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Izvorni znanstveni članak

OUTLINE OF METALLOGENESIS OF THE WEST CARPATHIANS

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Metallogenesis of the West Carpathians appears to be polycyclic and polygenetic. Its characteristic feature is a superposition of younger mineralization acts on older ones. These processes in some places are accompanied by regenerations. A variability and multicyclic character of the metallogenesis accords with a permanent tectonical mobility of the area which was only interrupted by short episodes of relative stillness in its early Paleosoic to Quaternary development.

Metalogeneza Zapadnih Karpata je policiklička i poligenetska. Njena karakteristika je superpozicija mlađih orudnjenja na starije. Mjestimice ti su procesi praćeni regeneracijom. Raznolikost i mnogostruka opetovanost metalogeneze u skladu je s trajnom tektonskom mobilnosti tog područja, izuzev kraćih razdoblja mirovanja, od donjeg paleozoika do kvartara.

The metallogenic division of the West Carpathians expressed firstly by Koutek (1963) then by Varček (1963) and by Ilavský & Sattran (1980) concides generally with the main geostructural units.

The Outer Carpathians represented by the Flysh belt and by the Neogene Carpathian foredeep seems to be of a little importance from the endogenous mineralization point of view.

The Klippen Belt is interesting by its unique geotectonic position as boundary between Outer Carpathians and Inner West Carpathians.

The Inner West Carpathians which are extended south of the Klippen Belt are the main bearers of extremly variable endogenous mineralisation. It is hovewer a region where the mutual spatial overlapping of Hercynian and Alpinian metallogenetic phases complicates the decoding of their development.

In the metallogenetic clasification of the Inner West Carpathians we consider the scheme of geotectonic and magmatic evolution of the Carpathians wich recognizes the following stages:

The Late Kaledonian to Paleo-Hercynian stage, the Neo-Hercynian stage, the Paleo-Alpinian stage, the Meso-Alpinian stage and the Neo-Alpinian stage.

The Late Kaledonian to Paleo-Hercynian stage (Silurian-Devonian) is the oldest metallogenetic stage which was up to now proved in the West Carpathian territory. It is marked by a bimodal volcanism (Grecula, 1982) connected with hematite-magnetite and Mn-ores of the Lahn-Dill type and pyrite, copper-pyrite, pyrite-polymetallic volcanosedimentary deposits (Ilavský, 1964). These deposits are known especially from the Spiš-Gemer Ore Mts. (Smolník). Their equivalents are occurences in the crystalline rocks of the Core mountains namely in the Nízke Tatry Mts. (Helps deposit) and in the Malé Karpaty Mts. (Pezinok deposit). From the general point of view it is posible to compare them with similar occurrences on the East of the West Carpathians — eg. on the territory of the Sowiet and Rumunian Carpathians (eg. Rodna) as well as on the West of them eg. in the Bohemian massif (Jeseníky). Thus it is possible to accept Kräutner's (1970) inclusion of these occurrences into a common Hercynian belt.

The Neo-Hercynian stage is connected with a regional granitization of all the Core mountains. It has brought an essential substance overeworking of the basement of the Core mountains. Nevertheless, if we do not consider the possibility of genetic boundage of the Hercynian granitoide magmatism to the scheelite mineralization and to the small occurrences of Mo, Au and Sb ores, this magmatism is metallogenetically not very significant and in this types of mineralizations have not always been proved the Variscan age according to structural criteria. The scheelite deposits rather extended in the crystalline units of the

West Carpathians have many corresponding features with similar deposits of Eastern Alps nevertheless their age and genetic relations are so far uncertain (Rozložník & Slavkay, 1979). The West Carpathian scheelite mineralization is most probably conected with granite intrusions.

The Permian orogenic phases which has brought U was well as Cu mineralization appears to be also important.

The Alpinian metallogenetic epoch is the bearer of important acts of endogenous mineralization on the West Carpathian territory. The opinions on the genesis and the age of some members of this epoch are divergent, still it is a fact that it has yielded the highest number of ore formations in the West Carpathians, through its Paleoalpine, Mesoalpine and Neoalpine stages.

