ARCHAEOLOGY OF ARMENIA IN REGIONAL CONTEXT

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Institute of Archaeology and Ethnography

ARCHAEOLOGY OF ARMENIA IN REGIONAL CONTEXT

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The present volume reflects recent achievements of Armenian archaeology realized by local and international specialists. It is the result of a conference dedicated to the 60th Anniversary of the Institute of Archaeology and Ethnography, NAS RA held in Yerevan during 2019. The Institute is a multi-profile scientific organization, which conducts fundamental and applied investigations in the fields of archaeology, cultural anthropology, folklore studies, ethnosociology, epigraphy, archaeobiology, physical anthropology. As the national center of investigation of material and non-material cultural heritage, the Institute tries to provide scientific parity to the leading regional and international centers in the above-mentioned spheres.

Cover - Martiros Saryan, Mt. Aragats, 1929

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Dragons under Microscope: Determination and Identification of the Geological Sources of Vishap Stone Stelae

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Abstract. This article reports the results of the a first-of-its-kind archaeo-geological survey of the vishaps located in the area of the Tirinkatar and Karmir Sar volcanoes on the southern slope of mount Aragats, Armenia. The survey identified the petrographic and petrochemical features of the rocks from which the vishaps were carved. The results indicates that the vishaps were produced from rocks found nearby, consistently favouring the softer tuff lava (rocks intermediate in structure and formation between lavas and volcanic tuffs) and tuff over the harder-to-work basaltic andesites.

Keywords: Aragats, Tirinkatar, Karmir Sar, vishap (dragon) stone stelae, interdisciplinary studies.

Introduction

Archaeology and geology come across in many points. The present research realized by the interdisciplinary team is concentrated on the upper reaches of Ampur and Amberd rivers, of apical, south part of mount Aragats and includes geological, petrographic and petrochemical study and identification of rocks in order to clarify the genetic relationship between the monumental stone stelae known as vishaps (or dragon stones) and the lava flows of different age and different types. The survey focused on the vishaps of Karmir Sar, an archaeological site located in the area of the Tirinkatar and Karmir Sar volcanoes on the southern slope of mount Aragats. Vishaps are imposing prehistoric stone stelae with animal reliefs, for which date have been proposed ranging from the 2nd to the 5th millennia BC. These stelae are found in the mountains of the Armenian Highland, usually around or above the altitude of 2000 m asl. Given their remote locations, one wonders how exactly the stones to produce them were chosen, what were the logistics of their erection, and, specifically, from how far away where the stones dragged up to their erection point? In this article, we contribute towards answers to these questions, essentially proving that the vishaps were produced from local tuff lavas, accurately selected from nearby sources. This research once again confirms the great potential of geo-archaeological investigations.

The Aragats Volcano Massif: Geology and Geomorphology

The Aragats volcano massif was formed as a result of repeated manifestations of volcanic activity over a long period of time. Its geology has been the object of study of generations of scholars since the borderline of the 19th and 20th centuries (G. Abich, A. Pastoukhov, F. Oswald) but especially during the Soviet period (P. Lebedyev, O. Karapetyan, A. Reinhardt, A. Zavaritskiy, A. Aslanyan, N. Dumitrashko, A. Gabriyelyan, F. Milanovski, S. Karapetyan, K. Karapetyan, K. Shirinyan, et al.). These and other later studies focused on the geological structure of the massif, its tectonic position, the stratigraphy of the individual components of its volcanogenic and fluvioglacial formations, as well as the petrochemistry and genesis of individual lava flows, among other issues. The rocks of the ancient foundation, occurring at the base of the volcano massif, are represented by intensively dislocated deposits dating to the Eopalaeozoic, Upper Cretaceous, Palaeocene-Middle Eocene, while in the periphery they date to the Oligocene and Miocene. The foothill areas of the Aragats massif are large depressions – Ararat, Shirak, Aparan – filled with Neogene and Quaternary deposits (Fig. 1).

The Aragats volcano massif has the shape of a huge convex shield with four peaks in the middle. The volcanogenic formations, reach a thickness of 1.5 km,

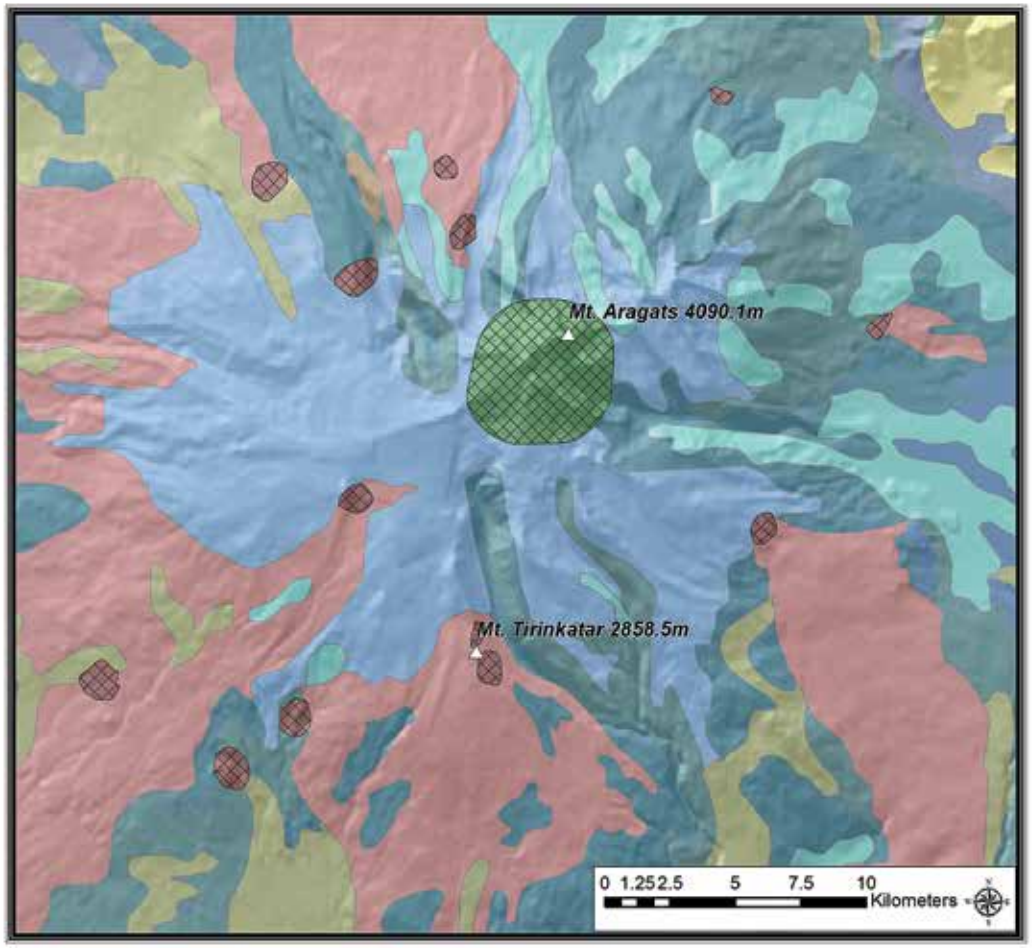


Fig. 1. Geological scheme of Aragats volcano (By: Dmitri Arakelyan).

and they are represented by diverse lavas of andesite-basalts, andesites, andesite-dacites, rhyolites, etc., their tuffs and tuff breccias, interbedded by sedimentary formations of Quaternary period. The diameter of the massif, lying at an average height of 1000 m, is approximately 60 km at the height of peaks from 3879 to 4090.1 m asl. The four jagged peaks are the remains of the volcanic cone. They surround the crater, extended by water-glacial erosion to a diameter of 2 km and with a depth of 300–400 m (Amaryan 1972). Near the peak there are 10 glacial circuses 3–4 km long and 1–2 km wide. This is also the center of the modern glaciation of Armenia, with an area covering up to 2–3 km^2. The ice is firn, which shows that the glacier is in retreat. From an orohydrographic perspective, this is a significant place: besides the numerous rivers originating from the summit, there are almost 100 lakes located here (Gusakov 1901; Lichkov 1931).

