СПИСАНИЕ НА БЪЛГАРСКОТО ГЕОЛОГИЧЕСКО ДРУЖЕСТВО,
год. 86, кн. 3, 2025, с. 141–146

REVIEW OF THE BULGARIAN GEOLOGICAL SOCIETY,
vol. 86, part 3, 2025, p. 141–146

Hydrothermal mineralization and alteration in the Ilovica Cu-Au porphyry deposit, Eastern Macedonia

Milica Nikolova Panevska, Blagica Doneva, Orce Spasovski

University "GoceDelcev"-Stip, Faculty of Natural and Technical Sciences Republic of North Macedonia;
E-Mails: milicanikolova@yahoo.com; blagica.doneva@ugd.edu.mk; orce.spasovski@ugd.edu.mk

Milica Nikolova Panevska, Blagica Doneva, Orce Spasovski. 2025. Hydrothermal mineralization and alteration in the Ilovica Cu-Au porphyry deposit, Eastern Macedonia. – *Rev. Bul. Geol. Soc.*, *86*, 3, 141–146, https://doi.org/10.52215/rev.bgs.2025.86.3.141.

Abstract. As a result of the latest detailed studies carried out by the Phelps Dodge company and continued by the Euromax company, the Ilovitsa deposit has been classified as a Cu-Au porphyry deposit. The Ilovitsa deposit represents one of the most significant porphyry Cu-Au deposits located within the Tertiary intrusive complex, which has undergone intense hydrothermal alteration, typical for porphyry systems. The following types of alteration are distinguished within the deposit: weak propylitic alteration, advanced argillic alteration, quartz-sericite-pyrite ("phyllic") alteration and potassic metasomatism with the presence of intermediate argillic alteration, and supergene sulphide alteration.

Keywords: Ilovica, porphyry deposit, hydrothermal mineralisation, porphyry systems, granodiorite, granite.

Introduction

The Ilovitsa deposit is located in the southeastern part of the Republic of Macedonia within the Ograzhden Mountains, at a distance of about 17 km from the town of Strumica, near the village of Ilovitsa (Fig. 1a). In the Republic of Macedonia, "Ilovica" deposit represents one of the most significant Cu-Au porphyry deposits. It is a part of several porphyry systems of the eastern Macedonia and northern Greece associated with igneous complexes, and is one of the deposits of the type of Bucovik-Kadiica deposit in Macedonia and Scurries deposit in Greece. According to the regional geotectonic position, the Ilovica deposit belongs to Serbian-Macedonian Massif (Zagorchev et al., 2008) and the Serbian-Macedonian Metallogenetic Zone (Jankovic, 1977), in belt, in which the geological structure includes late Proterozoic to Palaeozoic metasediments and granitoides. The processes that took place in the frame of the SMM have caused the formation of volcanic apparatus, domes and regional dislocations, as the Tupal dislocation and dislocation Besna Kobila-Osogovo (Aleksandrov, 1992). In fact, the occurrence and spatial distribution of magmatism and ores are a function of the structural control factor or the disjunctive depth structures that occur in the Ograzhden granite massif and are oriented along the boundaries of the main geotectonic units: the Serbian-Macedonian massif and the Vardar zone.

Geological setting

The Ilovica deposit is located in a northwest-southeast oriented Cenozoic magmatic arc, that covers large areas of Central Romania, Serbia, Macedonia, Southern Bulgaria, Northern Greece and Eastern Turkey (Tomić, 1936; Stojanović, 1971; Westra, 2005; Schefer et al., 2011; Schmid et al., 2013). The Illovica porphyry system is about 1.5 km in diameter and is associated with a poorly exposed dacite-granodiorite system, emplaced along the northeast border of the northwest-southeast oriented Strumica graben (Rakicevic et al, 2008; Sinclair, 2008). The geological location of the deposit is controlled by major north-south transverse faults and minor northwest-southeast faults parallel to the graben fault boundary.

At the surface, the Ilovitsa intrusive complex outcrops as a central dacite breccia diatreme with a diameter of approximately 1.3 km. (Bird, Morris, 2012; Wheeler, 2015). The diatreme is intruded by at least one dacite and two granodiorite porphyry stocks that have generated several hydrothermal pulses, resulting in widespread multi-phase veining within a mineralized stockwork (Jankovic et al., 1995).

