INTRFLOW VARIEGATED HORIZONS OF THE JAVAKHETI VOLCANIC PROVINCE

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Abstract. The article presents a brief description of interflow horizons from several locations of Javakheti - the villages Khertvisi, Toloshi, Khando, Kilda, Gelsunda and Akhalkalaki, which is related to the issue of boluses identification. This event was studied for the first time in Georgia by the group of the article authors.

Key words: Javakheti volcanic province; interflow horizons; red bolus.
საკვანძო სიტყვები: ჯავახეთის ვულკანური პროვინცია; ლავათშორისი ჰორიზონტები; წითელი ბოლუსები.

გაფართოებული რეზიუმე

ჯავახეთის ვულკანური პროვინციის ლავთშორისი ფერადი ჰორიზონტები. მ. კავსაძე, გ. ვაშაკიძე, ქ. გაბარაშვილი, თ. ბერიძე, კ. ლობჟანიძე, ვ. გაბუნია. ჯავახეთის ვულკანური პროვინციის ფიზიკური ვულკანოლოგიის კვლევის ერთ-ერთ მნიშვნელოვან მიმართულებას ლავათშორისი ვულკანოგენურ-დანალექი წარმონაქმნების შესწავლა წარმოადგენს. ამ ჰორიზონტების შესწავლა ვულკანური პროცესის განვითარების, გარემოს ეკოლოგიური პირობების და ამ პირობების შეცვლის შესახებ მნიშვნელოვან ინფორმაციას იძლევა. კვლევების ეს მიმართულება პერსპექტიულია რეგიონის პალეოლანდშაფტისა და პალეოეკოლოგიური რეკონსტრუქციებისთვის.

ამ ჰორიზონტებს დიდი ხანია იცნობს ქართული გეოლოგიური საზოგადოება როგორც ლავათშორის ნალექებს, მაგრამ მათი ღრმა კვლევა არსად არ არის წარმოდგენილი და მხოლოდ საველე განსაზღვრების საფუძველზე მათ ან გამოწვის, ან ძველი ნიადაგების ჰორიზონტებად მოიხსენებენ. არადა, სწორედ ვულკანური წარმონაქმნების შეცვლის ეს პროდუქტები იძლევა წარმოდგენას გარემოს პალეოეკოლოგიურ პირობებზე.

ჩვენი ჯგუფის მიერ, არაერთი წამყვანი სპეციალისტის მოსაზრების საფუძველზე (Widdowson, Walsh, et al., 1997; Turner, Hopper, et al., 1986; Shilman, 1986) და საკუთარ დაკვირვებებზე დაყრდნობით, შემუშავდა ბოლუსის განსაზღვრა. აღნიშნული განსაზღვრა არ უნდა მივიჩნიოთ აბსოლუტურ წესად, არამედ მიმდინარე სამუშაო ვარიანტად, რომელიც გაგვიადვილებს ბოლუსების გამიჯვნას სხვა მსგავსი ნალექებისგან.

ჩვენი აზრით, ბოლუსები ორ დიდ ვულკანურ ეპიზოდს შორის მცირე პაუზისას წარმოქმნილი სუსტი გამოფიტვის პროდუქტია, რომელიც ცხელი პიროკლასტური მასალის წყალთან კონტაქტისას, სწრაფი გაცივების შედეგად წარმოიქმნება. მას ახასიათებს

მცირე სიმძლავრე, მინერალური და ქიმიური შემადგენლობის სიახლოვე საწყის ქანთან, ამასთან, შეცვლის პროდუქტებიდან აუცილაბლად უნდა შეიცავდეს სმექტიტურ თიხას, ცეოლითებს და რკინის ჰიდროჟანგებს.

ჯავახეთის ვულკანური პროვინციის ფარგლებში შეირჩა საყრდენი ჭრილები, რომელიც ნათლად წარმოაჩენდა ფიზიკური ვულკანოლოგიის თავისებურებს და ლავათშორისი ჰორიზონტების შეცვლებში განსხვავებებს. ეს ჭრილები მდებარეობს სოფლების ხერთვისის, ტოლოშის, ხანდოს, ქილდას, გელსუნდას და ახალქალაქის მიმდებარე ტერიტორიაზე.

საველე სამუშაოების დროს აღებული ნიმუშების ქიმიური XRF-ანალიზი განხორციელდა ხელსაწყო Spectrosceute geo გამოყენებით, პეტროგრაფიული აღწერები გაკეთდა მიკროსკოპების Optica და Amscop საშუალებით, ხოლო XRD ანალიზი ჩატარდა ДРОН-2,0 Cu-antikat. ყველა კვლევა შესრულდა ალექსანდრე ჯანელიძის სახელობის გეოლოგიის ინსტიტუტის გეოლოგიური კვლევის კომპლექსურ ლაბორატორიაში და, ნაწილობრივ, პეტრე მელიქიშვილის სახელობის ფიზიკური და ორგანული ქიმიის ინსტიტუტის ლაბორატორიაში.

