ON THE QUESTION OF THE SO-CALLED SECONDARY QUARTZITES OF MADNEULI AND OTHER GOLD-BASE METAL DEPOSITS OF THE BOLNISI MINING DISTRICT, SOUTHEASTERN GEORGIA

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Abstract. On the question of the so-called Secondary Quartzites of Madneuli and other gold-base metal deposits of the Bolnisi mining district, Southeastern Georgia. A. Magalashvili. At the VMS Madneuli deposit, several types of high-silica rocks are classified as Gold-bearing Secondary Quartzites. It is demonstrated that some of these correspond to advanced argillic alteration, while others to the 'white smokers' and transitional formations. An effort is made to categorize these rocks and explore their relationship with mineralization.

Key words: Madneuli deposit; secondary quartzite; ore genesis.

საკვანძო სიტყვები: მადნეულის საბადო; მეორეული კვარციტები; მადანის გენეზისი.

გაფართოებული რეზიუმე

მადნეულის და ბოლნისის მადნიანი რაიონის სხვა ოქრო-პოლიმეტალური საბადოების ე. წ. მეორეული კვარციტების საკითხისთვის, სამხრეთ-აღმოსავლეთი საქართველო.

ა. მაღალაშვილი. განხილულია ბოლნისის მადნიანი რაიონის მადნეულის ოქრო-სპილენძ- პოლიმეტალურ და სხვა მსგავს საბადოებში არსებული ე.წ. მეორეული კვარციტები, რომელთა გარკვეული ნაწილი ოქროს შემცველია და მუშავდება. ნაჩვენებია, რომ ნაწილი ამ ქანებისა წარმოადგენს მადანშემცველ და მადანმომიჯნავე ჰიდროთერმულ მეტასომატიტებს, რომლებიც წარმოდგენილია კვარც-სერიციტული, კვარც- სერიციტ-ქლორიტული და სხვა შედგენილობის მქონე ქანებით და უპასუხებენ საერთაშორისოდ მიღებული მჟავე მეტასომატოზის - „advanced argillic alteration“-ის კატეგორიას. ოქროს შემცველი მეორეული კვარციტების ნაწილი წარმოადგენს ე.წ. “თეთრი მხრჩოლავებიდან” ქიმიური გამოლექვის შედეგად წარმოქმნილ პროდუქტს, რომლის დიდი ნაწილი არ განეკუთვნება მეტასომატიტებს. მეორეული კვარციტების მესამე ტიპი განეკუთვნება გარდამავალ ტიპს და წარმოადგენს ორი ზემოაღნიშნული ქანის ბრექჩიას, რომლის ნატეხები წარმოდგენილია პირველი - მეტასომატური კატეგორიით, ხოლო მატრიქსი განეკუთვნება „თეთრი მხრჩოლავების“ ძარღვულ და ნაწილობრივ, მათივე ზემოქმედებით არალითიფიცირებული ფსკერული ნალექების მეტასომატური შეცვლის პროდუქტს. განხილულია მეორეული კვარციტების, მათ შორის მადნეულის საბადოზე არსებული წარმონაწმნების, გენეზისის შესახებ არსებული წარმოდგენები. შეთავაზებულია „მეორეული კვარციტების“ უფრო დაზუსტებული კლასიფიკაცია.

INTRODUCTION

The term "secondary quartzite" (SQ) was first introduced by E. Fedorov and V. Nikitin in 1901 to describe hydrothermally silicified volcanics in the Ural Mountains (Geological..., 2024).

Later, M. Rusakov and N. Nakovnik, based on the mainly Kazakhstan examples, incorporated SQ into Soviet geological terminology, recognizing it as a distinctive feature of hydrothermal formations. Nakovnik (1968, p. 8) defined SQs as "products of hydrothermal alteration of rocks (…), characterized by the constant presence of quartz (including chalcedony and opal), rutile, sulfides or iron oxides, and, in some cases, aluminous minerals, sulfates, and native sulfur" (Mishin & Berdnikov, 2003). This definition, although foundational, was broad and has since been refined by various authors based on the geological characteristics of the studied examples. Consequently, rocks that vary significantly in composition and formation conditions are often grouped under the same term.

