LAVA/SEDIMENT INTERACTION RESULTED IN A PEPERITE TEXTURE: AN EXAMPLE FROM BOLNISI DISTRICT, GEORGIA

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Abstract. A thin layer of carbonate breccia, with limestone fragments in a red clay and calcite matrix, lies between Pliocene-Pleistocene basaltic lava and Danian limestones. Rare basaltic pieces suggest peperite formation due to lava interaction with wet breccia, with fluidal shapes from ductile deformation. This interaction varied with water saturation.

Key words: fluidal peperite; lava flow-wet sediment interaction; subaerial volcanism; Georgia.
საკვანძო სიტყვები: ფლუიდური პეპერიტი; ლავა/სველი სედიმენტის ურთიერთქმედება; სუბაერული ვულკანიზმი; საქართველო.

გაფართოებული რეზიუმე

ლავა/სედიმენტის ურთიერთქმედებით წარმოქმნილი პეპერიტული ტექსტურა: მაგალითი ბოლნისის რაიონიდან, საქართველო. რ. მიგინეიშვილი, მ. კავსაძე. თანადროული დანალექი და მაგმური პროცესების სივრცეში ზედდებისას, შეიძლება მოხდეს ურთიერთქმედება ცხელ მაგმასა და სუსტად კონსოლიდირებულ და სველ დანალექ ქანს შორის; ეს იწვევს მაგმის ფრაგმენტირებას და ფრაგმენტების შერევას დანალექ ქანში. წარმოიქმნება ქანი სახელად პეპერიტი, სადაც ცემენტი დანალექი წარმოშობისაა, ხოლო კლასტები - მაგმური, რომლებიც ცემენტზე ახალგაზრდაა (Skilling, White, McPhie, 2002).

შპს „კავკასიის სამთო ჯგუფის“ მიერ, სოფელ მუხრანას მახლობლად, გაიბურღა ხუთი სადაზვერვო ჭა, რომლებმაც გადაკვეთა ზედა პლიოცენ-პლეისტოცენური ახალქალაქის წყების ბაზალტები, დანიური ხრამის წყების და აგრეთვე კამპანურ-მაასტრიხტული თეთრიწყაროს წყების კირქვები და მერგელები (ნახ.1). ამას გარდა, მათ გადაკვეთეს კარბონატული ბრექჩიის თხელი (1-110 სმ) შრე, რომელიც იკავებს მკაფიო სტრატიგრაფიულ დონეს ახალქალაქის და ხრამის წყებებს შორის და შედგება ქვეშმდებარე კირქვების დაკუთხული და სუსტად მომრგვალებული კლასტებისაგან. მისი მატრიქსი წარმოადგებს რკინის ჟანგის მიერ წითლად შეფერილი თიხის და კრისტალური კალციტის ნარევს. ერთ-ერთი ჭის კერნში, კარბონატული ბრექჩია შეიცავს გადამფარავი ბაზალტის ფლუიდური ტიპის პეპერიტულ კლასტებს, რომლებიც ხასიათდება ამების მსგავსი კონტურებით (ნახ. 2). ამგვარი მორფოლოგიის პეპერიტი გამოიძერწება ხოლმე პლასტიური დეფორმაციის რეჟიმში (Busby-Spera and White, 1987) და მიუთითებს დინამიკურ ურთიერთქმედებაზე, რომელიც ხდებოდა სუსტად ლითიფიცირებულ და სველ კარბონატულ ბრექჩიის შრესა და მასზე მოძრავ გავარვარებულ ბაზალტურ ლავურ ნაკადს შორის. აღნიშნული ჭის კერნში, მის ბაზალტურ ნაწილში, უშუალოდ კარბონატულ ბრექჩიასთან კონტაქტში, დაფიქსირდა მცირე ნაპრალის და აგრეთვე

ბაზალტში არსებული სფეროიდული სიცარიელების გარკვეული ნაწილის შევსება კარბონატული ბრექჩიის წვრილნატეხოვანი ცემენტით. ეს მოვლენა მიუთითებს სველი და სუსტად ლითიფიცირებული შემცველი სედიმენტის მობილურ მდგომარეობაზე, რაც დამახასიათებელია პეპერიტების წარმოქმნის პროცესისთვის (Kokelaar, 1982; Goto and McPhie, 1996; Doyle, 2000; Dadd and Van Wagoner, 2002).