კვლევების შედეგად ვასკვნით, რომ ხერთვისი I-ის, ტოლოშის, ხანდოს, გელსუნდასა და ახალქალქის ლავათშორისი წითელი დეპოზიტები XRF და XRD ანალიზის შედეგების მიხედვით წარმოადგენს წითელ ბოლუსებს, ანუ აკმაყოფილებს ბოლუსის ჩვენს მიერ შემუშავებულ განმარტებას.

ხერთვისი III-ისა და ხანდოს მოწითალო, ნაცრისფერი და შავი ჰორიზონტები არც ბლუსებს წარმოადგენს, არც პალეონიადაგებს, არც ლატერიტებს და არც გამოწვის ჰორიზონტებს. სავარაუდოდ, ეს საღ პიროკლასტიკასა და ბოლუსებს შორის გარდამავალი ეტაპის ჰორიზონტებია.

ჩვენი აზრით, ხანდოს, გელსუნდასა და ახალქალაქის ფერად ჰორიზონტებში დაფიქსირებული ფანქრისებური ფორმები წყლის აორთქლებისას გაჩენილ ბზარებთან უფრო მეტ მსგავსებას ავლენს, ვიდრე ლავურ განწევრებასთან. ამასთან, ამგვარი ფორმები მხოლოდ წვრილმარცვლოვან გრუნტებში გვაქვს და არ გვხვდება მსხვილ პიროკლასტურ დეპოზიტებში, ვინაიდან ეს უკანასკნელი არაჰომოგენურ გრუნტს წარმოადგენს. ე.ი., ამგვარი ფორმების წარმოქმნა ხდება არა კრისტალიზაციისა და გაცივების პროცესში, არამედ აერაციულ გარემოში მაღალი ტემპერატურის პირობებში თიხა-ქვიშიანი გრუნტების მიერ წყლის სწრაფი, ინტენსიური კარგვისას - განწევრების პროცესისგან საკმაოდ განსხვავებული პროცესის დროს. ამიტომ ვფიქრობთ, რომ პიროკლასტურ მასალაში წარმოქმნილი ფანქრისებური ფორმების მიმართ არ უნდა ვიხმაროთ ტერმინი „ფანქრისებრი განწევრება“, არამედ ვიხმაროთ ტერმინი „ფანქრისებრი“ გამოშრობის ნაპრალები, ან გვალვის „ფანქრისებრი“ ნაპრალები, ან სულაც „ფანქრისებრი“ შრობის ბზარები.

ქილდას წითელი ჰორირიზონტი, მახასიათებლების მიხედვით, ორი ლავის ცხელ კონტაქტად უნდა მივიჩნიოთ.

წარმოდგენილი სტატია საწყისი კვლევების მასალას ეყრდნობა. კვლევები გრძელდება და ჯგუფის წევრები ყოველწლიურად ავსებენ და აზუსტებენ ბოლუსებთან დაკავ-

შირებულ მონაცემებს, რომელიც ეტაპობრივად იქნება წარმოდგენილი პუბლიკაციების სახით.

INTRODUCTION

The Javakheti Volcanic Province (Fig. 1) extending over the area of synonymous highland is situated in central part of the Lesser Caucasus Mountain system and is an important center of voluminous post-collisional volcanism. The area boundaries correspond to the Childyr Lake (Chrdili Lake), Shirak and Bazum ridges on the south, the Mtkvari (Kura) River upper reaches on the west, the Trialeti Ridge composed of the Paleogene volcanogenic-sedimentary rocks on the north. The eastern distribution limit of young volcanics corresponds approximately to the Tsalka–Gomareti–Dmanisi-Stepanavan line, though three large flood basalt lava flows extend along the Mtkvari (Kura), Mashavera and Khrami valleys outside the delineated area. The sequence of volcanics erupted from Neogene to Quaternary, and mostly during the Pliocene epoch. The volcanics form a part of continental flood basalts that are spread across southern Georgia, central and northern Armenia and NE Turkey, which was named by Sheth et al. (2015) as South Caucasus Continental Flood Basalt (CFB) Province (Gabarashvili et al., 2019).

