HYDROTHERMAL ALTERATIONS – A POWERFUL TOOL FOR THE EXPLORATION OF ORE DEPOSITS: A CASE STUDY FROM THE ZLATUSHA ORE OCCURRENCE, THE WESTERN SREDNOGORIE METALLOGENIC REGION, BULGARIA

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ABSTRACT. Hydrothermal alteration of host rock has always been one of the most powerful tools in mineral exploration. Each type of deposit presents particular configurations of alteration assemblages in time and space. The correct interpretations of hydrothermal events give information about ore genesis and the location of ore bodies. “Classic” alteration assemblages (phyllic, potassic, argillic, propylitic etc.) may be present in a different type of deposits, but occur in different space configurations and, the particularities of each single deposit pose additional challenges in data interpretation and exploration endeavors. The Zlatusha ore occurrence is situated in the Western Srednogorie metallogenic region, part of the Late Cretaceous Apuseni-Banat-Timok-Srednogorie magmatic and metallogenic belt. The occurrence is epithermal, in particular of a low sulphidation, and gold-bearing type. Genetically and spatially, it assembles to the volcanic structure of the Zlatusha paleovolcanic centre. This study presents new field, petrographic, and XRD data about hydrothermally altered host rocks. Several styles of peri-ore alteration are distinguished – propylitic, quartz-sericite-pyrite (phyllic), argillic – as well as some transitional subtype assemblages. The hydrothermal processes are complex and possibly overprinting one above the other. Based on the interpretation of the hydrothermal alterations, potential ore zones and bodies have been located.

Key words: hydrothermal alteration, mineral exploration, epithermal deposit

ХИДРОТЕРМАЛНИТЕ ПРОМЕНИ КАТО ИНСТРУМЕНТ ПРИ ПРОУЧВАНЕТО НА РУДНИ НАХОДИЩА: ПРИМЕР ОТ РУДОПРОЯВЛЕНИЕ ЗЛАТУША, ЗАПАДНОСРЕДНОГОРСКА МЕТАЛОГЕННА ОБЛАСТ, БЪЛГАРИЯ

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РЕЗЮМЕ. Хидротермалните промени на вместващите скали винаги са представлявали силен инструмент в процесите на проучване на полезни изкопаеми. Всяко находище се отличава с индивидуална конфигурация на променливи асоциации във времето и пространството. Правилните интерпретации на хидротермалните събития предоставят информация за рудния генезис и местоположението на рудните тела. „Класическите“ хидротермални минерални асоциации (филитови, калиеви, аргилитови, пропилитови и др.) могат да се наблюдават в различни типове находища, но се проявяват в строго индивидуални пространствени конфигурации, което поражда допълнителни предизвикателства в интерпретацията на данните и фактите. Рудопроявление Златуша се намира в Западносредногорската металогенна област, част от Апусени-Банат-Тимок-Средногорския магматичен и металогенен пояс от Късна креда. Рудопроявлението е епитермално, по-конкретно ниско сулфидно и злато-съдържащо. Генетично и пространствено асоциира с вулканските продукти на Златушенския палеовулкански център. В това изследване се представят нови теренни, петрографски и рентгенофазови данни за хидротермално променени скали. Разграничени са няколко типа околорудни изменения – пропилитов, кварц-серицит-пиритов, аргилизитов, както и някои преходни разновидности. Хидротермалните процеси са комплексни и вероятно наложени един върху друг. На базата на интерпретацията на хидротермалните разновидности са локализирани потенциални рудни зони и тела.

Ключови думи: хидротермални промени. проучване на полезни изкопаеми, епитермално находище

Introduction

Hydrothermal alterations are powerful tools for the exploration of ore deposits; they provide critical clues about the processes and conditions that formed ore mineralisations.

The Zlatousha ore occurrence is situated in the Western Srednogorie zone in Bulgaria, which in a regional aspect belongs to the Late Cretaceous Apuseni-Banat-Timok-Srednogorie magmatic and metallogenic belt (Popov et al., 2002). The belt hosts a lot of economic Cu- and Au-rich porphyry and epithermal deposits.

Previous work concerning the Zlatousha ore occurrence presents data about host rocks, hydrothermal alterations, and some genetic aspects (Ferdov and Kunov, 2002).

The aim of this study is to add new data about structures, types, and styles of hydrothermal altered rocks.