პეპერიტი და მასთან ასოცირებული წარმონაქმნები არ დაფიქსირდა ბაზალტური ლავა/კარბონატული ბრექჩიის კონტაქტის სხვა გადაკვეთებში. შესაძლოა, სუბაერულ პირობებში, კარბონატული ბრექჩიის შრე არათანაბრად იყო გაჟღენთილი წყლით და ლავა/სედიმენტის ურთიერთქმედება ინტენსიური იყო მხოლოდ იქ, სადაც შრე მაქსიმალურად იყო დასველებული.

INTRODUCTION

The coincidence of penecontemporaneous geological events in space, such as sedimentary and igneous, including effusive and intrusive, can lead to the interaction between hot magma and poorly consolidated, typically wet sediments (Skilling, White, McPhie, 2002). Due to magma-sediment density contrasts, quenching and autobrecciation, forceful mechanical stress, and hydromagmatic explosions, the magma is fragmented and mingled with host sediment to form peperite. Peperite clast morphology can vary from blocky to fluidal indicating brittle or ductile deformation regimes, respectively (Busby-Spera, White, 1987).

The study area is in the Bolnisi district, in southeastern Georgia, near the Mukhrana village. Here the LTD Caucasian Mining Group (CMG) has recently constructed five exploration drillholes, one of them has intersected peperite, the origin of which is discussed in this paper.

The territory of Georgia and the Caucasus as a whole is part of a single Alpine–Himalayan orogenic system that formed from Jurassic–Cretaceous to the present (Jankovic, 1997). This system developed as a result of the convergence of the African, Arabian, Indian, and Indonesian plates and their collision with Eurasia in the area of the former Tethyan oceans (Adamia, Shavishvili, 1979; Adamia Sh. et al., 2010; Gamkrelidze, Dumbadze, Kekeliya, 1981; Gamkrelidze et al., 1999; Zakariadze et al., 2007; Gamkrelidze, Shengelia, 1999). Bolnisi district is situated in the 350-km-long Somkheto-Karabagh tectonic zone of the Lesser Caucasus. The latter is the southernmost part of the Caucasus and developed in the framework of the northeast verging Jurassic-Cretaceous subduction of a northern branch of the Neotethys under the Eurasian continent and closed in Late Cretaceous (Rolland et al., 2011).

The Bolnisi district is characterized by Hercynian basement, unconformably capped by the Upper Carboniferous molasse, as well as by the Upper Jurassic-Cretaceous arc association (Yilmaz et al., 2000). In ascending section these formations are followed by pre-collisional Eocene volcano-sedimentary sequences; post-collisional Upper Miocene-Lower Pliocene basalt-andesite-dacite-rhyolitic subaerial lava sheets and pyroclastic rocks; and, Upper Pliocene-Holocene mainly basaltic subaerial lavas (Adamia et al., 2011).

The Bolnisi ore district is known for its gold and copper deposits hosted by Upper Cretaceous subduction-related bimodal volcanic formations (Moritz et al., 2016). One of the most significant in the province is the Madneuli (Migineishvili, 2005) deposit mined for more than 50 years and producing copper concentrate and gold Dore alloys. The Caucasian Mining Group Ltd recently revealed several new mining targets clustered around the Madneuli. Ongoing geological exploration is still underway.

GEOLOGIC FORMATIONS AND DRILLHOLE COLUMNAR SECTIONS IN THE STUDY AREA

The CMG five drillholes provided additional lithologic and structural data pertinent to this case study. The drillholes intersected the following formations: (i) the Campanian-Maastrchtian Tetritskaro suite; (ii) the Danian Khrami suite; and (iii) the Akhalkalaki Upper Pliocene–Pleistocene suite (Fig. 1).

The Tetritskaro suite is largely composed of grey and bright-white limestones (mainly of the lithographic type), marls, and rare interlayers of variegated tuffs. Sometimes it contains large (0.6-0.8m) concretions of smoky flint. This suite is confined mainly to synclinal structures and is conformably stratified with underlying or overlying deposits. Based on fossils of Ammonites, Inoceramids, Globotruncanas, and other typical Cretaceous fossil groups, collected here, the lower part of the Tetritskaro suite is ascribed to the Campanian stage, and its upper part - to the Maastrichtian stage (Gambashidze, 1979; Gambashidze, 84).

