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Petrology

First Evidence of Hyaloclastites at Madneuli Deposit, Bolnisi District, Georgia

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(Presented by Academy Member David Shengelia)

ABSTRACT. The Madneuli copper-gold polymetallic-deposit is a major deposit in Southern Georgia, which is still under development. It is located in the Artvin-Bolnisi zone, which is part of the Late Cretaceous Tethyan metallogenic belt. Several lithofacial units were outlined in the Madneuli open pit and their depositional setting was interpreted as submarine. The presence of rhyodacitic hyaloclastites in the host rocks is one of the supporting evidence of this setting. The hyaloclastite rocks represent the host rocks of the Madneuli upper Cretaceous rocks (Mashavera suite). Two types of hyaloclastite are recognized at the Madneuli deposit: hyaloclastite with pillow-like forms and hyaloclastite with glassy like selvages. The petrographic description shows a different nature: hyaloclastite with glassy like selvages represented by devitrification of volcanic glass, which is replaced by quartz-K-feldspar overgrowth crystals in the groundmass and elongated k-feldspar porphyry phenocrysts. Classical perlitic cracks were identified during thin section observation. The hyaloclastite with pillow-like forms consists of relicts of volcanic glass, large pumice clasts – surrounded by phyllosilicate and it still is possible to identify the fluidal nature of groundmass.

Silicified rhyodacitic hyaloclastite is interpreted as a result of water-rock interaction, in response to rapid chilling and quench fragmentation of lava. *© 2012 Bull. Georg. Natl. Acad. Sci.*

Key words: *hyaloclastite, lobe hyaloclastite, pillow like form, glassy selvage.*

The identification and interpretation of major facial units, based on detailed field and petrographic descriptions is a powerful tool for determining paleogeography and geotectonic environment of volcanic successions, which in turn is a key for determining the depositional environments of ore deposits. The Madneuli deposit lacked such modern and detailed studies of volcano and volcano-sedimentary facies architecture based on physical volcanology aspects. The Madneuli deposit is described as volcanogenic massive sulfide (VMS) deposit with transitions to epithermal type deposit. According to current classification schemes based on host rock compositions, the Madneuli deposit can be classified as bimodal-felsic VMS type [1]. The upper Cretaceous Rhyodacitic hyaloclastic facies unit is the part of the host rock succession of the Madneuli deposit attributed to the Mashavera suite and represented by lavas, pyroclastics, volcanogenic-sedimentary and sedimentary rocks of rhyodacitic compositions [2].

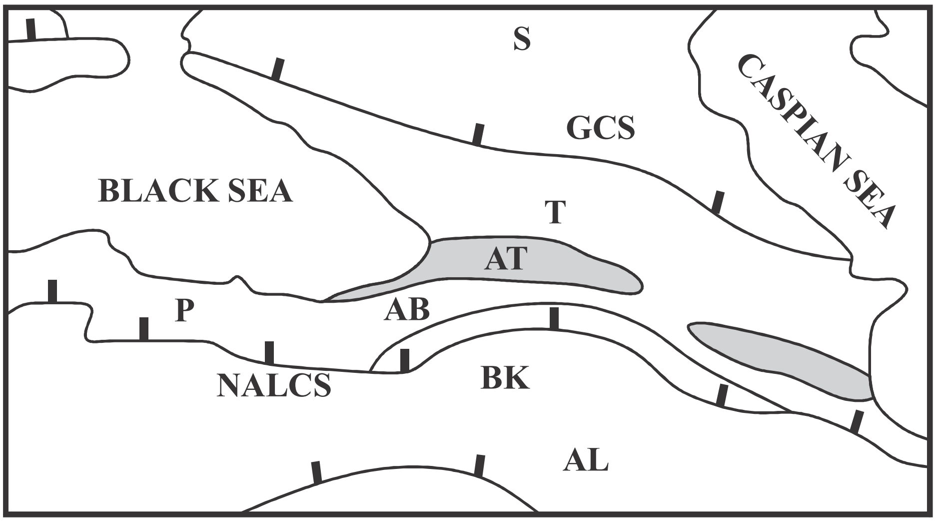

Fig. 1. Location map of the Madneuli deposit (adapted from Yilmaz et al. 2000). Abbreviations: S – Scythian Platform; GCS – Greater Caucasus Suture; T – Transcaucasus; AT – Southern Black Sea Coast-Achara-Trialeti Unit; AB – Artvin-Bolnisi Unit; P – Pontides; BK – Bayburt-Karabakh Imbricated Unit; NALCS – North Anatolian-Lesser Caucasian Suture; AI – Anatolian-Iran Platform.