The Ilovica porphyry is centered on a hill of more than 400 metres (m) of absolute relief, surrounded at lower elevations by numerous small dykes and irregular bodies of dacitic tuff and breccias and intermediate volcanic rocks. The Ilovica porphyry is situated on a hill over 400 metres (m) high, surrounded at lower elevations by numerous small dikes and irregular bodies of dacitic tuff and breccia and intermediate volcanic rocks.

The Ilovicha magmatic complex is located in the Lower Paleozoic granite. The granite is locally weakly foliated, coarsely porphyroblastic and forms a roughly northwest-elongated body measuring 4 to 12 km, cutting through Precambrian micaceous schists and gneisses. Parts of the main dacite diatreme locally contain abundant xenoliths of basement granite close to the lithological contact.

Hydrothermal mineralization

From a historical perspective, the mineralogy of the Ilovitsa deposit has been very poorly studied. Among the rare data on mineralization in the area of the village of Ilovitsa are the reports of Stoyanovich (1971) and Denkovski et al. (1973), explanation notes of geological map, sheet Strumitsa (Rakichevic et al. 1973), as well as preliminary data of Denkovski et al. (1993), Bogoevski (1998) and others. In all the above-mentioned studies, the main focus is on the occurrence of gold, copper, lead and zinc in the Viro-Ilovitsa area, with very little attention paid to the mineralogical characteristics of the ore formation. This situation continued even during the period of intensive copper exploration in Ilovitsa, carried out by the American company Phelps Dodge between 2004 and 2007. The first results of more detailed mineralogical studies of this deposit appear in the works of Donkova (2006), Aleksandrov and Bombol (2008), Rogozhareva (2009) and others.

The mineralogical studies conducted so far show that the Ilovitsa deposit is characterized by stockwork and stockwork-impregnation copper mineralization of the porphyry type, accompanied by all the typical characteristics of porphyry mineralization such as mineral associations and the sequence of deposition of ore minerals. The main carrier of copper mineralization in the Ilovitsa deposit is chalcopyrite, most often accompanied by pyrite. Depending on the depth of mineralization, the accompanying minerals vary from typical Fe-hydroxides, through developed secondary sulfides such as chalcocite, covellite, bornite and characteristic sulfides such as molybdenite, galena, sphalerite and associated sulfosalts such as tetrahedrite and tennantite, as well as silver and gold tellurides. At greater depths, high-temperature oxide associations mainly magnetite, hematite, martite dominate together with pyrrhotite, chalcopyrite and chalcopyrite. In addition to the intensive sulfide and sulfosalt parageneses, minerals of the noble metal group have also been identified, which are regular companions of porphyry ore systems. Of particular importance is native gold, found as individual fine grains in chalcopyrite and in the hydrothermally silicified mass within the host rock (Fig. 1b).

Fine grains of platinum-group minerals, silver tellurides (hessite), and gold-silver tellurides (petzite) have also been found.

Oxide paragenesis is developed by nodular and disseminated aggregates of magnetite (locally martitized) and classically developed hematite rods in combination with chalcopyrite of later generation. Hematite occurs as large euhedral individuals with a plate-like and flaky appearance, as compact aggregates with plate-like and radiated-fibrous to bundle-like forms in quartz-ore veins, which locally reach up to 20 mm in thickness and cut through the altered rock. The size of hematite individuals and aggregates varies widely – from small needles about 0.01 mm to plate-like and prismatic aggregates with a size of 1–2 mm (Fig. 1c, d).

Pyrite is one of the most common ore minerals in the Ilovitsa deposit. Observations show that pyrite is more abundant at medium to shallow depths, while at depths above 400 m it becomes noticeably scarce. In some cases, chalcopyrite segregations are observed in the pyrite, as well as pyrrhotite inclusions (“bird’s eye texture”) and pyrrhotite-chalcopyrite inclusions, often formed after the decomposition of cubanite. Hematite, magnetite and quartz inclusions occur less frequently. Close relationships between pyrite and chalcopyrite are very common, especially at medium temperatures of formation.

Chalcopyrite is the main ore mineral and the primary copper carrier. It occurs as individual aggregates, vein fillings, and in contact with pyrite, magnetite, sphalerite, and galena grains. Larger individual chalcopyrite grains are often intensely corroded (Fig. 1e).

