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A HEAVY MINERAL ASSOCIATION AND ITS PALEOGEOGRAPHICAL IMPLICATIONS IN THE EOCENE BRKINI FLYSCH BASIN (SLOVENIA)

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Abstract: The heavy mineral assemblages of the Brkini Flysch Basin (Western Slovenia) have been studied in some detail, and new minerals, hitherto not mentioned in the literature have been found. Among these, Cr-spinels, ilmenites and one orthopyroxene were recognized. All of them were chemically characterized. Chemical analyses on garnets have been carried out in order to discriminate between different end-members and they turned out to be similar to those found in both the Julian (Slovenian) and Istrian basins located to the NW and SE of Brkini, respectively. The chemistry of Cr-spinels suggests that both peridotitic (type-II and minor type-I peridotites Cr-spinels) and volcanic spinels are present. This fact suggests that the Outer Dinarides of former Yugoslavia, where type-I peridotites are present, began to be eroded by Middle Eocene. Moreover, similarities between the minerals of Brkini and those of the Julian and Istrian basins show that supplies from both the NW and the SE areas are present.

Key words: Brkini, flysch, chemistry of heavy minerals, Cr-spinel.

Introduction

Mineralogy and petrography of flysch formations provide important information on the composition and role of source rocks and consequently on the general paleogeography of basins. In the framework of this type of research, several authors studied in a first stage the heavy mineral assemblages in order to define the paleogeography of the different basins (Wildi 1985; Winkler & Ślączka 1992, 1994; Faupl et al. 1998; Von Eynatten & Gaupp 1999). A second stage of knowledge is the study of the chemistry of some heavy minerals to better discriminate the source rocks. These studies were performed on Cr-spinels (Pober & Faupl 1988; Arai & Okada 1991; Cookenboo et al. 1997; Sciunnach & Garzanti 1997; Lenaz et al. 2000), garnets (Morton 1985b; Di Giulio et al. 1999; Von Eynatten et Gaupp 1999), and pyroxenes (Ernst & Shirahata 1996; Schweigl & Neubauer 1996; Acquafredda et al. 1997; Krawinkel et al. 1998).

In the area of the SE Alps and Outer Dinarides several flysch basins are present: the Claut Basin, the Clauzetto Basin, the Julian (or Slovenian) Basin, the Vipava Basin, the Brkini Basin and the Istrian Basin (Fig. 1). The mineralogy of some of them was studied by Magdalenic (1972: Istrian Basin), Kuščer et al. (1974: Slovenian Basin), Orehek (1972: Brkini Basin), Lenaz & Princivalle (1996: Cr-spinel from Istrian Basin), Lenaz et al. (2000: Cr-spinel from Claut and Julian Basins).

The Brkini Flysch Basin (Lower–Middle Eocene; Slovenia, Croatia) covers an area between the Julian Basin (Maastrichtian–Middle Eocene; Italy and Slovenia) and the Istrian Basin (Middle–Upper Eocene; Italy, Slovenia and Croatia). Biostratigraphical, sedimentological, and mineralogical studies were performed (Piccoli & Proto Decima 1969; Orehek 1972, 1991; Khan et al. 1975; Bonazzi & Tunis 1990; Pavlovec et al. 1991; Bonazzi et al. 1996; Tunis & Venturini 1996).

In this study we will better define the chemistry of the heavy mineral assemblages of the Brkini sandstones in order to provide new information on provenance areas. Moreover we will compare these new data from the Brkini Basin with those from the Julian and Istrian basins with the aim of establishing whether supplies are from the SE as suggested by Orehek (1972, 1991) or from the NW as suggested by Tunis & Venturini (1996).

Geological setting

The Brkini flysch has a synclinal structure and it belongs to the Rijeka synclinorium sensu lato (Sikic & Plenicar 1975). The flysch area of Brkini borders with the Cretaceous thrust of Mt Sneznik in the northeast. At its southern margin, early Eocene limestone of the Čičarja plateau represents the boundary with the flysch deposits. The contact here may be marked also by basal grey-brown, sometimes slightly cherty marls and marly shale (Sikic & Plenicar 1975; Orehek 1991).