Field and petrographic evidence presented in this paper shows that rhyodacitic hyaloclastites are hydrothermally altered and strongly silicified, and are evidence of a submarine depositional environment. The hyaloclastite is lobe hyaloclastite, which is one of the important characteristic facial units of the rocks hosting VMS deposits. In the open pit the periphery part of the lava lobe is still observed, which has a ring structure with internal columnar joints (Fig.2a).

Regional geological setting

The Bolnisi ore district is located in the Artvin-Bolnisi tectonic zone, which is continuing to the West into the Turkish Pontides and farther West to the Bulgarian Srednegoria tectonic zone (Fig. 1). The Artvin-Bolnisi Unit is bordered to the North by the Adjara-Trialeti unit (Santonian-Campanian back-ark) and the Imbricated Baiburt-Karabakh unit to the South (Upper Cretaceous fore-arc). It represents the northern part of the southern Transcaucasus and the central part of the Eastern Pontides, which formed the active margin of the Eurasian continent.

The Artvin-Bolnisi unit is characterized by a Hercinian basement, which consists of Precambrian and Paleozoic granites-gneisses and plagiogranites and late Variscian granits [3] overlain by Carboniferous volcano-sedimentary rocks [4] (Adamia et al.). Within the Bolnisi volcanic-tectonic depression, there are Cretaceous, Paleogene, Pliocene and Quaternary sedimentary rocks. Three main formations are distinguished within the Albian-Upper Cretaceous volcano-sedimentary unit: 1) terrigenous-carbonate (Albian-Senomanian), 2) volcanogenic (Turonian-Santonian) and 3) carbonate (Campanian-Maastrichtian) units [4]. Jurassic and Cretaceous rocks consist of volcaniclastic rocks, limestones and calc-alkaline magmatic arc rocks (andesite, dacite, rhyolite, and basalt and volcaniclastic rocks intruded by granitoids). The sequence is unconformably overlain by Maastrichtian – Paleocene limestone and turbidite. The Lower Eocene formation consists of terrigenous clastic rocks. Middle Eocene volcanic rocks overlie unconformable older rocks and are conformably overlain by Upper Eocene shallow-marine clastic rocks. The youngest rocks in the region are Quaternary volcanic rocks and alluvial sedimentary rocks.

Hyaloclastites

Field and petrographic descriptions

a. Glassy-like selvages hyaloclastite type. The best-exposed section of the hyaloclastite rock formations is in the eastern part of the Madneuli open pit. It is charac-