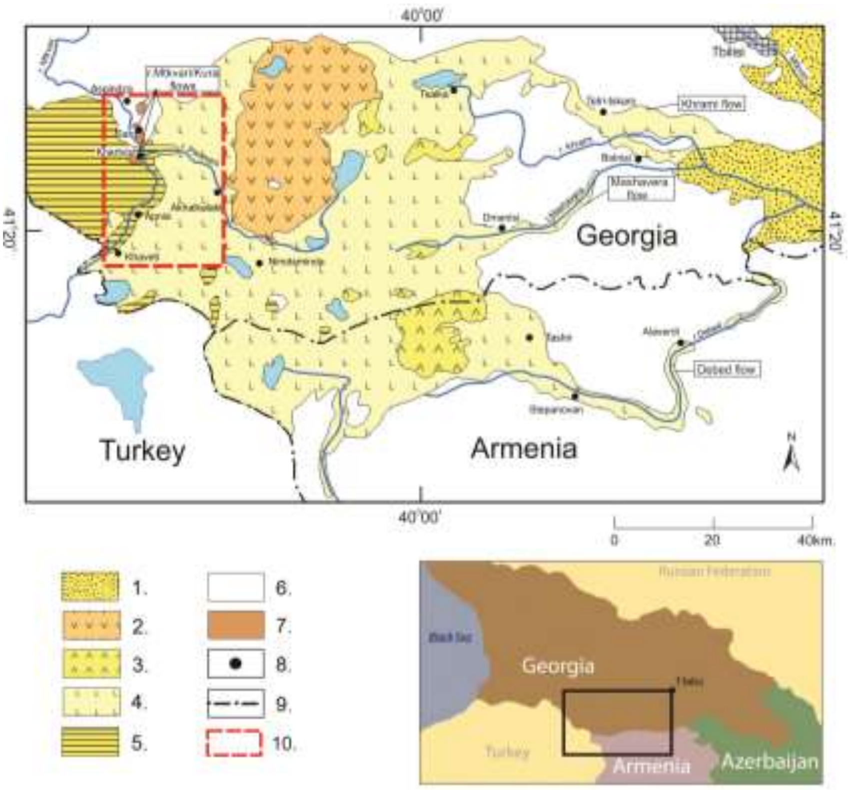

Fig. 1. Geological Sketch Map of Javakheti Volcanic Province (modified from V. Lebedev et al. 2008)

1. Quaternary sediments; 2. Late Quaternary dacite volcanics of the Samsari ridge; 3. Pliocene andesites, dacites and rhyolites of Javakheti ridge; 4. Pliocene volcanics of Akhalkalaki suite (basalts, sub-alkaline basalts, andesite-basalts, andesites); 5. Late Miocene Volcanics of Goderzi suite (andesites, dacites); 6. Pre- Neogene igneous and sedimentary formations; 7. Mtkvari(Kura) flows; 8. Settlements; 9. State Border; 10. Study area.

Despite active research by Georgian and foreign investigators in this province, documentation of the physical volcanology of these widespread basalt lavas seems to be missing in literature. Since 2016 the authors of the article have undertaken the study of physical volcanology of the Javakheti lava flows in order to build robust volcanic facies architecture of the province, which is the first of its kind. These studies have already revealed some important physical volcanological features, which can be used to identify volcanic and sedimentary facies that can shed light of emplacement dynamics of the eruptions and paleoenvironment (Beridze et al., 2017). The comprehensive study of the interflow sediments including bole beds is being undertaken for the first time as well. The interflow sedimentary units (boles) keep an important record on paleoenvironmental conditions existed during major eruptive events and are essential for paleo-landscapes and paleo-ecological reconstructions.

THE STUDY HISTORY OF THE INVESTIGATED AREA

The study of the geology of Javakheti has a long history - starting with Abich (Von Abich, 1879), probably there is not a single great geologist working in Georgia who has not studied different aspects of the geology of this area. In this regard, the greatest contribution was made to the study of volcanism in the region by G. Dzotsenidze (Dzotsenidze G., 1954), N. Skhirtladze (Skhirtladze N., 1958), G. Zaridze (1961), B. Tutberidze (2004), O. Dudauri, V. Lebedev, G. Vashakidze (Lebedev et al., 2008), and others. Important for us data were found in the contributions by D. Jigauri (Jigauri D, 1975), and G. Maisuradze (Maisuradze G., 1981).

THE ACTUALITY OF THE PROPOSED RESEARCH

Despite the extensive bibliographic data, information about sedimentary horizons between lava flows is fairly limited, and the study results of the phenomenon called bolus horizons of weathering was presented for the first time in Georgia by our group to the geological community at the mineralogical society conference (Kavsadze et al., 2018).

These horizons have long been known to the Georgian geological community as interflow deposits, but their in-depth studies have not been presented anywhere, and only on the basis of field determinations they are called either baked horizons or paleosols. However, these products of volcanic rocks alteration provide essential information of the paleoecological conditions of the environment.

BRIEF INFORMATION ABOUT BOLUSES

The study of boluses, or as they are called in the English-language literature "boles" by the world's leading volcanologists, sedimentologists and pedologists, began in the 50-ies of the 20th century and has acquired a wide scope today, due to the ecological content mentioned above.