Sampling and analytical techniques

The samples from the hydrothermal altered rocks are collected from the mineralised zones. Polished thin sections were prepared to determine the structures and paragenetic relationships of the primary and secondary minerals in order to characterise the hydrothermal alteration assemblages.

Geology

The Zlatousha ore occurrence is of a low sulphidation deposit type (Sabeva et al., 2019), located in the Burel Ore Field (Popov and Popov, 2022) in the Western Srednogorie Mountain, as it is determined by the Upper Cretaceous volcanic and plutonic rocks.

Genetically and spatially, it is related to the Zlatousha paleovolcano (Bairaktarov, 1989; Velev and Nedialkov, 2010). The volcanic structure is not well preserved, and is composed mainly of volcanoclastic (epiclastic and pyroclastic) rocks and less distributed lava flows and subvolcanic bodies. In some cases, a sequence of epiclastic products overlain by pyroclastic agglomerate covered by lava flows is distinguished.

The layers of pyroclastic and effusive rocks are subhorizontal, with a thickness of between 2 and 6 m. Several dykes and subvolcanic bodies are also established. To the north and northeast of the village of Zlatousha, several isometric to less elongated subvolcanic stocks are intruded in volcanoclastic rocks and the intensive hydrothermal alteration is related with some of these magmatic events.

During the mapping of the hydrothermal alterations and lithology, two main extensive and homogeneous altered zones (phyllic to argillic alteration) were mapped. The southern one has west-northwest strike direction. Possibly related to this is the other fault and hydrothermal system with northeast-southwest strike direction.

The field results show typical structural control of the hydrothermal processes and ore mineralisation, hosted by vertical to subvertical strike-slip fault system.

Hydrothermal alterations

Several styles of alteration are distinguished: propylitic, quartz-sericite-pyrite (phyllic), argillic, and some transitional subtypes of assemblages. The hydrothermal processes are complex and possibly overprinted one above the other. They affect different types of volcanic rocks – porphyry, volcanoclastic, and hydrothermal breccias.

Phyllic (quartz-sericite-pyrite) alteration

Phyllic alteration affects the coherent (subvolcanic) porphyry diorite and hydrothermal breccia bodies.

Hydrothermal breccias, whether as highly permeable host rocks or when directly fragmented during ore-forming activities, can provide favourable sites for ore forming fluids and can form high-grade ore bodies in porphyry and epithermal deposits. Breccias generally occur as steep, pipe-like bodies and are typically formed at the top of the intrusion.

The phyllic altered breccias at the Zlatousha ore occurrence are generally monomictic, matrix to clast, ore matrix-supported. They are composed of volcanic (andesitic) clasts and hydrothermal matrix. The fragments are ellipsoidal to subangular. The matrix is around 5-8 %, and is almost composed of secondary, hydrothermal minerals – quartz, sericite, muscovite, potassium feldspar, and rare biotite (Fig. 1).