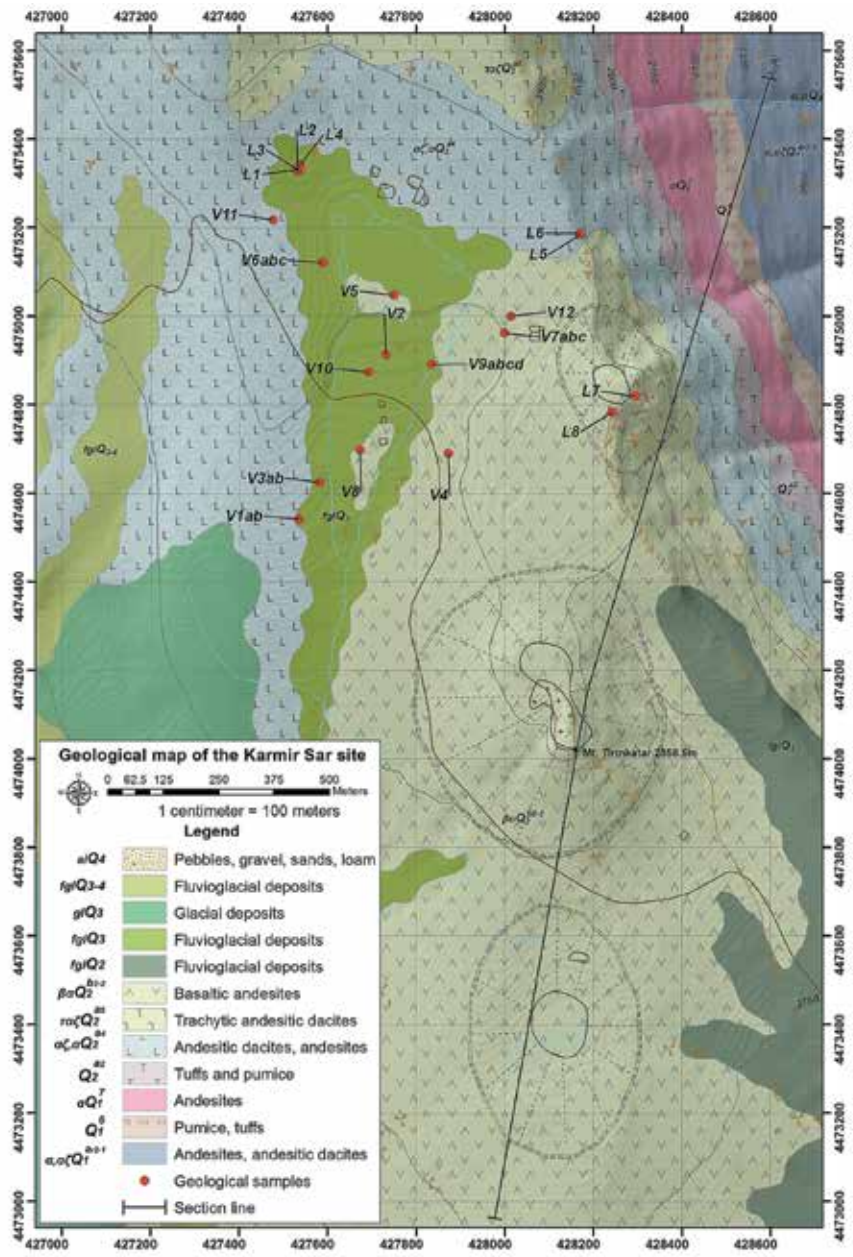


Fig. 2a Geological map (Scale 1:10 000) of Tirinkatar volcano and its surroundings with sampling points from vishaps (index V) and lava flows (index L) (By: Arshavir Hovhannisyan and Dmitri Arakelyan).

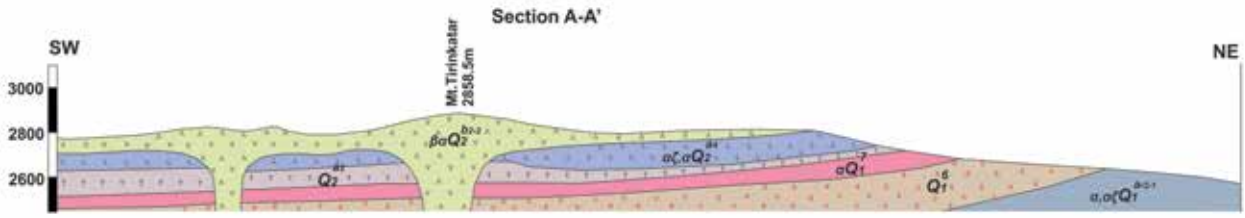


Fig. 2b Geological section along the A-A´ line (By: Arshavir Hovhannisyan and Dmitri Arakelyan).

A geologic survey was published at a 1:50000 scale in 1960–1970s, detailing the stratigraphic sequence of eruptions, their age, petrochemical and other features of lavas and tuffs of all Aragats volcano massif (Amaryan 1972). The present research, concerning the area of mount Tirinkatar, is based on cartographically referenced data of the detailed dissection of rocks composing the Aragats volcano massif, based on the most important stratigraphic geological sections of volcanic formations, according to individual slopes

and sites, marking out the suites, sub-suites and packets, separated by washouts, or lacustrine, lacustrine-fluvial or water-glacial deposits, and in some areas even traced by cross bedding (Amaryan 1972).

Geological Structure of Mount Tirinkatar

Along the right bank of the Amberd river, at the base of the geological section, are located the most ancient Upper Pliocene formations of the site, represented by andesites, andesite-dacites and dacites of the Upper Aragats subsuite (Fig. 2/a). The surface of lavas is eroded, knobby and uneven. Andesite-dacites are thin, plate-like, with giant concentrically-conchoidal joint of light gray ground mass. They have a cryptocrystalline, microlitic structure: the ground mass is of dark color, it is characterized by hyaline and hyalopilitic structures. Inclusions are rare, and they are represented by plagioclase – andesine and pyroxene.

Quaternary deposits are represented by volcanogenic, lacustrine, lacustrine-fluvial, glacial and alluvial-delluvial deposits, and according to the time of formation, they are divided into Lower, Middle and Upper Quaternary.

Along the right flank of the gorge of the Amberd river the mentioned Upper Pliocene andesitic lavas are replaced by packets of gently dipping up to 10° southward Lower and Upper Quaternary formations. Yellowish-brown pumiceous tuffs occur below with thickness up to 5 – 8 m, which are overlain by lavas of andesites with thickness up to 5 m. Above them brick red volcanic tuffs of Artik type are observed with thickness of up to 5 – 8 m, in some areas turning into pumice stones and pitch-black pechstein rocks.

An andesite-dacite cover occurs on all of the above lavas and tuffs, overlying all mentioned in the section formations and widespread in the western part of the site; its thickness in some areas reaches 15 m. Andesite-dacites and dacites at the bottom of the cover are light gray with a bluish tint, upward they are dark gray with light inclusions of plagioclase.

The packet of andesite-basalts with thickness of 1 to 10 m with lava flows, directed down the slopes to the south at a distance of 21 km, forms a cover, overlying all mentioned deposits. The andesite-basalts of gray and dark gray color are characterized by porphyritic structure. Eruption centers of andesite-basalts are fixed by three slag cones, one of which is mount Tirinkatar. The relative height of slag cone is 50 – 60 m (Fig. 2/a).

The western slope of mount Tirinkatar (Kizilziarat) is covered by Upper Quaternary glacial and water-glacial loamy sands, loams, as well as boulder-blocky deposits. In the valley of the river Amberd water-glacial deposits merge with modern fluvial deposits forming terraces (in the western part of the site). The thickness of fluvioglacial deposits in some areas reaches 100 – 150 m.

Geological Identification of Archaeological Objects – the Vishaps and Volcanic Rocks[1]

The geological research concentrated on the upper reaches of Ampur and Amberd rivers, of apical, south part of mount Aragats, included geological, petrographic and petrochemical study and identification of rocks in order to clarify the genetic relationship between the monumental stone stelae known as vishaps (or dragon stones) and the lava flows of different age and different types at Karmir Sar/Tirinkatar. Twelve vishaps were found located in a kind of high altitude sacred landscape dating back at least to the Middle and Late Bronze Ages (ca. 2200 – 1200 BC) and perhaps considerably earlier, to the end of the 5th century BC (cf. Gilibert et al. 2012; Bobokhyan et al. 2018; Hnila et al. 2019) (Figs 6 – 15). The vishaps are concentrated in the areas of Quaternary fluvioglacial deposits, from which, according to our observations, they were carved. The fluvioglacial deposits in their turn were formed due to erosion of volcanic lava flows as a result of the "work" of glaciers.

Research was carried out with the identification of small individual fragments, which were carefully split off from the vishaps, as well as from various volcanic rocks distributed over the research area.

The interstream area of Ampur and Amberd rivers marked by elevations of Tirinkatar and Karmir Sar is predominantly composed of Middle Quaternary lava formations (Zavariskiy 1944; 1947; Aslanyan 1950; 1956; Amaryan 1972; Meliksetian 2012), among which single flows of andesitic dacites and andesites of lower packet, trachitic andesite-dacites and basaltic andesites are distinguished. Pumiceous tuffs, both of Lower Quaternary and Upper Quaternary age, forming the eastern slopes of Tirinkatar and Karmir Sar, are overlain by packets of lavas of andesitic composition and they do not crop out in this area. Trachitic andesite-dacites form the most northern part of the site and they are outside the research area (Fig. 2/a,b).

1 The present research was partly funded by the State Committee for Science of the Ministry of Education and Science of the Republic of Armenia under the scientific topic code 18T-1E171.