The Danian-aged Khrami suite is composed of limestones similar to the underlying Tetritskaro suite limestones. The lower boundary of the Khrami suite can be assumed based on its thickness of 40m and the presence of Oyster and echinoid Danian fossils. The Cretaceous–Paleogene boundary in this region, as elsewhere in the world, is marked by the mass extinction of species that used to be widespread in the earlier periods. Meanwhile, a flourishing of Paleogene habit microforaminifera also occurred here (Gambashidze, 1979).

Upper Pliocene–Pleistocene Akhalkalaki suite largely consists of basaltic lavas, less often of lenses of fluviatile to lacustrine and alluvial deposits, pyroclastic rocks, and andesitic basalts (Adamia et al., 2010; Adamia et al., 2011). This stage of magmatism was about 2 Ma long and lasted from 3.75 to 1.75–1.55 Ma (Lebedev et al. 2008), releasing considerable volumes of lava. Due to low viscosity, basalts flooded the landscape on a regional scale, spread over large territories, and generated a new landscape of subdued relief – Javakheti Highland's spacious lava plateau. Successive eruptions formed 100 to 300 meters accumulations of nearly horizontal flows.

Late Pliocene-Early Pleistocene mammalian fauna, as well as fossils of Early Pleistocene hominins, have been recovered at the lower level of the Akhalkalaki suite, in lacustrine sediments, at the Dmanisi historical and archaeological site (Gamkrelidze, 1964; Gabunia et al., 1999; Vekua et al., 2002; Pontzer et al., 2010). Dmanisi hominins inhabited the Earth some 1.85–1.75 Ma ago and are the best-preserved fossils of early Homo. The basalts' radiometric age (2.0±0.5 Ma) is in consent with faunistic data (Tutberidze, 2004).

Each drillhole intersected a thin layer of carbonate breccia occupying the distinct stratigraphic level between subaerial Upper Pliocene-Pleistocene basaltic lava flow and underlying Danian limestones (Fig.1). A special case is the drillhole KIRDDH2 that crossed breccia layer twice (at 26.5.0m and 49.5m). It can be explained by the tectonic displacement of the breccia layer along a fault zone represented by tectonically crushed rocks (interval of 27-36m). Laterally, the breccia is traced for a distance of 300 m. It doesn't typically survive erosion for long, so it cannot be found in a surface outcrop. Its thickness is changeable and varies widely, from 1 to 110 cm.