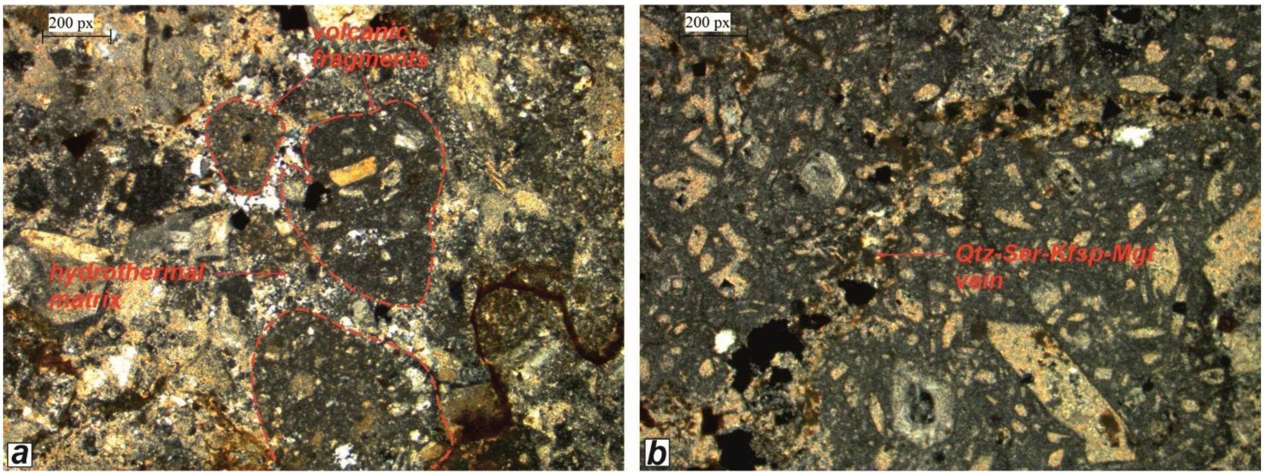

Fig. 1. Phyllic altered hydrothermal breccias: a) – Structural features (XPL); b) – Quartz-sericite-potassium feldspar veinlet (XPL)
XPL – cross polarised lights*; *PPL – plain polarised lights

Quartz almost prevails in the matrix and in two types of veins: quartz-sulphides and quartz-potassium feldspar-sericite veinlets (Fig. 1). Sericite is developed in the matrix and replacement of the plagioclase phenocrysts. Muscovite occurs in the veins and forms nests in groundmass of volcanic fragments. The type of alteration is phyllic with diagnostic minerals, such as quartz, sericite and pyrite. The existence of potassium feldspar and rare biotite corresponds to potassium-silicate alteration. Porphyry rocks are also affected by phyllic alteration. The host rocks are classified as porphyry diorite to granodiorite. Phenocrysts are plagioclase, amphibole, biotite, and rare quartz. Typical hydrothermal minerals are quartz, sericite, muscovite and rare hydrothermal biotite (Fig. 2).

Propylitic alteration

Propylitic alteration is observed in the periphery of mineralised hydrothermal zones, and based on the mineralogy is presented by two types: (1) quartz-epidote-sericite and (2) quartz-carbonate (calcite)-chlorite.

The first one is related with plagioclase and amphibole bearing porphyry diorite. The host rock undergoes intensive hydrothermal alteration, and primary magmatic structures and features are totally destroyed and altered. Hydrothermal minerals replace all the phenocrysts and microlites of the groundmass.

Quartz prevails under other hydrothermal minerals. It is abundant in groundmass, where it built nests in association of epidote.

Epidote appears in association with quartz and as individual grains and clusters in groundmass.

Hydromica (sericite) is an altered product over plagioclase phenocrysts. Chlorite is rare (Fig. 3).

Low-temperature propylitic alteration is developed under porphyry dacites, with phenocrysts of plagioclase, amphibole, biotite, and quartz. Calcite and chlorite are hydrothermal minerals. Calcite mainly develops in groundmass and fills vesicles. Chlorite is rare and replaces mafic minerals (amphibole) (Fig. 4).

Argillic alteration

The filed and petrographic studies did not show typical mineral assemblages for the argillic type of hydrothermal alteration. Established secondary minerals, such as kaolinite, quartz, and zeolites, are possible to be related to some low-temperature hydrothermal event. The rocks affected by these alterations are monomictic tuffaceous sandstones to breccia-conglomerates.