The term "bole" in Scots means mud, bog dirt and was first recorded in Scottish sources in 1338. In Greek-Latin sources, "bolus" means a pill, since red boluses, which are smectic clays, were used to make pills for intestinal infections. Here, the same term was used to refer to the land lump. The Latins called "bolus" clay from Leucas and Lemnos. In recent years, Russian researchers (Peryazeva, Plyusnin et al., 2001) use both the term "red bole" and "red bolus".

The authors of the article have decided to choose "bolus" as the Georgian volcanological term, since "bole" would create some confusion.

Red bolus is primarily a color term. It refers to clay pigments ranging from red through yellowish and pink shades to brown. Among them the most widespread is "terra rossa", salmon color (pink-orange) and brown.

Red boluses have been used as a dye, medicine and food additive (and in some places to this day) since ancient times, mainly in Armenia, Iran, the Mesopotamian states and in general in almost all regions of the Fertile Crescent. In painting and applied art, bolus paints are still widely used today both as a pigment (for example, "Armenian bole") and as a primer (especially for smoothing the gold-ground surfaces of wooden furniture and frames) (Fig. 2).

Fig. 2. 14th-century gold-ground Italian painting where the gold leaf has worn away to reveal the red bole beneath (The New Oxford American Dictionary. 3rd ed. 2013).

TERMINOLOGICAL CONFUSION

Despite a millennial history of studies, there is still no consensus on the criteria needed to identify boluses. We often come across cases when different researchers call the same object a bolus (red bole), a laterite soil, a paleosol, and a baked horizon. The formation of an agreed opinion here has not yet happened, and this somewhat complicates the qualification of these formations.

Due to many contradictions, some scientists use differential analysis when determining boluses, in particular, excluding laterites, red earth soils and the baked horizon, i.e. hot contact. Since, unlike bolus, there are more or less established ideas about the listed events: laterite (Fig. 3) is considered to be an eluvial sediment obtained as a result of deep chemical weathering (dissolution and hydration), the formation of which requires the infiltration of torrential rain water characteristic of a humid tropical or subtropical climate into the ground, which is accompanied by the massive migration of elements by both ground water and capillary water (Widdowson, Walsh, et al., 1997). Besides, boluses (boles) are found between lava flows, and thus formed in the time breaks (a few decades to thousands of years) between successive eruptions, whereas the laterites have developed on top of the continental flood basalts sequences over tens of millions of years after volcanism ceased. Boles are generally local-scale features, whereas the laterites have a regional-scale distribution (Duraiswami, et al., 2020).

For red earth soils (Fig. 4) formation, aside from tropical rains infiltration, seasonal migration of groundwater capillary rise and accumulation of certain organic material (humus) is required.

Hot contact implies the iron oxides and hydrogen oxides formation during onlapping of two lava flows and the presence of a watery surface between them, which gives the lava a red color.

Fig. 3. Laterite (Crosta lateritica, 2019).

Fig. 4. Red earth soil (Urushadze, 2014).

At present the genetic interpretation of boluses is fairly diverse. Some researchers think that boluses (Fig. 5) are considered to be the formation of weak weathering products when the pyroclastic material between two lava flows interacts with water. At the same time, in this case water might be both atmospheric precipitations and from lakes, swamps, rivers, and seas. For the final formation of the bolus hydrothermal process is essential as well (Widdowson, Walsh, et al., 1997). According to other interpretations the boluses might be alteration products of lava flow bases or lava flow tops, weathering products of flowtop and flow-bottom breccias in CFB lava flows, or represent altered volcanic ash or inter-flow sediments (Duraiswami et al., 2020 and references herein). Various shades of red and brown are the most common colors of boles, but nowadays green, yellow, purple, gray, or black boles are also described and studied. The color of boles is mostly conditioned by their mineral composition (Duraiswamy, et al., 2020 and references herein).

Based on the opinion of a number of leading experts (Widdowson, Walsh, et al., 1997; Turner, Hopper, et al., 1986; Shilman, 1986) and our own observations, we have developed a definition of bolus that should not be considered an absolute rule, but a working option which makes it easier to distinguish boluses from other similar sediments.

We consider that boluses are the products of weak weathering formed during a short break between two large volcanic episodes as a result of rapid cooling of hot pyroclastic material in contact with water, and are characterized by small thickness, and are close by mineral and chemical composition to the original rock. Besides, as alternation products it must contain smectic clay, zeolites and iron hydroxides.

After formation of the laterite complete profile only aluminum and iron oxides remain from the initial rock. Red earths are also formed as a result of complete transformation of the initial rock, representing the uppermost productive layer of the soil, and it must contain a certain amount of organic matter for productivity. Baked (hot) contact develops as a result of wet interaction of two lava flows and does not undergo other transformations aside of iron oxide (hematite) formation and developing of weak argilization in the contact zone. Besides, the bolus composition resembles that of the initial rock composition. In particular, by chemical composition SiO_2/Al_2O_3 value in laterites is 2 and in red earths - ≤2, whereas in boluses it slightly differs from the initial rock's composition. The content of Ca, Na, K, Ti is slightly reduced as well.

