Divergent drift of Adriatic-Dinaridic and Moesian carbonate platforms during the rifting phase witnessed by triassic MVT Pb-Zn and SEDEX deposits; a metallogenic approach

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ABSTRACT

Early-intracontinental rifting of Pangea was a result of thermal doming in Uppermost Permian time giving rise to the formation of horst-graben structures, followed by slow subsidence, marine transgression and evaporite deposition. The consequences of incipient magmatism and a high heat flow are numerous geothermal fields and subterrestrial hydrothermal siderite-barite-polysulfide deposits (PALINKAŠ et al., 2016). Advanced rifting magmatism as a successive stage in the Middle Triassic brought intensive submarine volcanism, accompanied by coeval sedimentation of chert and siliciclastics, building up volcanogenic-sedimentary formations. Volcanic activity with explosive phases and the generation of large volumes of pyroclastic rocks in the rifts produced concomitant mineralization with numerous sedimentary exhalative (SEDEX) deposits of Fe-Mn-Ba-polysulfides. The passive continental margin of northern Gondwanaland is flanked by the Adria-Dinaridic carbonate platfom, while the Moesian carbonate platform is a counterpart on the European passive continental margin. They were divergently drifted in the course of the advanced rifting. A fast growing carbonate platform, developing gradually, covered evidence of the earlier intracontinental rifting and their ore formations. However, the carbonate platforms themselves host specific Pb-Zn deposits, well known as a Mississippi valley type, (MVT) or Bleiberg-Mežica type according the traditional european terminology. Triassic MVT and SEDEX deposits are symmetrically situated on the both sides of the divergent passive margins in this early history of the Tethyan ocean. The paper gives a brief description of the MVT and SEDEX deposits, in the two carbonate platforms and rifts in between, formed synchronously and in a similar manner on opposing sides of the diverging continental margin.

Keywords: Triassic MVT Pb-Zn deposits, SEDEX deposits, Adriatic-Dinaric-Moesian carbonate platforms, Tethyan advanced rifting

1. GEOLOGICAL FRAMEWORK

Metallogenesis brings together knowledge of regional geology and ore petrology. Their mutual contributions are beneficial to the interpretation of plate tectonics models of orogenic processes (JANKOVIĆ & PETRASCHEK, 1987; JANKOVIĆ, 1997). The Alpine-Balkan-Carpathian-Dinaride (ABCD) metallogenic and geodynamic provinces are a result of the Wilson cycle, which includes phases of early intracontinental rifting (PALINKAŠ, et al.., 2010, 2016; STRMIĆ et al. 2009), advanced rifting (KISS et al., 2016), oceanization, subduction and emplacement of ophiolites (KARAMATA et al., 1997); collisional and postcollisional deformation events with synkinematic granite plutonism (CVETKOVIĆ et al, 2004). The rifting and oceanization processes took place almost synchronously within the vast circum ABCD area, in Mid-Triassic time, creating the symmetrical emplacement of Adriatic-Dinaric and Moesian carbonate platforms, on the passive continental margins of Gondwana and Euroasia. The symmetry was emphasized by deep marine basins in between, gradually developing into the oceanic crust of Tethys (HAYDOUTOV & YANEV, 1997). The scenario is outlined by the symmetrical distribution of ore deposits characteristic for the rifting metallogenesis, MVT Pb-Zn ores in carbonates (Bleiberg-Mežica type) and SEDEX iron-manganese-polymetallic ore sediments (Red Sea type). The early symmetry of the tectonostratigraphic and metallogenic phenomena along the line of extension and opening of the future Tethys was subsequently "spoiled" by the continental convergence of Africa and Eurasia mainly from the Middle Jurassic, as intra-oceanic subduction, through the Middle Cretaceous ocean-continent subduction, and Upper Cretaceous continent-continent collision to the present time. It developed a complex geometry of the collisional interfaces, with interfingering microplates giving rise to discontinuous sutures, diachronous magmatism, and obduction of oceanic crust on the passive continental margin, leading to variable thickening, followed by extension and collapse (HEINRICH & NEUBAUER, 2002).

