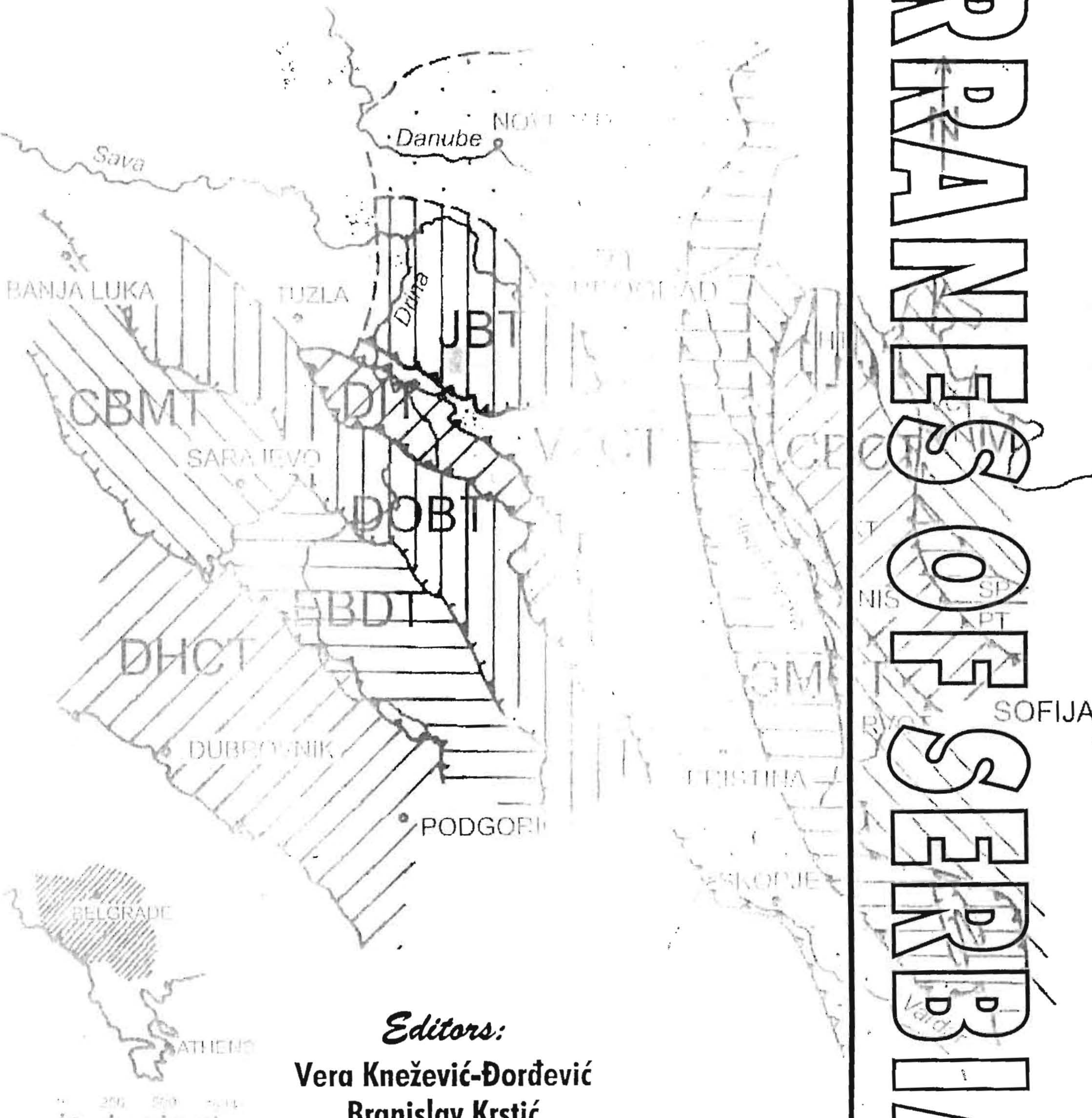
The Formation of the Geologic Framework of Serbia and the Adjacent Regions

Dedicated to Academic Stevan Karamata

"TERRANES OF SERBIA"



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TYPES OF LATERITIC WEATHERING CRUST ALONG THE VARDAR RIVER, REPUBLIC OF MACEDONIA

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Abstract: *This paper is a brief account of the structural-metallogenic features of Ni-silicates and Fe-Ni deposits in the Vardar zone along the Vardar River valley in the Republic of Macedonia.*

Two type of lateritic crusts were determined: primary lateritic crusts - in situ (Groot, Gradište etc) and redeposited lateritic crusts (Ržanovo, Studena Voda, Rakle, Nikodin etc.).