Sampling. In total, 23 petrographic samples were taken from 12 vishaps and their fragments (samples by indexing from V1 to V12) and 8 samples from all varieties of volcanic rocks from the environment of mount Tirinkatar (Fig. 1/a, cf. Figs 16–17). Those are the rocks which are widespread in the vicinity of the study area (geological samples by indexing from L1 to L8). The aim of sampling is to obtain the maximum petrographic, as well as petrochemical information, for determination of genetic relationship between vishaps and volcanic rocks: namely, to determine from which particular local volcanic rock each specific vishap was carved, or to disprove the supposed relationship. Since not all of the vishaps were intact (some of them have been broken into several parts during long time of their existence), from the very beginning of our work we were not sure that all of their parts found and assembled as a "puzzle" with some missing pieces can actually belong together instead of being parts of other unknown stelae. We had to sample all the individual pieces as well, in order to avoid a mistake (Tab. 1). Several of the crushed parts of vishaps were scattered throughout the area, and although we managed visually to assemble all their fragments and practically adjust them to each other, still there were some doubts about such a purely architectural approach, since by the intensity of erosion and mineral backlight of erosion crust of parts of vishaps, they were still different. Almost all samples underwent petrographic examination (see Annex 1). And the four most typical samples of vishaps underwent silicate analysis, to obtain besides petrographic information also petrochemical background for the classification of a specific type of volcanic rock which had been the building material for vishaps.

Table 1 List of vishap sampling.

Vishap N/N	N/N of sample taken
V 1	V 1a; V 1b
V 2	V 2
V 3	V 3a; V 3b
V 4	V 4
V 5	V 5
V 6	V 6a; V 6b; V 6c; V 6fr
V 7	V 7a; V 7b; V 7c
V 8	V 8; V 8fr
V 9	V 9a; V 9b; V 9c; V 9d
V 10	V 10
V 11	V 11
V 12	V 12

Petrography and petrochemistry. Petrographic analysis was done using a polarizing microscope with 200 and more magnification. Under the microscope, in transparent thin sections, made from the vishap samples, was studied the structural and textural features of vishap rocks, distribution of mineral grains inside the crystals of the studied rock, determining rock-forming minerals by their crystal-optical characteristics.

Vishaps, specifying the territory of fluvioglacial formations to the west of the top of Karmir Sar (Fig. 2/a) are characterized by superficial weathered thin crust of iron-magnesium oxides – desert crust.

In accordance with petrographic features, as well as petrochemism (Tab. 2) they are mostly carved from vulcanites (tuff lavas) of andesite–andesite-dacite composition. Mostly they chemically fall into the andesite field, partially deflected to dacite (Fig. 3). Actually, the most part of vishaps (V1–V7; V9; V11) carved from tuff lavas - rocks intermediate in structure and formation between lavas and volcanic tuffs.

Table 2 Chemical composition of rocks from which the vishaps were carved (silicate analysis).

	$Si0_2$	$Ti0_2$	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	Ka_2O	P_2O_5	H_2O	S	Burn losses	∑
V 1a	61,30	0,86	17,86	3,38	0,56	0,08	1,34	3,86	2,80	2,30	0,55	1,86	0,68	2,66	100,09
V 3b	63,60	0,85	17,50	2,03	1,96	0,09	1,08	3,22	2,80	2,70	0,57	0,45	0,96	2,40	100,21
V 6c	64,66	0,87	18,63	2,65	1,40	0,06	0,87	2,38	2,90	2,80	0,59	0,55	–	1,73	100,09
V 8	59,94	0,82	17,85	2,41	2,52	0,14	2,70	5,66	2,60	1,50	0,46	0,84	–	2,60	100,04

Note: *From all 23 samples, the most differentiated 4 samples were selected for analysis, in terms of physical properties (color, hardness, porosity, specific gravity, texture, structure, etc.). № V8 – andesite (andesite lava); №№ V 1a and V 3b – andesite (tuff lavas of andesite composition); № V 6c – dacite (dacite lava). The analyses were carried out in the chemical laboratory of the Institute of Geological Sciences of NAS RA. Prepared by A. Nazaryan.*

The andesite-dacites and dacites spread within the site Karmir Sar–Tirinkatar, like all volcanogenic rocks forming the Aragats volcano massif, have petrographic features similar in mineral composition (see Annex 1). The association of inclusions in them is represented by plagioclase, two pyroxenes and magnetite.

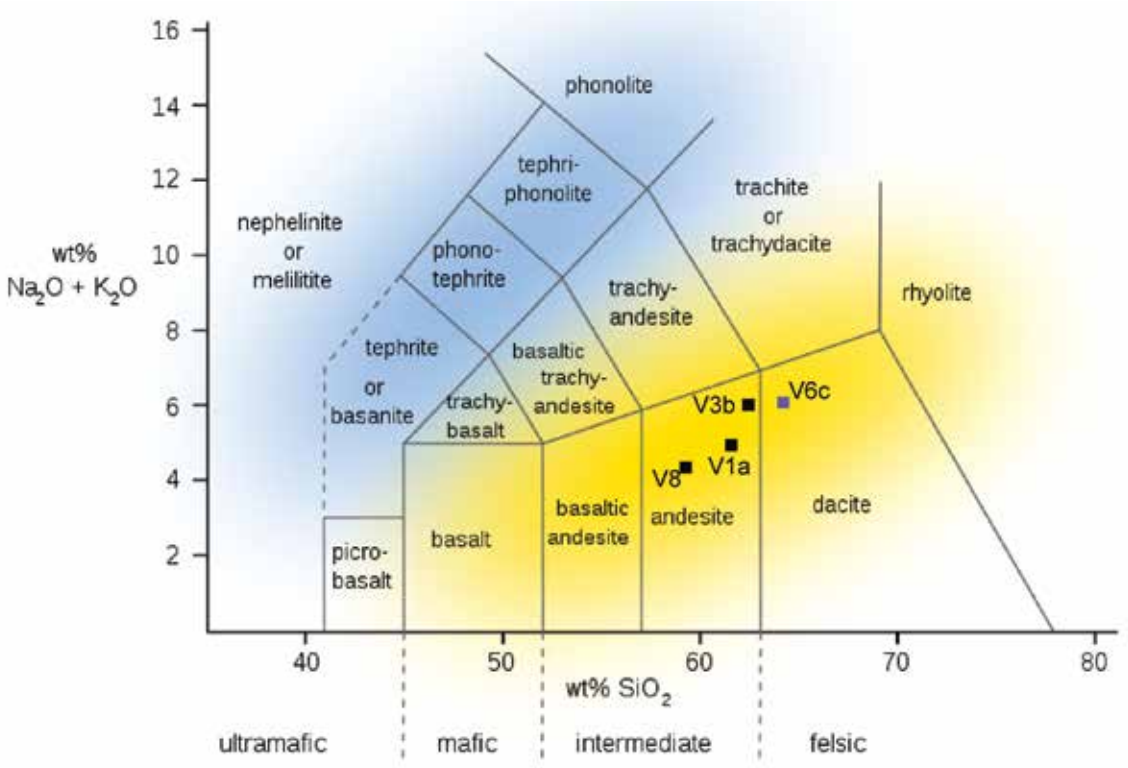


Fig. 3. Petrochemical classification of samples taken from vishaps (By: Arshavir Hovhannisyan).

Among phenocrysts two generations of plagioclases often stand out. The structure of the ground mass varies within the same thin section.

Plagioclase is predominantly andesine or andesine-oligoclase, it is polysynthetic twinned and has a zonal structure, which is emphasized by the distribution of melt inclusions in the outer zone. Clinopyroxene is represented by augite (Shirinyan 1970; Ghukasyan 1985; Djerbashyan 2010). Rhombic pyroxene with pleochroism in greenish tones for Ng, pinkish or pinkish yellow Np, was previously defined as hypersthene (Shirinyan 1970; Ghukasyan 1985): by the content of ferrous iron based on microprobe studies its composition is verified as bronzite (Djerbashyan 2010). Cristobalite sporadically occurs in rocks and it is spread both along the volcanic glass, and in some areas along the walls of the pores.

The mineral composition of both lava and pyroclastic formations of the Aragats volcano massif is uniform, indicating their close genetic relationship, and, unfortunately, does not make it possible to use the peculiarities of their composition for even deeper differentiation of various sites.

Discussions and Conclusions

The following critical factors were taken into account in petrographic studies of characteristic features of vulcanites: 1. nature of the rock ground mass, its structure and texture features, color of volcanic glass, 2. number of inclusions of rocks, their relationship with ground mass, their dimension and relationship between basic minerals, 3. characteristics of phenocrysts; their morphology, degree of erosion by melt inclusions, nature of their distribution in crystals, 4. quantity, size and shape of pores which make up 10–20% of the rock volume.

According to these factors, it has been determined that vishap V 12 was carved from tuff, and the majority of vishaps – №№ V 1 (samples V-1a V-1b), V 2, V 3 (samples V-3a and V-3b), V 4, V 5, V 6 (samples V-6a and V-6fr.), V 7 (samples V-7a and V-7b and V-7c), V 9 (samples V-9a, V-9b, V-9c, V-9d) and V 11 were carved from tuff lavas-in this case – tuff lavas of andesitic composition (rocks intermediate in structure and formation between lavas and volcanic tuffs). There is an opinion that tuff lavas were formed under conditions of aerosol-type creeping flows, characterized by high speed of movement (Karapetyan 1985; 1988).