Fig. 5. Red bolus (Gerta, 2017).

According to marker minerals content, hydrargillite $Al(OH)_3$, boehmite AlO[OH], diaspore $HAlO_2$ are considered as essential components. In the red earths initial/primary minerals nearly no longer exist, but presence of humus substance that should not be less than 7.7 % and of the relics of herbal detritus (roots) is essential (only black soils comprise more amount of humus – up to 11 to 17 %). Bolus should necessarily comprise smectic clays, zeolites, and iron hydroxides and in some cases presence of oxides is essential as well.

Time needed for the generation of these formations is important as well. In the formation of laterites, in addition to climatic, anthropogenic and biogenic factors, time is an important factor. Formation of thick Deccan laterites (more than 50-80 meters in southern Ghat Province) named as superballs by Widdowson et al. (1997), continuously developed uninterrupted during entire Tertiary after the eruptions had ceased.

The thickness of red earths is greater. For example, their thickness reaches 200-300 meters along the Black Sea coastal line of Achara. As for their formation time, it depends on the climate changes and varies in the wide range.

The thickness of boluses varies inat most 8-10 meters range. It was believed that they needed millennia to form. Then this time was reduced to centuries, and finally, during the last activity of Kilauea (7 june, 2023), under the heavy rain conditions, both direct observers and those who were watching this event on television saw that formation of red boluses took place in 24 hours' time.

There is an opinion according to which the boluses are formed on the basis of pyroclastic material (e. g. Widdowson et al., 1997). Our studies have confirmed this opinion and have revealed that the boluses from Javakheti volcanic province were formed as a result of pyroclastic material alternation.

Below the results of our study of interflow horizons of Khertvisi, Toloshi, Gelsunda, Akhalkalaki, Kilda and Khando are presented.

RESEARCH METHODOLOGY

Chemical XRF-analysis of collected samples were carried out using „Spectrosceute geo“, petrographic descriptions were conducted on microscopes Optica and Amscop (USA), and XRD-analysis was performed using DRON-2.0 Cu-antikat device. All studies were performed at Complex Laboratory of Geological Research of Al. Janelidze Institute of Geology and, partially in the laboratory of the Melikishvili Institute of Physical and Organic Chemistry of Tbilisi State University.

THE STUDY AREA OF THE JAVAKHETI INTEFLOW HORIZONS

Representative sections showing characteristic features of physical volcanology of the lava flows and variations in interflow horizons alterations were selected in the area of the Javakheti volcanic province (Fig. 6).

The exposures of young lava flows were studied in the vicinities of the village Khertvisi: section Khertvisi I -near the village Khertvisi entrance and section Khertvisi III – on the right bank of the Mtkvari River.

Five lava flows composed of several flow lobes were established in the Khertvisi I section (Fig. 7). The horizon of pyroclastic flow deposits consisting of coarse rock fragments was distinguished between the lobes 17 and 18 of the 5th Flow.

Fig. 6. Javakheti volcanic province with indication of studied sections on Google map:
1. Khertvisi I, 2. Khertvisi III, 3. Toloshi I, 4. Kilda, 5. Khando, 6. Akhalkalaki “pencils” (along the Akhalkalaki highway), 7. Gelsunda.


1

2

Fig. 7. Khertvisi I: 1. General view; 2. Red Bolus exposure under the lava flow.

According to XRF analysis results the SiO_2/Al_2O_3 ratio in the basalt (bedrock) is 3.01 and for the red horizon is - 3.54. According to X-Ray diffraction analysis (XRD) aside from primary minerals – plagioclases and pyroxenes, reflection peaks of montmorillonite (16,068Å), illite (13,53Å), heulandite (3,996Å, 2,931Å) and mordenite (8,23Å, 6,44Å) as well as weak reflection peaks of β-hydrohematite (2.56Å, 3,30Å, 1,612 Å) and hydrogoethite (4,178Å, 2.45Å, 2,69Å) are observed. In the thin section the rock was classified as an argillized and limonitized lithics- and crystals-rich (lithocrystaloclastic) tuff exhibiting rhombic micro-jointing (Fig. 8). In the lithic clasts primary basalt textural-mineralogical features are preserved.

The section Khertvisi III is composed of one flow (Fig. 9) with the red pyroclastic horizon at the base comprising coarse rock clasts.