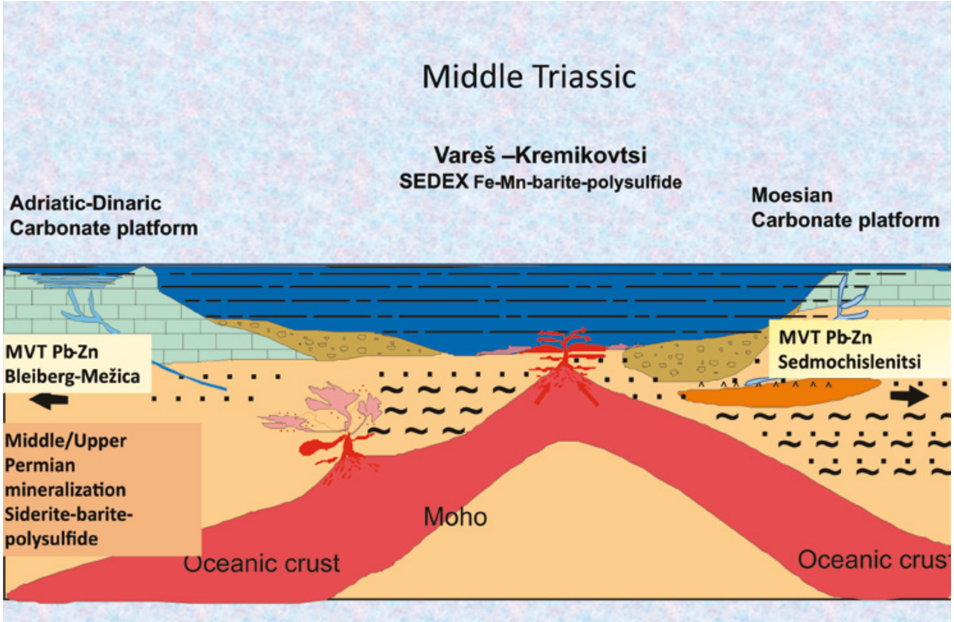

Figure 1. Middle Triassic advanced Tethyan rifting. The drawing depicts the formation of characteristic MVT type of deposits within the carbonate platforms. The SEDEX type deposits are formed in respons to volcanic activity within a rift basin, including hydrothermal exhalation and deposition of the sedimentary ore load.

2. THE MVT Pb-Zn (BLEIBERG-MEŽICA TYPE) AND SEDEX DEPOSITS, MARKERS OF TRIASSIC RIFTING PROCESSES

2.1. MVT Pb-Zn DEPOSITS IN THE ADRIATIC-DINARIDIC CARBONATE PLATFORM

Triassic carbonate-hosted lead-zinc deposits (Alpine-type/ MVT) in the Alps and Dinarides are placed within the Adriatic-Dinaridic carbonate platform, a passive continental margin of Gondwana. Carbonate-hosted, low-temperature, Pb-Zn deposits are contemporaneous with the advanced Tethyan rifting in the Middle Triassic. The most important deposits are those in the Northern and Southern Calcareous Alps, Bleiberg-Kreuth (ZEECH & BECHSTÄDT, 1994; Austria), Mežica and Topla (DROVENIK et al., 1980; Slovenia), Raibl and Salafossa (OMENETO, 1979; Italy). These deposits, so far, provided more than 10 Mt of Pb-Zn metal. The mineralization is generally stratabound in carbonates of the Ladinian and Carnian stages. Usually they are combined under the term "Bleiberg type" and have often been compared with MVT deposits (EBNER et al., 2000).