In the interior of the syncline, numerous folds and dissected flysch sections are observed, so, due to strong folding, several smaller synclines were formed. For this reason and for wide vegetation cover, the stratigraphic sequence of the flysch of Brkini has never been described as a whole (Pavlovec et al. 1991). Pavlovec et al. (1991) described its basal part near Košana, Sv. Trojica and Leskovec. Tunis & Venturini (1996) noticed that the succession continues with siliciclastic turbiditic strata interbedded with calcarenite, sandy carbonate and marl followed by thin interbedded sandstones and marlstones intercalations. Then, debris flow levels, siliciclastic turbidites and

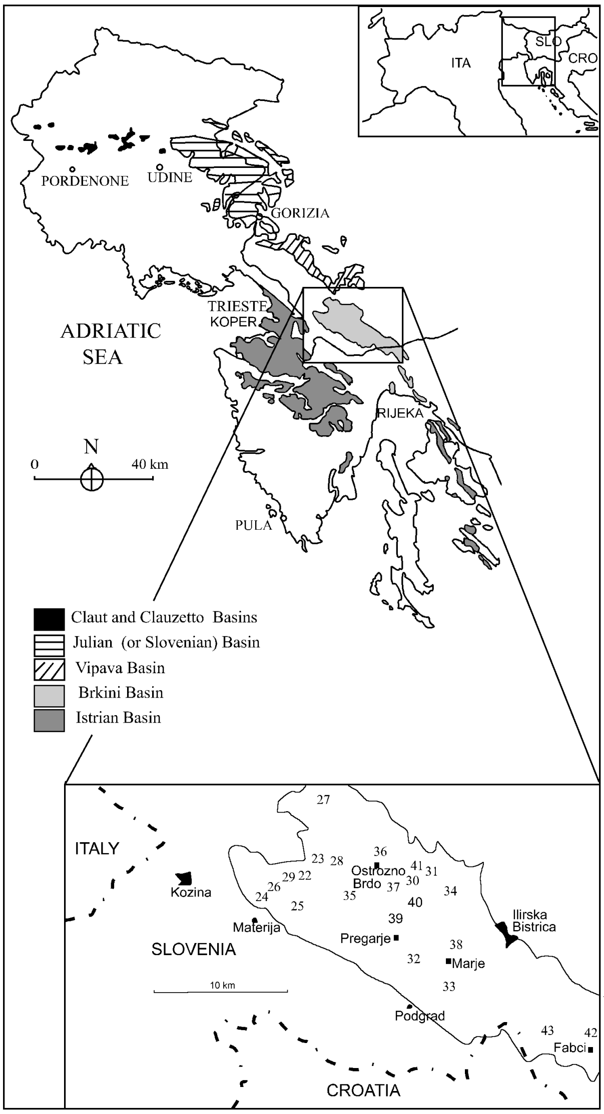

Fig. 1. Flysch deposits of the SE Alps and Outer Dinarides and sample locations (numbers).

sandy carbonate turbidites occur and, near the top of the sequence, coarse quartz sandstones are significant. The succession is closed by less than one hundred meters of siltites and fine sandstones presumably representing a molassic facies (Lutetian and/or post-Lutetian; Tunis & Venturini 1996).

The biostratigraphy of the flysch area of Brkini was investigated by Piccoli & Proto Decima (1969), Khan et al. (1975), Pavlovec et al. (1991), Tunis & Venturini (1996) who examined the planktonic foraminifers and the calcareous nannoplankton of a few sections. On the basic of the scarce paleontological information, the clastic Eocene deep-sea sediments belong to the Lower–Middle Eocene and the flysch succession may have a thickness of about 1000 meters.

The flysch consists mainly of interbedded sandstones and marlstones: the ratio of marlstone to sandstone bed thickness changes as do the average thickness of the beds the lithology and the sedimentary structures, sometimes significantly, throughout the stratigraphic column. The sandstone beds are siliciclastic turbidites, the matrix of the usually well sorted sandstones is carbonate.

The siliciclastic turbidite beds are normally graded with occasional flute casts. Amalgamation can be found, cross bedding, convolute bedding lamination and other sedimentary structures are usually well developed and also dewatering structures can be observed in the thickest beds. Plant debris is frequent especially in the upper part. Some siliciclastic turbidites have layers of plant debris at both their bases and tops.