Lateritic crusts are genetically related to the processes of lateritization of the Jurassic serpentinites which took place in warm and wet climate. They are basically nickeliferous-ferrugineous in which Ni content amounts to 1%, Fe to 32 %, and Cr to about 2.5 %. Co, V, Mn, Ti etc. occur as accompanying components.

KEY WORDS: weathering, lateritic crust, Vardar river, Macedonia

1. INTRODUCTION

Although occurrences of nickeliferous mineralization in weathering crust in the Vardar Zone were known before 1941, their exploitation started after 1970. The FENI Metallurgical Plant in the town of Kavadarci was built to process the mineral raw materials. Nickel and nickeliferous iron deposits in the western ophiolite belt (in Albania and Greece) started the process of exploitation much earlier than those in the Vardar Zone.

The conditions for occurrence of the deposits in the Vardar Zone were studied by many geologists. The most important studies were carried out by MAKSIMOVIĆ (1952a, 1959b, 1966, 1981), IVANOV (1962, 1975) and STOJANOVIĆ (1960). Recently, intensive investigations in the deposits in the Kožuf district were carried out by BOEV (1982, 1988), BOEV and JANKOVIĆ (1996).

2. STRUCTURAL-GEOLOGIC AND METALLOGENETIC FEATURES OF THE LATERITIC CRUSTS

Silicate nickel and nickeliferous iron deposits in the Vardar Zone are situated in a relatively narrow belt of ophiolites striking Fruška Gora in the north to Eubea in the south continuing further to Anadolia in Turkey. Spatially, in one part genetically, the primary deposits are related to the peridotite complexes of Jurassic ophiolite formations, or more precisely to the weathering crusts which developed on the peridotite/serpentinites which themsevles developed in conditions of wet and warm climates under the influence of surface factors. Although these deposits have features of lateritic products they can not be classified as ordinary lateritic deposits.

Most of the fossil weathering crust was eroded during later processes, particularly in conditions of dissected paleorelief. Residual Ni-silicate deposits remained in places where they developed and were covered by younger sediments, that protected them from further erosion or where fossil crusts redeposited in surrounding basins or nearby carstified vugs/troughs. Deposits and occurrences of silicate nickel and nickeliferous iron are located in several smaller metallogenic units, mainly ore fields and districts. These metallogenic units are situated in the Serbo-Macedonian metallogenic province.

Metallogenetic analysis carried out along the course of the Vardar River determined three ore districts: the T. Veles-Klepa, Rakle-Nikodin and Kožuf. They all have their own specific features with respect to lateritic crusts and include several characteristic deposits.

3. TYPES OF LATERITIC CRUSTS

Based on results obtained from investigation carried out on lateritic crusts along the course of the Vardar River two types can be distinguished:

1. primary lateritic crusts - in situ and
2. redeposited lateritic crusts.

Development of economically important nickel and nickeliferous iron deposits could take place during the development of weathering crust. Deposits of silicate nickel and nickeliferous iron are distinguished based on mineral composition.

3.1. Silicate Nickel Deposits

The following types of silicate nickel ores can be distinguished based on their chemical composition: a. ferruginеous b. magnesian and c. siliceous.

1. Ferruginеous or nontronite ores retain the structure of serpentinite. They are plastic and powdery when dry. Nontronite and nontronized serpentinite prevail in their composition. They also contain beidelite, chlorite, asbolane, opal, carbonates, gypsum, rarely nickeliferous hydrosilicates.

2. Magnesian or serpentinite ores are very similar to serpentinites in their physical appearance. They consist of serpentinite and nontronite with minor cerolite, nickeliferous hydrosilicates (garnierite, revdenskinite), calcedony, opal, iron hydroxides and manganese as well as carbonates (aragonite and magnesite).

3. Ocher siliceous ores are quartz silicified ores developed mainly of calcedony and opal which form vuggy cavernous shapes filled with loose material, mainly iron hydroxides. The Groot and Gradište deposit belong to this type of deposits.