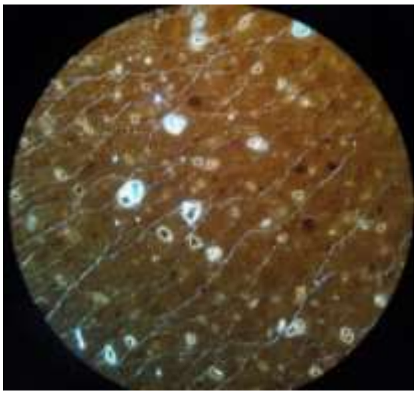

Fig. 8. Photomicrograph of the Khertvisi I red horizon XPL (X40).

According to XRF analysis results the SiO_2/Al_2O_3 ratio in the basalt is 3.55 and for the red horizon is – 3.085. According to XRD analysis in the red horizon montmorillonite-vermiculite (15,399 – 13,53Å), and goethite (4,133Å) was identified. Zeolites are not present. In the thin section the rock was classified as a lithic rich (lithoclastic) tuff (Fig. 10), where lithic clasts have completely preserved their primary texture and mineral composition. The cement represents highly argillized and ferruginous glass. The rock is very porous.

The Toloshi village section is located on the left bank of the river Mtkvari, behind the village, overlooking the entrance road to Khertvisi. 15 lava flows were recorded here. Between the flows 14 and 15 there is a graded (probably lacustrine sediments) red colored horizon up to 6 m thick (Fig. 11).

Fig. 9: Khertvisi III: 1. General view; 2. Hand specimen from the red horizon; 3. Coherent lava flow; 4. Red bolus exposure at the bottom of the lava flow.

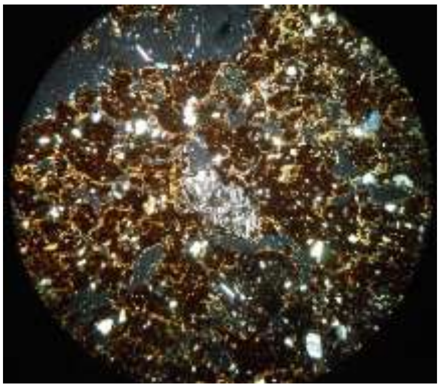

Fig 10. Photomicrograph of the lithic clasts rich tuff. XPL (X40).

According to the XRF analysis results of the Flow 16 sample the SiO_2/Al_2O_3 ratio is 2,771 which indicates the facies change (the rock is the andesite-basalt) and for the red horizon is - 3.085. In this case the ratio is close to the primary rock value. According to XRD analysis in the red horizon abundant montmorillonite (16,068Å), goethite (4,133Å) and heulandite (3,996Å) have been identified. In the thin section the rock was classified as lithics and crystals rich vitric (litocrystalovitroclastic) tuff where clasts have preserved the primary rock texture and composition. Crystal's clasts are represented by plagioclase interstitions (Fig.12), cement is represented by highly altered to clay (argillized), zeolitized and limonitized glass.

1

2

3

Fig. 11. 1 - General view of the Toloshi-I section exposure; 2, 3 - Outcrops of the Toloshi variegated horizons.

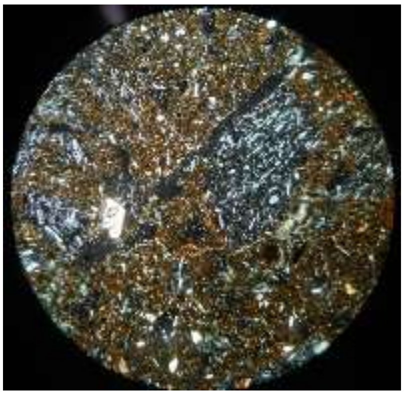

Fig. 12. Photomicrograph of the Toloshi red horizon. XPL (X40).

The flow with multiple lobes is exposed in the vicinity of village Kilda. Here the red horizon is developed between two lava lobes (Fig. 13).

According to the XRF analysis results of Kilda SiO_2/Al_2O_3=2,81, and according to XRD analysis the mineral composition of the rock is close to basalt. However, the presence of calcite (3,029Å, 1,807-1,791Å) and goethite (4,133Å) was established as well. In the thin section the rock specimen is classified as basalt with doleritic (ophitic) texture where interstitials are completely replaced by iron hydroxide (goethite), traces of calcite and heulandite (3,952Å) are observed, argillization was not established (Fig. 14).

Fig. 13. 1, 2 - Kilda lava flow; 3, 4 - Red horizon.

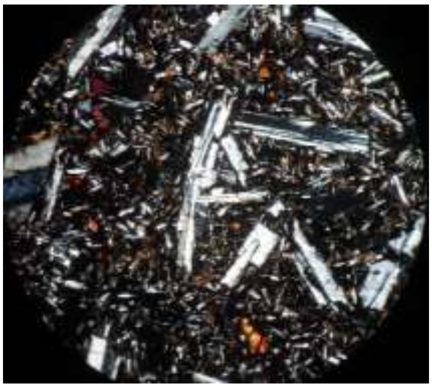

Fig. 14. Photomicrograph of the Kilda red horizon XPL (X40).