Orehek (1972, 1991) suggested by studying the flute casts that the direction of the deposition was from the SE and partly from the east, and recognized in rocks buried under the Adriatic Sea and in the rocks of Gorski Kotar (Croatia) the source area of the Brkini flysch. In spite of this, Tunis & Venturini (1996) recognized some sections measured in the western sector that the direction of deposition was from the NW as in the nearby Cormons (Slovenian Basin) and Vipava flysch, suggesting that the Brkini Basin was the eastern prosecution of the Slovenian trough. Anyway, a direction of deposition from the SE is very common in the central eastern part of the Brkini Basin (research in progress). The turbidity currents that delivered siliciclastic turbidites moved mainly parallel to the WNW–ESE striking axis of the basin (Orehek 1991), whereas calciturbidites were delivered from a carbonate paltform in the S–SW.

Orehek (1972) also studied the mineralogy and petrography of the Brkini sandstones, reporting that the average content of sandstone is about 43 % quartz, 5 % feldspar, 28 % calcite, 21 % rock fragments and 3 % micas. As regards the heavy minerals, Orehek (1972) recognized pyrite (16 %), opaque minerals (48 %), rutile (7 %), zircon (4 %), tourmaline (3 %), and garnet (22 %).

Methodology

All the rocks sampled for this study are classified as lithic graywackes. The main constituents are quartz and calcite; plagioclases, clay minerals and dolomites are minor. K-feldspars (microcline) and micas (muscovite, chlorite, biotite) are very rare.

Sandstones were crushed and divided into different grain size. Heavy minerals were looked for in the 63–125 μm fraction where they are most abundant (Morton 1985a). Successively they were recognized under the microscope. Some of them were handpicked, mounted in epoxy resin and analysed by electron microprobe. About 140 spinel and a few ilmenite crystals were analysed using a Cameca SX50 electron microprobe (15 kV accelerating voltage, 10 nA beam current) at the University of Tasmania (Australia). Garnet and pyroxene crystals were analysed using the Cameca/Camebax electron microprobe (15 kV accelerating voltage, 10 nA beam current) at the University of Padova (Italy).

X-ray diffraction data of the orthopyroxene crystal were recorded on an automated KUMA-KM4 (K-geometry) diffractometer, using MoKα radiation, monochromatized by a flat graphite crystal. The $h\ k\ l$ and $h\ {-k}\ l$ reflections were collected up to 60° of 2θ with ω–2σ scan mode. The peak-base width was 2.5° 2θ and the counting times were variable from 20 to 40 s, as a function of peak σ. The intensities were corrected for absorption according to North et al. (1968). 30 reflections were accurately centred and used for cell parameter determination (a = 18.3030 (7) × 10^{-1} nm, b = 8.8593 (9) × 10^{-1} nm and c = 5.2108 (3) × 10^{-1} nm). Structure refinement was performed by means of SHELX-93 program (Sheldrick 1993). The structure refinement was carried out assuming fully ionized Mg vs. Fe^{2+} both in M1 and M2 sites, $Si^{2.5+}$ for T sites and $O^{1.5-}$ for the six non-equivalent oxygens (Rossi et al. 1983). Reflections with I > 3 (σI) were considered as observed and were used for the refinement. All the atoms were treated anisotropically, and all the parameters were varied simultaneously during the structure refinement, using the weighting scheme proposed by the refinement program.

Results and discussion

In this study, besides the minerals identified by Orehek (1972), as rutile (Fig. 2), zircon (Fig. 2), tourmaline, pyrite and garnet, new heavy minerals such as Cr-spinel (Fig. 3), ilmenite, and one unique orthopyroxene crystal (Fig. 3) were recognized and analysed.

Cr-spinel

Cr-spinel is present in all the flysch basins of the SE Alps and Outer Dinarides, from the Claut and Clauzetto basins (Lenaz et al. 2000), through the Julian Basin (Lenaz et al. 2000), and the Istrian Basin (Magdalenic 1972; Lenaz & Princivalle 1996; Lenaz 2000). Among heavy minerals, normally found in sediments, Cr-spinel is particularly useful to basin analyses. Unlike silicate heavy minerals, such as pyroxene and olivine, it is resistant to low-grade alteration and mechanical breakdown. In addition, it is a widespread accessory mineral in ultramafic and mafic intrusives, cumulates, rocks belonging to volcanic suites and some metamorphic rocks. Therefore, detrital Cr-spinel deriving from mantle peridotites and volcanic rock types is indicative of igneous and tectonic activity of the source areas.