These rocks are softer compared to andesites. Unlike typical lavas, tuff lavas contain inclusions of porous pumiceous-slag material. The glassy matrix of tuff lavas is fine-porous – vesicular, it always makes up the most part of the rock, and the mineral fraction is equal to 8–10%. The texture of tuff lavas is ataxitic, fluidal. Coloring of volcanic glass is due to the degree

of its oxidation; with complete oxidation glass acquires a reddish color. Inclusions of glass fragments are usually of dark color, and they stand out clearly against the background of the rock. Relatively large fragments have an elongated shape in the form of lenses; in the relatively thick rocks they are intensely welded and deformed. Porphyritic segregations of the rock are immersed in a glassy mass; they are idiomorphic, occasionally being represented by fragments. Porosity ranges within 13–20%. Gray and dark gray rocks are characterized by higher density. In primary bedding tuff lavas are not observed within the mentioned area.

Though among boulder fluvioglacial formations of Karmir Sar andesites and andesite-dacites are found in large numbers (see on the map 2a the points of samples of volcanic rocks: №№ L 1, L 2, L 3, L 4), as a building material for vishaps they were used in rare cases. Those are the vishaps №№ V 8 and V 10 (andesite), which are characterized by more decrystallized ground mass and lower porosity compared to tuff lavas, and which are identical to the bedrock exposures of andesites of Middle Quaternary packet, highly developed within the mentioned area (see Fig. 2/a, sample №№ L 2, L 3, L 8).

Geological samples, taken from lava formations №№ L 1, L 4, are represented by andesites with pores filled with carbonate and partially by limonitized clayey mass.

Variations of chemical composition of tuff lavas (as well as of andesites), in our opinion, relate to a greater extent to the content of silica and are due to uneven development of cristobalite – crystalline silica in the rocks pores.

Basaltic andesites (sample L 6), which are widely spread (not less than andesites) among the rocks of the site, as well as slagged rocks of volcanic cones of basaltic andesites (sample L 7), were not used.

Interestingly, the vishaps № V 4, V 7 and V 12 are located outside the area occupied by fluvioglacial deposits, and by hypsometric marks, most likely mark the same level of the assumed lake shore of glacial origin, existing at that time. And it is possible that those vishaps by the age of creation and establishing may vary from the rest.

Samples from vishap № V 6 are four in number: № V 6a and V 6fr (fragment, found during excavations: Operation F, coll. 6.29) are gray tuff lavas. Meanwhile V 6b and № V 6c are pinkish gray andesite-dacites, on which fluvioglacial deposits occur. It means, that the sample V 6fr in fact belongs to vishap V 6, meanwhile V 6b and V 6c differ from it, i.e., they are not fragments of the Vishap V 6 (see Table 3).

The tuff lavas of the samples № V 1a and № V 1b, as well as samples № V 3a and № V 3b and № V 9a, V 9b, V 9c, V 9d are identical to each other, that is, they belong to the vishaps V 1, V 3 and V 9 respectively, and are made from the same rock, in this case – from tuff lava (tuff lava of andesitic composition).

Samples from vishap V 7 (blocks № V 7a, № V 7b and № V 7c) are petrographically similar and belong to the vishap V 7.

Table 3 Petrographic variety of materials of vishaps.

Material of vishaps	Indexing of samples and individual fragments of vishaps											
Tuff lava (tuff lavas of andesitic composition)	V 1a V 1b	V 2	V 3a V 3b	V 4	V 5	V 6a V 6fr	V 7a V 7b V 7c		V 9a V 9b V 9c V 9d		V 11	
Andesite (andesite lavas)								V 8 V 8fr		V 10		
Andesitic dacite (andesitic dacitic lavas)						V 6b V 6c						
Tuff												V 12

Samples from vishap № V 8 are two in number both being of the same andesite: it means that № V 8fr (fragment, found during excavations: Operation D, coll. 17.1) belong to the stela № V 8.

Sample from vishap № V 10 is made from andesite.

Some samples of the rocks, judging by the uneven coverage by limonitization of ore mineral (not all grains of ore mineral are limonitized, but only in some part of the thin section), were in an aggressive environment. Those are the samples № V 2, № V 7b and № V 7c, as well as № V 11, in which iron hydroxides not only replace the ore mineral, but also cover the walls of some cavities and vesicles in the form of a film.

Fig. 4. Vishap 1, 210x90x30 cm (1a), 90x40x30 cm (1b, 1 m to the N-W of 1a), unexcavated (Photo: Pavol Hnila).

Fig. 5. Vishap 2, 327x49x41 cm, excavated in 2015, (Photo: Pavol Hnila).

Thus, it can be concluded that:

a. All vishaps were built from local volcanic material, specifically from the tuff lavas (rocks intermediate in structure and formation between lavas and volcanic tuffs) of average (andesitic) composition, andesites, and tuffs which are widespread in the area (see Tab. 3 and Annex 1).

b. Basaltic andesites, which are equally easy to find on site, were not used as building material for vishaps.

c. Some fragments of vishaps (V 6b and V 6c), which by visual observations were previously considered identical and belonging to one and the same vishap (V 6), turned out not to be the related, implying the existence of further vishaps still to be identified (cf. Fig. 9).

d. Some remoteness of three vishaps (V 4, V 7 and V 12) has been observed, which are at one hypsometric level, and, most likely, that was the shoreline of a seasonal lake of glacial origin, existing at that time. And it is possible that those vishaps by the age of creation and establishing may vary significantly from the rest.

Annex 1

Thin section V 1a

Tuff lava of andesite

The texture of the rock is ataxitic, the structure is porphyritic, in some places the ground mass is of cryptocrystalline structure, in other places it is of hyaline structure with vesicular texture.

The ground mass is non-uniform, it is represented by volcanic glass; the aggregate of very fine microlites and indeterminable crystallites is fixed by volcanic glass of light gray color with a pinkish tint; the other areas are made of brownish-gray volcanic glass, fine vesicular with rare microlites.

The rock phenocrysts make up 10–12% of the thin section surface and are mainly represented by plagioclase, as well as clinopyroxene and rhombic pyroxene. Plagioclase forms transparent long prismatic polysynthetically twinned crystals up to 4mm in size. Rhombic pyroxene – hypersthene is represented by thin prisms 1–1.5 mm long; it poorly pleochroates in greenish-pink tones, fading is direct, elongation is positive. Clinopyroxene forms short prisms of the same size with a well defined cleavage. Fine grains of ore mineral occur in association with pyroxenes.

Thin section V 1b

Tuff lava of andesite

The texture of the rock is ataxitic, the structure is porphyritic, in some places the ground mass is of cryptocrystalline structure, in other places it is of hyaline structure, with fine vesicular texture.

The rock phenocrysts are represented by plagioclase, clinopyroxene and single grains of olivine and make up about 10% of the rock.

Plagioclase forms long prismatic twinned crystals up to 3mm in size. Clinopyroxene is represented by short-prismatic crystals of slightly greenish color with a well defined cleavage; the size does not exceed 1–1.5 mm. The grains of olivine are of the same size, they have a rounded shape.

The ground mass is represented by unevenly decrystallized light brownish volcanic glass, in some places fine vesicular. It is made up of very thin aggregate of fine microlites of feldspar; in the light brownish glass areas of almost transparent volcanic glass are distinguished with numerous indeterminable crystallites.

Thin section V 2

Tuff lava of andesite

The texture of the rock is ataxitic, the structure is porphyritic; the structure of the ground mass is hyaline with perlitic and fine vesicular texture.

Areas of brownish-greyish-brown and light gray volcanic glass are observed in the rock.

Phenocrysts in the rock occur relatively rarely up to

7% and are represented by plagioclase and clinopyroxene, the size of which does not exceed 2 mm. Plagioclase forms prismatic twinned crystals; clinopyroxene is characterized by short prismatic grains.

Brownish-greyish-brown areas are represented by poorly decrystallized vesicular volcanic glass with perlitic jointing, in which microlites of plagioclase are observed here and there, as well as grains of ore mineral are found in the halo of iron hydroxides.

The areas made of light-gray volcanic glass are more uniform; phenocrysts occur in them less often.

Thin section V 3a

The rocks of thin sections 3a and 3b are similar

Tuff lava of andesite

The texture of the rock is ataxitic, the structure is fine-porphyritic, the structure of the ground mass is hyaline; the texture is close to perlitic, vesicular.

In the thin section plane areas of greyish-brown vesicular limonitized glass with perlitic jointing are observed; decrystallization of the nuclear part of perlitic globules is observed, the structure of which is distinguished due to concentration of limonite product in the shells of the globules; their size does not exceed 0.15 mm.

The areas of light gray volcanic glass of hyaline structure are more uniform.

Phenocrysts make up 15–17% of the rock and are represented by short prisms of twinned plagioclase up to 2 mm in size and fine prisms of clinopyroxene; their aggregates are observed here and there. Thin small prisms of hypersthene occur. The ore mineral magnetite forms fine grains.

Thin section 3 b

Tuff lava of andesite

The texture of the rock is ataxitic, the structure is porphyritic, in some places the structure of the ground mass is hyaline, in other places it is cryptocrystalline; the texture is perlitic, vesicular.

In brown-greyish-vesicular volcanic glass with perlitic jointing and rare phenocrysts the areas of volcanic glass are distinguished, less colored – grayish brown, of cryptocrystalline structure with a large number of sub phenocrysts and less defined perlitic texture. Perlitic globules are made of brownish volcanic glass with a thin shell of decrystallization. The small hollows have an irregular shape.