Table 1: Chemical analyses of materials of lateritic weathering crusts from the Groot deposit

	1	2	3	4	5
MnO	0.35	0.18	0.11	0.10	0.10
Al_2O_3	0.45	2.43	0.55	0.40	0.92
Tot Fe_2O_3	5.27	47.21	10.39	9.49	8.33
MgO	27.60	5.02	34.40	33.86	35.84
Na_2O	0.38	0.18	0.09	0.06	0.07
K_2O	0.20	0.83	0.20	0.20	0.20
SO_3	0.06	0.08	0.06	0.06	0.06
P_2O_5	0.9	0.4	0.6	0.6	0.6
SiO_2	25.06	21.87	44.09	44.30	42.64
CaO	15.32	3.24	0.10	0.06	0.17
TiO_2	0.02	0.22	0.02	0.02	0.02
Cr_2O_3	0.02	1.17	0.02	0.02	0.25
NiO	0.11	1.17	0.37	0.33	0.31
H_2O (105)	0.81	0.44	0.64	0.63	1.03

The geological composition of the Groot deposit consists of ultrabasic rocks, laterites and Cretaceous limestones (Fig. 1).

Nickel content ranges from 1.5 to 3 %, whereas iron from 30 to 40 %. Nepouite-garnierite are the basic nickel bearers in the deposit. Chemical composition of the lateritic crust in the deposit is shown in Table 1.

3.2. Nickeliferous Iron Deposits

Nickeliferous iron deposits are very common in the Vardar zone. They are mainly redeposited and located in the footwall of Upper Createaceous sediments. They are in the shape of layers and mainly developed on serpentinites in the footwall of some sedimentary series.

The mineral composition of ores is very complex, and in some cases differs largely from the primary composition of the redeposited lateritic material. Hematite and magnetite are most common in addition to a fan of silicate minerals such as chlorite, talc, stilpnomelane etc as well as the carbonate group represented by calcite and dolomite, and occasionally magnesite.

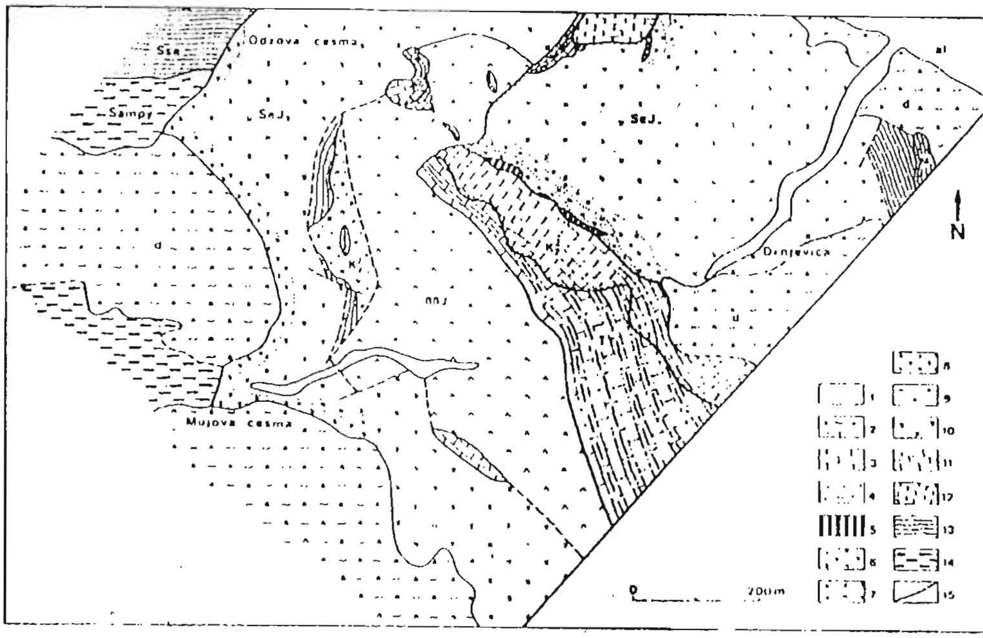

Fig. 1. Geologic map of the Groot deposit
1. Alluvium, 2. Delluvium, 3. Turonian limestone, 4. Turonian quartz conglomerate and sandstone, 4. Turonian nickeliferous pisolitic ore, 5. Low grade nickel mineralization with jasper, 6. Lateritic crust, 7. Leached serpentinite, 8. Serpentinite with magnesite occurrences, 9. Diabase, 10. Serpentinite/ Peridotite, 11. Triassic limestone with chert, 12. Carboniferous marble, 13. Quartz-sericitic schist, 14. Amphibolite, 15. Fault

Ržanovo, Studena Voda, Rakle etc belong to this group of deposits.