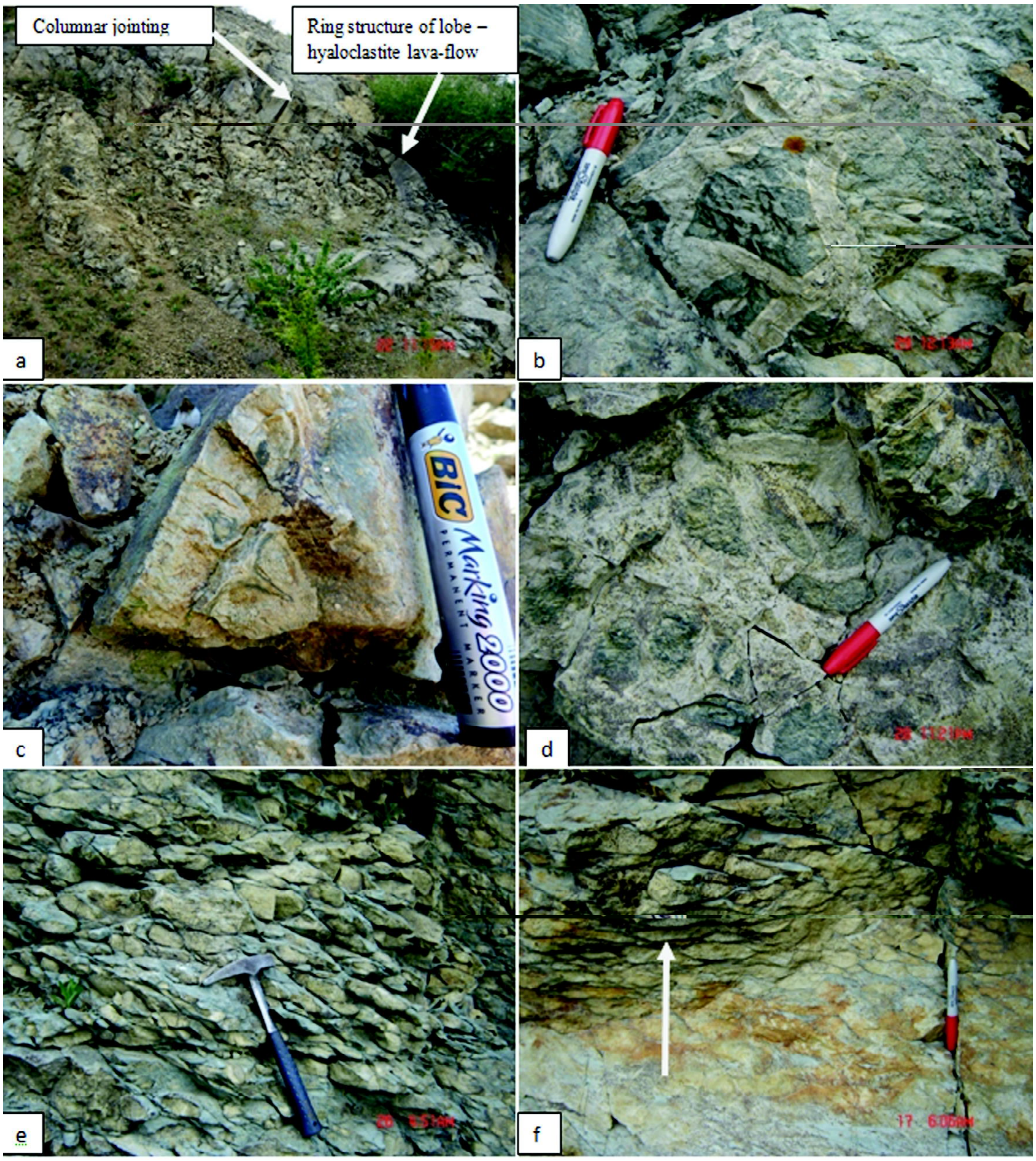

Fig. 2. Representative examples of hyaloclastite outcrops at Madneuli open pit. a. The margins of a lobe hyaloclastite flow with internal columnar joints, b. Carapace breccia, c. The alteration process in the coherent intrusive, d. Glassy-like selvage hyaloclastite-pseudo-breccia, with whitish and grayish-greenish parts, e.Pillow-like shapes in hyaloclastite, f.Transition zone from massive to pillow parts in pillow-like hyaloclastite.

terized by intense silicification-devitrification and chloritization. At the outcrop scale, the hyaloclastite gives the apparent impression of a breccia flow body with whitish rims around grey-greenish rock fragments. In fact, this apparent breccia texture is the result of weathering and alteration. The quenching process begins in the coherent part of the intrusive and increases toward the peripheral part of the flow (Fig. 2c). The whitish "rims"- within the flow are 1to-3 cm-thick, and in thin section they have the same texture as the grey-greenish "cores" (Fig. 2d), the difference is that the whitish part consists of a less amount of the phenocrysts than the greenish part. It is concluded that formation of such whitish zones, giving to the rock an apparent breccia