Bornite occurs in bornite–chalcopyrite aggregates up to 0.1 mm in size, euhedral to subhedral in

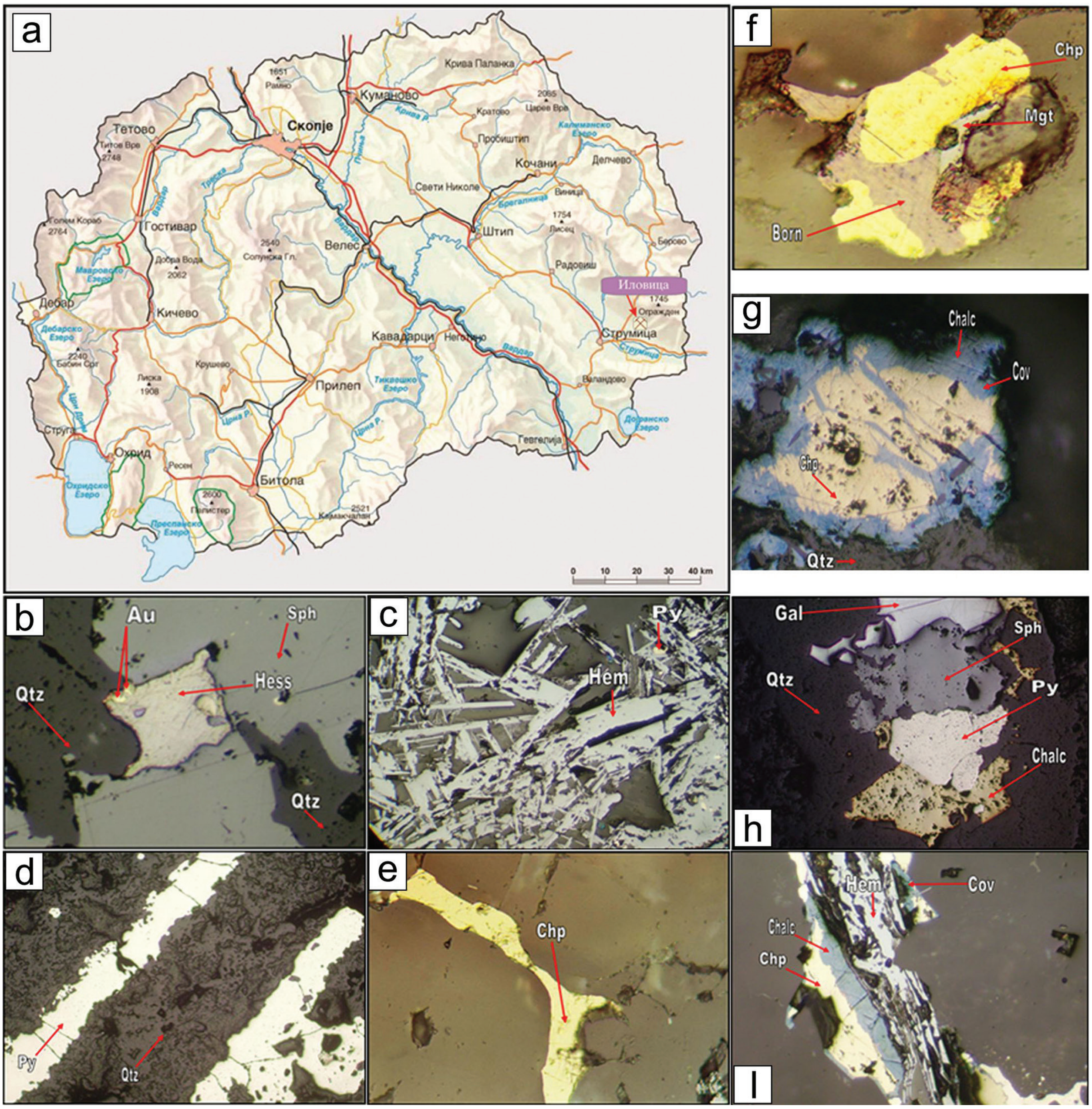

Fig. 1. (a) Geographical location of the "Ilovica" deposit – Strumica; (b) Large grain of hessite with grains of native gold, within a massive sphalerite matrix; hessite and sphalerite are intensely corroded by coarse quartz; (c) Characteristic relict hematite aggregate showing small relict pyrite grains (yellow), surrounded by siderite (dark); (d) Typical pyrite veinlets in quartz–pyrite vein; (e) Characteristic stockwork massive chalcopyrite, partially corroded by quartz; (f) Complex chalcopyrite–bornite–magnetite aggregate with characteristic corrosion and relict texture. Active corrosion of chalcopyrite and bornite by quartz. Magnetite is relict; (g) spongy and corroded chalcopyrite aggregate intensely altered by chalcocite and covellite (200×); (h) Typical polymetallic vein with distinct grains of chalcopyrite (yellow), pyrite (creamy), sphalerite (dark gray), galena (gray-white), and quartz (dark). Corroded chalcopyrite (upper right) and galena (upper left) relicts by quartz are clearly visible. Parallel nicols, 50×; (i) Polymetallic vein in altered (mostly quartz) host rock. Clear corrosion is visible: chalcopyrite by quartz and chalcocite, later by rod-like hematite and covellite, followed by intense corrosion of pyrite (lower right) by quartz and chalcopyrite. Parallel d nicols, 200×.