Phenocrysts make up 17–20% of the rock and are mostly represented by long prismatic crystals of twinned plagioclase up to 3–4 mm in length, less by thin prismatic crystals of hypersthenes and grains of clinopyroxene up to 0,7 mm in size.

Thin section V 4

Tuff lava of andesite

The texture of the rock is ataxitic, the structure is porphyritic, the structure of the ground mass is hyaline, the texture is fluidal.

The rock – andesite is characterized by the presence of fine and lighter small lenses of volcanic glass, oriented to

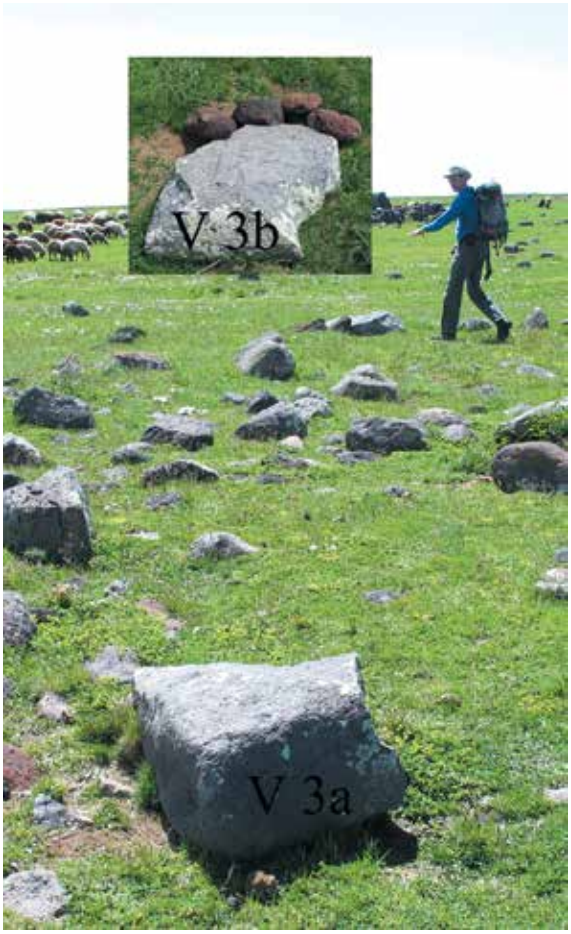


Fig. 6. Vishap 3, 85×56×25 cm (3a), 90×45×25 cm (3b, 10 m to the N of 3a), unexcavated (Photo: Alessandra Gilibert).

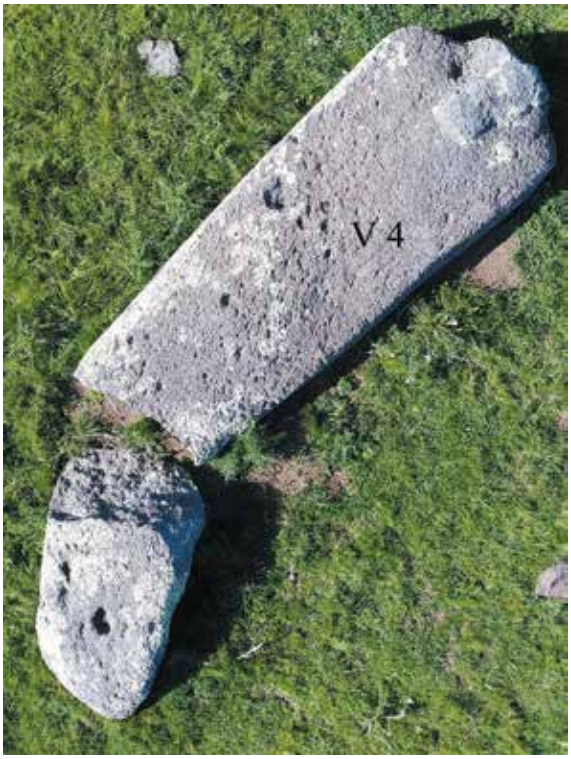


Fig. 7. Vishap 4, 435×112×40 cm, unexcavated (Photo: Pavol Hnila).

Fig. 8. Vishap 5, 148×73×35 cm, unexcavated (Photo: Arsen Bobokhyan).

Fig. 9. Vishap 6, 272×84×33 cm (1a), 54×47×30 cm (6b, found 20 m to the N-E of 1a), 95×45×30 cm (6c, found 15 m to the W of 6a), excavated in 2017 (Photo: Arsen Bobokhyan).

Fig. 10. Vishap 7, 181×98×62 cm (7a), 52×80×48 cm (7b, found during excavations 80 cm to the S-E of 7a), 54×70×56 cm (7c, found during excavations of Vishap 12, 1 m to the W of it), excavated in 2019 (Photo: Pavol Hnila).

Fig. 11. Vishap 8, 350×94×58 cm, excavated in 2016 (Photo: Pavol Hnila).

Fig. 12. Vishap 9, 95×80×25 cm (9a), 82×44×35 cm (9b, found 4 m to the E of 9a), 71×47×43 cm (9c, found 40 m to the S from 9a), 97×76×39 cm (9d, found 10 m to the E from 9a), unexcavated (Photo: Arsen Bobokhyan).

the plane of fluctuating texture, which is distinguished due to oriented distribution of phenocrysts and flattened vesicles. Their concentration in certain directions determines the rock texture. The size of glass lenses ranges from fractions of a millimeter up to 0.5–0.7 cm and they are represented by more decrystallized volcanic glass with cryptocrystalline structure; on the periphery of the lenses decrystallization of secondary minerals is observed. Flattened vesicles are characterized by the same dimensions; radiolith formations of isotropic mineral are observed in some of them.

The ground mass of andesite consists of slightly brownish-greyish brown non-uniform vesicular volcanic glass with fine impregnation of ore mineral and phenocrysts of plagioclase and occasionally of clinopyroxene. Sometimes they occur in fine-grained aggregates.

Phenocrysts make up 15–17% of the rock and are represented by plagioclase and clinopyroxene; plagioclase forms prismatic polysynthetically twinned crystals up to 4–5 mm in size; in large crystals the microinclusions of volcanic glass are observed. Clinopyroxene is represented by fine grains.

Thin section V 5

Tuff lava of andesite

The texture of the rock is ataxitic, the structure is porphyritic, the structure of the ground mass is hyaline, the texture is poor fluidal, fine vesicular.

The surface of the thin section is mainly represented by non-transparent coarse-vesicular and limonitized brownish gray volcanic glass with poor fluidization. In the limonitized volcanic glass the small areas of fine-vesicular poorly decrystallized grayish-brown volcanic glass are poorly distinguished.

The inclusions in both varieties of volcanic glass are represented by plagioclase and clinopyroxene, which make up up to 15% of the rock. Phenocrysts of plagioclase of long prismatic habitus up to 4 mm in size are characterized by microinclusions of volcanic glass, they have andesine composition. Clinopyroxene of slightly greenish color is represented by small prismatic crystals. The ore mineral is magnetite.

Rock fluidization is manifested by oriented location in the limonitized glass of elongated areas of greyish-brown glass, as well as large vesicles stretched in the same plane.

Thin section V 6a

Tuff lava of andesite with fritted fragments of slagged glass

The texture of the rock is ataxitic, the structure is fine-porphyritic, the structure of the ground mass is cryptocrystalline and hyaline; and the texture is vesicular, fluidal.

In the thin section plane the sub-parallel banded elongated areas of slightly brownish-greyish-brown and greyish-brown vesicular volcanic glass are distinguished different in color, including round shape corroded fragments of andesite-basalts 3–4 mm in size. The binding volcanic glass of brownish-greyish-brown color is characterized by cryptocrystalline structure and uneven limonitization, the greyish-brown glass is of hyaline structure. Vesicles in the glass are mostly of small size, they are elongated by fluidity; compara-

tively large vesicles are observed on the border of volcanic glasses differing in color and decrystallization.

Phenocrysts make up 15–17% of the thin section surface and are predominantly represented by plagioclase of prismatic habitus up to 1 mm in size, in rare cases 2 mm. In addition to them grains of clinopyroxene and ore mineral are observed.

Slagged glassof have micro-porphyritic structure with hyalopilitic structure of the ground mass. The microphenocrysts are represented by grains of clinopyroxene, and the ground mass is made of brownish-blask slagged volcanic glass with microlites of plagioclase.

Thin section V 6b

Andesite-dacite

The texture of the rock is ataxitic, the structure is porphyritic, the structure of the ground mass is microlitic; the texture is vesicular, fluidal.

Areas of volcanic glass of greyish-brown-brownish (70–75%) and brownish-gray color are characterized by equal distribution of microlites of plagioclase and vary in size of phenocrysts and vesicles, elongated according to the fluidity of the rock. In the volcanic glass of dark color both inclusions and vesicles are characterized by large size. In the light glass the vesicles on the walls are filled with secondary poorly crystallized products.

Phenocrysts make up about 15–17% of the rock and are mostly represented by prisms of polysynthetically twinned plagioclase up to 3 mm in size, as well as by crystals of clinopyroxene of lesser size up to 1.5 mm.