The Paleoalpine stage began in the Lower Triassic by a rift — like opening and desintegration of Hercynian continental crust and by diversified sedimentation, also marked by oceanization. During the Jurassic-Cretaceous a collisionnape closing took place. From the metallogenetic stand — point the recurrent Paleoalpinian volcanism is important. The Meliata group is the bearer of basic and ultrabasic rocks and Lahn-Dill hematite deposite (eg. Držkovce, Licince, Lúčka, Bôrka). The Triassic complex of higher nappes contains Paleovolcanites with Pb-Zn mineralization (Ardovo, Drienok). The last ones strongly resembles the development and position of the Pb-Zn deposits in Northern Calcareous Alps.

The Mesoalpinian stage is, according to our present knoweledges, the most productive and the most frequent stage in the West Carpathian territory. Its peculiarity lies in the fact that it represents a polyphase and substantialy variable mineralization process which is nearly simultaneous with the tectono-metamorphism and the granite magmatism represented by granites of the Gemeric type. The isotopic age of the Gemeric granites was determined by various methods as Permian, Jurassic to Cretaceous (Cambel et al., 1980), which is in contrast with their uniform petrography. According to geological criteria they are somewhat younger than the last i. e. the Alpinian Cretaceous metamorphosis of the Spiš-Gemer Ore Mts.

In case of Gemeric granites the connection with the Sn-mineralization has been already proved and the connection with W, Mo, Au and U, REE mineralization of perimagmatic position as well as the indirect connection of the younger quartz-antimonite ore formations. From all the mentioned formations the siderite one is regionally the most frequent. We can find it mostly in Paleosoic rock on the territory of the Spiš-Gemer Ore Mts. (Rožňava, Nižná Slaná, Rudňany) but it is also present in the Veporic and Tatric region. It is present in both the metasomatised carbonate bodies of Silurian, Devonian and Carboniferous and in a great number of ore veins. The last ones are often simultaneously the bearers of relatively younger Cu-rich quartz-sulphidic associations. The mentioned quartz-antimonite phase which is often situated in the proximity of the gemeric granite bodies seems to be the youngest phase of the Mesoalpinian ore mineralization.

The development of the deposits of magnesite and siderite formations in the West Carpathian territory has a lot of common features with the development of these in the Eastern Alps. In the West Carpathians territory we did not confirm up to now other than the hydrotermal-metasomatic origin of the magnesite (Jelšava, Košice) and siderite (Nižná Slaná) stratiformal deposits.

The mineralization of the siderite formation in the West Carpathian area take place after main the Alpinian compressive processes because ore veins appear to be younger than the cleavage and up-thrusts created by these processes (Rozložník, 1984a). On the other hand the siderite formation had to come to existence before the Upper Eocene because it contains its fragments.

At the creation of the magnesite and siderite formations the influences of metamorphism and remobilisation were also evidently active, because they were connected both spatially and temporaly to the origin of the Alpine types of veins (albitite, fuchsite, chlorite, sericite and so an). As it is in the Eastern Alps (cf. Petracshek, 1974) some indications of hybride origin of magnesite and siderite formations also exist here (Rozložník, 1984a).

When looking for the source of the siderite formations, it must be taken into account that it is a formation of regional extent. It itself indicates that the source cannot be local and shallow. In terms of geochemistry the siderite formation represents a migration of vast amounts of Fe, Mg, Mn, Cu and other metals into the upper parts of the crust in the form of both large and small deposits and occurrences of siderite, ankerite, magnesite and talc. In the Spiš-Gemer Ore Mts. there is no exposure where traces of such a migration would not be observed as well as trace of a younger mineralization with a relatively high Cu, Co-Ni, Bi, Ag, Hg, Pb-Zn contents etc. What was said above suggestes that the siderite formation must have a deepseated source, moreover of basic nature. Such a source could be explained by an existence of a deeply underthrusted unit affected by basification (e. g. similar to the Penninicum — Vahicum by Mahel, 1982) underlying a substancial part of the Inner West Carpathians

