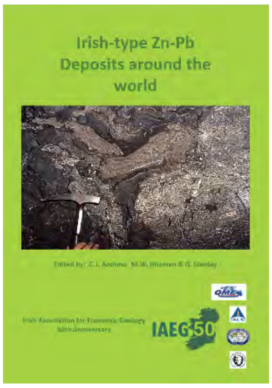

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The Sedmochislenitsi Zn-Pb-Cu-Ag deposit, NW Bulgaria: could it be Irish-type? A review of the evidence

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To cite this article: Andrew, C.J . (2023) The Sedmochislenitsi Zn-Pb-Cu-Ag deposit, NW Bulgaria: could it be Irish-type? A review of the evidence. *In:* Andrew, C.J., Hitzman, M.W. & Stanley, G. '*Irish-type Deposits around the world*', Irish Association for Economic Geology, Dublin. 407-424.
DOI: **https://doi.org/10.61153/MOXI6363**

To link to this article: https://doi.org/10.61153/MOXI6363

The Sedmochislenitsi Zn-Pb-Cu-Ag deposit, NW Bulgaria: could it be Irish-type? A review of the evidence

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Abstract: Sedmochislenitsi is a stratiform-stratabound Zn-Pb-Cu-Ag deposit hosted in Triassic carbonates in the NW of Bulgaria. The deposits have been compared to the Alpine-type Zn-Pb deposits of Raibl, Salafossa, Mezica-Topla and Bleiberg-Kreuth located in the area of the Italian, Slovenian, Austrian border however Sedmochislenitsi differs significantly from these deposits in the fact that it contains a et al body of copper mineralization comprised of chalcopyrite, bornite and tennantite with significant amounts of silver sulphosalts and native silver. Historically many authors have attributed the deposit to being of MVT-affinity whilst others have hinted at the deposits of being SEDEX-type. However, to date, despite some convincing analogies with some of the deposits in the Irish Midlands nobody as yet, has discussed the possibility of them being an Irish-type Zn-Pb deposit. This paper evaluates the evidence.

Keywords: Triassic, Bulgaria, Sedmochislenitsi, Medna-Plakalnitsa, Iskar Carbonate Group, Alpine-type

Introduction

The Triassic carbonate-hosted stratiform-stratabound base-metal deposits in the Western Balkan Mountains of NW Bulgaria comprise more than 120 occurrences of lead, zinc, copper and silver mineralization located to the south of the regional town of Vratsa. This also includes the large (>250Mt) iron-barium (plus sub-economic lead-zinc) Kremikovtsi deposit situated to the north of Sofia, which, together comprise the Kremikovtsi-Iskar Orefield.

The base-metal mineralization in Western Balkan crops out largely along the flanks of the deeply incised River Iskar and its tributaries between 300 to 1600m above mean sea level in a physiographic area known the Vrachanski Karst.

The Sedmochislenitsi deposit, located approximately 35 km north of Sofia, is the most significant and the best studied of these Zn-Pb-Cu deposits and is hosted within Triassic (Anisian-stage) limestones and dolomites of the Iskar Group (Figure 1). The deposits have been compared to the famous Alpine-type Zn-Pb deposits of Raibl, Salafossa, Mezica-Topla and Bleiberg-Kreuth located in the area of the Italian, Slovenian, Austrian border which are hosted in the slightly younger (Karnian-stage) Wetterstein limestones. Largely due to this similarity Minčeva-Stefanova (1967, 1972, 1973, 1975, 1988) attributed Sedmochislenitsi to being an MVT-type deposit of Alpine affinity. Other authors have noted the possible interpretation of sedimentary features within the mineralization and have hinted at the deposits as being SEDEX-type (Rentzsch, 1963; Palinkas *et al.*, 2016; Marinova & Damyanov, 2016). However, to date, notwithstanding some convincing analogies with some of the deposits in the Irish Midlands nobody as yet, has discussed the possibility of them being Irish-type Zn-Pb deposits.

Sedmochislenitsi differs significantly from the other Alpine-type deposits in the fact that it contains a substantial body of copper mineralization comprised of chalcopyrite, bornite and tennantite with significant amounts of silver sulphosalts and native silver. In addition, the presence of Ni-sulphides and arsenides and mercurian copper minerals bears close comparison with some of the Irish deposits such as Tynagh and the Lisduff Oolite mineralization at Lisheen.

This paper is largely a review of the published literature on the ore deposits and on the host stratigraphy and regional setting, drawing comparisons with classical Irish-type Zn-Pb (Cu) deposits.

To date the published research contemporary with the mines' operating period (1902-1995) has described the general features of the deposits including the stratigraphic and tectonic setting and the composition and style of the mineralization, but many issues remain unresolved (Marinova & Damyanov, 2016). Dating of the mineralization is vague and based entirely on Pb isotope data, the sources of metals and fluids are poorly defined, and the geodynamic setting of the deposits requires re-evaluation in a modern context. As such genetic models proposed to date have been considerably different and often contradictory. This paper is a review of the published data from the standpoint of considering whether or not the Sedmochislenitsi mineralization can be considered as being Irish-type.

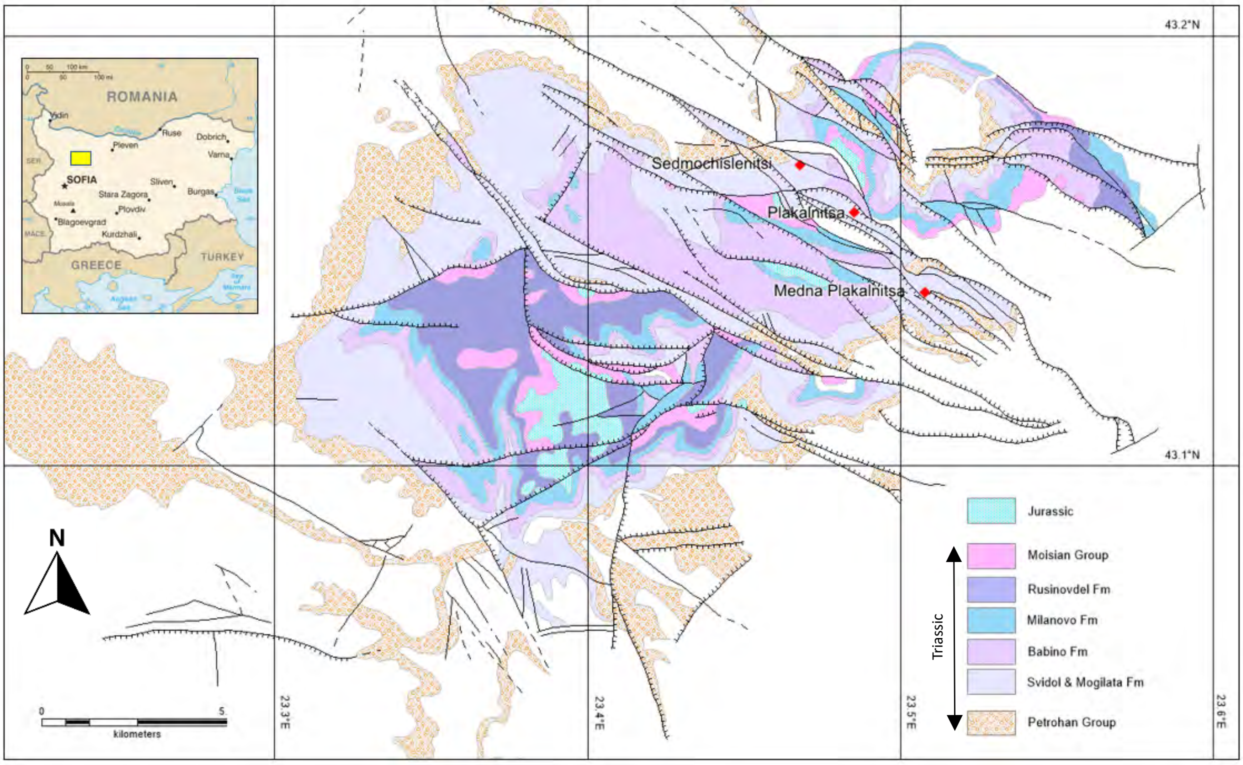

***Figure 1**: Geological map of the Vratsa Triassic district showing the locations of the Sedmochislenitsi mines.*
(Geology from Bulgarian Geological Survey Maps K3425-Berkovica, K3436-Vratsa, K-3447-Sofia & K3448-Botevgrad)

History

It is believed that the Thracians were the first to start mining for copper in the district around 2000 BCE, continued then by the Romans for both lead and copper from 29 BCE. In the Middle Ages (13th-14th Centuries) groups of Saxon ore miners settled in the mineral-rich regions of south-eastern Europe commenced mining operations which continued under Ottoman rule into the 19th Century by Dalmatian miners who, after primitive smelting, sent the impure metal to Dubrovnik.

In 1902 the commencement of the Medna-Plakalnitsa Mine on the south-eastern end of the Sedmochislenitsi mineralized zone marked the start of the mining industry in post-Ottoman Bulgaria in the Vratsa District. In 1904 Eng. P. Todorov started exploration of the deposit and in 1907 received a concession under the name "*Saint Sedmochislenitsi*". Shortly after was a period of tremendous exploitation of the resource which, in the absence of any nearby smelter, ore and concentrate were exported to England and, between 1916-1918 to Germany to satisfy the needs of the Flanders battlefields. Later the mines became the property of the shareholding company "*Ruda*" which started reclamation and exploration work in the area of the old Sedmochislenitsi mine and in 1924 the company was sold to the German company *George von Gesches* of Breslau.

After the Second World War, in 1949 State sponsored geological mapping, exploration drilling and underground development commenced and in 1952 two thousand tonnes of lead-zinc ore were mined. Between 1952 and 1960 45,000m of diamond drilling and 3300m^3 of underground development was completed. In 1959 the "Mir" flotation plant was built to process lead-zinc, lead and copper ores mined by room and pillar methods accessed from several adits at elevations of 800m and 950m above MSL by the Elisiena Mining and Metallurgical Complex (later known as Eliseina EAD).

The Mir mine became infamous due to the failure of its tailings dam on 1st May 1966 when a mudslide of 220,000m^3 flowed about 7km, destroying most of the village of Zgorigrad, and eventually reaching the town of Vratza, where the main square was covered by a 20cm thick layer of slimes. The contemporary socialist regime tried all possible ways to stifle news of the catastrophe and according to some witnesses, the police conducted house-to-house searches to confiscate any photographs local residents had taken after the disaster. Officially, the number of lives lost was declared as 107, although the toll of this disaster was almost certainly much higher with over 2,000 injured (Lucchi, 1985).