Thin section V 6c

Andesite-dacite

The structure is porphyritic, the structure of the ground mass is hyalopilitic; the texture is fine and coarse-vesicular, fluidal.

The amount of inclusions does not exceed 10–13% of the thin section plane, and they are represented by plagioclase, rhombic pyroxene and clinopyroxene. Plagioclase of andesine-oligoclase composition is represented by long prismatic polysynthetically twinned crystals 2–3 mm in length, in some places with fritted contours, and short-prismatic small crystals 0.5–0.7 mm in size. Rhombic pyroxene–hypersthene forms thin prismatic crystals up to 0.5 mm in size, it poorly pleochroates in greenish-pink tones, fading is direct, elongation is positive. Clinopyroxene of greenish-dirty color is less common, it forms short-prismatic grains.

The ground mass is represented by brown-greyish-brown volcanic glass with numerous microlites of plagioclase with rare and small rash of ore mineral. The small areas of glass enclosed in the ground mass resemble the rock described in thin section 6b. Rock fluidization is mostly manifested by oriented location of microlites of the ground mass, as well as small and large vesicles, the sizes of which reach 4–5 mm. Small vesicles on the walls have outgrowths of mineral of yellowish-brownish color in transmitted light and isotropic in crossed nicols.

Fig. 13. Vishap 10, 285×59×56 cm, excavated in 2013 (Photo: Pavol Hnila).

Fig. 14. Vishap 11, 213×50×38 cm, excavated in 2018 (Photo: Alessandra Gilibert).

Fig. 15. Vishap 12, 355×78×51 cm, excavated in 2018 (Photo: Pavol Hnila).

Thin section V-6 fragment

Tuff lava of andesite

The structure is fine-porphyritic, the structure of the ground mass is hyaline; the texture is perlitic, vesicular.

Phenocrysts, the size of which does not exceed 2 mm, make up 7–8% of the thin section surface.

They are mostly represented by small prismatic crystals of twinned plagioclase up to 1 mm in size, only a few reach 2 mm. Clinopyroxene also forms small thin prisms; small grains of magnetite occur in association with clinopyroxene.

The ground mass is represented by brownish gray volcanic glass with perlitic texture, which in some places is not very clearly manifested. The vesicles in glass are quite rare and they are distributed unevenly; up to 4 mm in size.

Thin section V 7a

Tuff lava

The texture of the rock is poorly distinguishable, ataxitic, the structure is porphyritic, the structure of the ground mass is cryptocrystalline, microlitic and hyalopilitic; the texture is vesicular.

The areas of brownish-brown and greyish volcanic glass differ in the structure of the ground mass. It is cryptocrystalline microlitic in the first case and hyalopilitic in the second. In the latter there is also poorly manifested fluidization. In the brownish-greyish-brown volcanic glass a small area of limonitized brownish-black glass is observed. Small vesicles are quite rare; large vesicles up to 4 mm in length occur more often. Radiolith formations of isotropic mineral are observed in some vesicles.

The inclusions make up about 7–10% of the thin section surface. Phenocrysts of plagioclase of prismatic habitus are up to 2 mm in size. The grains and small prisms of pyroxene occur less often and are small up to 1 mm in size.

Thin section V 7b

Tuff lava

The ataxitic structure is very poorly manifested. The structure is porphyritic, the structure of the ground mass is hyaline and cryptocrystalline; the texture is perlitic, vesicular.

Phenocrysts make up up to 5–8% of the thin section surface and are represented by plagioclase, clinopyroxene and hypersthene. Plagioclase mainly occurs in the form of crystal fragments, and only single crystals hold prismatic habitus no larger than 1.5 mm in size; clinopyroxene and hypersthene are characterized by more preservation – prisms no more than 0.5 mm in length; their agglomerates are observed here and there.

The ground mass is represented by vesicular brownish-greyish-brown volcanic glass of hyaline structure, which sometimes alternates with glass of cryptocrystalline structure with perlitic texture. There is an extremely uneven distribution of ore mineral in the glass. The impression is that the glass pieces with impregnation of ore mineral are assimilated by volcanic glass. The glass is unevenly limonitized; iron hydroxides are observed in the halo of frequent impregnation of ore mineral and they even line the walls of vesicles in the glass by a thin film. However, areas with ore mineral completely unaffected by limonitization are observed.

Thin section V 7c

Tuff lava of andesite

The texture of the rock is ataxitic, perlitic; the structure is porphyritic, the structure of the ground mass is hyaline.

The areas of brownish-greyish-brown and light brown glass of vesicular volcanic glass differ not only in color but also in size and frequency of perlitic globules. Their boundaries are almost indistinguishable; in some places they are detected by the merging of individual pores into elongated cavities up to 5–6 mm in length. In the volcanic glass with rare distribution of perlitic globules the agglomerate of plagioclase crystals is observed. Iron hydroxides are developed on the walls of some vesicles.

Phenocrysts are represented by plagioclase of prismatic habitus up to 2–2.5 mm in length, as well as by small prismatic indides of pyroxene. The grains of ore mineral occur in association with pyroxene.

Thin section V 8

Andesite lava

The structure is porphyritic, the structure of the ground mass is pylotaxitic; the texture is fluidal, porous.

Phenocrysts make up up to 17–20% of the thin section surface and are mostly represented by plagioclase and clinopyroxene, as well as by single crystals of olivine. Plagioclase forms prismatic polysynthetically twinned crystals up to 3 mm in length, large crystals contain microinclusions of volcanic glass. Clinopyroxene is represented by short prisms up to 1.5 mm in length; olivine is characterized by rounded shapes, with rare small cracks of iron hydroxides. The ground mass is a thin felt of microlites and rare blades of plagioclase, bonded by brownish-greyish-brown volcanic glass; microlites of plagioclase wrap around the rock inclusions. Hollows of irregular shape are observed in the rock with a transparent isotropic mineral, overgrown on the walls by a thin stripe. Microbunches of slagged glass are observed in the rock.

Thin section V-8 fragment

Andesite

The structure is porphyritic, the structure of the ground mass is hyalopilitic; the texture is perlitic, fine vesicular.

Phenocrysts are represented by prismatic crystals of plagioclase 2–3 mm in size and clinopyroxene up to 1.5 in size.

The ground mass is made up of brownish gray volcanic glass with microlites scattered in it and occasionally blades of plagioclase, small grains of clinopyroxene and very rarely of ore mineral. The perlitic rock texture is expressed very clearly. Vesicularity is very thin and vesicles are quite rare.

Thin section V 9a

Tuff lava

The structure is porphyritic, the structure of the ground mass is hyaline; the texture is fluidal.

The rock consists of slagged non-uniform volcanic glass of fluidal texture, in which the texture is distinguished due to oriented distribution of sub phenocrysts, pores and cavities.

Large phenocrysts are rare and are represented by long prisms of twinned plagioclase 2–3 mm in size with microinclusions of volcanic glass; clinopyroxene is represented by short-prismatic crystals 1–1.5 mm in size. The sub phenocrysts are mainly represented by short-prismatic crystals of plagioclase, clinopyroxene and hypersthene up to 0.7 mm in size, sometimes of angular-rounded shape. Their agglomerates are observed in the rock up to 4–4.5 mm in diameter. Grains of ore mineral up to 0.5 mm in size occur.

Small pores of the rock sometimes are connected by conductors forming cavities oriented in the plane of fluidal texture. The outgrowths of isotropic mineral of radiolith structure are sometimes observed on the walls of the cavities.

Thin section V 9b

Tuff lava

The texture is ataxitic due to alternation of areas of volcanic glass differing in color. The structure is porphyritic, the structure of the ground mass is hyaline.

The areas of limonitized brownish volcanic glass are observed in the grayish-brown fine-vesicular volcanic glass. The boundaries between them are indistinguishable in some places, elongated hollows are sometimes observed.

In the limonitized volcanic glass the comparatively large phenocrysts of plagioclase often have fritted shape, iron hydroxides develop along the cracks. Dendrite-like segregations of ore mineral are observed in the volcanic glass itself. The walls of the vesicles are distinguished by the concentration of iron hydroxides. The outgrowths on the walls of radiolith formations of isotropic mineral are observed in some vesicles.

The size of the rock phenocrysts does not exceed 2–2.5 mm; clinopyroxene and rhombic pyroxene occur in fine grains, sometimes the agglomerates of plagioclase and pyroxene grains are observed.

Thin section V 9c

Tuff lava

The texture of the rock is ataxitic, the structure is porphyritic, the structure of the ground mass is cryptocrystalline, in some places hyaline; the texture of cryptocrystalline glass is perlitic.

The rock is mainly represented by dark grey vesicular volcanic glass of cryptocrystalline structure with thin microlites in which the inclusions of brownish-greyish-brown, sometimes limonitized fine-porous glass of hyaline structure are observed.

Phenocrysts are quite rare and are represented by long prismatic crystals of polysynthetically twinned plagioclase up to 5 mm in size, often fragmented; clinopyroxene and hypersthene are represented by small prisms up to 0.7 mm in length.

On the walls of the pores, as well as in the glass of cryptocrystalline structure itself radiolith formations of isotropic mineral are observed.