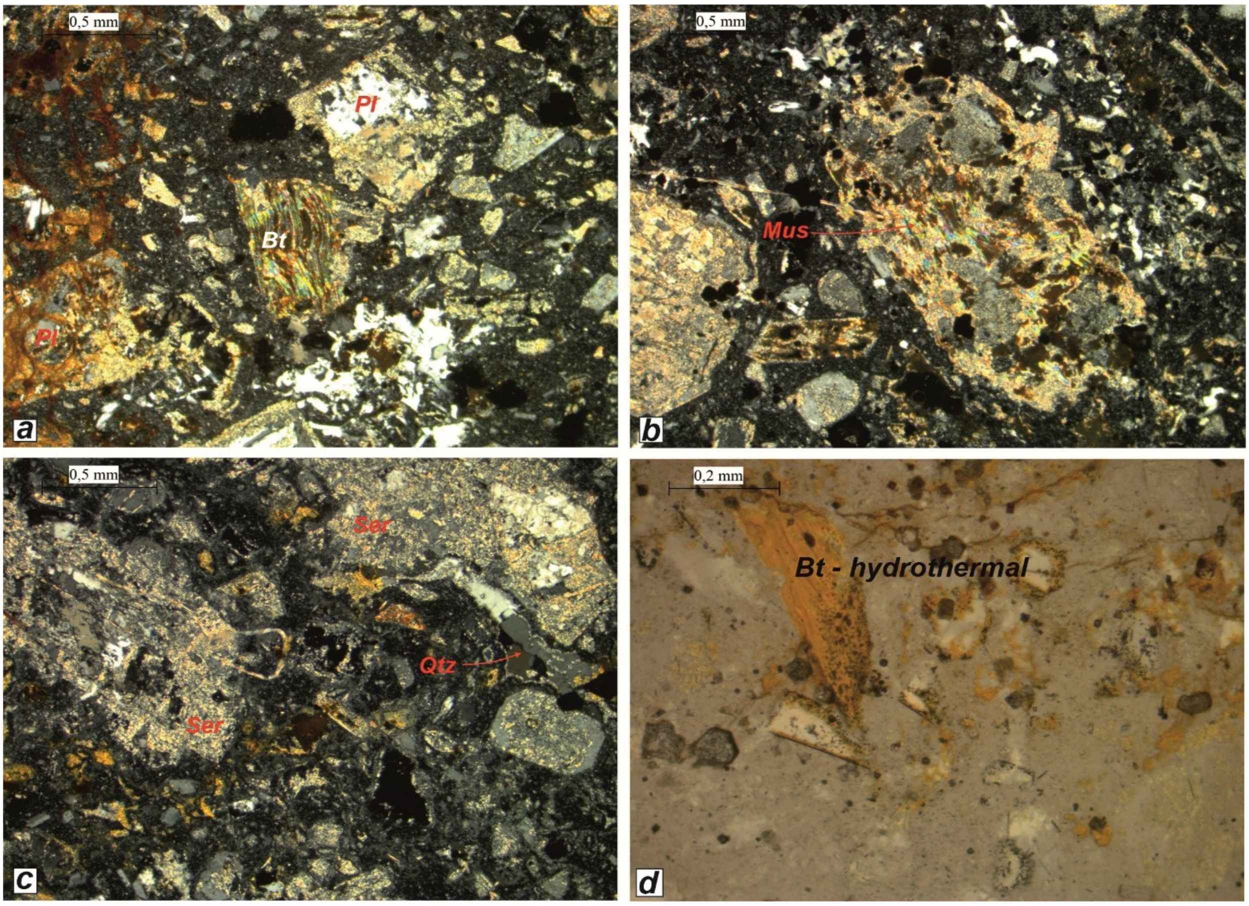

Fig. 2. Phyllic altered porphyry diorite to granodiorite: a) – Plagioclase and biotite phenocrysts (XPL); b) – Hydrothermal muscovite (XPL); c) – Hydrothermal quartz-sericite (XPL); d) – Hydrothermal biotite (PPL)

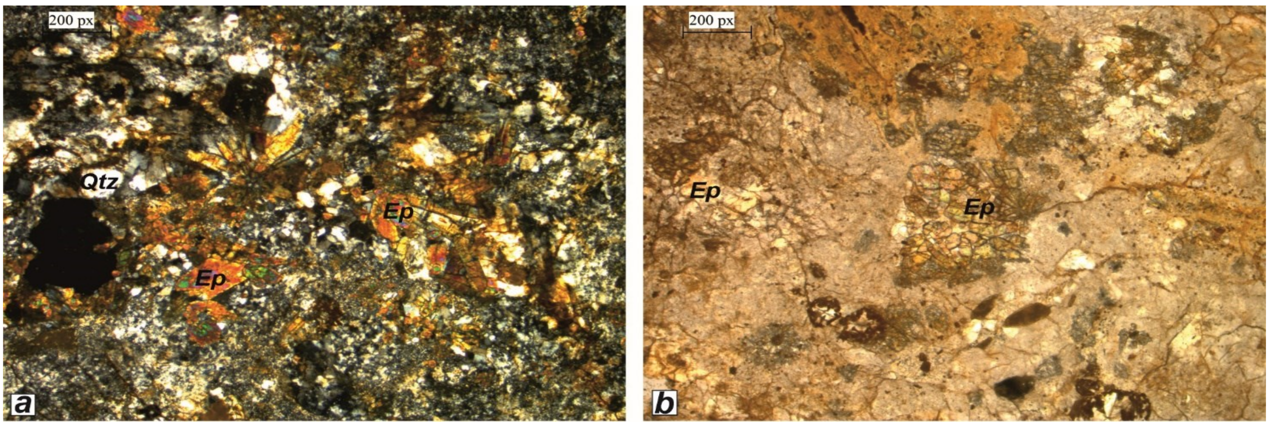

Fig. 3. Propylitic altered porphyry diorite: a) – Quartz and epidote (XPL); b) – Epidote (PPL)