The Medna-Plakalnitsa and Sedmochislenitsi mines thus operated for around 90 years until closure in 1998 with a total recorded production for Medna-Plakalnitsa (1902-1978) of 649,400 tonnes at 1.41% Pb, 1.43% Zn and 1,380,400 tonnes at 1.45% Cu and for Sedmochislenitsi (1950-1995) of 10,673,200 tonnes at 1.00% Pb, 0.63% Zn, 44 g/t Ag and 765,100 tonnes at 0.72% Cu. (Милев *et al.*, 1996).

Geological Setting

As Marinova & Damyanov (2016) astutely note, the Triassic carbonate-hosted stratiform to stratabound base-metal deposits

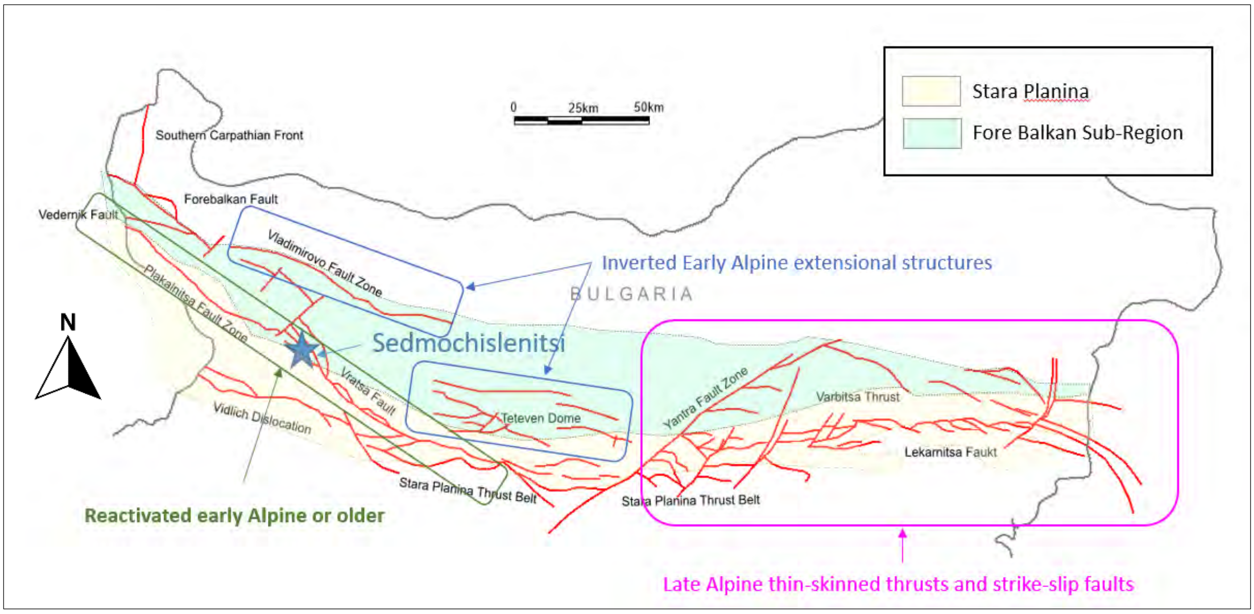

***Figure 2**: Map of the Balkan and Stara Planina tectono-stratigraphic zones showing principal structures. (After Vangelov et al 2013).*

in the Western Balkan, have well defined regional geological and tectonic settings, style of mineralization, mineralogical and geochemical data. Their genesis, however, remains controversial in the framework of plate tectonic models, and is not supported by comparative analysis of possible geologically similar candidates within the adjacent Tethyan domain.

The area lies within the central-eastern part of the Alpine "Western Balkan Tectonic Zone" of Ivanov (1998). The mineralized Triassic succession forms the base of the Mesozoic cover over the pre-Mesozoic Balkan terrain – a Precambrian to Cambrian ophiolite-island arc assemblage, unconformably overlain by a Palaeozoic sedimentary sequence. The Mesozoic was accreted to the Palaeozoic basement of the Moesian platform (located to the north) in Upper Carboniferous times.

The Upper Permian to Upper Triassic sequence represents a complete transgressive/regressive cycle of several hundred meters of continental and shallow-marine sediments including both early- and late-stage evaporites. The initial (embryonic) rifting processes are indicated by the presence of differential subsidence and by mafic and intermediate volcanics hosted within the Lower Triassic succession.

The facies distribution shows generally ESE-WNW expansion of the basin as deposition was controlled mainly by sea-level fluctuations reflected in wide lateral transition and migration of the facies belts. Relatively deep-water sediments were deposited in the East Balkan area, and they could be interpreted as a western prolongation of the Palaeo-Tethyan back-arc Küre Basin (Ustaömer & Robinson, 1997; Robertson *et al.*, 2004).

During the Norian Stage of the late Triassic tectonism caused basin closure and formation of a regional-scale unconformity at the Triassic- Jurassic boundary.

The western part of the Western Balkan Tectonic zone is formed by the Berkovitsa block, an anticlinorium comprising a Palaeozoic core and Mesozoic cover. From north and south this block is bound by large deep crustal faults known as the Plakalnitsa fault zone and Pop-Sokolets faults respectively (Bončev, 1961). These are complex fault zones associated with the formation of additional folds and horizontal dislocations (along the bed surfaces). The vertical displacement along the Plakalnitsa fault zone is about 4,000m and that along the Pop-Sokolets fault over 1,500m (Bončev, 1961; Vangelov *et al.*, 2013).

The area which hosts the stratiform to stratabound mineralization is a part of the large Berkovitsa anticline which includes a number of broad second-order synclines and anticlines (Figure 3).

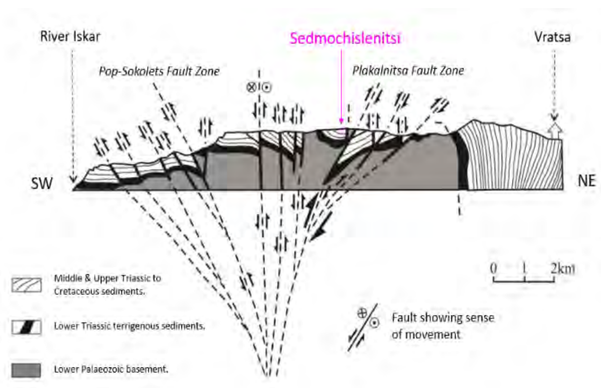

***Figure 3:** Schematic section across the Dragoybalkan (Vratsa) Fault Zone and position of Sedmochislenitsi.*

(After Rentzsch, 1963)

Stratigraphy

The pre-Mesozoic basement includes metasediments and metavolcanics of varying metamorphic facies. The overlying Triassic succession forms the base of the Mesozoic cover and is subdivided into three units: the Petrohan Terrigenous Group consisting predominantly of fluvial deposits; the Iskar Carbonate Group (~480m thick) composed of shallow-marine carbonates and mixed siliciclastic-carbonate rocks; and the Moesian Group represented by siliciclastic-carbonate and carbonate rocks (Chemberski *et al.*, 1974; Tronkov, 1981). The Petrohan Terrigenous Group and the lowermost part of the Iskar Carbonate Group show a pronounced cyclical character.

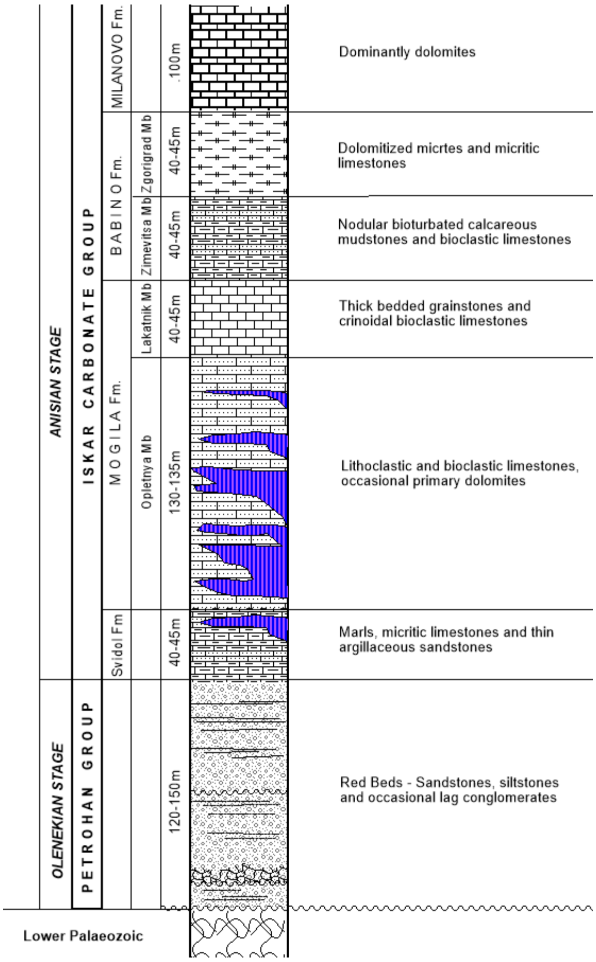

***Figure 4:** Stratigraphic column of the Triassic sequence at Sedmochislenitsi and position of the mineralization (in blue). (Modified after Ajdanlijsky et al. 2019)*

The mineralization at Sedmochislenitsi is entirely hosted within the Anisian-aged Svidol and Mogila Formations. The Anisian Stage of the Triassic has been described by Ajdanlijsky *et al.,* (2019) as being a crucial time interval in Earth's history to understand carbonate platform reorganization and the incipient break-up of the supercontinent Pangaea.

The lowermost part of the Triassic is dominated by terrigenous red beds mainly representing fluvial but also, rarely, alluvial deposits that litho-stratigraphically are referred to as the Petrohan Terrigenous Group (Tronkov 1981). The uppermost 50–55m of the Petrohan Terrigenous Group is comprised of fluvial channel and near-channel sandstones and overbank silts, becoming thinner bedded and increasingly argillaceous towards the top (Figure 4).

The lowermost part of the Iskar Carbonate Group is represented by a transitional continental to marine, mixed siliciclastic–carbonate, tidal-dominated succession of the Svidol Formation (Ajdanlijsky *et al.,* 2018), followed upwards by the essentially carbonate successions of the Mogila, Babino and Milanovo Formations (Figure 4).