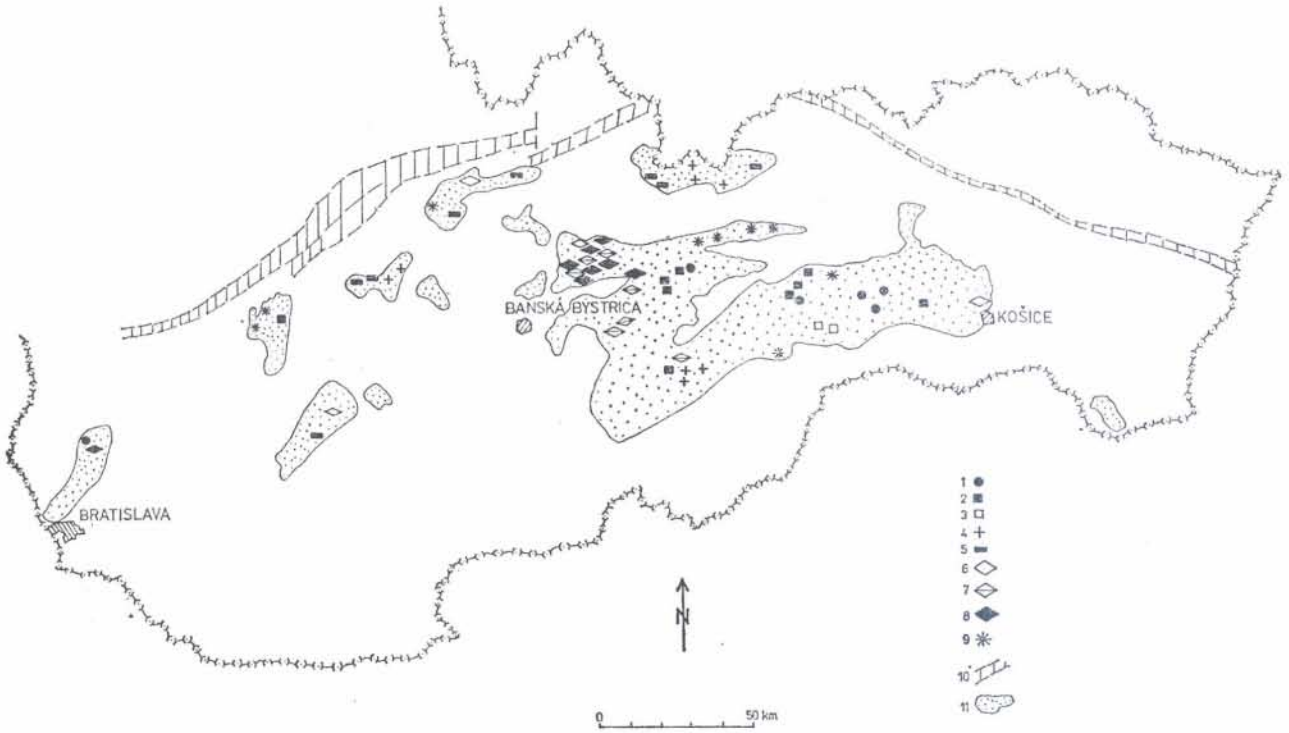

Fig. 1 *Paleozoic mineralization of the Inner West Carpathians* (compiled by the author from various sources mainly from Ilavský & Sattran, 1980)

1 — volcanogenic-sedimentary pyrite (± Cu, Pb-Zn, Au-Ag), 2 — occurrences of Fe-ores of the Lahn-Dill type, 3 — occurrences of Mn-ores of the Lahn-Dill type, 4 — small quartz veins with gold, 5 — veins of polymetalic ores (Cu-Pb-Zn), 6 — occurrences of molybdenite, 7 — occurrences of sheelite, 8 — deposits of antimonite with gold, 9 — occurrences of uranium ores, 10 — the Klippen Belt zone, 11 — surface distribution of Paleozoic unites. Note: some occurrences especially of group 4, 5, 7 and 8 according to their age relation are uncertain, hence they are also mentioned among Mezozoic occurrences.

beneath relatively light crystalline masses. Then siderite formation could be considered as a product of the Early Alpine remobilization of that unit under the influence of heat flow penetration (Rozložník, 1984a). During the Upper Cretaceous small deposite of bauxite on the karst surface originated.

Up to Upper Cretaceous the West Carpathians appear to have a lot of common with the Eastern Alps not only by their general geological development but also metallogeneticaly. In both mentioned regions in the Upper Cretaceous the scheelite, magnesite and siderite formations appear to be the connecting element. In the Upper Cretaceous there is a principal turn of the West Carpathians. They tend to be closer to the South Carpathian regions and the Balkanian.