In Brkini sandstones Cr-spinels are the most abundant heavy minerals and show significant compositional variations of different parameters such as Mg/(Mg + Fe^{2+}) (Mg#), Cr/(Cr + Al) (Cr#), FeO/Fe_2O_3 ratios and TiO_2 wt. % content. These variations suggest different sources related to mantle peridotites and mantle-derived volcanic rocks. According to Lenaz et al. (2000), Cr-spinels from the Brkini Basin were subdivided in two major groups on the basis of their TiO_2 content and FeO/Fe_2O_3 ratio: the peridotitic group (TiO_2 < 0.2 wt. %; FeO/Fe_2O_3 > 3) and the magmatic group (TiO_2 > 0.2 wt. %; FeO/Fe_2O_3 < 4).

Peridotitic Cr-spinels predominate over magmatic ones. Peridotitic Cr-spinels show Cr# number ranging between 30

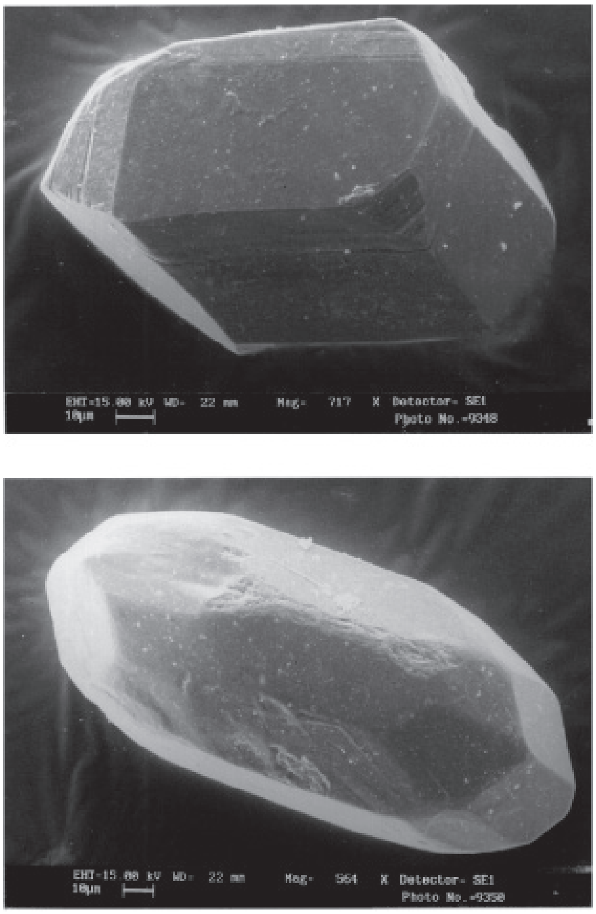

Fig. 2. Above: Rutile crystal, SEM. **Below:** Zircon crystal, SEM.