The Svidol Formation comprises a supratidal evaporite argillaceous carbonate setting of intertidal to shallow subtidal carbonate flats. Its thickness ranges from 27m in the southern part to 46m in the northern part of the area being described.

The superceding shallow marine Mogila Formation (Assereto *et al.,* 1983) is comprised of sandstones, flaser and linsen bedded siltstones and mudstones and argillaceous limestones and dolomites.

The lowest part of the Mogila Formation (the Opletnya Member and the principal host to the mineralization at Sedmochislenitsi), ranges from 130m to over 180m in thickness, and is dominated by well-pronounced cyclicity bounded by transgressive surfaces and comprises micritic and argillaceous limestones, dolomitic limestones and dolomites while siliciclastic–terrigenous and siliciclastic–carbonate rocks, comprise an insignificant part of the succession as occasional thin beds. Detrital quartz and clay are restricted to discrete thin levels whilst grainstones containing ooids, peloids and bioclasts are dominant, locally with well-developed crossbedding and bioturbation. Laminated mudstones, often with synsedimentary pyrite are common in the lowermost part of the member. (Ajdanlijsky *et al.,* 2018). An important feature of the lower part of the Opletnya Member is the occurrence of hardgrounds bounding cyclic parasequences, an aspect that may have significance during mineralization.

Synsedimentary deformation, some showing a sigmoidal geometry and slump folding, along with clast supported lag conglomerates, are observed throughout almost the entire Opletnya Member suggesting some contemporaneous tectonism. Other common features of the Opletnya Member are erosional surfaces locally showing channel morphology which, in many cases, have channel flanks that are steep to almost vertical, indicating a relatively advanced degree of early lithification of the sediment into which the channel was cut. (Ajdanlijsky *et al.,* 2019).

Dolomite-dominated intervals are interpreted as the shallowest, high-salinity sedimentary environment in the Opletnya Member. Desiccation cracks and tepee structures mark episodes of subaerial exposure, indicating the establishment of tidal flats under a semi-arid climate. These climatic conditions are favourable for microbially-mediated dolomitization of microbial mats (Rizzi & Braithwaite, 1996; Petrash *et al.,* 2017) and/or early diagenetic reflux dolomitization (Adams *et al.,* 2018).

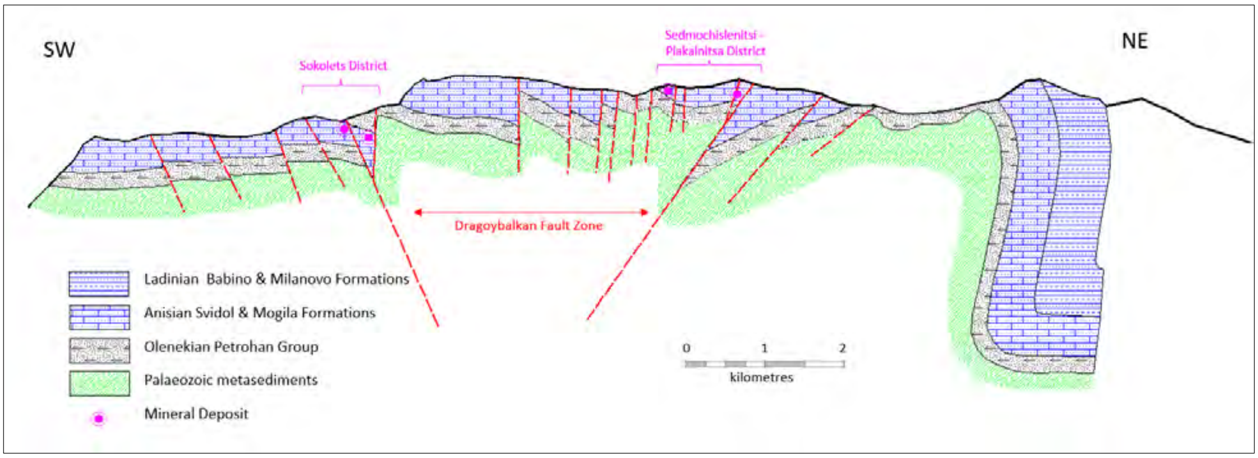

***Figure 5:** Geological cross-section through the Sokolets and Sedmochislenitsi ore district. (After Minčeva-Stefanova, 1965).*

The overlying Babino and Milanovo Formations consist of carbonate and mixed siliciclastic-carbonate rocks of the Iskar Carbonate Group (Tronkov 1981), and the upper part is represented by terrigenous-carbonate and carbonate rocks of the Moesian Group (Chemberski *et al.*, 1974). Fabric selective dolomitization is widely developed throughout the Opletnya Member and the overlying Zgorigrad Member of the Babino Formation. Chatalov (2018) presented petrographic and geochemical evidence for early diagenetic dolomitization of the intertidal and supratidal deposits (including the dolomicrites) in the Opletnya Member notably of trace fossil burrows. The dolomitization of such burrows in limestones occurred during

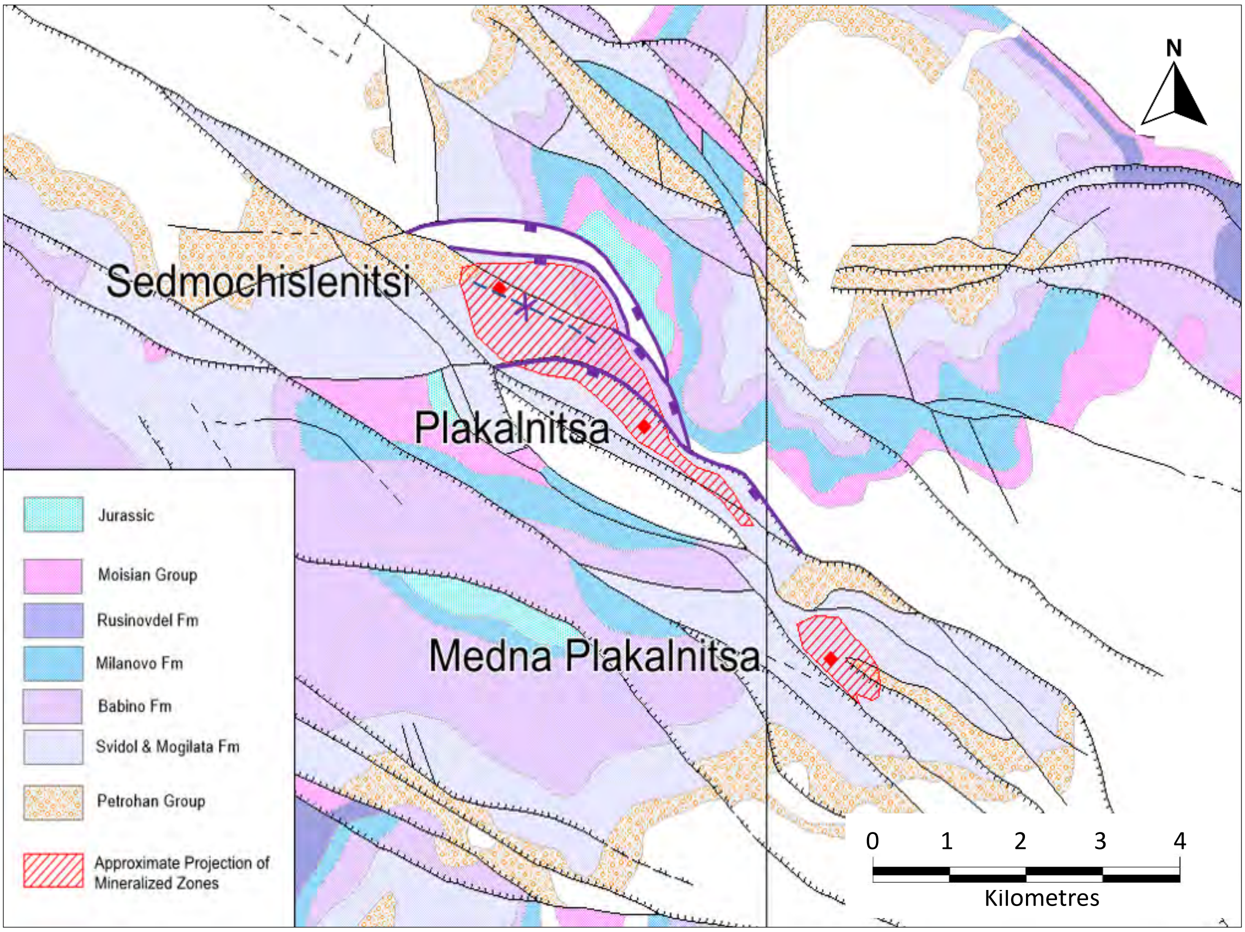

***Figure 6:** Geological map of the deposit showing the principal curvilinear faults and location of the hangingwall syncline. Note the predominant Alpine thrust belt trend through the Plakalnitsa-Sedmochislenitsi District.*

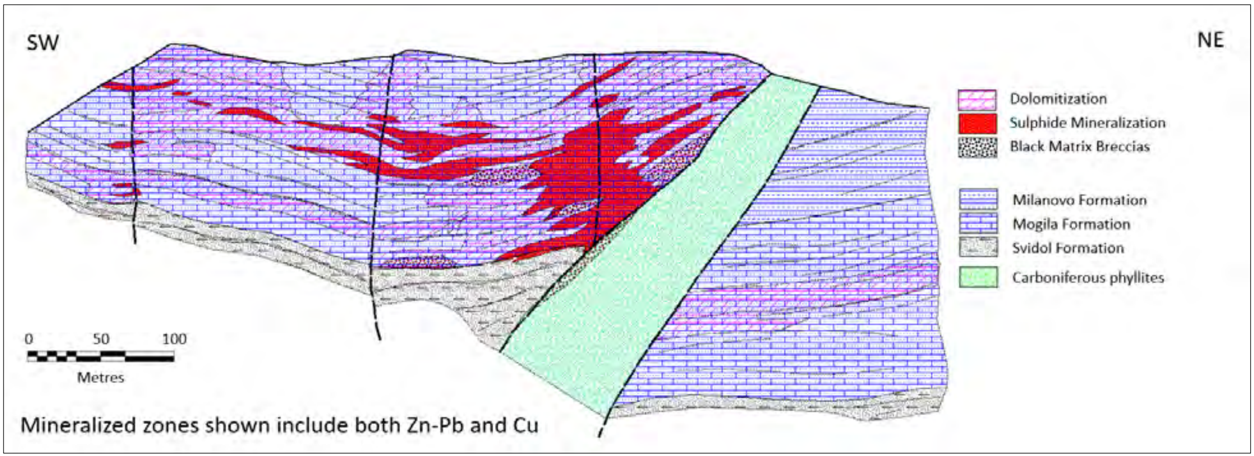

***Figure 7:** Cross section through the Sedmochislenitsi deposit showing mineralization and dolomitization. (After Minčeva-Stefanova, 1965).*

the early diagenesis with a local source of Mg from non-evaporitic solutions with low Mg / Ca ratio and being microbially mediated and controlled by bacterial sulphate reduction (Chatalov, 2018). The carbon for dolomite formation was largely derived from seawater and/or dissolution of precursor carbonate sediments, and partly derived from the decomposition of organic matter.