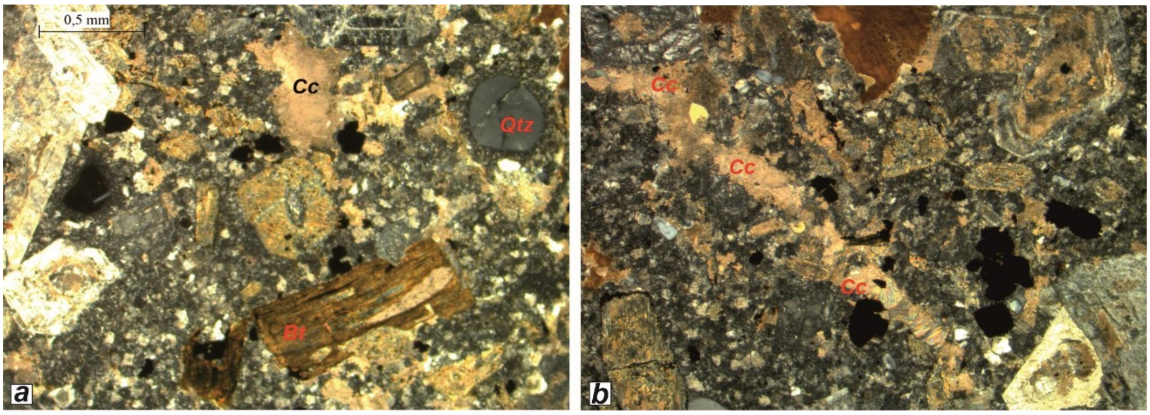

Fig. 4. Propylitic altered porphyry granodiorite: a) – Quartz and biotite phenocrysts (XPL); b) – Hydrothermal calcite (XPL)

Conclusions

Hydrothermal alterations play a crucial role in exploration geology, especially when searching for porphyry and epithermal deposits. These deposits are often associated with hydrothermal systems where mineral-rich fluids alter the surrounding rocks, creating distinct alteration zones that can serve as indicators of ore presence.

The identification of alteration zones can guide exploration by indicating the potential location and size of ore bodies. For instance, in porphyry systems, the presence of potassic alteration may point to the centre of the deposit, while phyllic and argillic can indicate the upper and lateral extents. In epithermal systems, silicification and advanced argillic alteration can signal areas of potential high-grade mineralisation. By mapping these hydrothermal alteration patterns, geologists can more efficiently target drilling efforts, thereby reducing exploration costs and increasing the likelihood of discovering economically viable mineral deposits.

The Zlatousha ore occurrence

Petrographic examination of the **phyllic alteration** demonstrates the existence of a mineral replacement susceptibility, with mafic silicates being the most susceptible to replacement by sericite and quartz, followed by cores of plagioclase to all the plagioclase phenocrysts, if the intensity of alteration was high. This type of alteration is locally texturally destructive, and the abundant pyrite indicates sulfur addition.

In some cases, phyllic alteration is associated with hydrothermal brecciated bodies (pipes), and is located at the intersection of two major fault systems. The breccia is dominated by clasts of andesites and quartz-sericite matrix.

In the western segment of the deposit, phyllic alteration is transitional to potassium-silicate metasomatic type (potassium feldspar-biotite), or there is overprinting of alteration processes. Typical phyllic mineral assemblages show the southernmost mineralised zone.

Propylitic alteration is observed in the periphery of ore zones, and is represented of two types: (1) Quartz-epidote-sericite and (2) Quartz-carbonate-chlorite

No typical mineral assemblages for **argillic alteration** is present.

Acknowledgements

This study is supported by the KP-06-N74/6 project “Remote sensing and field studies of porphyry copper and epithermal ore systems from the Western Srednogorie metallogenic region” funded by the National Science Fund of Bulgaria, Competition for funding fundamental scientific research – 2023.

The fieldwork was carried out with the support of *Velocity Minerals LTD*.

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