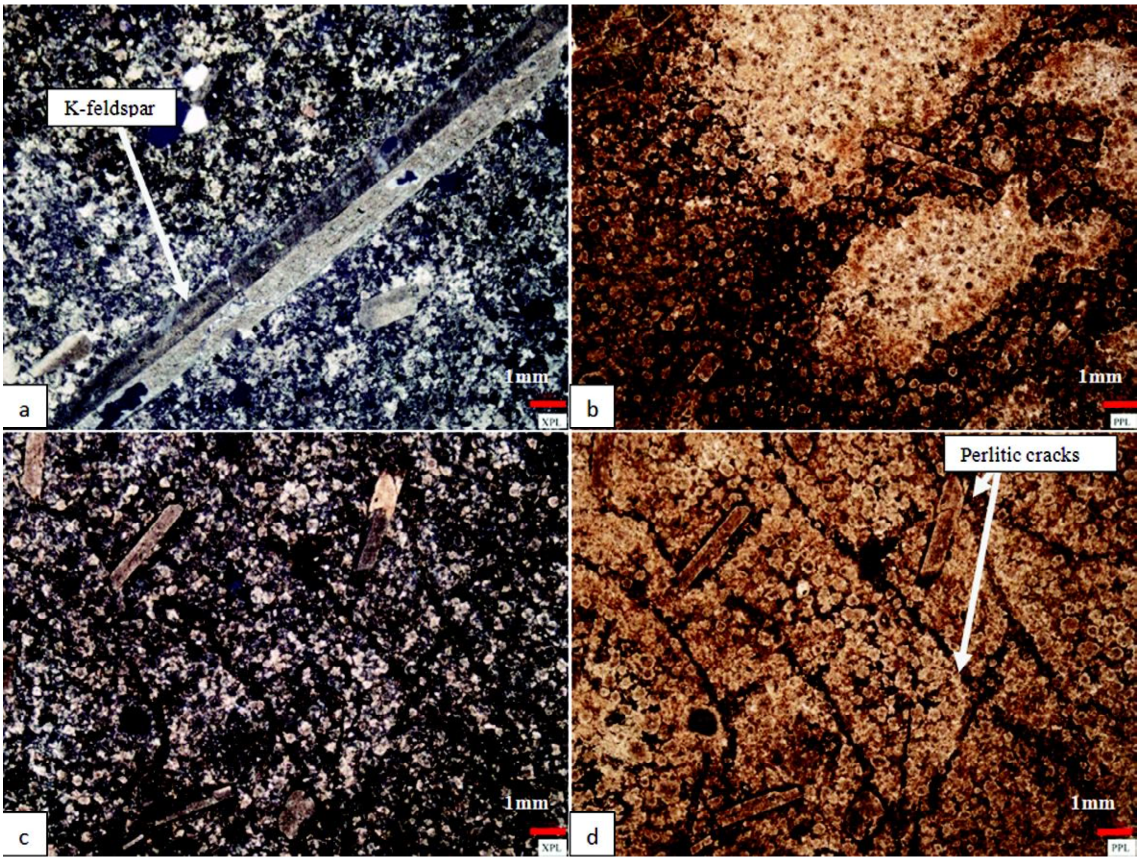

Fig. 3. Petrographic observations of glassy-like selvage type of the hyaloclastite. a. Elongated phenocryst of K-feldspar, b. The alteration processes: whitish and gray-brownish colors (crossed nicols), c. Perlitic cracks in glassy groundmass (crossed nicols), d. the perlitic cracks go around the edges. (plane-polarized light)

texture in the distal part of the hyaloclastite flow is a product of quench fragmentation during lava – water interaction. The chaotic character of the carapace breccia (Fig. 2b), their local distribution at the flow top, the absence of bedding and grading and lack of broken crystals suggest an origin predominantly due to autobrecciation [5] .This type of hyaloclastite rock is characterized by perlitic texture, which usually is recognizable with a hand lens or otherwise in thin section, in some exceptional cases macro-perlitic texture can be recognized at the outcrop scale within the Madneuli open pit. This hyaloclastite type contains round and oval-shaped amygdalae filled with quartz-chlorite or a fine-grained carbonate – clay mass.

b. The hyaloclastite with pillow-like forms are exposed on three bench levels in the eastern part of the open pit where typical small pillow shapes occur (Fig.2e). Along the same section, here is also a gradational transition from massive lava to the pillow-like shaped part (Fig.2f). Moreover, pillow-like forms occur within the massive rhyodacitic lava flow. The matrix surrounding the pillows is a bluish-colored altered rock of the same rhyodacitic composition as the pillow. The thickness of local outcrops is small and varies within 5-8 m.