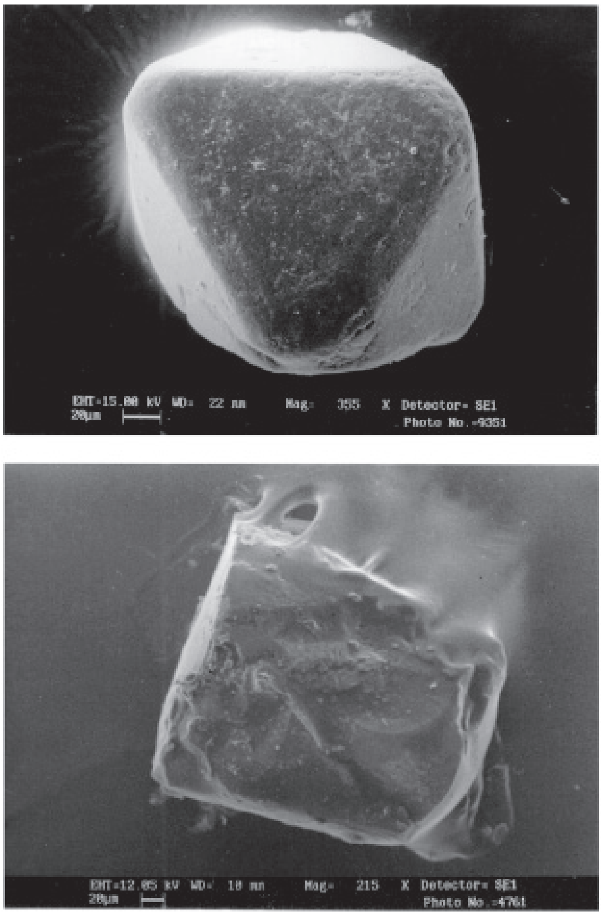

Fig. 3. Above: Cr-spinel crystal, SEM. **Below:** Orthopyroxene crystal, SEM.

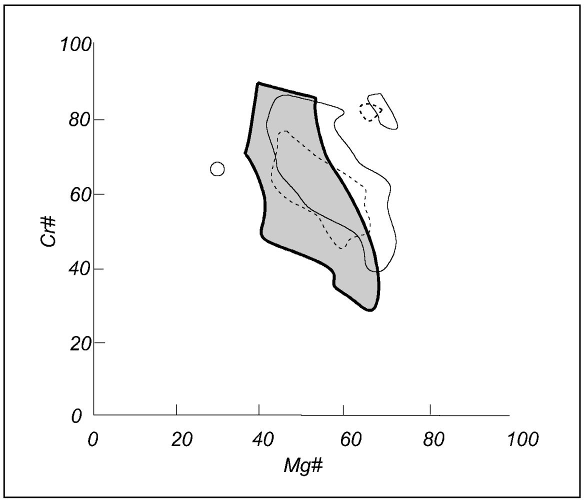

Fig. 4. Cr# vs. Mg# diagram for peridotitic spinels (TiO_2 < 0.2 wt. %; FeO/Fe_2O_3 > 3). Dotted field: Brkini Basin spinels; solid line: Julian Basin spinels (Lenaz et al. 2000); dashed line: Claut Basin spinels (Lenaz et al. 2000). Cr# = Cr/(Cr + Al); Mg# = Mg/(Mg + Fe^{2+}).

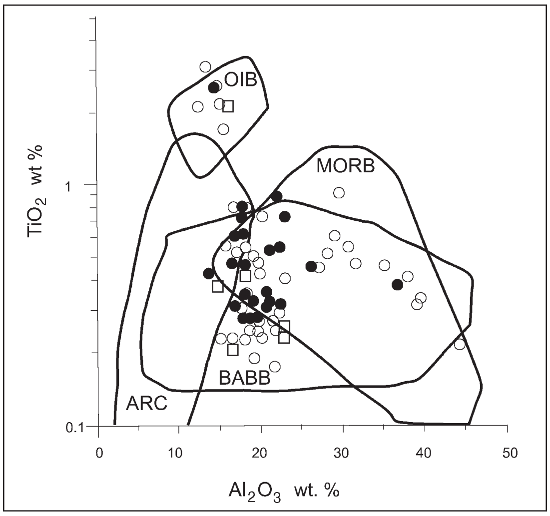

Fig. 5. Al_2O_3 vs. TiO_2 diagram for volcanic spinels (TiO_2 > 0.2 wt. %; FeO/Fe_2O_3 < 4). Full circle: Brkini Basin spinels; open circle: Julian Basin spinels (Lenaz et al. 2000); open square: Claut Basin spinels (Lenaz et al. 2000). Arc, OIB, MORB, BABB fields are from Kamenetsky et al. (2001).

Table 1: Chemical composition and structural formulae of Cr-spinels. Fe_2O_3 calculated on the basis of spinel stoichiometry. Cr# = Cr/(Cr + Al); Mg# = Mg/(Mg + Fe^{2+}).