During the Tertiary development the West Carpathians were changed to a quasi-platformal area. This evolution was accompanied by the formation of molasse and by a very extensive volcanism. It is the onset of the Neoalpinian stage which has brought a number of ore formations e. g. as the Eocenian sedimentary Mn-ores in Inner-Flysh basins (Kišovce, Švábovce near Poprad) or the most imporant ones Fe-skarns and Cu-porphyry ore formations, polymetallic vein (Cu-Pb-Zn, Au-Ag) and the Hg-As formation connected with Tertiary volcanism (Burian et al., 1985). The neovolcanites of the West Carpathians have the geotectonic and metallogenetic features which are typical for »Volcanic zones of the tectonomagmatic activisation« defined by Twalchrelidse (1978). It is a process, where a thickening of the sialic quasiconsolidated crust has been followed by its thinning. This process is ascribed in the studied case to the Pannonian basin mantle diapire of in the manner of the »Great basin« (Stegena et al. 1973). The location of the Tertiary volcano/plutonic centres as well as associated (the Late Tertiary) ore mineralization ones within the Middle and the Eastern Slovakia is very probably connected with the boundary zone of a thinner/thicker crust between the »Pannonian block« and the »Slovak block« respectively. All the important the Neogene volcanoplutonic and ore mineralized in Mid-Slovakia-e.g. Banská Štiavnica, Pukanec, Rudna nad Hronom, Nová Baňa, Kremnica, Javorie, Pol'ana as well as in East Slovakia — e.

Fig. 2 *Mezosoic mineralization of the Inner West Carpathians* (compiled by the author from various sources mainly from Ilavský & Sattran, 1980)

1 — occurrences of sedimentary Mn-ores, occurrences of sedimentary Fe-ores, 3 — occurrences of sheelite, 4 — mineralization of Sn-W-Mo ores of greisen type and porphyry type, 6 — deposits of metasomatic magnesite and talc, 7 — deposits of metasomatic siderite, 8 — veins of siderite, 9 — veins of siderite with a higher content quartz-sulfides, 10 — veins of quartz and antimonite, 11 — occurrences of cinnabar, 12 — occurrences of bauxite, 13 — the Klippen Belt zone, 14 — units of Pre-Tertiary Note: The position of some mineralizations (namelly 4, 5 and 10) is not explained on the whole hence they are also mentioned among Paleozoic occurrences.

g. Zlatá Baňa, Strechov, Makovica and Vihorlat (Morské oko, Kyjov), follow the traces of the steepest dip of the M-surface. (Rozložník, 1984b). The development of neovolcanic activities and the geothermal anomalies indicate the upwelling of a thermal diapire and the disintegrating and thinning of the sialic crust. The acid volcanites result from melting of sialic material, andesites have hybride origin and the basalts came from the mantle. The eruption of the products of neovolcanic activity did not follow a clasical succession. The acid and intermediate members overlap and change themselves both in time and space. Only basalts have their (Pliocene to Quaternary) final position according to the classical order. The volcanoplutonic centres are greatly changing in form and composition but manifest a relative indepedence of their development. This effect their metallogenetic specialisation. The resulting oreformations have different origin: 1. the earliest, high temperature skarn and porphyry Cu ores of the Zlatno type (nearly Banská Štiavnica) is bound to granodiority porphyry (Rozložník & Zábranský, 1971), 2. the hydrothermal vein-type polymetallic mineralization of the Banská Štiavnica type and precious metal mineralization the Kremnica type is in all probality bound to quartz-diorite porphyries, respectively to ryolites (Burian et al. 1985) and 3. lowtemperature Sb, Hg-As mineralization is probably connected with basalts — youngest products of volcanic activity (Rozložník, 1984b).

In Quartenary were originated the majority of gold placers.

The study of the metallogeny helps to understand the phases of the geotectonic development of West Carpathians and its relation to adjacent segments of Alpine structures.

The Early Paleosoic pyrite formation of the West Carpathians, the magnesite, siderite and scheelite formation links the West Carpathians with Eastern Alps. The skarn formation, the porphyry copper ore formation and the vein