Petrographic description

a. Glassy-like selvages type of hyaloclastite. This hyaloclastite contains less than 30% of phenocrysts. The matrix consists of devitrified volcanic glass with a mosaic texture, radial-shaped crystals of K-feldspar and spherules of quartz. Plagioclase microlites fill the spaces between spherulites and look like an overgrowth around them (Fig 3b, d). Porphyry phenocrysts include quartz, plagioclase and K-feldspar of different size. In some

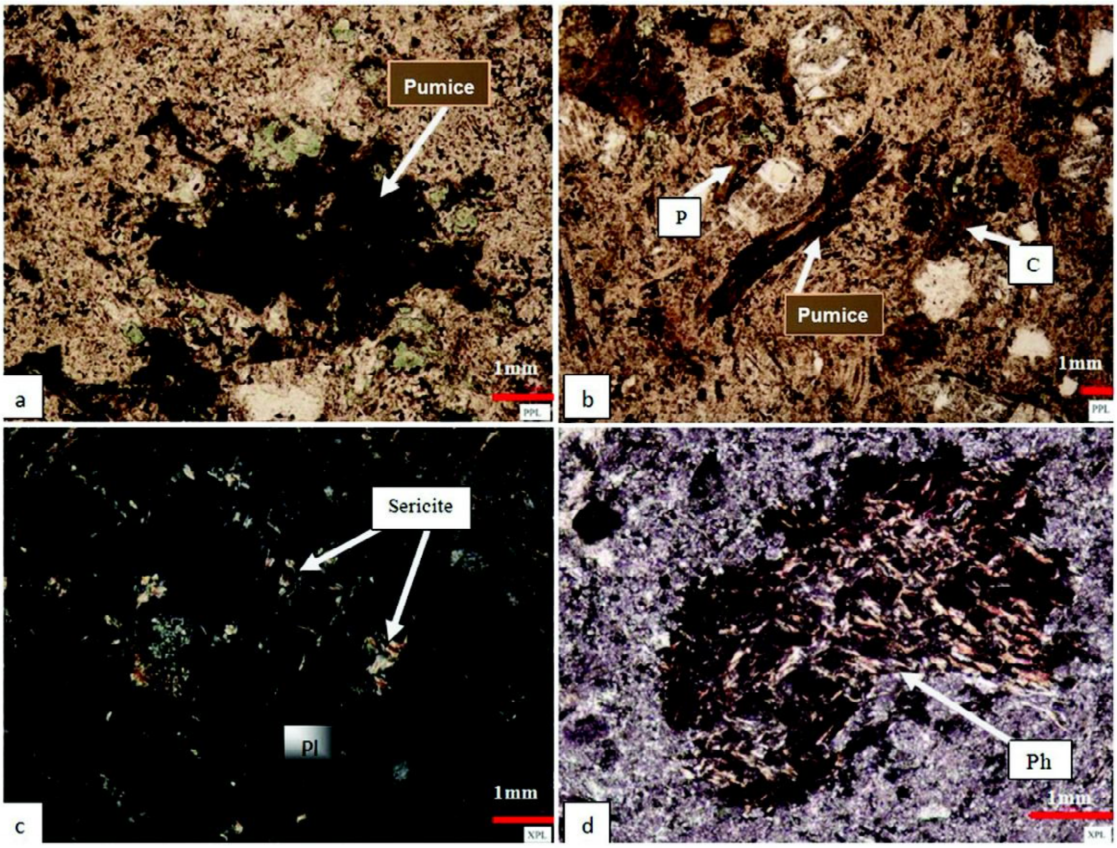

Fig. 4. Petrographic observations of pumice hyaloclastite. a. axiolitic devitrification of glass, b. remnants of platy and cuspate shapes of volcanic glass and pumice, c. sericite microcrystals along plagioclase crystal, d. phyllosilicate-rich pumice clast (Ph)

places they are associated in glomeroporphyric textures. Large and elongated sanidine crystal shapes are distinguished (Fig. 3a). Sericite alteration is developed in K-feldspar and plagioclase crystals. Spherulites with fine-grained quartz and feldspar are products of high-temperature devitrification of silicic volcanic glass. Subsequent recrystallisation of mosaic quartz-feldspar can destroy or modify such original devitrification textures [6].