The walls of some large vesicles in the glass of cryptocrystalline structure are filled with iron hydroxides.

Thin section V 9d

Tuff lava of andesite

The texture is ataxitic, the structure of the rock is porphyritic, the structure of the ground mass is cryptocrystalline; the texture is perlitic, vesicular and porous.

In the thin section plane the areas of fine vesicular gray and brownish volcanic glass are observed also varying in number and size of inclusions. Elongated pores or hollows of irregular shape are observed at the borders of their contact up to 5 mm in size. It is a grey volcanic glass with single phenocrysts of polysynthetically twinned plagioclase, forming long prisms up to 3 mm in size, as well as rare small grains of clinopyroxene and ore mineral. The caked fragments of limonitized volcanic glass of micro-porphyritic structure with rare blades of plagioclase are submerged in the grey volcanic glass.

Rock fluidization is manifested by the directivity of the smallest microlites in volcanic glass, as well as by the elongation of vesicles, the size of which does not exceed 0.5–0.7 mm. The outgrowths on the walls of radiolith formations of isotropic mineral are observed in some vesicles.

Thin section V 10

Andesite

The structure is porphyritic, the structure of the ground mass is hyalopilitic passing to microlitic; the texture is vesicular, fluidal.

The rock phenocrysts are mostly represented by small prisms of plagioclase and clinopyroxene 1–1.5 mm in size. The single long prismatic crystals of polysynthetically twinned plagioclase reach up to 5 mm in length, the prismatic crystals of clinopyroxene – up to 3 mm.

The ground mass consists of brownish-greyish-brown volcanic glass with numerous microlites of plagioclase and micrograins of clinopyroxene and ore mineral. Segregations of light grey volcanic glass occur, caked with brownish-greyish-brown glass, up to 1–1.5 mm in size. The vesicles elongated in one direction, the sizes of which reach 5 mm, as well as microlites of plagioclase oriented in the same direction, determine the rock fluidization.

Thin section V 11

Tuff lava of andesite

The texture is ataxitic, the structure is porphyritic, the structure of the ground mass is hyaline; the texture is vesicular.

In the grayish-brown volcanic glass of porphyritic structure the areas with frequent impregnation of limonitized ore mineral are observed, and the areas of dark brown volcanic glass with micro-porphyritic structure are observed with sub phenocrysts of clinopyroxene and plagioclase.

In the grayish brown volcanic glass the phenocrysts are represented almost in equal combination by plagioclase and clinopyroxene. The crystals of twinned plagioclase of long prismatic habitus up to 3–3.5 mm in length are quite rare, the short-prismatic crystals 1–1.5 mm in size are observed more

Fig. 16. Sampling process of volcanic rocks by Arshavir Hovhannisyan and Dmitri Arakelyan in L 1-4 area (Photo: Arsen Bobokhyan).

often. The short-prismatic crystals of clinopyroxene are opacitisized, in some places they form agglomerates. Grains of ore mineral are observed in association with them. Rare vesicles are sometimes filled with radiolith isotropic mineral.

Thin section V 12

Tuff

The structure is vitroclastic, psepho-psammitic, the cement is basal.

Varieties of slagged volcanic glass are observed in the thin section plane, which differ in structural and texture pattern, presence and size of inclusions, as well as in size and frequency of pores.

A fragment of non-rounded form of fine vesicular volcanic glass of brownish-gray color of micro-porphyritic structure with rare inclusions of prismatic crystals of polysynthetically twinned plagioclase and grains of clinopyroxene, and more rare inclusions of ore mineral, is characterized by fluidal texture; the texture is due to subparallel orientation of thin pores. The fragment has a zonal structure, which is manifested by a compacted outer zone on both sides and a vesicular middle part; the vesicles are often elongated into narrow cavities, oriented to the rock fluidity. The fragment is enclosed into fine-vesicular slagged brownish-black mass of perlitic texture with prismatic crystals of twinned plagioclase up to 3 mm in length and small crystals of clinopyroxene up to 1 mm in size (porphyritic structure). The crystals of plagioclase contain inclusions of the ground mass.

The binder mass is black-greyish-brown, structureless, the agglomerates of plagioclase and clinopyroxene grains are observed in it along the edges of the fragments described above.

Thin section L-1

Andesite

It is similar to L-4: the same fragments of carbonized rock.

The texture is ataxitic, the structure is porphyritic; the structure of the ground mass is pylotaxitic, the texture is fine-vesicular.

Phenocrysts are represented by plagioclase and clinopyroxene of prismatic habitus. The plagioclase is up to 1.5 mm in size, clinopyroxene is up to 1 mm. Fine crystals of hypersthenes occur 0.7 mm in length. In pylotaxitic mass the fragments of rock are observed carbonized and replaced by clayey material, possibly of volcanic glass; in some small fragments the globules of isotropic colorless glass are observed. At the same time cavities are observed, the walls of which are filled with carbonate with radiolith formations of isotropic mineral growing on the walls.

The ground mass is made up of brownish gray volcanic glass with microlites of plagioclase and small grains of clinopyroxene and ore mineral.

Thin section L-2

Andesite

The structure is porphyritic, the structure of the ground mass is pylotaxitic; the texture is fluidal, vesicular.

Phenocrysts are represented by plagioclase and pyroxene and make up about 15–17% of the thin section surface. Plagioclase forms long prismatic polysynthetically twinned crystals up to 5 mm in length. Crystals of clinopyroxene and hypersthene are 2–3 mm in length. The glomeroporphyry agglomerates of all mentioned minerals are observed.

The ground mass is made up of microlites of plagioclase and small grains of pyroxene fixed by brownish gray vesicular volcanic glass with frequent and fine impregnation of ore mineral.

Thin section L-3

Andesite

The structure is porphyritic, the structure of the ground mass is pylotaxitic; the texture is fluidal, vesicular.

Phenocrysts are represented by plagioclase of prismatic habitus 2–3 mm in size, less often by short-prismatic grains of clinopyroxene up to 1 mm in size. Phenocrysts are rather unevenly distributed in the rock; some crystals of plagioclase contain micro-impregnation of ore mineral.

The ground mass is unevenly decrystallized and depending on the content of microlites it is characterized now by hyalopilitic, then by pylotaxitic structures; it is made up of microlites of plagioclase, small grains of clinopyroxene and ore mineral fixed by brownish gray volcanic glass of vesicular texture; the vesicles are of elongated oval shape, they are distributed by the fluidity of the rock.

L-3 и L-4 are similar, but L-4 contains fragments of carbonized glass and vesicles more often.

Thin section L-4

Andesite Agglomerate

The texture is ataxitic, the structure is porphyritic; the structure of the ground mass is pylotaxitic and hyaline, the texture is vesicular.

In the brownish gray vesicular volcanic glass of pylotaxitic structure the rounded fragments of volcanic glass

Fig. 17. Sampling process of volcanic rocks by Arshavir Hovhannisyan and Dmitri Arakelyan in L 5-6 area (Photo: Arsen Bobokhyan).

of grayish brown color of hyaline structure occur, in some places with partial devitrification of volcanic glass; the fragments are carbonized on the periphery.

The ground mass of brownish gray vesicular volcanic glass besides the fragments contains microlites and rare blades of twinned plagioclase, grains of clinopyroxene and ore mineral.

Phenocrysts are represented by twinned plagioclase of prismatic habitus up to 3 mm in size and rare grains of clinopyroxene of irregular shape; they form agglomerates here and there. The vesicles of irregular shape are quite frequent up to 3–3.5 mm, the outgrowths of colorless mineral isotropic in crossed nicols are observed on the walls here and there.

Thin section L-5

Tuff Lava of Andesite

The texture is ataxitic, the structure is porphyritic; the structure of the ground mass is cryptocrystalline and hyaline.

In the thin section plane the areas of vesicular brownish gray glass are observed with hyaline structure and grayish-brown glass with cryptocrystalline structure of the ground mass.

Phenocrysts occupy up to 10% of the thin section surface, they are unevenly distributed in the rock and are represented by plagioclase of prismatic habitus 4–4.5 mm in size, and rare grains of clinopyroxene.

Thin section L-6

Basaltic Andesite

The structure is porphyritic, the structure of the ground mass is fine crystalline, microlitic.

Phenocrysts make up to 25% of the thin section surface; they are unevenly distributed and form agglomerates. They are represented by long prismatic crystals of polysynthetically twinned plagioclase 2–3 mm in length and by prismatic crystals of pyroxene up to 2 mm in size. In the agglomerates of phenocrysts the grains of magnetite up to 0.3 mm in diameter are also observed.

The ground mass is represented by a thin felt of microlites fixed by dark grayish-brown volcanic glass with small grains of pyroxene and ore mineral. The vesicles are of oval elongated shape up to 4–5 mm in size.

Thin section L-7

Slag

The structure is almost aphanitic, hyaline; the texture is pumiceous.

The rock is made up of slagged brownish black volcanic glass with numerous small and large pores and rare crystals of plagioclase with corroded peripheral membrane up to 0.7 mm in size, as well as even rarer and smaller grains of brownish clinopyroxene.