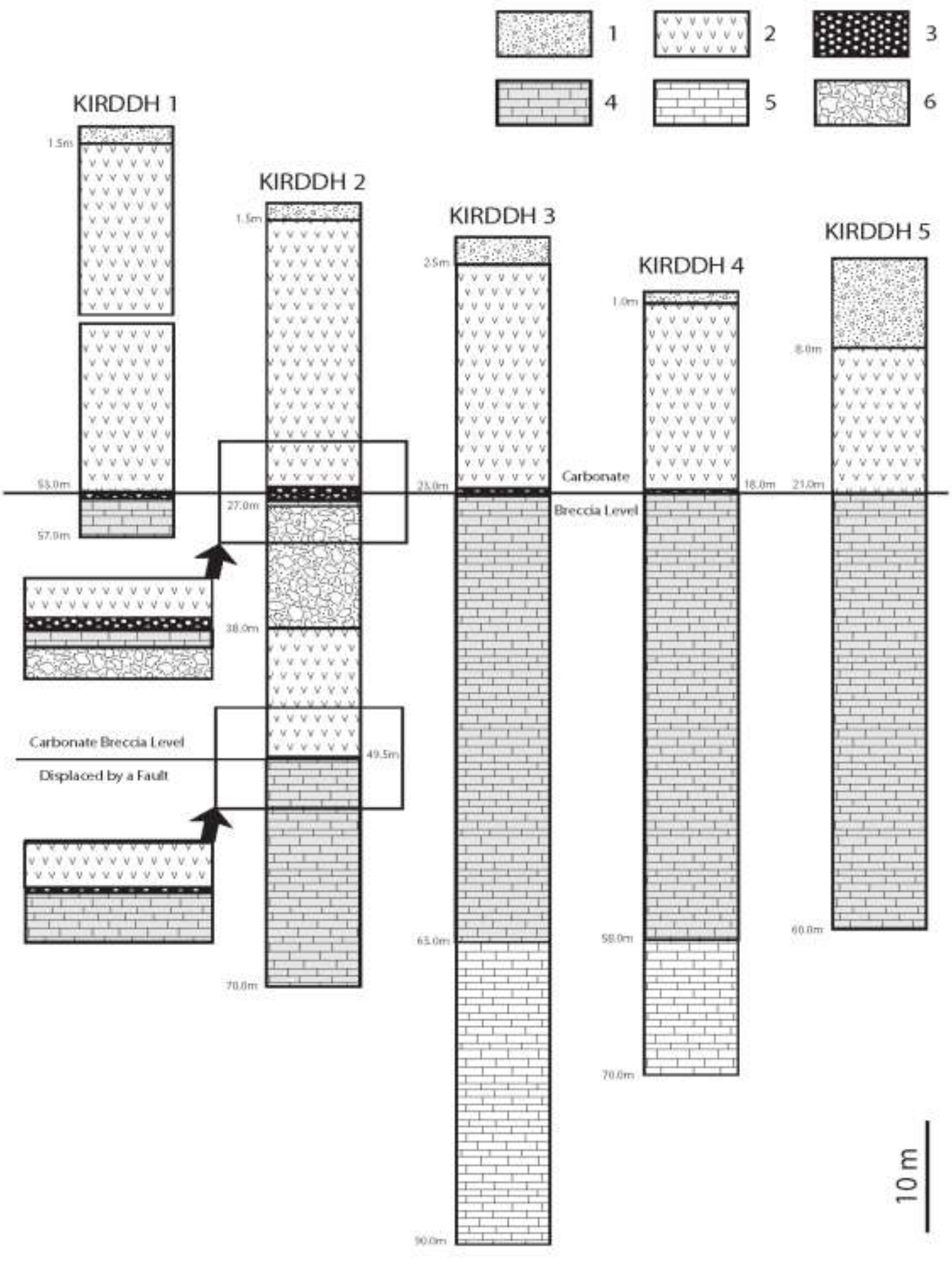

Fig.1. Drillhole columnar sections at the Mukhrana village, Bolnisi municipality. 1 - Eluvial and diluvial deposits; 2 - Akhalkalaki suite; 3 – Carbonate breccia; 4 - Khrami suite; 5 – Tetritskaro suite; 6 – Fault

zone presented by tectonically crushed rocks. For clarity, two intervals of the KIRDDH2 are highlighted separately and enlarged twice in scale.

The carbonate breccia comprises limestone fragments in a mixed matrix of red iron oxide-stained clay and crystalline calcite. This is angular to sub-rounded, millimetric to centimetric (up to 4cm across), poorly sorted, randomly oriented, loosely compacted, highly porous, matrix-supported breccia (Fig. 2). The limestone fragments of breccia contain abundant micro-fossil remains or bioclasts, complete or fragmented.

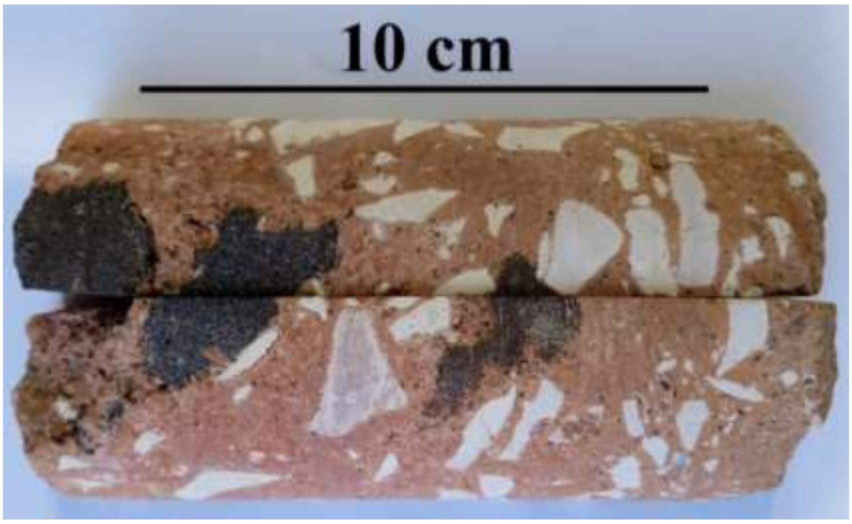

Fig. 2. Fluidal peperite with basaltic black clasts of a few centimeters size in carbonate breccia.

PEPERITE

The carbonate breccia that is intersected in the drillhole KIRDDH2, in the interval of 49.5-49.65 m, contains fluidal peperite clasts derived from overlying basaltic lava flow. Clasts are up to 4 cm across and have amoeboid margins (Fig. 2). Fluidal juvenile clasts are thought to be fragmented in the ductile regime (Busby-Spera and White, 1987). This type of peperite records a dynamic interaction of the carbonate breccia sediment with overlying basaltic hot lava during flow and final emplacement. No peperite was found elsewhere in the other drillhole intervals of the study area.