The groundmass contains perlitic cracks, identified during thin section observation. Perlitic cracks develop in response to hydration of the glass. Hyaloclastite with glassy-like selvages has a classical perlitic texture, where the cracks are distinctly arcuate and concentrically arranged around spherical cores. Hydration occurs after emplacement and during the later cooling history of the glass, or after complete cooling to surface temperature. In some thin sections perlitic cracks cut the elongated K-feldspar phenocrysts, but sometimes instead of cutting across the crystals, the perlitic cracks just go around the edges (Fig.3 c, d). The conclusion is that the first stage was devitrification of volcanic glass followed by crystallization of porphyry crystals and finally formation of perlitic cracks.

b. The hyaloclastite with pillow-like shapes. In thin section pillow-like hyaloclastite has a rhyolitic nature. The massive part of pillows has similar composition, though with some differences. The rock has a porphyritic structure while the groundmass consists of relicts of volcanic glass replaced by finely disseminated quartz and K-feldspar. Large pumice clasts are also present. Locally, the groundmass has a fluidal nature. Shards of volcanic glass have preserved their platy and cuspate shapes (Fig.4b). In some places, the matrix displays a vitriclastic texture

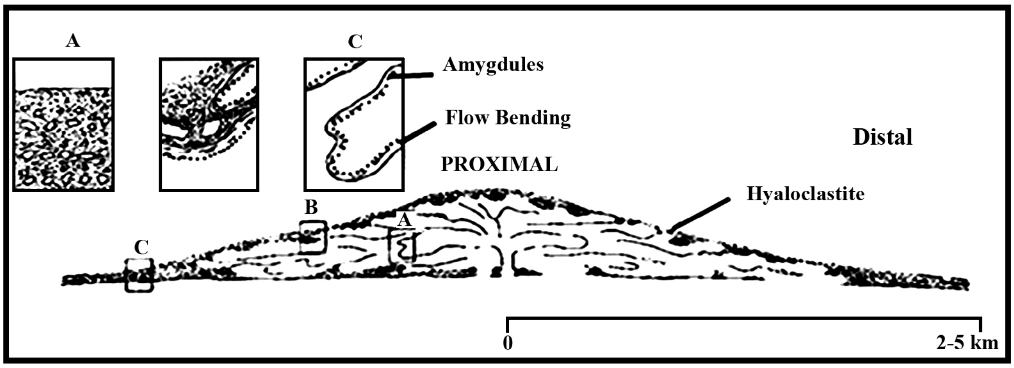

Fig. 5. Idealized cross-section through a rhyolitic lobe-hyaloclastite flow illustrating flow morphology and structures typical of proximal and distal facies (after Gibson et al., 1990)

accentuated by axiolitic devitrification of glassy components. The center of Fig.4a shows a relict pumice clast with destroyed internal vesicular microstructure. The brown rims of matrix shards are affected by axiolitic devitrification [6]. Crystals of biotite are present, with rare muscovite. The margins of K-feldspars are partly desorpded. In some places only crystal relicts are present filled by chlorite. Sericite alteration overprints plagioclase crystals (Fig.4c). In the massive part of the pillow hyaloclastite, phenocrysts are rare; they are concentrated in the mass between the pillows (pseudo cement). The pumice clast is surrounded by phyllosilicate (Fig.4d).

Interpretations

Subaqueous felsic lavas are typically divided into lobe-hyaloclastite flows, blocky subaqueous lavas and domes, cryptodomes, and regionally extensive felsic lavas. Volcanogenic-hosted massive sulphide deposits can be associated with the first three flow types [5]. Fig. 3 is an idealized cross-section through a rhyolitic lobe-hyaloclastite flow, which illustrates the flow morphology and structures typical of proximal and distal facies.