As a result, the term SQ has come to encompass any quartz-rich metasomatic rocks, with multiple subtypes and varieties, leading to a broad, sometimes ambiguous, definition that is of limited use for both scientific research and practical applications.

The evolution of the SQ concept reflects the diversity of these rocks and their association with various geological processes. It should be noted, that this term is predominantly used by geologists from the former Soviet bloc, while internationally the more specific term "advanced argillite alteration" is implemented.In particular, according to Franco Pirajno "Advanced alteration of argillites occurs due to intense action of acids and a more or less complete leaching of alkaline cations with complete destruction of feldspars and basic silicate phases. Dickite, kaolinite, pyrophyllite, barite, alunite and diaspore are typical mineral phases of this type of alteration. In addition, sulphides, topaz, tourmaline and a series of amorphous clays may be present" (Pirajno, 2009).

The importance of SQs is highlighted by several factors: (1) Their distinct composition, with quartz and high-alumina minerals, facilitates easy identification. (2) Their high quartz content makes them resistant to weathering, allowing for effective mapping, including through remote sensing techniques. (3) SQs are widely distributed in volcanic regions and are often associated with ore deposits that exhibit chalcophile characteristics. (4) They indicate substantial material transport and serve as markers for extensive paleo-hydrothermal systems. (5) SQs are frequently associated with deposits of gold, silver, copper, molybdenum, and base metals, as well as minerals like pyrite, alunite, and pyrophyllite (Mishin&Berdnikov, 2003).

Given these factors, the accurate identification and classification of SQs is of both scientific and practical importance.

SQs OF THE MADNEULI DEPOSIT AND SIMILAR DEPOSITS IN THE BOLNISI ORE DISTRICT

From the early exploration of the famous Madneuli gold-base metal deposit in the Bolnisi Ore District (BOD), SQs, including gold-bearing varieties having commercial value, were identified as a distinct facies, typically occupying the upper levels of the mineralization zone. However, there are exceptions, with individual SQ bodies found outside this general pattern (Gogishvili, 1964; Tkemaladze, 1982, among others). Over time, similar formations were recognized in almost all gold-base metal deposits in the BOD (Nazarov, 1966; Gogishvili, 1980; Tkemaladze, 1982; Natsvlishvili et al., 2018). As more data was gathered, it became apparent that these SQs often corresponded to different stages of mineralization or even stages of ore-magmatic system evolution, sometimes deviating from the classical definition of SQs.

The most representative SQs have been discovered and studied at the Madneuli deposit, the genesis of which is debated (Tkemaladze, 1982; Gugushvili, Omiadze, 1988; Magalashvili, 2002; Migineishvili, 2002; Moritz, 2016; and others) and which, according to our data, is a weakly hybrid, initially hydrothermal-sedimentary shallow-water (<200 m) VMS deposit with a superimposed by a nascent porphyry process and subsequently inhibited by caldera formation (Magalashvili, 1995; 2002; 2007). Below is a brief description of the SQs observed at the Madneuli deposit.

Despite their material and textural diversity (Gogishvili, 1980; Tkemaladze, 1982; Migineishvili, 2004; Magalashvili, 2004), three primary types of SQs can be distinguished:

1. Quartz-sericitolites (light gray to white), often with chlorite, kaolinite, alunite-kaolinite, and sometimes represented even with monoquartzite varieties. These are associated mainly with the lower ore-hosting levels, where gold is generally absent. These SQs correspond to the advanced argillic alteration facies, formed by leaching of ore-hosting pyroclastites and terrigenous material deposited in shallow-water conditions (<200 m). Fragments of these rocks are found in the upper-level SQs and in sterile rhyolitic and rhyolitic-dacitic ignimbrites that overlie the ore-bearing strata (Gugushvili&Omiadze, 1988).