An important aspect in understanding the genesis of the base-metal mineralization could be its inter-relationships with this early diagenetic dolomitization as is seen in many of the deposits in the Irish Midlands.

Structural Setting

Structurally, the area belongs to the eastern part of the West Balkan tectonic zone. As part of the Alpine thrust belt, it wa subject to multiple collisional and compressional events (in Late Triassic, Mid-Late Jurassic, Mid-Cretaceous, Late Cretaceous and Mid-Eocene) due to the accretion of proximal and exotic continental fragments to Eurasia during the closure of the Tethys Ocean (Dabovski *et al.*, 2002).

The ore deposits and occurrences in the Vratsa Ore District are located along three regional, steep, normal faults of predominant NW to E-W and WSW strike and length up to 700-800m, which, from north to south are known as the Plakalnitsa, Pop-Sokolets and Izdremets Faults.

Yovchev (1961) thought these faults were conduits for fluids from the Palaeozoic to the Oligocene and were responsible for the formation of the stratiform-stratabound base-metal deposits whilst Minčeva-Stefanova (1988) and Popov *et al.* (1989) considered that the locus of the base-metal mineralization to be controlled by the intersections of these faults with other, less-pronounced NE-trending structures. These tectonic relationships led these authors to attribute the stratiform-stratabound base-metal deposits in the Western Balkan to being epigenetic and post-Lower Cretaceous in age.

The principal fault zone seen in the immediate vicinity of the mineralized bodies, and which forms a crescent-shaped (in plan view) wedge of Carboniferous phyllites is the defining bounding structure to the north and east of the mineralization (Figures 7 and 9). Along strike to the south-east a series of additional crescent shaped faults join the principal fault zone suggestive of a listric complex. This fault pattern is anomalous in an area dominated by long NNW-SSE trending thrusts which they clearly predate.

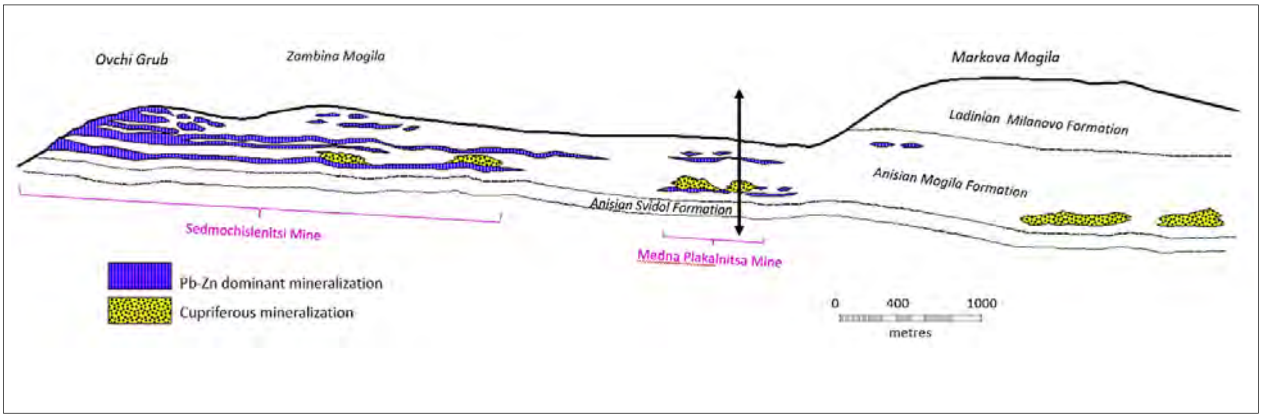

***Figure 8:** Long section from Sedmochislenitsi to Medna-Plakalnitsa and Mogilata. After Minčeva-Stefanova (1965, 1972, 1978).*

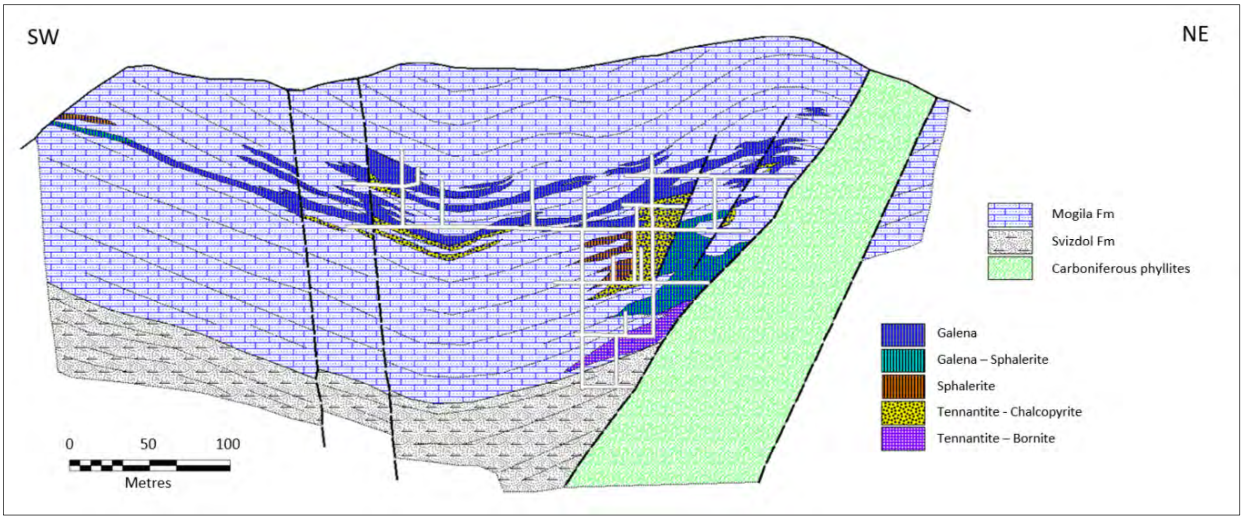

Figure 9: *Cross section through the Mir mine of Sedmochislenitsi showing the different types of mineralization. (After Atannasova, 2015)*

Morphology of the mineralized bodies

The mineralization at Sedmochislenitsi is restricted to the Svidol Formation and the lowermost 130-140m of the Mogila Formation (effectively the Opeletnya Member) (Rentzsch, 1963; Ajdanlijsky *et al.*, 2019). At Kalaminata, south-east of Medna-Plakanitsa, minor Zn-Pb mineralization is seen at similar stratigraphic levels (Figures 4, 7 & 8).

The mineralized lenses at Sedmochislenitsi lie within a shallow hangingwall syncline which extends along an axis aligned parallel to the main fault (~130^{o}) and extends for up to 360m along this direction and for up to 40m perpendicular to this axis, ranging in thickness from a few cms to in excess of 20-30m (Figure 6).

Dolomitization mirrors this distribution forming a halo to mineralization close to the fault but some of the mineralized horizons, especially the Zn-Pb, extend out with the dolomite zone into unaltered limestones (Figure 7). All the mineralized horizons lie within the Anisian, and no mineralization is seen in older units other than traces of sphalerite within the Carboniferous tectonized shales of the main fault zone in the Studenite Korita section of the Sedmochislenitsi mine on the 850m, 900m and 950m levels.

Pb-Zn Bodies

The Pb-Zn mineralized bodies occur predominantly as stratiform lenses varying from a few centimetres to up to 8m in thickness averaging around 2m. The mineralized lenses can form several stacks to comprise larger bodies on the hangingwall of normal faults. The Pb-Zn lenses are predominantly developed in the upper levels of the Anisian sediments and are only developed at lower stratigraphic horizons in the immediate hangingwall of larger faults.

Rentszch (1963) records that multiple mineralized horizons are present and noted for example that in drillhole C-32 some 16 mineralized levels were intersected but the number of horizons diminished to 3 less than 150m to the SW.

Cu-Pb bodies

The Cu-Pb mineralized bodies occur from the base of the Anisian sediments and form diffuse wedge -shaped breccia bodies on the hangingwall sides of faults and are superimposed on the earlier Pb-Zn generally stratiform bodies. Some remobilization of chalcopyrite and galena has occurred into minor faults in the hangingwall of the major fault zone notably where WSW and NW faults intersect (Rentszch, 1963). At Medna-Plakanitsa the major cupriferous mineralized body lies approximately 30m above the base of the Svidol Formation and is up to 20m in thickness and is strongly rheomorphically deformed (Konstantinov, 1954; Rentzsch, 1963) whilst at the shallow mimne workings at Parvi Rupi and Vtori Rupi the dominantly cupriferous mineralization is also strongly sheared and tectonized (Figure 10).

A typical feature of the geologic relationships of the individual mineralized zones is that they appear to be localized and/or thickened in synclines in places where faults trending parallel to the main footwall fault are cut by oblique or transverse faults of limited displacement. In some places the mineralization in the calcareous rocks is bound on the footwall by faulted slivers of Carboniferous mudstones/phyllites. Notably the displaced part of the same calcareous rocks on the hangingwall of such wedges do not contain any significant mineralization (Minčeva-Stefanova, 1961, 1965).

Mineral Paragenesis

Five types of “ore” were recognized in the deposits:

1) Zinc ore
2) Lead-Zinc Ore
3) Lead Ore
4) Copper Ore – Chalcopyrite / Tennantite
5) Copper Ore – Tennantite / Bornite

However, within these simple “economic” categories more subtle mineralogical associations have been defined (Minčeva-Stefanova, 1961, 1965; Rentzsch, 1963; Atanassov & Kirov, 1973).