This paper describes two types of rhyodacitic hyaloclastite, which are exposed in the open pit of the Madneuli deposit: (1) hyaloclastite with pillow-like forms and (2) hyaloclastite with glassy-like selvages. They correspond to the section B in Fig.5. Hyaloclastite with glassy-like selvages refers to a breccia facies, morphologically associated with carapace breccias and occur along the upper surface of the distal part of flows. By contrast hyaloclastite with pillow-like forms is pumiceous hyaloclastite, which consists of pumice fragments and volcanic glass. The lobe-hyaloclastite flow is inflated by successive pulses of new magma, which feeds its large lobes. They generally follow a very irregular path to the flow front, where they form smaller lobes and locally they have small sized pillow-like shapes [5]. The Madneuli lobe-hyaloclastite flow is massive in general, though locally ribbed, flow laminated and columnar jointed.

As documented by reference 6, lobe-hyaloclastite flows are mostly fissure-fed flows, associated with seafloor spreading and are emplaced in both deep water and shallow (<500m) water environments.” In the open pit lobe-hyaloclastite flows are associated with turbiditic volcanoclastic deposits and peperites, which clearly documents that hyaloclastite was formed in submarine environment, however there is no evidence to constrain the exact water depth during hyaloclastite formation.

Conclusions

- Spherulites in the hyaloclastite are strong evidence for the high temperature devitrification of volcanic glass, which is replaced by quartz-K-feldspar overgrowth crystals in the groundmass and columnar jointing, which occur inside the lobe flow in the open pit.

- Rapid quenching forms a glassy-like selvage along the edge of the lobe. It is constantly broken and spalled to produce more hyaloclastite.

- Both types of hyaloclastite with different textures are lobe hyaloclastite. The formation processes took place in one lobe body, which was inflated by successive pulses of new magma. In some places the ring structure of lobe hyaloclastite lava-flow with columnar jointing inside part of the lobe is presented.

- The lobe hyaloclastites, described in this paper, resemble other hyaloclastites from well-known deposits in the world, common in submarine felsic successions, is one of the important characteristic facial units of the rocks hosting VMS deposits.

- Two types of rhyodacitic lobe hyaloclastite flows are described in the open pit: hyaloclastite with glassy-like selvages and hyaloclastite with pillow like forms. Absence of different resedimented rock fragments, the gradational contact with coherent lavas, their laterally discontinuos character, absence of bedding suggests their in situ hyaloclastite nature.

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პეტროლოგია

ჰიალოკლასტიტები მადნეულის საბადოს შემცველ წყებაში

ნ. ფოფხაძე

ი. ჯავახიშვილის სახ. თბილისის სახელმწიფო უნივერსიტეტის ა.ჯანელიძის გეოლოგიის ინსტიტუტი, თბილისი
(წარმოდგენილია აკადემიის წევრის დ.შენგელიას მიერ)

მადნეულის ოქრო-სპილენძ-პოლიმეტალური საბადო სამხრეთ საქართველოში ერთ-ერთი უმთავრესი საბადოა, რომელიც კვლავ ათვისების პროცესშია. ის განლაგებულიაართვინ-ბოლნისის ზონაში, რომელიც თავის მხრივ ტეთისის გვიანცარცული სარტყელის ნაწილს წარმოადგენს. მადნეულის კარიერის ფარგლებში გამოყოფილი იქნა რამდენიმე ლითოფაციალური ერთეული და მათი დალექვის გარემო განისაზღვრა როგორც წყალქვეშა. საბადოს შემცველ ქანებში რიოდაციტური შედგენილობის ჰიალოკლასტიტების არსებობა ამ დებულების ერთ-ერთ უტყუარ მტკიცებულებად არის მიჩნეული. ჰიალოკლასტიტები საბადოს შემცველი მაშავერას წყების შემადგენელი ნაწილია.

საბადოზე გამოიყო ჰიალოკლასტიტების ორი ტიპი: ჰიალოკლასტიტები ბალიშისებრი ფორმებით და ჰიალოკლასტიტები მინისებრი არშიებით. სილიციფირებული რიოდაციტური ჰიალოკლასტიტების წარმოშობა განაპირობა წყლისა და ქანის ურთიერთქმედებისას ლავის მყისიერმა გაცივებამ და, შედეგად, მისმა ფრაგმენტაციამ.

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