The discussion of the origin of the Pb-Zn ores is still controversial. There is a general agreement on their formation by low temperature fluids. The lead model ages older than the host rocks, suggesting metal derivation from the Palaeozoic sediments in the autochthonous basement. However, the source and the concentration mechanisms of Pb-Zn metals deposits are not yet fully understood.

Apart from the above "majors", there are more than 200 similar Pb-Zn occurrences known in the External Dinarides, the Southern Alps and the Northern Alps. Some of them are briefly reviewed below.

St. Jakob Pb-Zn deposit hosted by non-metamorphosed dolostones is located on the Medvednica Mt. in the south-western part of the Zagorje-Mid-Transdanubian zone. The vein-type mineralization has a simple paragenesis, galena, minor sphalerite and pyrite with quartz and calcite as gangue minerals (ŠINKOVEC et al, 1988). Pb isotopes are anomalous and may be classified as Bleiberg-type according to the Doe and Zartman model, yielding 490 Ma (PALINKAŠ, 1985). FI studies in quartz gave the following characteristics: $NaCl$-$CaCl_2$-H_2O composition, 6-19 wt.% NaCl equ., temperature of homogenization (T_H: 80-230°C, mean 130°C). The $\delta^{34}S$ values of galena and sphalerite vary between +7 and +10 ‰ (BOROJEVIĆ ŠOŠTARIĆ, 2004).

Pb-Zn deposits in the Middle Triassic carbonates also occur also in the Ivanščica Mt., in the **Ivanec** deposit, in the Zagorje-Mid-Transdanubian zone (ŠINKOVEC et al, 2000), on the eastern slopes of Petrova gora Mt. in the **Svinica** deposit, and in the **Srb** deposit in the Lika region. All of them are accommodated within the units belonging to the Mesozoic carbonate platform of the External Dinarides.

The **Olovo** deposit, Central Bosnia, is hosted by Middle Triassic dolostones and limestones, evolved in reefal facies. The major ore minerals are Pb and Zn carbonates mainly cerussite and to a lesser extent smithsonite (KUBAT, 1988).

2.2. SEDEX Fe-Mn-BARITE-POLYMETALLIC DEPOSITS IN THE DINARIDIC RIFT ENVIRONMENT

Vareš metallogenic province in Central Bosnia owes its ore load to processes during the advanced rifting in the evolution of Tethys. Coeval magmatism produced spilites, basalts, keratophyres and diabases interbedded with Ladinian sedimentary rocks (PAMIĆ, 1984; KISS et al., 2016). The **Vareš** deposit with the Smreka, Droškovac and Brezik deposits are taken as the *loci typici* for mineralization of Mid-Triassic Tethyan rifting. The deposits contain hydrothermal, stratiform siderite-haematite-chert beds. The ore mineralization is intercalated into Anisian and Ladinian sequences and distinctly zoned vertically, reflecting gradual changes of redox conditions in the depositional environment during basin subsidence. The sequence began with bituminous, thinly bedded black shales with abundant pyrite and base metal sulphides, overlain by barite and siderite, all of which were deposited under reducing conditions. Clastic rocks and oolitic limestone rest upon this metalliferous series and are succeeded by another metalliferous series with haematitic shale and siliceous haematite beds, which in contrast to the footwall rocks were deposited under oxidizing conditions. The overall mineralization consists of siderite, Mn-enriched haematite, barite, pyrite, marcasite, chalcopyrite, galena, sphalerite, tetrahedrite and Pb-sulphosalts. The $\delta^{34}S$ values of barite vary from +21 to +29 ‰. The chemical compo-