Cr - SPINELS

	Peridotitic		Volcanic	
Sample	**30-1**	**30-61**	**36-55**	**36-69**
TiO_2	0.04	0.09	0.44	0.38
Al_2O_3	6.66	41.32	13.87	37.38
Cr_2O_3	62.72	26.57	45.35	29.82
Fe_2O_3	1.87	1.61	8.65	3.84
FeO	20.33	13.79	24.42	12.55
MnO	0.19	0.07	0.29	0.12
MgO	8.26	16.09	6.27	16.93
Total	100.07	99.54	99.29	101.02
Numbers of cations on the basis of 4 oxygens				
Ti	0.001	0.002	0.011	0.008
Al	0.266	1.371	0.551	1.239
Cr	1.685	0.591	1.208	0.664
Fe^{3+}	0.048	0.034	0.219	0.081
Fe^{2+}	0.577	0.325	0.688	0.295
Mn	0.005	0.002	0.008	0.003
Mg	0.418	0.675	0.315	0.710
Total	3.000	3.000	3.000	3.000
Cr#	86.3	30.1	68.7	34.8
Mg#	40.1	65.3	25.8	65.3

and 86. These compositions mainly correspond to Cr-spinel from transitional type-II peridotites and in lower extent (about 5 % of spinel population) to type-I peridotites (Dick & Bullen 1984). Only a few magmatic Cr-spinels (Cr# between 35 and 69) were recognized (about 15% of spinel population).

The chemical analyses of the peridotitic (sample 30–1, 30–61) and volcanic (sample 36–55, 36–69) Cr-spinels having respectively the highest and the lowest Cr# are shown in Table 1.

Cr-spinels are ubiquitous in all the Late Cretaceous–Upper Eocene flysch basins of the SE Alps and Outer Dinarides. Lenaz et al. (2000), studying the nearby Julian and Claut flysch basins, recognized that peridotitic Cr-spinels with harzburgite affinity are present (Cr# between 50 and 90). To the south, that is in the Istrian Basin, Lenaz (2000) recognized both type-I and type-II peridotitic spinels (Cr# between 14 and 72; type-I peridotite Cr-spinels about 17 % of spinel population). In Fig. 4 the Brkini peridotitic Cr-spinels are compared with those from the Julian and Claut basins (Lenaz et al. 2000). Cr-spinels from Brkini are rather similar to the ones from the Claut and Julian basins, but it should be noticed that, in Brkini Basin, Cr-spinels with type-I peridotites affinity, are also present, although they were not recognized in the Claut and Julian basins.

As regards volcanic Cr-spinels (Fig. 5; fields are from Kamenetsky et al. 2001) in the Julian and Claut basins, Lenaz et al. (2000) found magmatic Cr-spinels with OIB (ocean island basalts), BABB (back arc basin basalts) and MORB (middle ocean ridge basalts) affinities. Differences between BABB and MORB affinities were recognized in the Cr-spinel from Julian Basin utilizing silicate melt inclusions. Unfortunately, in Brkini Cr-spinels, melt inclusions are not present, and this does not allow us to discriminate if they are BABB or MORB-related. However, by analogy with Julian Basin Cr-spinels, we suppose that Brkini Cr-spinels with low Al_2O_3 (15–25 wt. %) content are related to BABB, while spinels with high Al_2O_3 (> 25 wt. %) are related to MORB.

Crystal-chemical studies on Cr-spinels from Brkini are currently in progress.

Ilmenite

Ilmenite grains, sometimes with apatite inclusions, were recognized only in the molasse sediments (top of the sequence). Ilmenite grains were found also in the Istrian Basin (Lenaz 2000). In both basins ilmenite grains are very scarce. Ilmenite analyses are reported in Table 2.

Pyroxene

Only one orthopyroxene crystal has been found. It was analysed by means of single crystal diffractometer in order to rec-

Table 2: Chemical composition and structural formulae of ilmenites**.** Fe_2O_3 calculated on the basis of ilmenites stoichiometry.

ILMENITES

Sample	**36-5**	**36-4**	**36-24**	**36-19**
TiO_2	49.92	49.66	49.51	48.96
Al_2O_3	0.05	0.05	0.08	0.03
Cr_2O_3	0.00	0.01	0.00	0.00
Fe_2O_3	5.80	6.16	5.95	6.79
FeO	43.20	42.90	42.57	42.35
MnO	0.55	0.47	0.59	0.55
MgO	0.64	0.72	0.76	0.63
Total	100.16	99.97	99.46	99.31
Number of cations based on the basis of 3 oxygens				
Ti	0.944	0.941	0.942	0.934
Al	0.001	0.001	0.002	0.001
Cr	0.000	0.000	0.000	0.000
Fe^{3+}	0.110	0.117	0.113	0.130
Fe^{2+}	0.909	0.904	0.901	0.899
Mn	0.012	0.010	0.013	0.012
Mg	0.024	0.027	0.029	0.024
Total	2.000	2.000	2.000	2.000