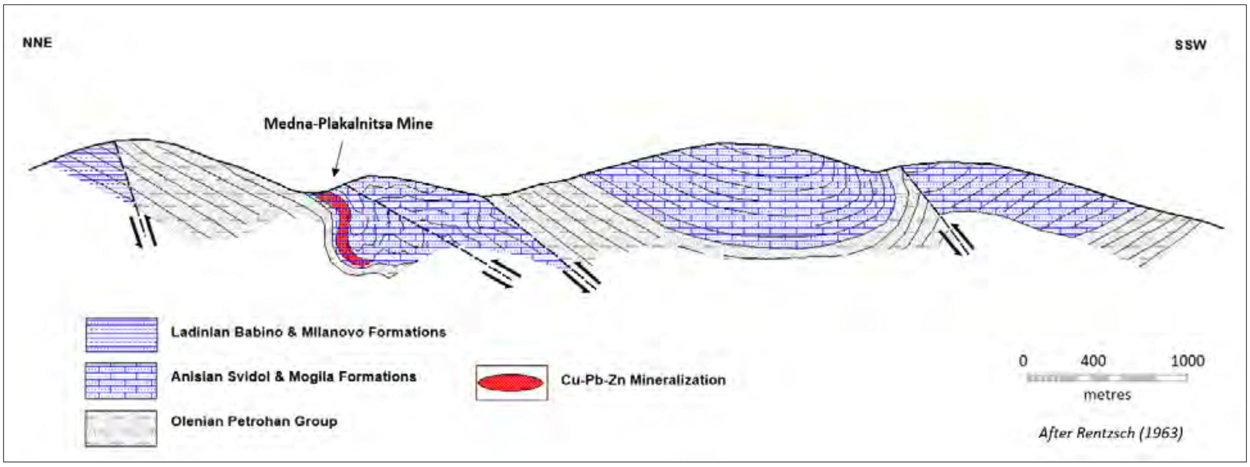

Figure 10: *Cross section through the Medna-Plakalnitsa Mine (After Rentszch, 1963).*

The zinc-lead mineralization consists of the following mineral parageneses (according to the order of deposition) (Figure 11).

1) *Phase of pre-ore dolomitization* (found only occasionally), represented by dolomite, pyrite and calcite.

2) *Pyrite pre-ore phase* — with pyrite, marcasite, bravoites and dolomite.

3) *Dolomite-sphalerite phase* — with dolomite, sphalerite, arsenopyrite, pyrite and galena. It determines to a great extent the zine mineralization in the deposits. It has a massive texture and is deposited metasomatically amid the pure limestones. At first dolomite metacrysts are formed, followed by the fine-grained sphalerite replacing in varying degrees the remains of the calcareous rocks between dolomite rhombohedra. Galena metacrysts surrounded by pyrite grow on these two minerals.

4) *Galena-sphalerite phase* with sphalerite (small-grained and *schalenblende* type), galena, pyrite (metasomatic and melnikovite-pyrite type), marcasite, bravoite, wurtzite, arsenopyrite. The deposition of this paragenesis begins after intensive tectonism of the enclosing sediments which also may have determined the high supersaturation of the solutions (Minčeva-Stefanova, 1965).

5) *Galena phase* consisting of galena, sphalerite, pyrite and dolomite. It is deposited in numerous veinlets cross-cutting and parallel to the beds. There are clear indications that sphalerite, pyrite, and dolomite are redeposited on account of the earlier parageneses.

6) *Three barite and carbonate (mainly dolomitic) phases* with which the zinc-lead mineralization generally comes to an end. Barite is the dominant phase with minor quartz, cleiophane, galena, calcite, cobaltian smithsonite, and sporadically fluorite together with medium-grained dolomite. The minerals fill veinlets and numerous minor cavities and can probably be considered as a manifestation of post-ore dolomitization subsequent to the zinc-lead mineralization of phases 1-5.

Within Phases 1-5 there is a distinct vertical zonation of the mineralization with the following zones developed from bottom to top in the zinc-lead mineralization: 1) iron sulphides-sphalerite; 2) sphalerite; 3) galena-sphalerite; and 4) predominantly galena zone.

The mineralization paragenetic phases described above are cross-cut or brecciated by the subsequent lead-copper phase which is preceded by abundant barite mineralization of phase 6).

Considerable differences in mineral composition exist among the copper mineralization from the middle and lower levels of the mines.

Two clear-cut mineral parageneses have been recognized by Atanassov & Kirov (1973):

7) *Tennantite-chalcopyrite-galena association,* which is characteristic of the middle levels of the deposit. Tennantite and chalcopyrite are the main ore minerals, whereas galena, sphalerite, tetrahedrite and high-silver freibergite (up to 22.2 wt% Ag) are present in smaller amounts along with pyrite and marcasite. A sequence of silver minerals, mainly sulphosalts, is paragenetically connected with this association; these are pyragyrite, pyrostilpnite, stephanite, polybasite, pearseite, acanthite, jalpaite and minor amounts of native silver.

8) *Tennantite-bornite association,* wherein the main ore minerals are tennantite, bornite, chalcopyrite and primary chalcocite, is characteristic of the lowest levels. It is accompanied by another well-defined silver mineral association: stromeyerite, pearceite, acanthite, silver amalgam, chalcocite, neodigenite, tetrahedrite, carrollite, siegenite, wittichenite and comparatively large amounts of native silver which is usually mercury-hearing.

The mercury content in mercurian silver varies over a wide range even within a single mineral grain (Atanassov, 1969). The silver from samples containing cinnabar and balkanite ($Cu_9Ag_5HgS_8$), shows a higher and more constant mercury content.

Figure 11: *Diagramme to show the mineralogical paragenesis in the Sedmochislenitsi and Medna-Plakalnitsa mineralization. (Data from Minčeva-Stefanova, 1965 and Atanassov & Kirov, 1973).*

The lead-copper mineralization shows the following zoning (from bottom to top) regardless of whether it is deposited in dolomitic, calcareous or siliciclastic lithologies: 1) bornite zone; 2) chalcopyrite-tennantite zone; 3) chalcopyrite-galena with tennantite; and 4) galena zone with small amounts of chal copyrite and tennantite.

Mineralogy

Cubic and pyritohedral crystalline pyrite is extensively distributed throughout the sediments of the Middle Triassic but is not a dominant sulphide in either the Zn-Pb or Cu-Pb mineralized zones. Where pyrite does occur, it forms thin horizons of framboidal aggregates with occasional cubic crystal overgrowths. Globular and mamillated gel pyrite (melknikovite) is the dominant iron sulphide forming banded intergrowths with sphalerite in the Zn-Pb bodies. Globular masses of melknikovite often show pseudomorphs after gypsum at their core suggesting early diagenetic sulphidation.

Melknikovites and gel pyrites show a significant arsenic content of around 1% (Rentzsch, 1963). Marcasite is most common in the Zn-Pb zones where it occurs as radial growths within the melknikovite masses whilst in the cupriferous zones marcasite is most commonly seen as crusts around galena and chalcopyrite masses.

The sphalerite varies from light yellow to brown in colour with microprobe analyses showing Fe-content of the sphalerites ranging from 0.06 to 1.31 wt.% and Cd-contents up to 0.55 wt.%. Ga:Ge ratios are in the range 0.26-0.70 (Mladenova & Valchev, 1998). The sphalerite in the Zn-Pb mineralized zones is very low in copper, typically less than 0.02% whilst sphalerites from the cupriferous zones contain up to 1.0% Cu (Figure 12). This copper occurs as chalcopyrite exsolution ("chalcopyrite disease") in the more coarsely crystalline sphalerite in these zones.

The trace element geochemistry of sphalerites is quite different for the zinc-lead and copper-lead phases with As, Co, Ga, Ge, Ni and Tl showing associations with the zinc-lead phases and Ag, Cd, Fe and Hg with the cupriferous phases.

The sphalerite from the zinc-lead mineralization occurs in four distinct generations, the first two being the most abundant. Sphalerite 1 forms fine-grained aggregates. The colour varies from pale yellow to deep red-brown with numerous intermediate shades due to the fine mechanical impurities from the associated minerals. Sphalerite is intergrown with dolomitic crystals. The sphalerite 2 also forms fine-grained aggregates but colloform aggregates occur too. When occurring in veinlets, it may develop in symmetric or asymmetric bands parallel to the margins of the veinlets.

The mineralogy of cobalt and nickel varies within the zinc-lead and lead-copper mineralization. In the former, where pyrite is the main mineral, the two elements occur in the form of bravoite and nickelian and cobaltian pyrite albeit at very low levels (0.05-0.07%) whilst in the latter carollite, siegenite, cobaltite and niccolite have been recorded (Rentzsch, 1963; Minčeva-Stefanova, 1965). The galena averages around 900 g/t Ag with the silver predominantly contained in proustite.

Bornite was the most important ore mineral at the Medna-Plakalnitsa mine often forming mymerkitic intergrowths with chalcocite and also with small spherical aggregates of tennantite in the bornite. Chalcopyrite is most commonly seen occurs in association with tennantite and subordinately, galena. Chalcopyrite typically forms encrustations on the tennantite, as well as, somewhat conversely, in tennantite within cataclasis cracks.