In the same drillhole, near the contact with the carbonate breccia, basalt hosts a crack filled with fine-grained breccia cement. Its length is 10 cm, its maximum thickness is approximately 5 cm. The crack gradually pinches out. According to Kokelaar (1982) and Doyle (2000), the presence of sediment-filled fractures or joints in the parent intrusion/lava body implies that host sediments were unconsolidated or poorly consolidated, and most likely wet, at the time of interaction with the magma. Fluidization enhances sediment mobility and is a key factor in peperite formation.

The basalt lava body has many vesicles of 2-5 mm across, some of them, in the contact zone, are infilled with carbonate breccia cement. Infillings often are finer-grained, than the bulk of the host sediment. Such infillings are also inferred as indications of the host sediment mobility (Goto and McPhie, 1996; Dadd and Van Wagoner, 2002).

CONCLUSIONS

Interaction between subaerial Upper Pliocene-Pleistocene hot basaltic lava flow and an underlying thin layer of carbonate breccia in the Bolnisi district, Georgia resulted in the localized formation of fluidal peperite with amoeboid margins. Sediment-filled fractures and vesicles in lava flow suggest that the carbonate breccia was unconsolidated or poorly consolidated and wet when the lava flowed over them. A spatial restriction of peperite, as well as sediment-filled fractures and vesicles to just a single locality of the study area, might be caused by possible heterogeneity of water-saturation of the breccia layer at the time of the igneous-sediment interaction. The interaction presumably was intensified where the saturation was maximal.

REFERENCES

Adamia Sh.A., Shavishvili I.D. (1979). Model of tectonic evolution of the Earth crust of the Caucasus and adjacent territory//Geotectonica 1, pp. 77–84.

Adamia Sh., Alania V., Chabukiani A., Chichua G., Enukidze O., Sadradze N. (2010). Evolution of the Late Cenozoic basins of Georgia (SW Caucasus): a review//Geological Society, London, Special Publication, 340, pp. 239–259. doi:10.1144/SP340.11.

Adamia Sh., Zakariadze G., Chkhotua T., Sadradze N., Tsereteli N., Chabukiani A., Gventsadze A. (2011). Geol. of the Caucasus: A review//Turkish Journal of Earth Scien. 20, pp. 489-544.

Busby-Spera C.J., White J.D.L. (1987). Variation in peperite textures associated with differing host-sediment properties//Bull. Volcanol. 49, pp. 765-775.

Dadd K.A., Van Wagoner N.A. (2002). Magma composition and viscosity as controls on peperite texture: an example from Passamaquoddy Bay, southeastern Canada In: Skilling, I.P., White, J.D.L., McPhie, J. (Eds.), Peperite: Processes and Products of Magma-Sediment Mingling// J. Volcanol. Geotherm. Res., v.114. pp. 63-80.

Doyle M.G., (2000). Clast shape and textural associations in peperite as a guide to hydromagmatic interaction: Upper Permian basaltic and basaltic andesite examples from Kiama, Australia//Aust. J. Earth Sci., 47, pp. 167-177.

Jankovic´ S. (1997). The Carpatho–Balkanides and adjacent area: a sector of the Tethyan Eurasian metallogenic belt//Mineralium Deposita, 32, pp. 426-433.

Gabunia L., Vekua A. (1995). Plio–Pleistocene hominid from Dmanisi, East Georgia, Caucasus// Nature, 37, pp. 509-512.

Gabunia L., Joris A., Justus A., Lordkipanidze D., Muskhelishvili A., Nioradze M., Swicher C. III, Vekua A., Bosinski G., Ferring R., Maisuradze G. (1999). Neue hominidefunde des Altpalaolitischen fundplatzes Dmanisi (Georgian Caucasus) in kontext aktueller grabungsergebnisse//Archaologisches Korrespondezblatt Jargang., 29, pp. 451-488.

Gambashidze R.A. (1979). Stratigraphy of the Upper Cretaceous deposits of Georgia and adjacent regions of Azerbaijan and Armenia//Proceedings of Geol. Inst. of Acad. of Scie. Georgia, New Series 61, 226 p. (in Russian).