The Ržanovo deposit is typical of this group. The nickeliferous iron mineralization is located along the contact between Jurassic serpentinites and schists in the footwall as well as Cretaceous limestones in the hangingwall. The ore layer was explored from peak 955 meters to peak 470 meters through a vertical interval of about 500 m. with no signs of wedging out. The average thickness of the layer is about 30 meters and it behaves like a continuous body, although tectonic events on the field were very intense.

Spatially, the layer has a sub-vertical position and due to strong tectonic movements it has inverse position in the part of the Ržanovo deposit (Fig. 2).

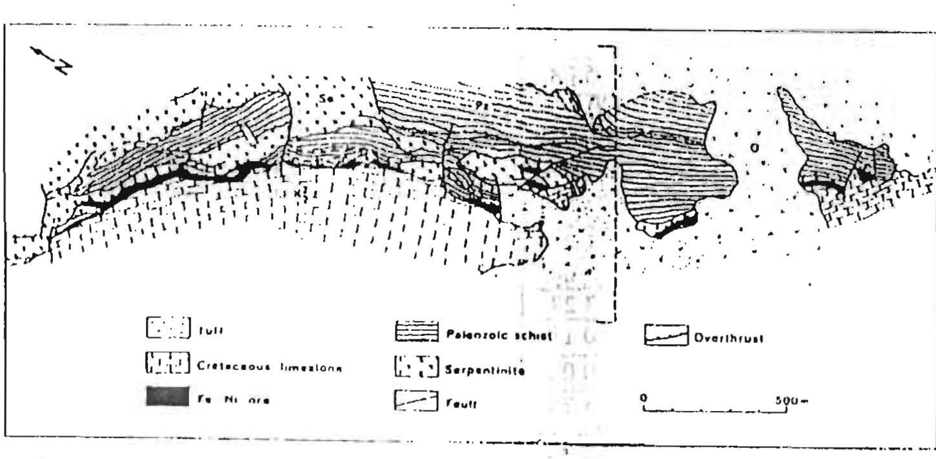

Fig. 2. Geologic map of the Ržanovo-Studena Voda zone

The following lithologic ore types can be distinguished in the Ržanovo ore layer: compact magnetite ore (I/1), schistose magmetite ore (II/1), oolite hematite ore (I/2), schistose hematite ore (I/3), compact hematite ore (1/4), riebeckite schists (II/8), stilpnomelane schists (III/1), dolomite schists (VI/1), talc schists (VI/6), serpnetinite ore (V/6).

The composition of these ore types is shown in Table 2.

Table 2: Chemical composition of major ore types in the Ržanovo deposit

	I / 1	II / 1	I / 2	I / 3	I / 4	II / 8	III / 1	VI / 1	VI / 6	V / 6
Al_2O_3	1.78	5.41	3.18	2.68	3.39	6.60	5.92	1.47	1.05	1.39
Tot Fe_2O_3	32.91	59.86	59.30	40.51	48.57	16.72	43.89	36.55	11.17	12.35
MnO	0.24	0.16	0.20	0.48	0.58	0.73	0.18	0.43	0.26	0.16
MgO	18.40	8.27	9.15	17.66	12.82	7.62	9.35	14.73	28.64	31.67
Na_2O	0.50	0.55	0.37	0.50	0.53	5.07	0.66	1.23	0.59	0.83
K_2O	0.10	0.10	0.10	0.10	0.10	0.22	0.79	0.19	0.18	0.20
P_2O_5	0.17	0.29	0.17	0.17	0.24	0.36	0.49	0.43	0.40	0.40
SiO_2	40.02	16.05	19.80	30.30	25.23	46.33	27.06	32.23	48.77	41.31
SO_3	0.47	1.26	0.48	0.47	0.61	2.82	3.48	0.72	0.26	0.26
CaO	0.98	1.03	2.00	0.99	1.03	1.98	1.27	6.73	1.63	1.37
TiO_2	0.02	0.13	0.05	0.03	0.05	0.28	0.20	0.01	0.01	0.01
LOI	2.65	2.18	1.94	3.39	2.95	0.16	3.40	2.61	5.67	9.68
H_2O	0.24	0.53	0.70	0.40	0.61	0.28	1.27	0.18	0.30	0.73
NiO	0.90	1.28	0.91	1.27	1.14	2.13	0.79	0.80	0.75	0.37
Cr_2O_3	1.68	3.86	1.99	1.93	3.25	7.00	2.93	1.49	0.36	0.39
Total	101.06	100.96	100.34	100.88	101.10	98.30	101.68	99.80	100.04	101.12

Mineral association of the ore in the Ržanovo deposit is as follows: magnetite, hematite, clinochlore, talc, sepiolite, magnesioriebeckite, lizardite, dolomite, phlogopite, stilpnomelane, quartz, albite, pyrite, maghemite, pyrrhotine, digenite and millerite.

