIJEVIĆ, M.D., 1995. *Geology of Yugoslavia*. Geoinstitut, 1–205, Beograd.

FILIPOVIĆ, I., 1996. *Geological characteristics and potentiality of geological resources in the Kolubara, Mačva and Podrinje regions*. Geološki zavod "Gemini", 1–21, Beograd.

FILIPOVIĆ, I., 2000: Paleozoic of the Jadar block terrane (NW Serbia). *Proceeding of the International Symposium of Geology and Metallogeny of the Dinarides and the Vardar Zone*, 66–68, Banja Luka–Serbian Sarajevo.

FILIPOVIĆ, I., JOVANOVIĆ, D., SUDAR, M., PELIKAN, P., KOVACS, S., LESS, G. & HIPS, K., 2003. Comparation of the Variscan – Early Alpine evolution of the Jadar Block (NW Serbia) and "Bükkum" (NE Hungary) terranes: Some paleogeographic implications. *Slovak Geological Magazine*, 9 (1): 23–40.

KEPPIE, J. D., & DALLMEYR, R.D., 1990. Introduction to terrane and the tectonic map of pre-Mesozoic terranes in Circum – Atlantic Planerozoic orogens. *IGCP Meeting, Abstract*, 223, Göttingen.

RADOIČIĆ, R., 1997. On the Rujevac – Veliki Majdan chaotic formation (Western Serbia). *Vesnik Zavoda za geološka i geofizička istraživanja, Serija A*, 47: 53–61.

Резиме

О просторном размештају геолошких ресурса у северозападној Србији (Јадар блок теран) и њихов однос са тектонским структурама

Јадарски теран оивичен је дубинским разломним зонама и тектонским меланжима за које је везан разноврстан спектар геолошких расурса: геотермалне и термоминералне воде, металичне сировине (Pb-Zn, As, Au, Cu и Sb), стене са матичним својствима за нафту и епицентри догођених земљотреса (сл. 1). Тектонске структуре – дубински разломи и тектонски меланжи у јужној половини Јадарске тектоностратиграфске јединице јасно су геолошки изражене и знатним делом доступне директним теренским проматрањима. Међутим, у северној половини ове јединице гранични разломи су покривени дебелим неогеним наслагама, па су они извучени на основу резултата бушења. Тако бушотине са аквиферима тријаских кречњака припадају Јадарском терану, а бушотине са офиолитима, северно од Саве, Вардарској зони.

На темељу нових научних сазнања евидентно је да је највећи број геолошких ресурса северозападне Србије везан за граничне разломе у ободним деловима Јадарског блок терана. Тиме не само да су сагледане просторне законитости у погледу размештаја геолошких ресурса (термалне и термоминералне воде и металичне сировине) и матичних стена за нафту, већ су истовремено и створене могућности за откривање нових сировинских потенцијала. Ту се превасходно мисли на следеће:

Економски значајне концентрације угљоводоника могуће је очекивати само у дубоким депресијама са импермеабилним покровима и са флуидно проводним дубинским граничним разломима. Такве потенцијале могла би представљати Качерска депресија и неогени басени Колубаре, Мачве и Семберије.

Хидротермална налазишта у Мачви и Посавотамнави су најзначајнија у јужном делу Панонског басена. Међутим, према нашем моделу не само да се постојеће резерве могу битно увећати већ, идући ка граничним разломима, треба очекивати и термоминералну воду, а у одређеним тектонским структурама у лежиштима нафте.