Geochemistry of Triassic metasediments from easternmost part of Sakar Unit, Sakar-Strandzha Zone, SE Bulgaria

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Abstract. Triassic metasediments from the easternmost part of Sakar Unit, Sakar-Strandzha Zone, SE Bulgaria, show a high variety in their mineral and chemical composition from shales, wakes, litharenites to arkoses. Geochemical signatures suggest low to moderate weathering degree at their source and upper continental crust composition. The Triassic metasedimentary rocks were derived from felsic to intermediate igneous rocks with some recycled sediment input. On tectonic setting discrimination diagrams, based on immobile trace elements, the studied metasediments fall in the fields of continental island arc and active continental margin.

Keywords: geochemistry, Triassic metasediments, Sakar unit, SE Bulgaria.

Introduction and geological setting

The bulk chemical composition of clastic sedimentary rock is a fundamental tool for paleogeographic and tectonic reconstructions (McLennan et al., 1993). Major and trace elements reflect the association of major and accessory minerals, respectively the mineralogical composition of the source rocks and tectonic setting of deposition (Bhatia, Crook, 1986). One consequent metamorphic event could completely obliterate the precursor mineral assemblages in metasediments with some detrital heavy minerals preserved but the geochemical features of the deposition environment are still notable.

In this paper, we present geochemical data on metasedimentary rocks from the eastern part of Sakar Unit, Sakar-Strandzha Zone (SSZ), SE Bulgaria, metamorphosed in greenschist to amphibolite facies. The SSZ (e.g., Chatalov, 1990; Ivanov, 2017) occupies the SE part of Bulgaria and NW Turkey and consists of Paleozoic metamorphic basement, unconformably overlain by thick Triassic–Jurassic metasedimentary cover. The Triassic metasedimentary rocks in eastern Sakar Unit belong to the Topolovgrad Group of Sakar Type Triassic, divided into three formations: Paleocastro, Ustrem and Srem (Chatalov, 1990). Chatalov (1990) published the first consistent geochemical dataset on the Triassic metasediments including major and some trace elements. Preliminarily geochemical data on metasediments from the Western Sakar Unit were reported by Vladinova et al. (2016) and revealed a continental island arc setting for the origin of the siliciclastic component. Bonev et al. (2022) gave additional data on geochemistry and geochronology mainly on arkoses-subarkoses compositions derived from acid magmatic rocks from continental arc.

Analytical procedures and sample description

The major elements of 15 whole-rock samples were analyzed by XRF at the Geochemical Laboratory of Sofia University “St Kliment Ohridski”, Bureau Veritas (Vancouver, Canada) and at the University of Karlsruhe (Germany). Trace elements were de-
termined by LA-ICP-MS at the Geological Institute (BAS), using whole rocks’ SiO₂ content as internal standards and NIST 610 as external standard. In all samples FeO and Fe₂O₃ contents were determined additionally. The sample composition ranges from garnet-bearing mica schists, staurolite-garnet mica schists, carbonate-bearing mica schists to metasandstones, and metaconglomerates (Fig. 1a–c). The samples were collected from the Paleocastro (mica shist, chlorite schists and garnet-staurolite shists) and Ustrem formations (metasandstones and metaconglomerates) where siliciclastic rocks are more abundant. At transition to the Srem Formation, the carbonate content in rocks increases and in our study, we selected only carbonate-bearing samples with LOI less than 10 wt% (having in mind that this parameter reflects also the presence of phyllosilicate minerals in the samples). The sampled outcrops are located in the vicinity of the town of Topolovgrad, as well as near Hlyabovo, Oreshnik, Srem, and Melnitsa villages. In the field, the metasediments show fine foliation, defined by phyllosilicate minerals for mica schists to massive textures of metasandstones and metaconglomerates.

**Petrography**

Muscovite, biotite, chlorite, feldspars, and quartz are the main minerals in schists. The foliation is traced by alternating phyllosilicate and quartz bands. Feldspar clasts are rounded with pressure shadows of muscovite and polygonized quartz. K-feldspar clasts show undulose extinction and microcline twinning (Fig. 1d). Opaque minerals (pyrite, magnetite, scheelite) and other accessory minerals (zircon, apatite, monazite, titanite) are related to the

![Field photographs and Microphotographs](Fig. 1)

**Fig. 1.** Field photographs: a) alternation of quartz-muscovite and chlorite-muscovite schists, in the vicinity of Hlyabovo village (Ustrem Formation); b) metasandstones, in the vicinity of Melnitsa village (Paleocastro Formation); c) alternation of metasandstone and calcite-biotite schists, in the vicinity of Srem village (Ustrem Formation); Microphotographs: d) K-feldspar porphyroclast in quartz-muscovite matrix, muscovite gneiss (XN); e) euhedral postkynematic garnet porphyroblast in fine grained mica matrix, garnet-bearing schist (XN); f) post-kinematic biotite porphyroblasts in calcite matrix, calcite-biotite schist (IIN); g) classification diagram for siliciclastic sediments (Herron, 1988); h) discrimination diagram for sedimentary provenance (Roser, Korsch, 1988); i) discrimination plot for tectonic setting (Bhatia, Crook, 1986).
The carbonate-silicate rocks are composed of epidote and biotite porphyroblasts in fine-grained matrix of epidote, calcite, quartz ± plagioclase (Fig. 1f). The post-kinematic biotite porphyroblasts include numerous long prismatic epidote, small calcite and quartz grains. The quartz is present either as single grains or in recrystallized lenses. The main accessory mineral is rutile.