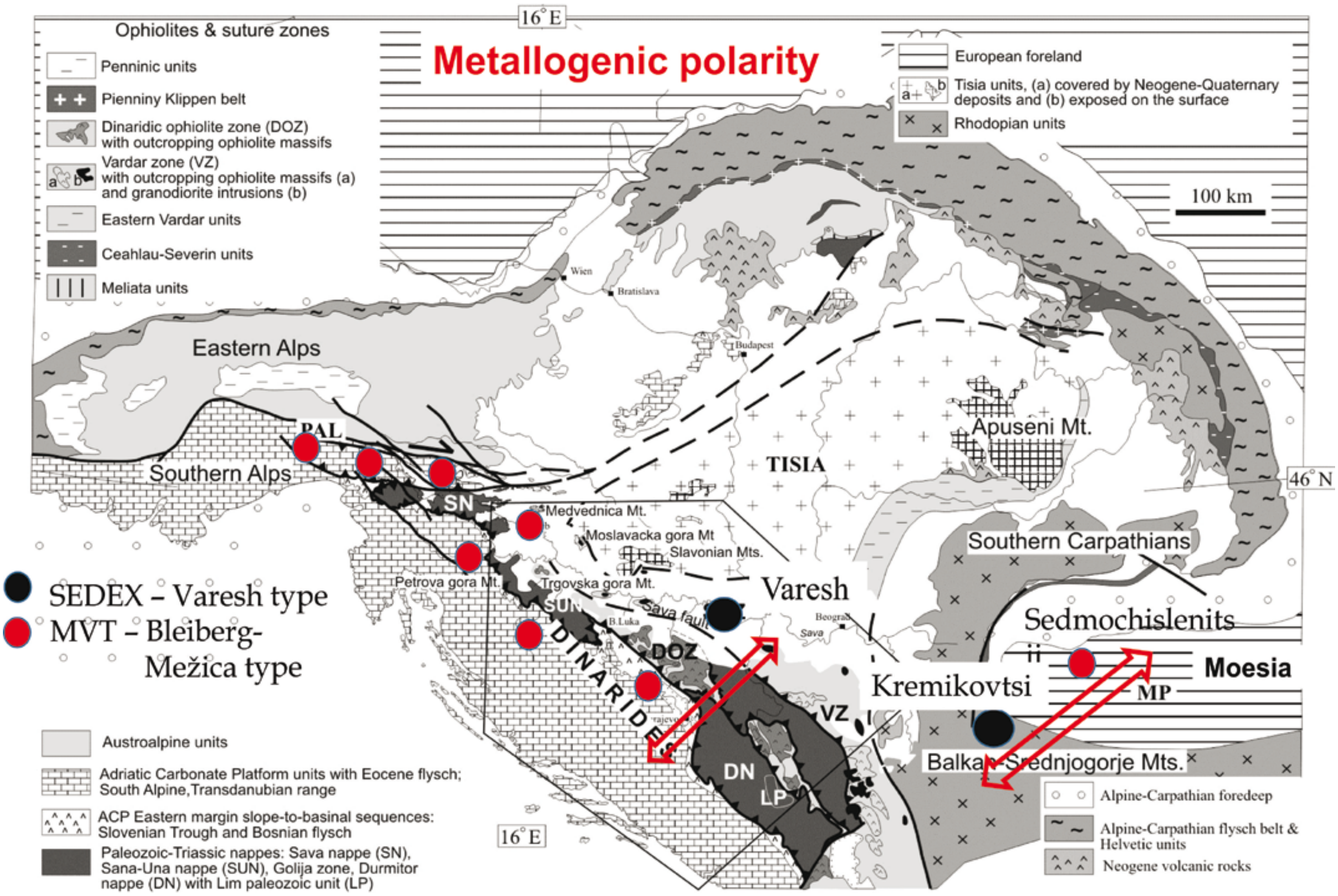

Figure 2. Metallogenic polarity of mineral deposits, related to the advanced Tethyan rifting. The two carbonate platforms, facing each other from the opposite passive continental margins of Gondwana and Eurasia, accommodate numerous MVT deposits in the Alps, Dinarides and Moesia. The newly formed, deep water marine basin, still with continental (not oceanic crust) is the home of the SEDEX deposit, formed by hot water, issuing their ore load primarily as sediments on the bottom of the Triassic sea.