On the left bank of the Chobareti River in the vicinity of Khando village, variegated interflow horizons (pinkish, red, gray, black) were observed (Fig. 15, 16). In this section a phenolmenon called "pencil jointing" is recorded (Sakrar, Chakranarayan et al, 2000).

1 2 3

Fig. 15. Hand specimen photos of grey (1), black (2) and red boluses (3).

According to Widdowson et al. (1997) black boluses formation is related to substantial deposition of ash with a devastating harmful impact on local flora and fauna. Therefore, the study of such horizons is important in the evaluation of the continental flood basalt eruptions on ancient biota and climate.

It should be noted that joints (e.g. columnar) develop in extrusive volcanic rocks (e.g. lava flows) by cracking due to cooling-driven contraction, and is accompanied by the formation of regular geometric shapes (e.g. Lamur, A. et al., 2018). In the case of red boluses, irregular, thin columns are formed, which do not resemble the jointing in basalt flows, but drought-induced desiccation cracks characteristic of clay-sand soils (Sarkar et al., 2000). Therefore, we believe (Kavsadze et al., 2022) for boluses, we should use the term "pencil-like" desiccation or shrinkage cracks and not jointing (Fig. 16-1).

According to the XRF analysis of the grey horizon SiO_2/Al_2O_3=4,649. By XRD analysis plagioclase (anorthite), montmorillonite and α-cristobalite were identified. In the thin section the rock specimen is classified as the crystal-rich (crystalloclastic) tuff (Fig. 17-1). XRF analysis of the black horizon revealed that SiO_2/Al_2O_3=3,973 and by XRD analysis montmorillonite, α-crystobalite, plagioclase, pyroxene, and traces of hematite were identified. In the thin section the rock specimen is classified as vitric (vitriclastic) argillized and fragmented tuff (Fig. 17-2). By the XRF analysis of the red horizons SiO_2/Al_2O_3=4,423 and by the XRD analysis hematite, montmorillonite, α-cristobalite and traces of chabazite were identified. In the thin section the rock specimen is classified as strongly altered crystal-rich vitric (crystallovitriclastic) tuff (Fig. 17-3).

1 2

Fig. 16. Khando interflow variegated horizons: 1. Grey and black horizons with developed in them “pencil-like” desiccation/shrinkage cracks; 2. Pinck-carroty (orange-red) and red horizons.

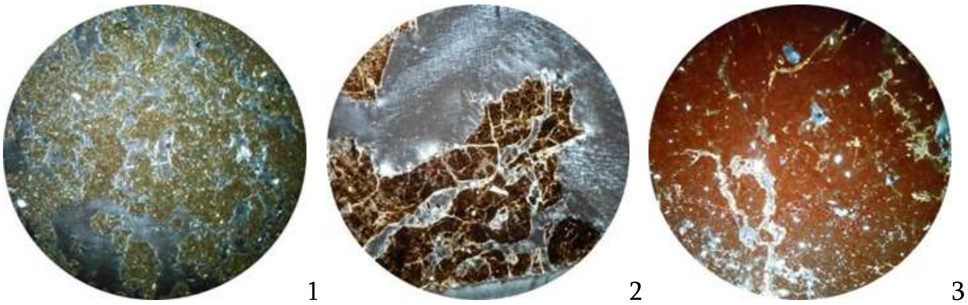

Fig. 17. Photomicrographs of 1. Grey, 2. Black and 3. Red boluses XPL (X 40).

Near the village of Gelsunda, across the road, almost 10-meters thick exposure of the red horizon is observed, with a fairly clear grading of the material and an intercalation of "pencil-like" dessication cracks (Kavsadze et all, 2022). The outcrop is steep and difficult to access, making sampling extremely difficult. However, we were able to obtain material from the horizon of pencils from the uppermost zone (Fig. 18).

Fig. 18. General view of the Gelsunda red horizons.

As can be seen from macro- and binocular photos of "pencils" (Fig. 19, 1 and 2), these formations do not have correct geometric shapes. The sizes of the "pencils" range from 2 X 0.5 cm to 9 X 2 cm. The surface under the binocular is filled by cracked yellowish material. According to the XRF analysis SiO_2/Al_2O_3=3,541. By XRD analysis the mineral of illite-montmorillonite series 17.673Å, anorthite-bytownite 3.493; 3.186Å, pyroxene 3.186; 3.003Å, mordenite 8.42; 3.996Å, and gothite 4.182; 3.363Å were distinguished. In the thin section the rock specimen corresponds to vitric (vitriclastic) tuff, widely argillized and limonitized. Growth of limonite concretions and replacement of plagioclases by zeolites is observed as well (Fig. 20).

a b

Fig. 19. Gelsunda "pencils": a – hand specimens; b – in the binocular microscope.