Metasandstones are composed mainly of quartz and feldspars. Muscovite, biotite, and chlorite define the foliation and in some samples, calcite is also present. Quartz, K-feldspar, and plagioclase form also larger porphyroclasts, surrounded by mica bands. Euhedral epidotes (~ 0.05 mm), hematite, pyrite, and zircon are the main accessory minerals.

The metaconglomerates are composed of quartz, plagioclase and K-feldspar porphyroclasts in a fine-grained quartz-muscovite matrix. The euhedral biotite porphyroblasts (~ 2 mm) include quartz and rutile. Biotite is partially replaced by chlorite, accompanied by rutile, magnetite and hematite aggregates. The accessory minerals (rutile, zircon, apatite and monazite) occur in the mica bands.

Geochemistry

The varying mineral composition of the studied samples reflects in strong SiO$_2$ content variation (49.70–84.40 wt%). SiO$_2$ has negative correlation with Al$_2$O$_3$, FeO, MgO, MnO, TiO$_2$, and P$_2$O$_5$ in accordance with the higher quartz content with increasing maturity of the sedimentary protolith. CaO, K$_2$O and Na$_2$O show poorer negative correlation with SiO$_2$, as they are present in more than one rock-forming mineral – feldspars, micas, and some calcite. K$_2$O and Na$_2$O have negative correlation and the K$_2$O/Al$_2$O$_3$ (0.11–0.39) and Na$_2$O/Al$_2$O$_3$ (0.02–0.40) ratios reflect the feldspar composition – from K-feldspar-dominated to the plagioclase-dominated samples. FeO/Fe$_2$O$_3$ ratio also shows significant variation from 0.20 to 1.60 with highest values in garnet-bearing schists, similar high variation is observed in Chatalov’s (1990) data (FeO/Fe$_2$O$_3$, 0.51–3.45).

In classification diagram by correlations of Fe$_2$O$_3$/K$_2$O with SiO$_2$/Al$_2$O$_3$, the metasediments fall in the fields of shales, wackes, litharenites, and arkoses (Herron, 1988) (Fig. 1g). The Chemical Index of Alteration (CIA) ranges from 50 to 75 for carbonate-free siliciclastic metasediments and indicates a low to moderate degree of chemical weathering (Nesbitt, Young, 1984). Discrimination functions (DF) after Roser and Korsch (1988) suggest quartzose sedimentary provenance with minor felsic to intermediate igneous input (Fig. 1h).

The major elements can be fractionated by weathering, diagenesis and metamorphism, which influence the primary geochemical composition. The immobile trace elements (REE, HFSE, Cr, Co, Th, Sc and Zr) are more reliable in studying sedimentary provenance and depositional setting (McLennan et al., 1993), as they are transferred almost directly into clastic sedimentary rocks. Using Th/U, Th/Sc, and Zr/Sc ratios, the metasediments from the eastern Sakar Unit show an upper crust features and follow the sediment weathering trend (McLennan et al., 1993). On La-Th-Sc, Th-Zr-Sc and La/Sc–Ti/Zr (Fig. 1j) discrimination diagrams for tectonic setting (Bhatia, Crook, 1986) the studied samples fall into fields of continental island arc and active continental margin.

The sum of REE content varies significantly from 50 to 440 ppm (most of the samples have values from 50 to 200 ppm). The lowest and highest values are observed in metasandstones. Chondrite-normalized patterns are typical for the continental crust – enriched in LREE (La$_n$/Sm$_n$ 2.12–4.76), flat HREE (Gd$_n$/Lu$_n$ 0.89–2.43) and negative Eu anomaly (Eu/Eu* 0.50–0.80). The negative correlation of SiO$_2$ and Eu/Eu* reflects the varying mineral composition from schists to metasandstones.

Conclusions

We present geochemical dataset and discuss the geochemical features of the Triassic metasediments from the Eastern Sakar Unit. The studied samples show a high variety in their mineral and chemical composition and on classification diagrams, they spread from shales to arkoses. Geochemical signatures suggest low to moderate weathering degree at their source and upper continental crust composition. The Triassic metasedimentary rocks were derived from recycled sediment material with some felsic to intermediate igneous input. The studied rocks differ from metasediments from western outcrops (Vladinova et al., 2016) with higher felsic igneous input and the presence of older recycled sediment material and are similar to geochemical features reported for arkoses and subarcoses from Sakar Unit (Bonev et al., 2022). On tectonic setting discrimination diagrams, based on immobile trace elements, the studied metasediments fall in the fields of continental island arc and active continental margin, in accordance with the geological evolution of the Black Sea region – continuous accretion of northern Gondwana margin to Eurasia from mid-Peleaozoic to Cimmerian (Okay, Nikishin, 2015).
References