massive aggregates, sometimes intensely corroded by Fe-hydroxides and quartz (Fig. 1f). Alongside bornite, supergene minerals such as chalcocite and covellite are found, often together and corroding chalcopyrite (Fig. 1g).

In some parts of the deposit, a characteristic polymetallic association occurs, consisting of sphalerite, galena, chalcopyrite, pyrite, tetrahedrite, and tennantite (Fig. 1h).

Sphalerite occurs as coarse-grained allotropic aggregates up to 1 mm in size within quartz–sulfide veins, associated with other sulfide minerals. Galena, similar to sphalerite, is found in quartz–sulfide veins as allotropic aggregates or as fine-grained impregnations and nests in the host rock, commonly associated with sphalerite, chalcopyrite, and pyrite. Tennantite occurs as inclusions in chalcopyrite, showing characteristic allotropic forms, but also along cracks within chalcopyrite.

The Ilovitsa deposit has a wide and relatively deep developed oxidation zone, dominated by iron hydroxide minerals, where nuggets of gold have also been recorded.

Based on all mineralogical studies, we can conclude that the established mineral association fully corresponds to a porphyry system and therefore the Ilovitsa deposit is classified as a porphyry copper-gold deposit. According to the established mineral associations for such a type of deposit, complex paragenetic relationships were also identified, expressed through multiple types of mineral parageneses. In the near-surface zones, low-temperature Fe-oxide and hydroxide parageneses dominate, which gradually pass into oxide-sulfide, sulfide-sulfosalt, and then high-temperature sulfide, sulfide-oxide and finally high-temperature oxide parageneses. The mineral parageneses mentioned include mostly common minerals typical of this type of mineralization, but the interrelationships between the individual ore minerals are much more complex, as shown in Fig. 1e), where mixed oxide-sulfide ore associations produce complex quartz-hematite oxide and quartz-pyrite-chalcopyrite sulfide parageneses. Bornite, chalcocite and covellite occur exclusively as secondary products after chalcopyrite aggregates, replacing them in the following sequence: chalcopyrite → bornite → chalcocite → covellite, during which they corrode and envelop chalcopyrite.

Alterations of the host rocks

In the area of the Ilovica deposit, several different types of hydrothermal alterations of the surrounding rocks have been developed. Their distribution within the porphyry Cu–Au system represents the final product of multiple phases of magmatic and hydrothermal activity, as well as supergene alterations that occurred near the surface.

The studied area is affected by intense alteration of the surrounding rocks, which is actually one of the typical diagnostic characteristics of porphyry-type copper deposits. Among them, the most significant distinguished types include silicification, alunitization, kaolinization, K-metasomatism, sericitization, chloritization, etc. They have been confirmed by both petrographic and X-ray diffraction analysis, which establishes that the rocks forming the Ilovitsa deposit are highly altered (Donkova, 2006).

Figure 2 shows several examples of established types of rock alteration according to petrographic analysis.

Microphotographs show that silicification occurs in two generations – as vein-metasomatic silicification, which completely replaces the primary mineralization, and as coarse-grained and fine-grained silicification (Fig. 2a). Among the observed alterations in granite, the most common are silicification, sericitization, kaolinization and chloritization, which usually occur together (Fig. 2b–e). Some parts of the rock mass are characterized by limonitization, with a significant presence of Fe minerals marking the base of the rock matrix (Fig. 2g). Hematitization is also frequently observed, with hematite grains filling open spaces in the rock. An illustration of hematitization is shown in (Fig. 2h). Furthermore, this figure shows that the volcanic rock is highly tectonized, i.e. strongly fractured with multiple cracks and has undergone intense alteration. The entire bedrock is veined with hematite grains that fill the cracks of the rock. The rock is a dacite breccia with a relict porphyry structure and a massive texture.