Only five of the mentioned mineral associations are constantly present: magnetite (11/16 %), hematite (40,41 %), clinochlore (10.65 %), talc (22.90 %), and magnesioriebeckite (13.60 %).

The amount of major and accompanying metals in the deposit amounts to 1.03% Ni, 32% Fe, 0.06% Co, 2 25% Cr.

Table 3: Chemical composition of major ore types in the Studena Voda deposit

	7781	7713	7718	7721	7723	7567	7569
SiO_2	18.55	33.61	35.15	18.76	25.07	28.64	21.56
TiO_2	0.42	0.23	0.56	0.29	0.31	0.42	0.58
Al_2O_3	11.12	5.08	12.15	8.21	8.46	5.35	8.40
Cr_2O_3	4.47	1.12	3.02	2.15	1.87	2.53	1.96
Fe_2O_3	35.47	26.13	5.25	40.38	37.59	35.11	42.64
FeO	12.53	2.50	7.86	3.88	6.44	5.99	7.07
MnO	0.42	0.36	0.45	0.34	0.38	0.45	0.63
NiO	1.91	1.20	1.40	1.35	1.26	2.01	1.12
MgO	7.86	20.00	20.59	16.18	9.22	10.50	6.75
CaO	x	3.27	0.90	3.37	1.57	1.25	1.46
Na_2O	0.06	0.11	1.07	0.13	1.92	2.45	0.40
K_2O	0.07	0.06	2.28	0.07	2.08	1.17	2.76
H_2O^+	6.16	5.75	8.54	5.15	3.58	3.57	4.30
H_2O^-	0.89	0.58	0.59	0.93	0.35	0.51	0.36
Total	99.93	100.00	99.91	101.19	100.10	99.95	100.26
Ni (%)	1.50	0.94	1.10	1.06	0.99	1.58	0.88

Besides Ržanovo, the Studena Voda, which has certain specific features, is an important deposit in this lateritic group. Geological relationships in the deposit are similar to those in Ržanovo, the difference being in the serpentinites located in the footwall of the ore layer. In Ržanovo they are located and compose the hangingwall of the ore layer due to the influence of strong tectonic movements.

In Studena Voda deposit the hangingwall is composed of Cretaceous limestones and Tertiary tuffs, whereas the footwall consists of nontronite clays and serpentinites or relicts of lateritic serpentinite weathering crust (Fig. 2).

The thickness of the layer amounts to 50 m and in part it is covered by series of tuffs.

The texture of the layer is not homogeneous and consists of a number of lithologic members or ore types (MAKSIMOVIĆ, 1982, BOEV, 1982, 1990): chlorite-hematite type (7781), talc-chlorite-hematite type (7713), chlorite-phlogopite talc-amphibole type (7718), hematite-chlorite type 7721), hematite-chlorite-phlogopite-amphibole type (7567), hematite-phlogopite-chlorite type (7569), phlogopite-albite ore type

The composition of major ore types of the Studena Voda deposit is given in Table 3.

The contents of basic ore metals in the Studena Voda deposit amount to 1.05 % Ni, 31 % Fe, 1.85 % Cr, 0.05 % Co.

4. CONCLUSION

Deposits of silicate nickel and nickeliferous iron in the Vardar zone are situated in a reletively narrow ophiolite belt. Spatially and in some part genetically, primary deposits are related to the peridotite complexes of the Jurassic ophiolite formations, or more precisely to the weathering crust which developed on the peridotites/ serpentinites which themselves developed in conditions of wet and warm climates under the influence of surface factors.

Most of the fossil weathering crust was eroded during later processes, particularly in conditions of dessected paleorelief. Residual deposits of Ni - silicate remained in places where they were either covered by younger sediments that protected them from further erosion or where fossil crusts redeposited in surrounding basins or nearby karstified vugs/troughs.

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