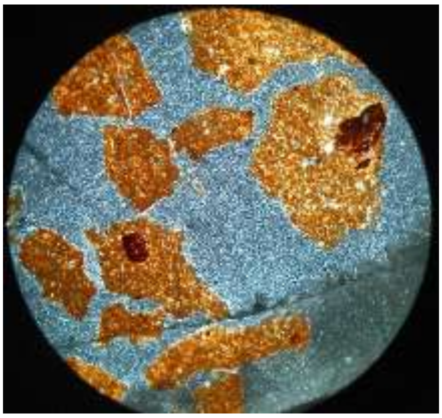

Fig. 20. Photomicrograph of the Gelsunda "pencils". XPL (X40).

The red horizon containing "pencil-like" desiccation cracks is observed at the base of the lava flow, which is exposed on the right bank of the river Paravani along the Akhalkalaki-Khertvisi highway (Fig. 21).

Fig. 21. Natural exposure of the Akhalkalaki red "pencils".

Macro- and microphotographs of both Gelsunda and Khando and Akhalkalaki "pencils" (sizes from 1×2 cm to 3×4 cm) revealed that they do not have correct geometric shapes. However, on the binocular photo of the Akhalkalaki "pencils", desiccation cracks on the surface have certain lecal, though irregular shapes. By observing them, we are convinced that these cracks are more similar to the cracks formed under the influence of higher temperature, during intensive evaporation of water, than to jointing (Fig. 22, 1-2-3-4).

According to XRF analysis SiO_2/Al_2O_3=3,608 and by XRD analysis weakly crystalline montmorillonite 17.673Å, illite10.1Å, morencite (nontronite) 12.63; 4.497Å, anorthite-bytownite 3.78; 3.20Å, mordenite 9.075; 5.125; 3.363Å and goethite 4.281; 3.363Å were identified. In the thin section the Akhalkalaki "pencils" correspond to widely argilized and limonitized lithic-rich vitric (lithocrystalloclastic-vitroclastic) tuff. Plagioclase and pyroxene phenocrysts are observed, limonite forms concretions as well as fills micro-cracks, some of plagioclase crystals are replaced by zeolite (Fig. 23).


1 2 3 4

Fig. 22. Akhalkalaki "pencil-like" desiccation cracks in hand specimens – 1, 3; 2, 4 – in the binocular microscope.

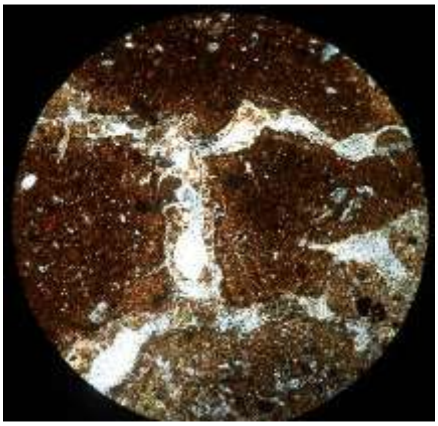

Fig. 23. Photomicrograph of the Akhalkalaki “pencils”. XPL (X40).

CONCLUSIONS

According to the results of XRF and XRD analysis, the inter-lava red deposits of Khertvisi I, Tolosi, Khando, Gelsunda and Akhalkalki represent red boluses, i.e. they meet mentioned above definition of the article authors, according to which they are the products of weak weathering formed during a short break between two large volcanic episodes as a result of rapid cooling of hot pyroclastic material in contact with water, and are characterized by small thickness, and are close by mineral and chemical composition to the original rock. Besides, as alternation products it must contain smectic clay, zeolites, and iron hydroxides. The reddish, gray and black horizons of Khertvisi III and Khando represent neither boluses, nor paleosols, nor laterites, and nor backed horizons. Apparently, these are transitional stage horizons between fresh pyroclastic rocks and boluses.

In our opinion, the pencil-like shapes observed in the variegated horizons of Khando, Gelsunda and Akhalkalaki are more similar to cracks formed during water evaporation than to lava jointing. However, such shapes are found only in fine-grained soils and are not observed in thick pyroclastic deposits, since the latter represents a non-homogeneous soil. This means that such shapes originate not during crystallization and cooling, but due to rapid water loss in clay-sand soils in an aerated environment under conditions of high temperature – during a process quite different from the joints’ formation process. Therefore, we think that we should not use the term "pencil jointing" for pencil-like shapes developed in pyroclastic material, but use the term "pencil-like" desiccation cracks, or "pencil-like" shrinkage cracks.

According to the characteristics, the red horizon of Kilda should be considered as a hot contact of two lava flows.

The presented article is based on the initial studies data and is still in progress. The article authors complete and refine the results of the bolus research, which will be gradually presented in the form of publications.

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