ognize the cell parameter (a = 18.3030 (7) × 10^{-1} nm, b = 8.8593 (9) × 10^{-1} nm and c = 5.2108 (3) × 10^{-1} nm) and the structure. Successively the same crystal was studied by means of electron microprobe and its chemistry was determined. Its formula is about $En_{85}Fs_{11}Wo_4$. Chemical and some structural data are reported in Table 3. Bertolo & Nimis (1993) distinguished volcanic, granulitic and high-pressure orthopyroxene on the basis of their structural data, but the pyroxene of our study does not plot in any of the fields recognized by them, therefore, it is not possible to clearly recognize its genesis. New occurrences of orthopyroxenes and new crystal chemical studies will yield probably to a better definition of the source. However, this is the first occurrence of orthopyroxene in the Brkini Basin and, to our knowledge, in all the basins from the SE Alps and Outer Dinarides.

Garnet

Garnets were recognized by Orehek (1972), but no chemical analyses were given in his paper. In this study, garnets were recognized in the whole sequence but, at present, only a few garnets from the molasse samples were analysed. Variable chemistry occurs and the analyses are reported in Table 4. Detrital garnets analysed in this study are almandine-rich (40–75 mol %), the spessartine component ranges between 0 and 16 mol %, and the pyrope content is particularly high in one grain (30 mol %). The pyrope-rich garnet is very similar to the garnets from amphibolites associated with the Dinaride ultramafics (Pamic et al. 1973) so that such a kind of source can be postulated. As regards the other garnets it is not possible to define a precise source. Some garnets are similar to those found in the Julian Basin while others are similar to those found in the Istrian Basin (Lenaz 2000) but more analyses are necessary.

Conclusions

The study of heavy minerals is important in reconstructing the history of a sedimentary basin. The occurrence of some types of heavy minerals is of particular interest, as they are related to well defined tectonic settings. In the case of the Brkini Basin new minerals, with respect to published data, have been identified and analysed, allowing a better knowledge of heavy mineral assemblages and tectonic evolution of source and depositional areas.

In the Brkini Basin, Cr-spinels with type-II peridotite and minor type-I affinities are present. A few volcanic Cr-spinels are also found. Ophiolites and mafic complexes occur widely in the Internal and Outer Dinarides of former Yugoslavia.

Table 3: Chemical composition and structural data of BK30 orthopyroxene.

Chemical analyses			Numbers of cations on the basis of 6 oxygens			Structural parameters		
SiO_2	55.08	(0.19)	T site	Si	1.9550	a_0 (nm × 10)	18.3030	(7)
TiO_2	0.13	(0.04)		Al^{IV}	0.0450	b_0 (nm × 10)	8.8593	(9)
Al_2O_3	1.25	(0.12)		Σ	2.0000	c_0 (nm × 10)	5.2108	(3)
Cr_2O_3	0.23	(0.04)						
FeO*	10.73	(0.19)	M1 site	Al^{VI}	0.0056			
MgO	29.79	(0.23)		Fe^{3+}	0.0273	Rsym	2.71	
MnO	0.25	(0.07)		Ti	0.0030	N obs. refl.> 3 σ	884	
CaO	2.53	(0.11)		Cr	0.0060	R1	2.33	
Na_2O	0.01	(0.01)		Mg	0.9339	wR2	5.86	
Total	100.00			Fe^{2+}	0.0236	GooF	1.255	
FeO	9.40			Mn	0.0006			
Fe_2O_3	1.48			Σ	1.0000			
Total	100.15							
						< M1 - O > (nm × 10)	2.081	(6)
Wo	4.93		M2 site	Ca	0.0952	V M1 (nm × 1000)	11.884	(8)
En	80.78			Na	0.0000	< M2 - O > (nm × 10)	2.189	(6)
Fs	14.29			Mg	0.6394	V M2 (nm × 1000)	12.954	(9)
				Fe^{2+}	0.2592	< TA - O > (nm × 10)	1.628	(5)
				Mn	0.0062	V TA(nm × 1000)	2.188	(4)
				Σ	1.0000	< TB - O > (nm × 10)	1.641	(5)
						V TB (nm × 1000)	2.254	(4)

Table 4: Chemical composition and structural formulae of garnets. Fe_2O_3 calculated on the basis of garnet stoichiometry.