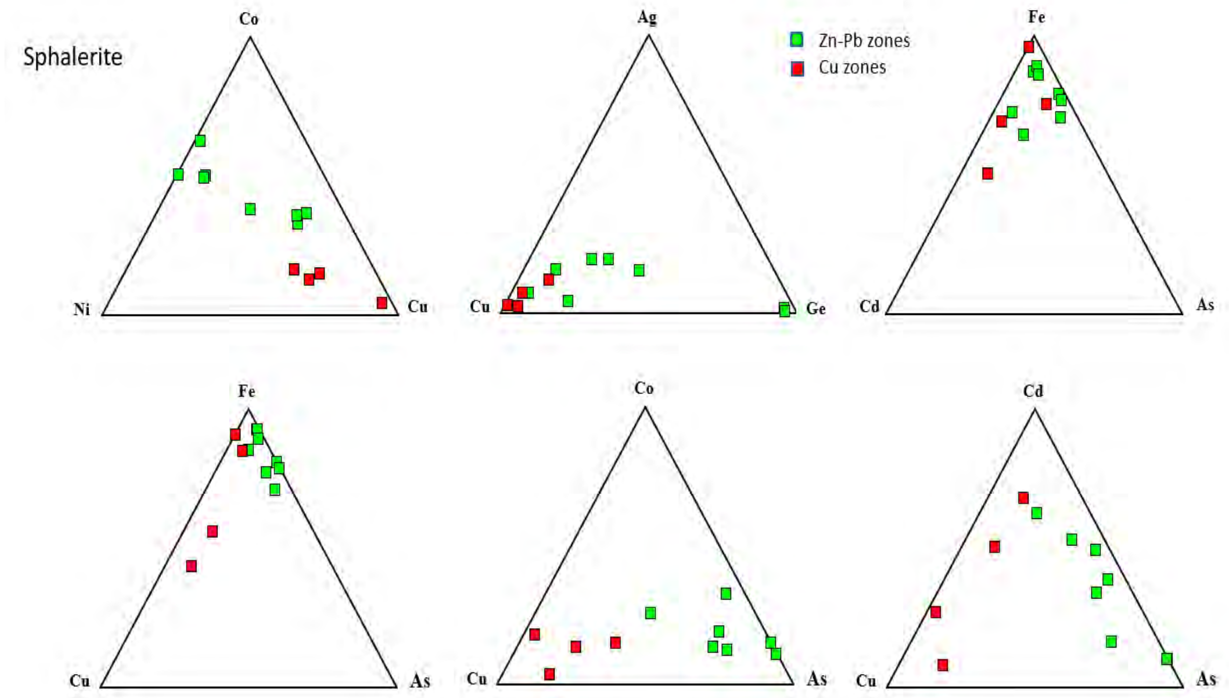

***Figure 12:** Ternary plots of various elemental associations within sphalerites from Sedmochislenitsi. (Data from Rentzsch, 1963).*

The tennantite is typically arsenian although antimony and bismuth is always present in analysed samples (Rentzsch, 1963).

Barite occurs in proximity to and within the cupriferous zones but very rarely in the zinc-lead zones. It typically forms grey to dark green to grey-black (due to bituminous inclusions) tabular and sheaf-like crystalline aggregates within secondary dolomites and also infills cavities as drusy white crystals. Monomineralic zones of barite replacement have been observed in a drillhole (DDH C-123) at the same stratigraphic level distal to the base-metal zones (Rentzsch, 1963).

Ore-Mineral Textures

The first geological description of the Plakalnitsa section of the deposit was by Janichevsky (1935) who noted that the mineralization comprised chalcopyrite, bornite, tetrahedrite, galena and "red" sphalerite with copper minerals which dominated the lead-zinc by 3-4 times. Janichevsky (*op cit*) described the mineralization to comprise of "mushy" impregnations, compact masses and lenses and scattered veinlets in dolomitic limestones with no sharply defined margins.

At Sedmochislenitsi the following ore textures are reported by Rentzsch (1963) and Minčeva-Stefanova (1965) to be the most frequent in the zinc-lead zones: massive, brecciated, banded, veinlet and disseminated textures.

Minčeva-Stefanova (1965) interpreted the brecciated texture to have formed as a result of the cementation of mineralized or unmineralized rock fragments with sulphide and carbonate minerals on the one hand and, on the other, as a consequence of replacement of sedimentary breccias in which the fragments and the cement are replaced in various degrees because of the differences in the contents of calcareous, dolomitic and marly constituents.

Rentzsch (1963) formulated a different interpretation noting that in Block 9 of the mine there is a resedimented breccia of sandy and intraclastic dolomite with fragments of melknikovite whilst in the conveyor drive of Block 12 concordant lenses of cross-laminated sphalerite-dolomite pelite with minor galena occur (Figure 13). These thin mineralized horizons have a distinctive sharp footwall which appears to be a scour surface and the granular sphalerite-dolomite overlying these surfaces shows grading and imbricated exfoliated rhythmic clasts of melknikovite/marcasite. Rentzsch (1963) describes in detail repetitive cyclicity of the stratified mineralized lenses of a unit comprising a basal horizon of dark grey bituminous dolomite gradationally passing up into a sandy dolomite with muscovite, then via a sharp contact into a horizon comprising cross-laminated and/or graded sphalerite-dolomite peloids with imbricate clasts of melknikovite crusts which he interpreted as being mudflows. The sphalerite-dolomite grains averaging 12 microns in diameter are typically "oolitic" with the outermost layer being pure sphalerite. Rentzsch (1963) describes in detail such features throughout the Zn-Pb mineralized horizons both in Sedmochislenitsi Blocks 9, 11 and 12 and in the 60-12A Stope at Medna-Plakalnitsa.

Rentztsch (1963) recorded peloids, up to 200 microns in diameter, of concentric sphalerite, Zn-bearing calcite and pyrite having features typical of bacterial colonies. Kucha *et al.* (2010) have reported similar peloids from Bleiberg which they interpreted as being *in situ* metabolic products of sulphate-reducing bacteria and that micro- and nanotextures suggest that

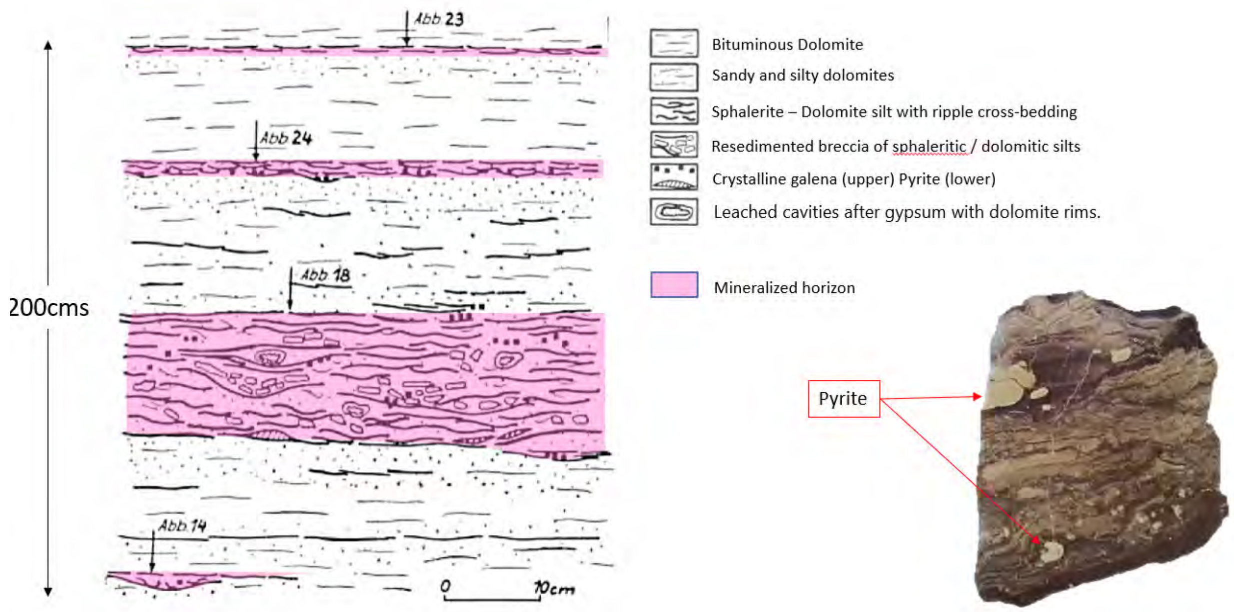

Figure 13*: Sketch of mineralized layers in Block 12 Haulage, Sedmochislenitsi, Mir Mine.*
(The "Abb" tags refer to identified index beds within the sequence.
(After Rentzsch, 1963)

the larger, μm-sized sphalerite globules formed by agglomeration of sphalerite nanospheres, as well as by replacement of peloids representing former bacterial colonies; the latter are now composed of Zn-calcite cores surrounded by serrated sphalerite rims. This, combined with geological and mineralogical evidence, suggests a significant role of bacteria during ore deposition at Sedmochislenitsi.

In the 65-1 stope of the Medna-Plakalnitsa mine a re-sedimentation breccia with geopetal lamination was clearly formed prior to Alpine deformation (Rentzsch, 1963).

In the north-western part of the Sedmochislenitsi mine, lenticular stratiform bodies of breccias were of major economic importance notably at Strašnata Voda where they were strongly mineralized with galena and with chalcopyrite-galena in the 900m Level at Mir. These breccias sometimes contained clasts of the earlier zinc-lead mineralization. The appearance of these breccias is closely similar to the "Black Matrix Breccias" seen at Lisheen, Galmoy, Pallas Green and Stonepark in the Irish Midlands.

The cupriferous mineralized bodies show greater intensity of sulphide mineralization with bedding parallel lenes of massive chalcopyrite, galena, pyrite, bornite and tennantite developed within barite bearing dolomites. Fabrics are generally indistinct but there is evidence of collapse brecciation and replacement of both clasts and wall-rock lithologies.

Dolomites

Minčeva-Stefanova (1965, 1972, 1978) identified up to twelve generations of dolomites within the mineralized bodies ranging from early low temperature low Mg/Ca ratio, diagenetic non-stoichiometric dolomites, interpreted by Chatalov (2018) to be microbially mediated to late ankeritic dolomites associated with the copper paragenesis. There are no studies examining the variation in the Fe or Mn contents of the dolomites although Rentztsch (1963) established a linear relationship between both Fe and Mn with the proportion of dolomitization.

Other studies

Fluid inclusion studies on the dolomites from the pre-sulphide mineralization have returned T_h values in the region of 120-140°C, whilst the tennantite-bornite-chalcopyrite mineralization averages around 160-180°C from coeval ankerite metacrysts whilst the lead mineralization averages 100-140ºC from measurements of isomorphic Fe in the dolomite structure contemporary dolomite and calcite (Minčeva-Stefanova, 1988).

Mladenova & Valchev (1998) utilized Ga/Ge geothermometric data from sphalerites to estimate precipitation temperatures of between 80-100ºC using the methods oulined by Moller (1987). However more accurate analyses for Ge and Ga in sphalerites of paragenetic Stages 3-5 by Vangelova *et al.* (2020) suggest temperatures closer to 120-130ºC.

Sulphur isotopic values of sulphides (pyrite, galena, and sphalerite) from the Sedmochislenitsi district range between $\delta^{34}S$ -27 to +15‰ for pyrite, from -24 to +14‰ for galena, and from -15 to -4.5‰ for sphalerite. The high scattering of $\delta^{34}S$ values was explained by different sulphur sources, leaching of sulphur from host rocks and bacterial and/or thermochemical reduction of seawater sulphate in the lower and middle Triassic with a mean of around $\delta^{34}S$ +15‰ (Dimitrov *et al.*, 1986).