Among the alteration types, silicification is dominant, fine-grained in nature, and developed within the rock matrix. Among the alteration types, fine-grained silicification is dominant. Supergene sulfide oxidation, leaching and argillization locally extends to a depth of over 150 meters below the surface (Carter, 2008). Based on the indicative minerals, as well as the current level of study and understanding of the alteration processes of the surrounding rocks in the Ilovica Cu-Au porphyry deposit, and according to the X-ray diffarction analysis of samples from several wells, the following types of alterations have been distinguished in the deposit: supergene sulfide alteration, weak propylitic alteration, advanced argillic alteration, quartz-sericite-pyrite (“phyllic”) alteration, potassic metasomatism with the presence of intermediate argillic alteration.

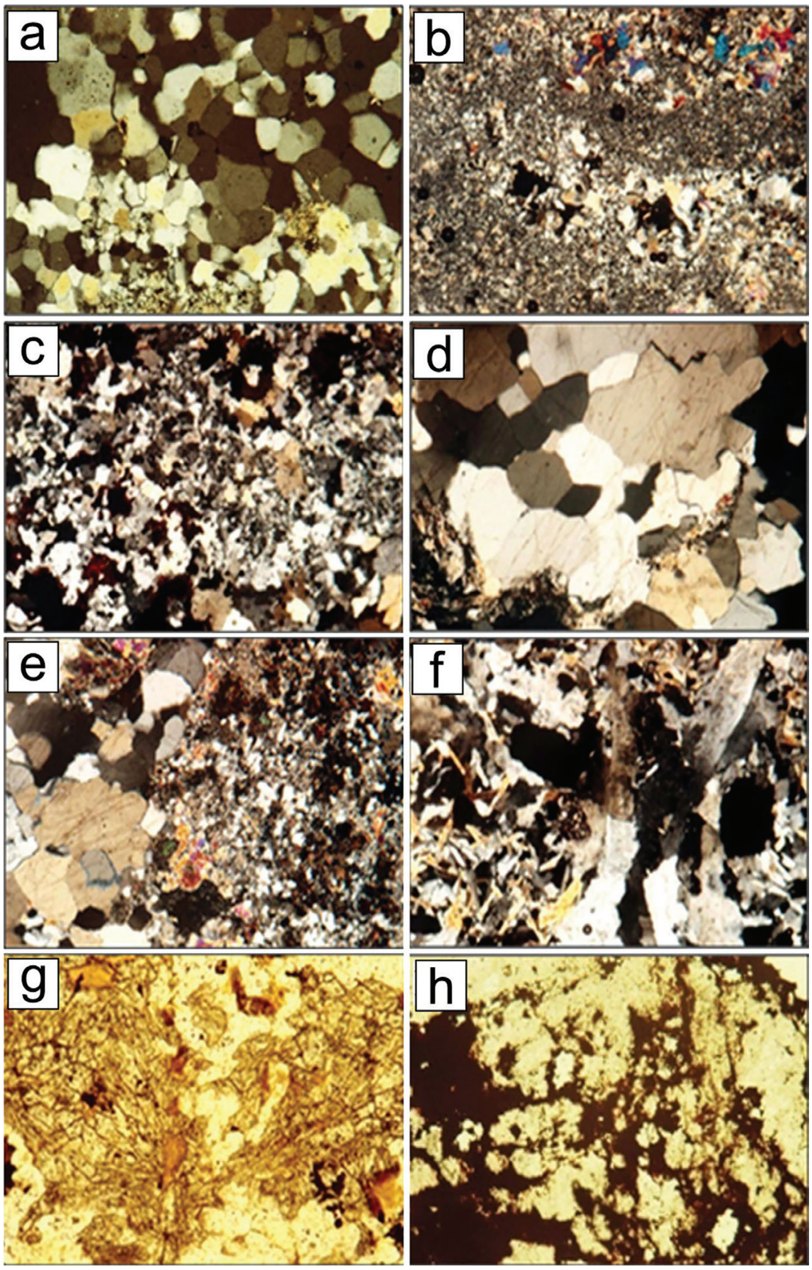

Fig. 2. Microphotographs of selected hydrothermal alterations (magnification 50×): (a) Two generations of silicification (coarse-grained and fine-grained); (b) Microgranite showing the presence of kaolinization and silicification; (c) Microgranite with silicification, sericitization, and kaolinization; (d) Albitic granite with subsequent silicification, sericitization, and chloritization; (e) Granite exhibiting silicification, sericitization, and chloritization; (f) Fine-grained granite showing sericitization; (g) Example of limonitization; (h) Example of hematitization.