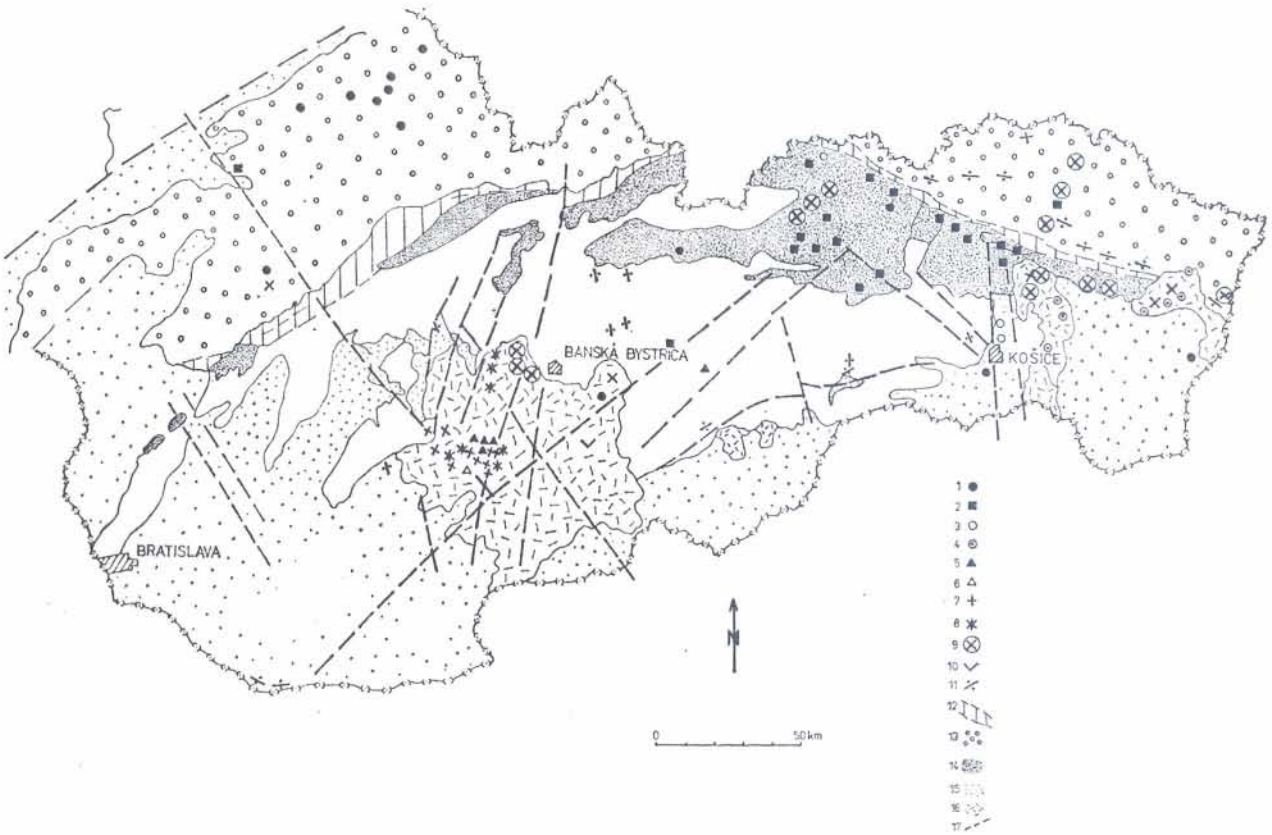

Fig. 3 *Tertiary mineralization of the West Carpathians* (compiled by the author from various sources mainly from Ilavský & Sattran, 1980)

1 — sedimentary and volcanosedimentary Fe-ores, 2 — sedimentary Mn-ores, 3 — volcanosedimentary deposits of pyrite and marcasite, 4 — iron opals, 5 — deposits of magnetite (± Cu, Pb-Zn) of skarn type, 6 — deposits of porphyry copper ore type, 7 — veins ore of polymetalic type, 8 — vein of precious metal mineralization type, 9 — occurrences of cinnabar — As-Sb mineralization, 10 — occurrences of volcanic sulphur, 11 — placers, 12 — the Klippen Belt zone, 13 — Inner-Westcarpathian Paleogene basins, 14 — Flysh — belt, 15 — Neogene basins, 16 — Neovolcanites, 17 — faults.

type polymetallic and precious ore formation connected with to Tertiary tecto-magmatic activisation, links from the metallogenic point of view the West Carpathians to the Pannonian massif, Eastern Carpathians and the Balkanides. The West Carpathians, from the metallogenetic point of view changed polarity more than once. After the breakdown of the Varisciden, they became a West Mediterranean region. From Upper Cretaceous they came under influence of the East Mediteranean belt. The Sn-W-Mo-U-REE mineralization, characteristic for the Gemeride granites, has no analogue in the neighbouring Alpine regions. A specific characteristic of the West Carpathians is also the abundant accumulation of Sb and Hg ores. These phenomena give the West Carpathians a sign of metallogenic specialization, and show certain geotectonic souvereignity in relation to the neighbouring regions.