sition of fluid inclusions in sphalerite and barite may be described as a $CaCl_2$-NaCl-H_2O system, which evolved under moderately high temperature, (Th between 110 and 230°C). Salinity ranges from 2 to 4 wt.% NaCl equ. In context with the Cl/Br ratio the fluids are assumed to have been derived from modified seawater (STRMIĆ et al., 2001; PALINKAŠ et al., 2003, PALINKAŠ et al., 2008). (Fig.1)

2.3. MVT Pb-Zn DEPOSITS IN THE MOESIAN CARBONATE PLATFORM

Triassic carbonate hosted Pb-Zn ore deposits represented by **Sedmochislenitsi** in the Moesian carbonate platform resemble in many respects those in the Alps and Dinarides (MINČEVA-STEFANOVA, 1972; MARINOVA & DAMYANOV, this issue).

The Pb-Zn stratabound ore deposits occur in the Balkanide region within an area of about 30 X 25 km. The host rocks are primarily dolomite of Anisian and partly of Rhaetian age. The ore bodies are elongated lenses and veins, mostly of metasomatic origin (CHERNEV, 1993). The openings along the bedding were favourable for ore deposition. Marl intercalations and thin-bedded dolostone packets were considered to be a screen for the ore fluids (KALAYDZIEV, 1982), while organic matter was a chemical reducer (MINCHEVA-STEFANOVA, 1988). Another structural factor is the intense fracturing of sediments near the regional faults. These areas contain rich sulfide mineralization (CHERNEV, 1993). The ore is represented by fine grained light-coloured sphalerite, schalenblende, pyrite, marcasite, galena, small amounts of arsenopyrite, bravoite [(Fe, Co, Ni)S_2], and sporadic Ag-Sb-sulfosalts. Dolomite, barite, quartz and calcite are typical gangue minerals.

2.4. SEDEX Fe-Mn-BARITE-POLYMETALLIC DEPOSITS IN THE MOESIAN RIFT ENVIRONMENT

The **Kremikovtsi** SEDEX deposit is situated approximately 15 km NE of Sofia. It lies in the southernmost part of the Kremikovtsi-Vratsa ore district, in the Western Balkanides, a northern branch of the Alpine-Himalayan collisional orogenic belt. The deposit is a product of Middle Triassic metallogenesis in the graben shaped structure adjacent to the Moesian carbonate platform (BAKARDZIEV, S. & POPOV, P., 1995). The ore forming processes took place in the advanced rift-related extension. The deposit is of the SEDEX type, consisting of stratiform pyrite and barite ore, and iron-manganese formations with low-grade sulphide mineralization. Primary zoning of the Kremikovtsi ore district extends vertically and laterally: pyrite, siderite barite, ferroan dolomite, ankerite, and haematite. It has a prominent feeder zone with stockworks and veins of iron carbonates-barite-sulfide in the underlying rocks (DAMYANOV, 1996, 1998). 3

3. CONCLUSION

The area of the Alpine-Balkan-Carpathian-Dinaride (ABCD) metallogenic and geodynamic provinces is a collage of variable crustal elements, and part of a long suture of the Tethyan Ocean, squeezed between the Gondwanian and Eurasian continental blocks. Introduction of plate tectonic models greatly contributed to the integrated interpretation of geological evolution in time and space. There are still, however, numerous disputes, in putting collage elements together. The crucial moments in the interpretation are the timing of incipient rifting and the creation of Tethyan oceanic crust. A number of oceanic slivers, recognized by Dinaridic, West Vardar and Central Vardar ophiolites, make a firm conclusion blurred. Metallogenic events, the formation of MVT Pb-Zn deposits in the Adriatic-Dinaridic and Moesian carbonate platforms, on opposite sides of the rift, and SEDEX deposits, formed in the rift itself, define spatially and constrain the timing of advanced Tethyan rifting, in the Mid-Triassic.

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