Conclusion

Recent studies and investigations of the Ilovitsa deposit have shown that it is a Cu-Au porphyry deposit located within the Tertiary intrusive complex, and closely related to intense hydrothermal alteration of the host rocks. Among them, the following types of hydrothermal alteration can be distinguished: weak propylitic alteration, advanced argillic alteration, quartz-sericite-pyrite ("phyllic") alteration and potassic metasomatism with the presence of intermediate argillic alteration, as well as hypergene alteration. Ore mineralization is most closely related to the zones where quartz-sericite-pyrite alteration and potassic metasomatism with the presence of intermediate argillic alteration are developed, as well as in their contact parts.

References

Aleksandrov, M. 1992. *Metalogenetic characteristics of the polymetallic ore field Sasa, East Macedonia*. Doctoral dissertation. Faculty of Mining and Geology, Stip, 264 p.

Bird, S., P. Morris. 2012. NI 43-101 Resource Estimate for Ilovitca Project, Macedonia. Moose Mountain Technical Services, British Columbia, Canada.

Carter, S. 2008. NI 43-101 Technical Report on the Copper Gold Resources on the Ilovitza Project, Macedonia (2008). Broad Oak Associates, Toronto, Canada.

Cifliganec, V. 1993. *Copper mineralization in the Republic of Macedonia: Types and distribution patterns*. Univ. Sv. Kiril i Metodij, Skopje, 303 p. Skopje, Macedonia.

Davies, R., Hope, R., Browner, H., David, D., Dippenaar, B., Zeitsman, P., Critcher, P., White, J., White, R., Digges La Touche, G. and Chamberlain, G. 2016. Feasibility Study – Technical Report, Ilovica Gold-Copper Project, Southeast Macedonia. Euromax Resources professional fund, 549 p.

Denkovski, G., V. Pop-Vasilev, D. Georgiev, Z. Stojkov. 1993. Report for geological investigation on the primary gold in the Ilovica-Štuka, Strumičko. Geoinstitut.

Donkova, A., 2006. *Analysis of the Prospecting Research of the Ilovica-Shtuka Site*, Undergraduate Thesis, Faculty of Natural and Technical Sciences – Štip, 70 p.

Forward, P., M. Ligovski, R. Davies. 2017. Resource modelling at the Ilovica-Štuka porphyry copper-gold deposit, Eastern Macedonia. – *Geologica Macedonica*, *31*, 1, 21–40.

Heinrich, C. A., Neubauer, F. 2002. Cu–Au–Pb–Zn–Ag metallogeny of the Alpine-Balkan-Carpathian-Dinaride geo dynamic province. – *Min. Dep*., 37, 533–540.

Janković, S. et al. 1995. The Besna Kobila-Osogovo metallogenic zone. – *Geologica Macedonica*, *9*, 1, 39–50.

Janković, S. 1977. Major Alpine ore deposits and metal logenic units in the north eastern Mediterranean and con cepts of plate tectonics. – In: Jankovic, S. (Ed), *Metallogeny and Plate Tectonics in the NE Mediterranean*. Fac. Min. Geol, Belgrade, 105–171.

Rakičević, T., M. Kovaćević, N. Radović. 2008. *Explanatory notes of Geological Map of Macedonia, sheet Strumica, 1:100 000*.

Schmid, S. M., D. Bernoulli, B. Fügenschuh, A. Kounov, R. Oberhänsli, S. Schefer, D. Van Hinsbergen, K. Ustaszewski. 2013. Similarities and Differences between Alps-Carpathians, Dinarides-Hellenides and Anatolides Taurides. – *EGU*, *15*, 3525.

Stojanović, M. 1971. Completed annual report for regional geological exploration of the region of eastern Macedonia.

Tomić, J. 1936. Lithological composition of the Ogražden. Geological Annals. Balkan Peninsula, knj. XIII, Belgrade, 80–91.

Zagorchev, I., C. Dabovski, N. Dumurdzanov. 2008. Tectonic structure of Bulgaria and Macedonia based on TRANSMED TRANSECT III. Eds: Boev, B., T. Serafimovski. – *Proceedings: The First Congress of Geologists of the Republic of Macedonia*, Ohrid, 75–83.

Westra, G. 2005. Report prepared for Phelps Dodge Exploration Corporation.

Wheeler Amec Foster. 2015. Ilovica Gold-Copper Project. Feasibility Study Technical Report. S2233-0000-BA00-RPT-1000.

The published material was presented at the National Conference with international participation GEOSCIENCES 2025.