Framboidal pyrite (Phase 2) is likely diagenetic, as evidenced by its low Co/Ni ratio (<1), size (~4 μm), and negative $\delta^{34}S$

values caused by bacterial sulphate reduction (BSR) whereas syn-ore mineral stage pyrite (Phase 4) has elevated Pb, Zn, Cu, As and Sb values (Figure 12). Pre-ore pyrite was likely formed in early Triassic diagenesis, and then enclosed by syndiagenetic to epigenetic pyrite. Isotopic fractionation in the hydrothermal fluids may have reached equilibrium by the time of the Pb-Zn-Ag mineralization (Stages 5/6) and that the positive shift of δ^{34}S values from Phase 7 to Phase 8 is primarily caused by thermochemical sulphate reduction (Dimitrov *et al.*, 1986).

Discussion on Genetic Models

Rentzsch (1963) and Tocco & Violo (1972) have proposed a *sedimentary-hydrothermal* genetic model based on the following observations: mineralization is concordant to the host lithology; syn-diagenetic ore textures are present; stratigraphic preference of the main mineralized zones to the lower levels of the Iskar Carbonate Group; the occurrence of localized fault-controlled stockwork and vein-like mineralization comprising higher-temperature assemblages in close proximity to and structurally and stratigraphically below the concordant mineralized zones which can be interpreted as feeder zones.

Textures and fabrics which include geopetal, collomorph and sphalerite-dolomite sediments can be interpreted to have been formed by deposition in open-space within the carbonate sequence. However, the general absence of coarse-grained cavity-lining textures and extremely limited zones of cross-cutting brecciation (collapse-type features) clearly indicate that large open spaces were not present prior to the onset of sulphide mineralization. Rentzsch (1963) has described that the better mineralized levels within the zinc-lead zones are laterally extensive and exhibit soft-sediment deformation fabrics and textures (Figure 13) but the fact that such horizons are not developed at the contact of dolomitization with calcareous host rocks strongly suggests that mineralization deposition was not a chemical control exploiting dissolution at the dolomite "front". Thus, the cyclic nature of the sedimentary package, whereby the flow of hydrothermal fluids was ameliorated by lithification differences during diagenesis is much more likely. Such permeability probably being enhanced by gentle flexing and bedding-plane slippage during fault movement.

Within the fluvial high-stand systems tract Petrohan Group and Svidol Formation (tide-dominated deltaic and tidal flat, transgressive tracts) sandstones and tidal flat calcarenites were pervasively cemented by carbonates during near-surface diagenesis, due to the presence of abundant bioclasts. Conversely, fluvial low-stand sandstones remained poorly cemented during near-surface diagenesis due to the lack of bioclasts, but were cemented by later calcite, dolomite and quartz overgrowths. (El-ghali *et al*. 2006) This variable lithification could have allowed the migration of hydrothermal fluids during mineralization which may also have been responsible for the calcite, dolomite and quartz overgrowths.

Konstantinov (1952) and Minčeva-Stefanova (1960, 1961, 1967, 1972) considered the deposits to be entirely epigenetic and that ore textures which imitate syn-sedimentary sulphide deposition are actually sedimentary textures inherited during metasomatic replacement by sulphides and that the genesis of the mineral deposits is related to (Eocene?) hydrothermal activity which has also caused the extraction of mobilized metals from the Palaeozoic basement.

However, the fact that there is clear evidence of the mineralization being deformed by Alpine tectonics at Medna Plakalnitsa must cast doubt on their interpretation at least on the age of the mineralization.

According to Minčeva-Stefanova (1960, 1961, 1967, 1972) the development of the concordant ore lenses is determined by bedding plane slip on layers of argillaceous marls on both the hanging and footwall of the mineralized zones and bedding parallel micro-fracturing formed during Alpine tectonics allowing the ingress of hydrothermal fluids. Whilst this may be observed in parts of the district (e.g. Sedmochislenitsi, Block 9), such argillaceous marl horizons are mainly only developed on the footwall (e.g. Sedmochislenitsi, Block 12) (Rentzsch, 1963).

Importantly rheomorphic deformation of the sulphides is clearly seen at Medna-Plakalnitsa and shearing and recrystallization of the ore minerals is seen at Vtori Rupi. However, no such deformation or recrystallization is seen in the relatively undeformed Sedmochislenitsi zone although geopetal cavity infills are certainly tilted in conjunction with gentle folding.

Unlike the Alpine (Drau Range) Zn-Pb deposits the mineral textures at Sedmochislenitsi do not exhibit crackle breccias and other evidence of hydrothermal karstification collapse. In addition the mineralogy is significantly more complex and the presence of spatially coincident, but paragenetically later cupriferous mineralization renders these Balkan deposits somewhat different despite their host-rocks being close in age.

Damyanov (1995) suggested that Triassic basaltic magmatism, could be the heat source to drive a convective hydrothermal system but the low Co/Ni content of the pre-/syn-ore pyrite suggests that both the Fe and base-metals are probably of non-magmatic diagenetic origin. However, with such a model strat-iform Fe(+Mn)-Ba (Kremikovtsi) and partly Fe-Pb-Zn (Sedmochislenitsi) orebodies have been deposited in palaeotopographic depressions near contemporaneously active fault zones; being followed by *diagenesis*, during which the majority of strata-bound Pb-Zn-Cu-Ag mineralization was deposited being controlled by the permeability of the host carbonate rocks at the boundary of the limestone to dolomite transition. Late-stage epigenetic stockwork and barite / base-metal mineralization was formed within feeder zones in fault zones as fluids boiled.

Comparison with typical Irish-type deposits

All Irish-type deposits are generally considered to show the following characteristics as to their structural and stratigraphic setting:

- Hosted on the hanging wall of normal fault zones, frequently overlying transtensional basement shear zones.
- Faults were syn-depositionally active during late rifting.
- Faults control margins of intra-platform basins, marked by significant carbonate facies and thickness variations.

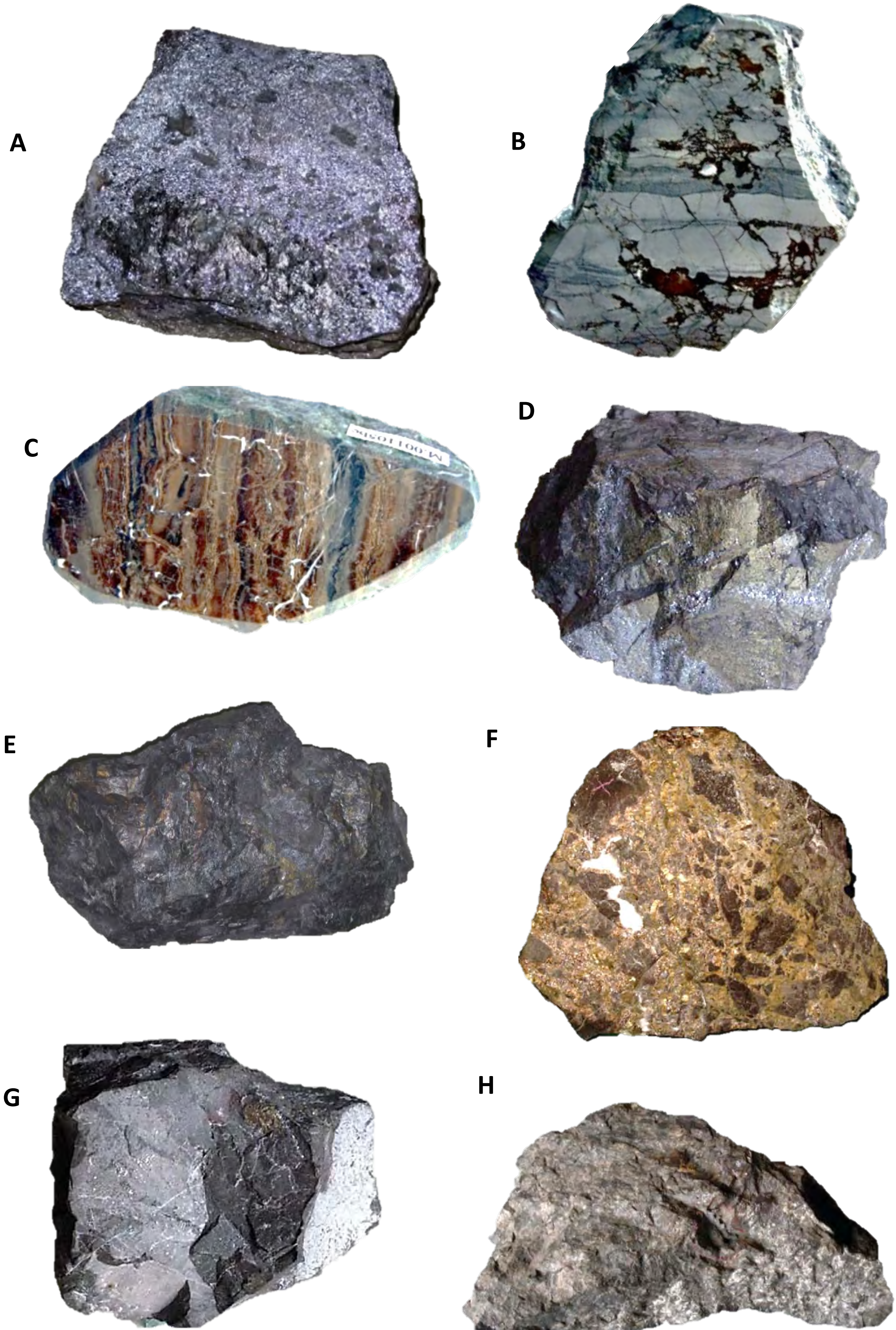
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Figure 14: *(Opposite page) Samples of various ore types from Sedmochislenitsi.*

A: *Galena, bornite and tennantite.* ***B:*** *Fracture filling sphalerite cutting early dolomite.* ***C:*** *Banded sphalerite var. schallenblende* ***D:*** *Galena-sphalerite mineralization with pyrite-marcasite spheroidal aggregates and framboidal pyrite.* ***E:*** *Compact mineralization bornite and chalcocite.* ***F:*** *Compact galena-chalcopyrite-minerals of fahlore group mineralization associated with metamorphosed organics.* ***G:*** *Mercurian silver, stromeyerite, chalcocite and bornite.* ***H:*** *Pyrargyrite in galena-sphalerite-chalcopyrite- freibergite mineralization.*

All samples are approximately 10cms on the long axis.