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Kratak pregled metalogeneze Zapadnih Karpata

L. Rozložnik

Područje Zapadnih Karpata je podijeljeno na tri geotektonske jedinice:

(a) *Vanjski Karpati* koji predstavljaju flišni pojas i neogeni »foredeep« od malog su značenja za endogenu mineralizaciju;

(b) *Pojas navlaka* (Klippen Belt) koji je granica između vanjskih Karpata i unutarnjih Zapadnih Karpata; te

(c) *Unutarnji Zapadni Karpati* južno od Pojasa navlaka, glavni nosilac vrlo varijabilne endogene mineralizacije. U toj jedinici autor razlikuje kasni kaledonski do starohercinski, neohercinski, staroalpski, mezoalpski i neoalpski metalogeni stadij.

U kasno kaledonsko-starohercinskom stadiju (silur-devon), najstarijem poznatom u Zapadnim Karpatima, prisutan je bimodalni magmatizam s ležištima hematita-magnetita, Mn ruda (Lahn-Dill tip), zatim ležišta pirita, bakronosnog pirita, polimetalnih sulfida vulkano-sedimentnog porijekla.

U neohercinskom stadiju utvrđena je regionalna granitizacija središnjeg dijela Karpata. Poznate su samo male pojave Mo, Au i Sb ruda. Pojave šelita koje su značajnijih razmjera imaju više sličnosti s ležištima Istočnih Alpi, ali im starost nije određena.

Permska orogena faza koja je dala ležišta urana i bakra je od ekonomskog značenja.

Alpska metalogena epoha dala je najznačajnija endogena ležišta, no geneza i starost nekih tipova je još uvijek diskutabilna.

Staroalpski stadij donjeg trijasa počeo je riftovanjem, s kojim su u vezi bazične i ultrabazične magmatske stijene, te hematitska ležišta tipa Lahn-Dill. Za paleovulkanite su vezana ležišta olova i cinka.

Srednjoalpski stadij je bio naproduktivniji u Zapadnim Karpatima. Mineralizacija je vezana za intruziju gemerskog granita s polifaznom mineralizacijom: Sn, W, Mo, Au, U, REE ležišta perimagmatskog položaja, te mlađa Sb-SiO_2 formacija. Najvažnija su ipak sideritska ležišta, uglavnom locirana u paleozojskim stijenama Spiš-Gemer planine, ali i u području Veporika u Tatri. Po autoru izvor metala za formiranje sideritskih ležišta je u duboko smještenoj podvučenoj tektonskoj jedinici izloženoj utjecaju bazifikacije za vrijeme alpske remobilizacije konvekcijske toplotne ćelije.

U gornjoj kredi važne su pojave šelita, magnezita i siderita.

Nakon gornje krede sličnost geološkog razvoja Zapadnih Karpata s Istočnim Alpama prestaje, jer se dalji razvoj približava onom u Južnih Karpata i Balkanida.

U mladoalpskom stadiju, u tercijaru, područje Zapadnih Karpata poprima karakter kvazi platforme, s formacijom molase i raširenim vulkanizmom. Nastaju eocenske sedimentne Mn rude u flišu, te Fe skarnovi i Cu porfirne rude, polimetalne rude, te Hg-As formacija, vezane na vulkanizam koji ima karakteristike vulkanskih zona tektonomagmatske aktivizacije. Orudnjeno područje Slovačke i odgovarajuće plutonsko-vulkanske stijene vezane su na granicu između deblje slovačke i tanje panonske kore. Razvoj neovulkanske djelatnosti i geotermalne anomalije ukazuju na izdizanje termalne diapire, te dezintegraciju i istanjivanje sialske kore.

U kvartaru su formirani zlatonosni nanosi.

U pogledu metalogeneze Zapadni Karpati su tokom geološke evolucije mijenjali svoj polaritet. U ranom paleozoiku vezani su na Istočne Alpe, nakon hercinske orogeneze postali su dio zapadnog Mediterana, a od gornje krede ulaze pod utjecaj istočnog mediteranskog pojasa.

Posebna karakteristika Zapadnih Karpata je obilje Sb-Hg rudnih pojava, što im daje specifičan geotektonski položaj i specijaliziranu metalogeniju u odnosu na susjedna područja.