2. Gold-bearing SQs: These include yellowish-white to grayish-pink, often loose, porous, and sometimes banded rocks that feature typical growth textures (e.g., ribbed) and breccia with fragments of"chimney vents". These rocks, representing the "white smoker" stage of hydrothermal activity, are characterized by quartz-sericite-barite and quartz-sericite-carbonate assemblages with anhydrite. They are not true metasomatites but are chemical sediments resulting from hydrothermal activity (Magalashvili, 2004). These deposits mark the end of the hydrothermal process in the VMS system and can, in some cases, form typicallithocaps (Sillitoe, 1995), especially where non-lithified sediments were replaced. In some cases, these rocks or their part that got into the oxidation zone acquire a yellowish-rusty, sometimes reddish color (Madneuli, Kvemo-Bolnisi, etc.).

3. Breccia bodies: These are more fragmented and typically located between the first and second SQ types. The matrix consists of coarser-grained gold-bearing SQ of the second type, while the fragments are composed of SQ of the first type. The genesis of these breccias is mixed, resulting from both boiling of the hydrothermal solutions (Migineishvili, 2002) and tectonic activity. Within the Madneuli, Sakdrisi, and other deposits of BOD, some of these rocks later also fell into the oxidation zone, underwent hypergenization, and currently contain practically no sulfides.

Since, as far as we know, the idea of mixed genesis of this type of SQ is being put forward for the first time; below we provide a more detailed descriptionof them.

The fragments in these breccias are composed of microcrystalline quartz, finely flaked sericite, and rarely cubic pyrite phenocrysts. Sericite often forms from feldspar phenocrysts or small lithoclasts within pyroclastic material. Occasionally, chalcopyrite and other sulfides are present, particularly in porous and/or loose zones. Visually and mineralogically, these breccias align with typical advanced argillic alterations. The matrix itself is an aggregate of relatively large-crystalline turbid vein quartz with barite, calcite, sericite, among which there are idiomorphic crystals of rhombohedral or pentagonal-dodecahedral pyrite, which is known to be characterized by an increased gold content and is an indicator of gold-bearing facies (Belikova, Salikhov, Berdnikov, 2003).

More brecciated varieties are distinguished by gold content, and gold is typically concentrated in the matrix, rather than in the fragments, which primarily consist of quartz-sericitolites and other hydrothermal rocks.

The relationships between the different SQ types are extremely complex, with instances of vertical and lateral zoning reversals, likely due to the volcanotectonic processes associated with caldera subsidence, which are common in almost all gold-polymetallic deposits of the BOD (Magalashvili, 2004).When tracing these and other rocks and ores, it is necessary to consider the complex calderal tectonics, as a result of which completely different rocks and ores have appeared at the same hypsometric level, which often leads to erroneous conclusions about the nature of host rocks, the forms of ore bodies, and their age.

DISCUSSION

Based on the preceding observations, it can be concluded that SQs at the Madneuli and other similar deposits of theBODrepresent formations of varying genesis and mineralogical composition.

- The “lower ore-hosting SQs” are characterized by fragmented, telescoped combinations of high-temperature SQ (advanced argillic alteration) and VMS ores of the “black” and “grey smoker” stages (Magalashvili, 1995). These rocks, which have undergone significant calderal and other tectonic deformation, extend beyond the ore zones and are primarily formed by metasomatism of underwater sedimentary pyroclastites (Gogishvili, 1980; Tkemaladze, 1982).
- The “gold-bearing SQs” are breccias formed by the cementation of fractured quartz-sericite metasomatites with "white smoker" materials. These are the primary gold-bearing facies in the Madneuli and other deposits of the BOD.
- The “gold-bearing chemical SQs” are primarily formed by chemical precipitation from hydrothermal fluids, and represent the syngenetic product of the "white smoker" stage of VMS hydrothermal-sedimentary processes (Magalashvili, 1995, 2002).

We disagree with the suggestion by Migineishvili (2004) that "… epigenetic ore mineralizationis localized in the body of secondary quartzites (...) indicates that the intermittent process of formation of secondary quartzite bodies preceded the process of ore formation" (Migineishvili, 2004, p. 763). This assumption seems unlikely, as it does not account for the convective hydrothermal systems required to form large ore bodies, nor does it explain the observed stratiform, syngenetic ores (Magalashvili, 1991). Moreover, proposed by the same author the six-stage model of Madneuli's and it’s SQs development, which excludes the release of hot hydrothermal solutions to the basin's bottom, is implausible given the scale and duration of the hydrothermal processes necessary for the formation of the Madneuli like deposits.