GARNETS

Sample	NV-a	NV-b	NV-c	NV-d	NV-e	NV-f
SiO_2	36.77	38.72	37.22	37.54	36.37	37.52
Al_2O_3	20.59	21.52	20.84	20.79	20.60	20.92
Cr_2O_3	0.01	0.02	0.02	0.05	0.02	0.01
MgO	2.33	8.10	4.51	1.82	2.27	4.62
FeO	30.65	17.73	33.35	29.09	32.93	31.11
Fe_2O_3	1.13	2.88	1.37	0.70	1.72	0.84
TiO_2	0.01	0.09	0.00	0.08	0.02	0.01
MnO	7.00	0.58	1.84	0.66	5.42	3.42
CaO	1.62	10.63	0.97	9.33	0.81	1.61
Total	100.11	100.25	100.11	100.06	100.16	100.06
Numbers of ions on the basis of 12 oxygens						
Si	2.982	2.948	2.977	2.995	2.959	2.990
Al	1.967	1.930	1.964	1.955	1.974	1.966
Cr	0.001	0.001	0.001	0.003	0.001	0.001
Mg	0.282	0.919	0.538	0.216	0.275	0.549
Fe^{2+}	2.078	1.128	2.230	1.941	2.241	2.074
Fe^{3+}	0.069	0.164	0.082	0.042	0.105	0.051
Ti	0.001	0.005	0.000	0.005	0.001	0.001
Mn	0.481	0.037	0.125	0.045	0.373	0.231
Ca	0.141	0.867	0.083	0.798	0.071	0.138
Total	8.000	8.000	8.000	8.000	8.000	8.000
Pyrope	9.44	31.13	18.06	7.22	7.57	18.35
Almandine	70.49	40.28	75.95	64.71	77.02	69.68
Spessartine	16.12	-	3.30	1.48	12.62	7.72
Andradite	2.29	5.26	2.61	2.09	2.32	2.00
Grossulare	1.59	23.00	-	24.10	-	2.18
Uvarovite	0.03	0.06	0.06	0.16	-	0.03
Schorlomite	0.03	0.26	0.01	0.24	0.06	0.03

Lherzolitic peridotites (type-I peridotites) are mainly exposed in the Outer Dinarides (Karamata et al. 1980), whereas harzburgites, dunites, gabbroid (type-II peridotites) and volcanic rocks are present in the Internal Dinarides (Karamata et al. 1980).

As regards the nearby Claut and Julian Basin, Lenaz et al. (2000) suggested that the source area of the type-II spinel should be located in the Internal Dinarides where harzburgite rocks outcrop. We suggest that the Brkini Basin was supplied from both the Internal and Outer Dinarides. This implies that by Lower-Middle Eocene, not only the Internal, but also the Outer Dinarides had been eroded and that their material was supplied to the Brkini flysch.

Ilmenites are present only in the molasse rocks at the top of the sequence (Lutetian and/or post-Lutetian; Tunis & Venturini 1996) and in the Istrian Basin (Middle–Upper Eocene) suggesting that an ilmenite-bearing source rock had been eroded at least by Lutetian times. It is not possible to define its source even if it possible that its supplies are from the Dinarides.

For the first time, pyroxene has been recognized in the SE Alps and Outer Dinarides flysch basins. Neither chemistry nor structural studies permits us to attribute it to a specific rock source; new occurrences and the related structural studies could probably yield in the future a better definition of the source rocks.

The garnets are similar to those found in the Julian Basin and to those in the Istrian Basin (Lenaz 2000). A pyrope-rich garnet can be associated with garnets from amphibolites related to Dinarides ultramafics. Other garnets cannot be related to a precise source rock.

Similarities have been recognized to the minerals of both Julian and Istrian basins (e.g. garnets) so that supplies from both the NW areas and the SE ones are present, confirming the paleocurrent data obtained by Tunis & Venturini (1996) and by Orehek (1972; 1991).

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