- Host rocks are typically the first major (stratigraphically lowest) clean carbonate unit in the sequence.
- Host rocks are more permeable or reactive than other lithologies in the sequence.
- Faults control margins of intra-platform basins, marked by significant carbonate facies and thickness variations.

Certainly, Sedmochislenitsi meets all of these parameters including the spatial association of listric faults and hanging wall synclines.

In terms of mineralization Irish-type deposit also have the following characteristics:

- The deposits comprise single or multiple stacked lenses; they are stratabound and display generally stratiform morphologies.
- The host sediments may contain debris-flow breccias and conglomerates, laminated sulphidites and banded ironstones.
- Some deposits display pre-mineralization, diagenetic or hydrothermal dolomite alteration of the host rocks but, importantly, dolomitization is not necessarily pervasive nor a prerequisite for ore mineralization.
- Irish-type deposits display complex sulphide mineral fabrics and textures ranging from laminated and graded exhalites to diagenetically early replacement of the host rock by colloform sulphides and infill of diagenetic solution cavities exhibiting geopetal fabrics, open-space fill, disruption brecciation and re-sedimentation, to replacive masses of coarse-grained crystalline sulphides. Mineralogically they are relatively simple comprising sphalerite, galena, Fe sulphides & barite, (minor Cu, Ag, As, Ni) in a gangue of calcite, dolomite & silica.
- Metals are laterally and horizontally zoned, typically being Pb-rich closest to feeder structures and at the base of the orebody.
- Sulphur isotopes show $\delta^{34}S$ from -44 to +14‰ indicative of two sources - bacteriogenic and hydrothermal - with the role of bacteria playing a major role in sulphur availability. This is a distinctive feature of classic Irish-type deposits.
- Evidence from fluid inclusions of fluid mixing is commonplace with a hot (100-240°C) metal-bearing low salinity (4-6 wt% NaCl eq.) fluid interacting with a saline to hypersaline (10-23 wt% NaCl eq.) H_2S-rich formation water.

Sedmochislenitsi certainly displays multiple stratabound stacked lenses notably in the Zn-Pb mineralized bodies.

Sedimentary breccias within the mineralized horizons have been described in some detail by Rentzsch (1963) and Ajdanlijsky *et al.* (2018) describe active sedimentary environments with cyclical erosion surfaces, lag conglomerates, soft sediment deformation and other features indicative of a tectonically active sedimentary depositional setting.

Dolomitization is complex ranging from very early fabric-selective by contemporaneous seawater to hydrothermal synmineral stages. Kalaydziev *et al.* (1982) estimated that in the Sedmochislenitsi deposit around 80% of the ore bodies are hosted by dolostones and around 20% in dolomitized limestones.

Sulphide fabrics and textures are certainly diverse and complex and show a temporal evolution and trace element assemblages that are not typical of classical MVT-type deposits. Metal zoning data is sparse but there is an observed vertical and lateral zoning within both the Zn-Pb and Cu-Pb mineralized bodies.

Unfortunately, only limited sulphur isotopic data is available but values of between $\delta^{34}S$ -27‰ and +15‰ for sulphides is within the range of the classic Irish-type deposits. The presence of gypsum pseudomorphed by iron sulphides also suggests the possibility of two sources - bacteriogenic and hydrothermal.

Fluid inclusion data is also sparse but results from the main copper mineralization have returned a range between 160-180^{o}C from coeval ankerite metacrysts, whilst the lead mineralization averages 100-140^{o}C from contemporary dolomite and calcite, certainly within the range of Irish-type deposits.

There are many textural features described by Minčeva-Stefanova (1960, 1961, 1967, 1972) and Rentzsch (1963) as being developed within the zinc-rich mineralized horizons which clearly illustrate that sedimentary processes were operating within an interconnected and open fracture system as the sulphides often display geopetal banding on a scale of up to a few centimetres. The sphalerite-dolomite sediments also contain fragments of colloform marcasite-melknikovite and gel pyrite along with organic-rich mudstone intraclasts and display a variety of textures, including grading, loading, and slumping. Such descriptions bear close similarity to those described at Navan by Anderson *et al.* (1998) and Boast *et al.* (1981) at Tynagh. Such features may be interpreted to indicate a relatively shallow and syndiagenetic timing for the zinc-rich mineralization at Sedmochislenitsi.

Boast *et al.* (1981) described the evolution of mineral deposition at the Tynagh deposit in Ireland as being:

1) An initial stage, dominated by the growth of clots of colloform and granular pyrite, possibly during the early diagenetic history of the host Waulsortian micrites;
2) The rapid geopetal precipitation of microcrystalline collomorph sulphides, largely sphalerite and marcasite, within a high-level dilatant fracture system developed in response to tectonic activity in the fault zone;
3) Subsequent veining and replacement of the host and earlier ore textures by an assemblage dominated by tennantite, chalcopyrite, bornite, arsenopyrite, medium to coarsely crystalline galena, and coarse sparry barite, *and;*
4) Finally, the precipitation of calcite within post-ore fractures and cavities, and the dolomitization of large bodies of unmineralized host Waulsortian limestones.

There is a quite extraordinary similarity between the mineralizing paragenesis at Tynagh and that described at Sedmochislenitsi.

Brand & Emo (1986) described the mineral paragenesis at Ballinalack as being:

1) Early diagenetic melknikovite / pyrite;
2) Dark colloform sphalerite-1 with melknikovite;
3) Pale colloform sphalerite-2 with bladed marcasite;
4) Crystalline honey blende sphalerite-3 with galena and barite;
5) Crystalline honey blende sphalerite-4 with blocky calcite and pyrobitumen;
6) Fracture-fill calcite and minor honeyblende sphalerite-5;

In the lower orebodies at Silvermines, Andrew (1995) has described the paragenesis as being:

1) Replacement by Fe-free dolomite with fine disseminated crystalline pyrite;
2) Fracturing accompanied by ferroan dolomite and melknikovite / marcasite;
3) Colour banded schallenblende sphalerite-1 lining dolomitization void space and fractures;
4) Dark colloform sphalerite-2 with galena;
5) Crystalline honeyblende sphalerite-3 and barite;
6) Arsenopyrite, chalcopyrite and Cu-Pb-Ag sulphosalts in areas close to the feeder faults at deeper levels

Whilst not totally mirroring the paragenesis at Sedmochislenitsi there are substantial similarities in terms of the number of generations of sphalerite in paragenetic Stages 3-5, the later generation galena and barite and the presence of pyrobitumen.

Again, this paragenesis is similar to the overall evolution at Sedmochislenitsi but although the paragenesis shows the same progressions it is not on its own diagnostic of being Irish-type.

Sedmochislenitsi and the Irish Midlands Zn-Pb deposits share a relatively simple mineral assemblage comprising pyrite-sphalerite-galena deposited in multiple phases within a lithifying carbonate host sequence and both show minor Ni-Co occurring within both early and late iron sulphides. In both locations the mineralization passes from an early iron (both sulphide and oxide) phase prior to the main Zn-Pb ore stage. Tennantite-tetrahedrite and arsenopyrite are minor components, generally late stage and located proximally to potential "feeder" structures.

At the Gortdrum Cu-Ag-Hg deposit in Ireland Steed (1975) demonstrated the following mineral paragenesis:

1) Pyrite and cobaltiferous pyrite;
2) Main chalcopyrite phase;
3) Bornite, chalcocite and minor chalcopyrite;
4) Chalcocite with stromeyerite and wittichenite;
5) Cinnabar, stromeyerite and native amalgam.

The Cu-Ag-Hg mineralization at Sedmochislenitsi is later than the Zn-Pb and bears strong paragenetic similarities to the Cu-Ag-Hg deposits not only to Gortdrum but also to that at Aherlow and Tullacondra in the Munster Basin. These Cu-Ag-Hg deposits both show an early Ni-Co enriched pyrite phase followed by increasing amounts of grey coppers and a final mercury-silver rich phase.

The Black Matrix Breccia described by Rentzsch (1963) and termed "mylonites" by Minčeva-Stefanova (1967) locally includes sulphide clasts, and thus would appear to be closely analogous to similar rocks commonplace in several deposits in the Irish Midlands (Lisheen, Galmoy, Pallas Green, Stonepark and, possibly, Silvermines. Such Black Matrix Breccias are generally considered to be spatially related to mineralizing processes in the Irish Midlands.

Conclusions

Taken together, the tectonic and stratigraphic setting, styles and relationships of the mineralization, trace element geochemistry, the temporal evolution of the mineralizing system, sulphur sources and their isotopic signatures provide sufficient evidence to draw the conclusion that Sedmochislenitsi could be classified as being Irish-type and has more than a passing resemblance to the principal aspects of the Tynagh deposit. Of course, the argument can only be advanced by further detailed studies.

The lack of detailed stable isotope data is a fundamental barrier in defining genetic models for Sedmochislenitsi and whether or not it is Irish-type. Access is now very difficult with the abandonment and closure of the existing mine workings and sample material on surface dumps is scarce and spatially unreferenced. However, the National Museum of Earth & Man in Sofia maintains 109 reference samples from the Sedmochislenitsi deposit donated in 1998 by the Geological Department of the mine when production ceased. (Atanassova, 2015).

Whether or not Sedmochislenitsi is definitively Irish-type or not, to some extent remains moot, but there are undoubted similarities, and significant differences from other Triassic Zn-Pb mineralization at a similar stratigraphic level in the Alps and northern Dinarides.

Acknowledgements

This paper was only possible because of the detailed observations and publications of a number of previous authors working whilst the Sedmochislenitsi mines were in operation, principally the late Prof. Jordanka Minčeva-Stefanova of the Bulgarian Academy of Sciences in Sofia together with Johannes Rentzsch whose Doctoral Thesis from Bergakademie Freiberg formed the core data sources, albeit drawing very different conclusions. To them I offer sincere thanks and admiration for their work. During the period 2002-2004 whilst engaged in mineral exploration in Bulgaria, I was fortunate to visit the Sedmochislenitsi and Medna-Plakalnitsa mine sites shortly after closure, but prior to site clearance, and also was able to venture into the decaying underground workings to observe some of the features of this intriguing deposit. Thanks, are also due to two anonymous referees who undoubtedly improved the text and concepts of the paper.

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