Gambashidze R.A. (1984). History of the geological development of Georgia in the Late Cretaceous era//Proc. of Geol. Inst. of Acad. of Scie. Georgia, New Ser. 8, 111 p. (in Russian).

Gamkrelidze I.P., Dumbadze G.D., Kekeliya, M.A. (1981). Ophiolites of the Dzirula massif and the problem of the Paleotethys on the Caucasus//Geotektonika 5, pp. 23-33.

Gamkrelidze I.P., Shengelia D.M., Shvelidze Iu.U., Vashakidze G.T. (1999). The new data about geological structure of the Loki crystalline massif and Gorastskali metaophiolites//Proc. of Geol. Inst. of Academy of Sciences Georgia, New Series 114, pp. 82-108.

Gamkrelidze I.P., Shengelia D.M. (1999). The new data about geological structure of the Dzirulla crystalline massif and the conditions of formation of magmatites//Proc. of Geol. Inst. of Academy of Sci. Georgia, New Series 114, pp. 46-71.

Gamkrelidze, P.D. (1964). Geology of the USSR. Georgian SSR. Moscow//"Nedra" X, 655 p. (in Russian).

Goto Y., McPhie J. (1996). A Miocene basanite peperitic dyke at Stanley, northwestern Tasmania, Australia//J. Volcanol. Geotherm. Res., 74, pp. 111-120.

Kokelaar B.P. (1982). Fluidization of wet sediments during the emplacement and cooling of various igneous bodies//J. Geol. Soc. London, 139, pp. 21-33.

Lebedev V., Bubnov S., Dudauri O. Vashakidze G. (2008). Geochronology of Pliocene volcanism of Javakheti highland (Lesser Caucasus). Article 2. Eastern part of the Javakheti highland//Regional Geological Correlation, 16, pp. 101-123 (in Russian).

Migineishvili R.R. (2005). Hybrid nature of the Madneuli Cu-Au deposit, Georgia//Geochemistry, Mineralogy and Petrology, 43, pp. 128-132. ISSN 0324-1718

Moritz R., Melkonyan R., Selby D., Popkhadze N., Gugushvili V., Tayan R., Ramazanov V., (2016). Metallogeny of the Lesser Caucasus: From arc construction to postcollision evolution//Society of Economic Geologists, Special Publication, 19, pp. 157-192.

Pontzer H., Rolian C., Rightmire G. P., Jashashvili T., Ponce de León M. S., Lordkipanidze D., Zollikofer Ch. P. E. (2010). Locomotor anatomy and biomechanics of the Dmanisi hominins//Journal of Human Evolution, 58(6), pp. 492-504.

Rolland Y., Sosson M., Adamia Sh., Sadradze N. (2011). Prolonged Variscan to Alpine history of an active Eurasian margin (Georgia, Armenia) revealed by 40Ar/39Ar dating//Gondwana research 20, pp. 798-818.

Skilling I.P., White J.D.L., McPhie J. (2002). Peperite: a review of magma-sediment mingling. In: Skilling, I.P., White, J.D.L.,McPhie, J. (Eds.), Peperite: Processes and Products of Magma–Sediment Mingling//J. Volcanol. Geotherm. Res., vol. 114, pp. 1–17.

Tutberidze B. (2004). Geology and Petrology of Alpine Late Orogenic Magmatism of the Central Part of Caucasian Segment//Tbilisi University Publishers, Tbilisi, pp. 1–340. (in Russian).

Zakariadze G.S., Dilek Y., Adamia Sh.A., Oberhaensli R.E., Karpenko S.F., Bazylev B.A., Solov'eva N. (2007). Geochemistry and geochronology of the Neoproterozoic Pan-African

Transcaucasian Massif (Republic of Georgia) and implications for island arc evolution of the late Precambrian Arabian–Nubian Shield//Gondwana Research 11, pp. 92-108.

Vekua A., Lordkipanidze D., Rightmire P., Agusti J., Ferring R., Maisuradze G., Mouskhelishvili A., Nioradze M., Leon M., Tappen M., Tvalchrelidze M., Zollikofer C. (2002). A new skull of early Homo Dmanisi, Georgia. Science, 297, pp. 85-90.

Yilmaz A., Adamia Sh., Chabukiani A., Chkhotua T., Erdogan K., Tuzcu S., Karabilykoglu M. (2000) Structural correlation of the southern Transcaucasus (Georgia)-eastern Pontides (Turkey)//Tectonics and magmatism in Turkey and the surrounding area. Geological Society, London, Special Publication, 173, pp. 171-182.

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