It should be noted that despite the opinion sometimes appearing in geological publications, it is impossible to imagine purely epigenetic ores for VMS deposits. At any deposit except for sedimentary-distal ones, it is completely natural that both epithermal (epigenetic) and syngenetic ores are initially present. This is due to the very nature of ore genesis, which is the seepage of a hydrothermal solution through the ore-bearing strata with simultaneous metasomatism of rocks and partial precipitation of ores and non-metallic minerals in cracks and other voids, and subsequent precipitation of the remaining "worked out" part of the solution at the very bottom of the basin, where syngenetic volcanogenic-sedimentary ores are formed (Fig. 1).

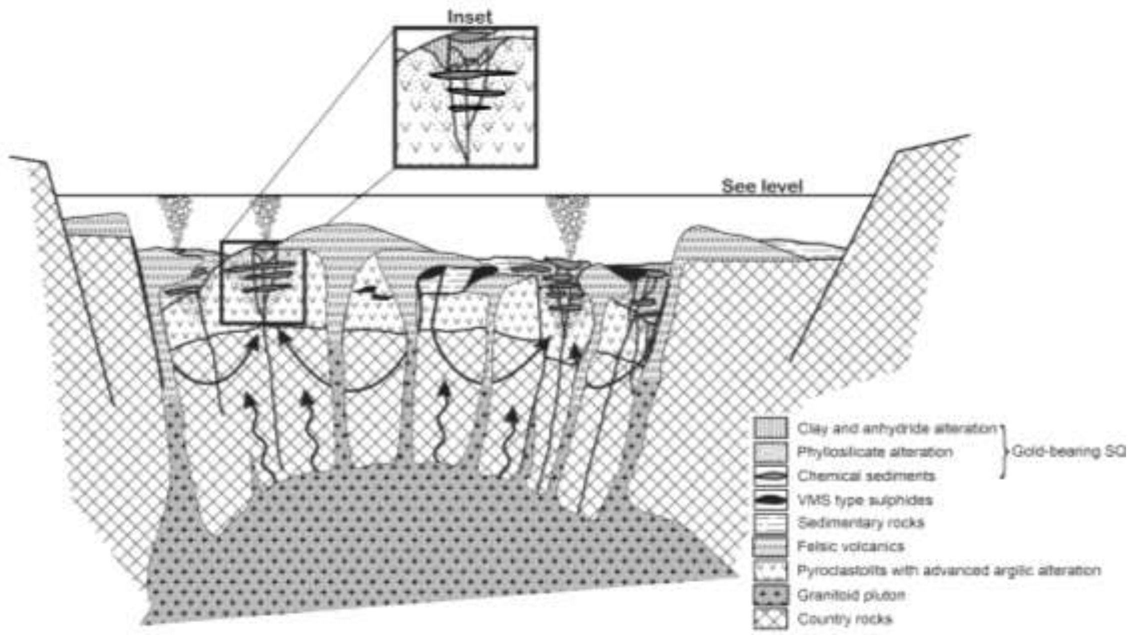

Fig. 1. Schematic model of a submarine caldera setting at the VMS stage of the formation of the Madneuli deposit and SQs. Modified from Van Kranendonk and Pirajno (2004).

CONCLUSIONS

In the Madneuli and other gold-base metal deposits of the BOD, the classical definition of SQ - specifically, advanced argillic alteration - is met primarily by the ore-hosting metasomatites located at lower levels, consisting of fine-crystalline quartz and sericite. The so-called "gold-bearing SQs" fall into two main categories: (1) hydrothermal-sedimentary deposits formed by chemical precipitation from "white smokers," and (2) transitional breccias between the first and second SQ types.

To avoid confusion, we propose that, when describing hydrothermal rocks in polymertallic deposits of the BOD (and similar deposits), the term "secondary quartzite" should be reserved for ore-bearing and near-ore quartz-sericite metasomatites that align with the internationally recognized concept of advanced argillic alteration. For SQs with similar mineral composition but associated with chemical deposition from "white smokers," we suggest using the term "chemical quartzite" or "chemically deposited quartzite."

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