Thin section L-8

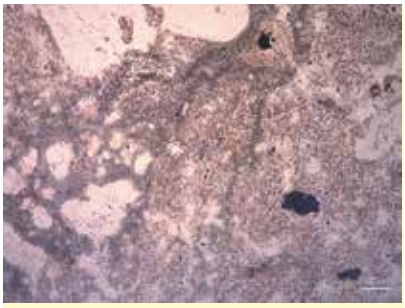
Andesite

The structure is porphyritic; the structure of the ground mass is hyalopilitic.

Phenocrysts make up to 20% of the thin section surface and they are mainly represented by plagioclase, less by slightly greenish clinopyroxene. The crystals of polysynthetically twinned plagioclase 2–3 mm in length are rare, the short-prismatic crystals 1.5 mm in length occur more often, they are often characterized by a lack of crystallographic faces and even in some cases by a fritted form. The relatively small crystals of prismatic habitus are corroded by the ground mass on the periphery. The small up to 0.7 mm crystals of clinopyroxene have prismatic habitus, the larger ones are characterized by irregular shape. The ground mass is made up of greyish-brown-brownish very fine vesicular volcanic glass with microlites and blades of plagioclase, micro-grains of clinopyroxene and rarely of magnetite. The vesicles are of rounded shape and they are few.

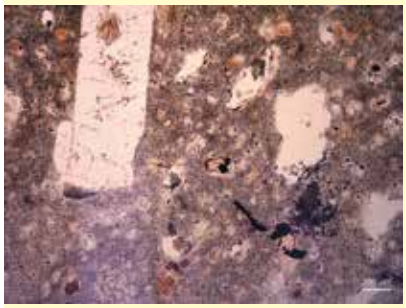
Thin Sections

V 01a

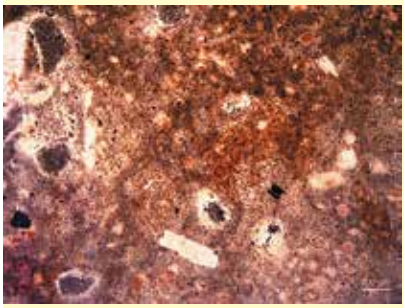


V 01b

V 02



V 03a



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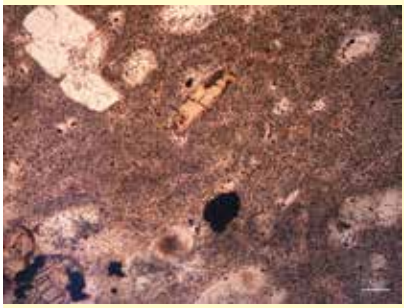
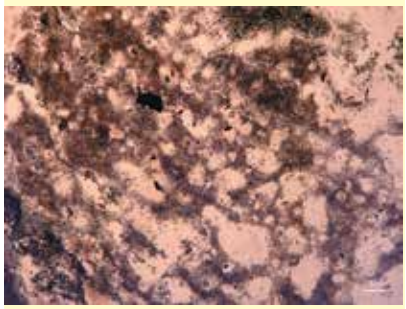
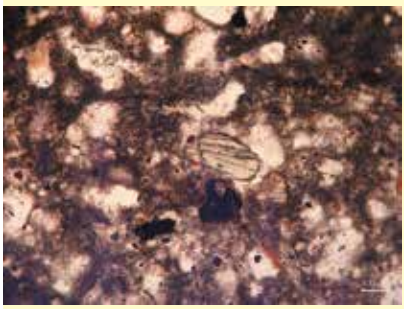


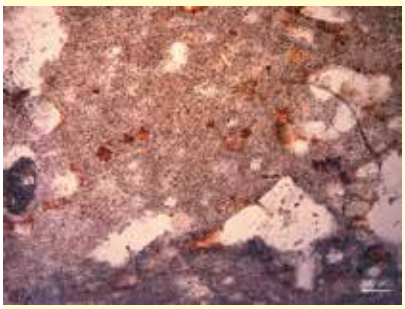
V 04



V 05



V 05'



V 06a

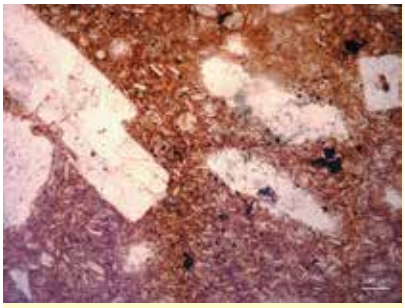
V 06a'

V 06b

V 06b'

V 1a	*Brownish-gray volcanic glass, fine vesicular with rare microlites; without analyser*
V 1b	*Light brownish and brownish-gray fine vesicular volcanic glass; without analyser*
V 2	*Vesicular volcanic glass with fine perlitic jointing; without analyser*
V 3a	*Areas of light gray volcanic glass of hyaline structure; without analyser*
3 b	*Brown-greyish vesicular volcanic glass with perlitic jointing and rare phenocrysts of twinned plagioclase; without analyser*
V 4	*Brownish-greyish brown non-uniform vesicular volcanic glass with phenocrysts of plagioclase, clinopyroxene and ore mineral; without analyser*
V 5	*The texture is poor fluidal, fine vesicular (***V 5** *without analyser;* **V 5'** *with analyser)*
V 6a	*Fragments of slagged glass.* **V 6a** *without analyser. Cryptocrystalline structure of the ground mass.* **V 6a'** *with analyser*
V 6b	**V 6b**. *Crystals of clinopyroxene and plagioclase. Crystals of plagioclase with microinclusions of volcanic glass; without analyser;* **V 6b'** *with analyser*

Thin Sections

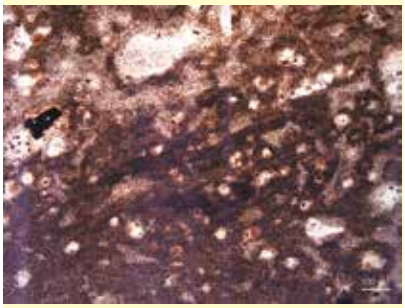


V 06c

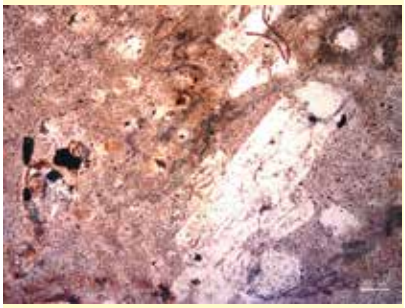
V 06c'

V 06fr

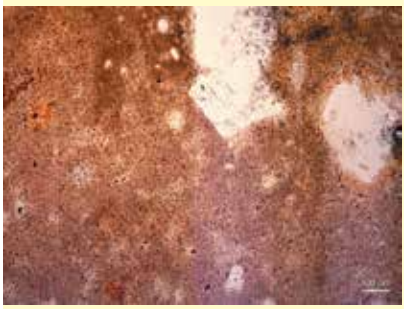
V 06fr'



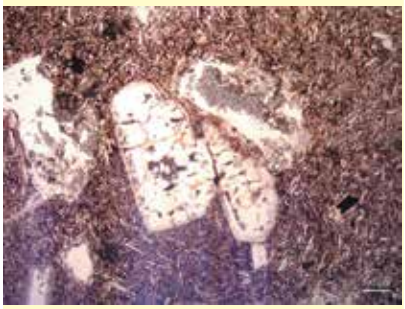
V 07a



V 07b

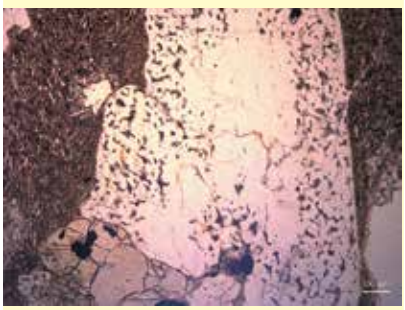


V 07c

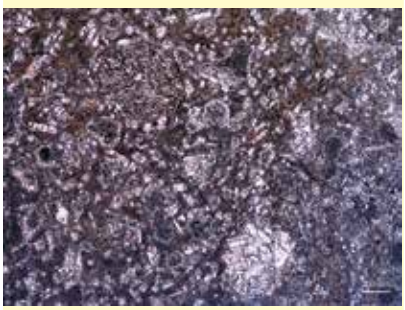


V 08

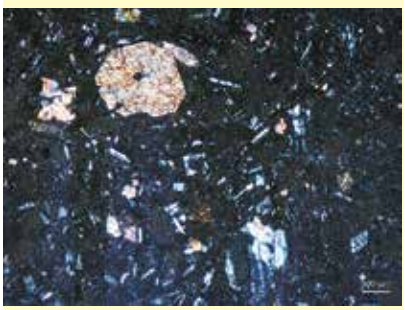
V 08'



V 08''



V 08fr

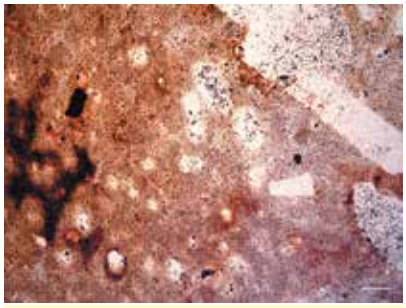


V 08fr'

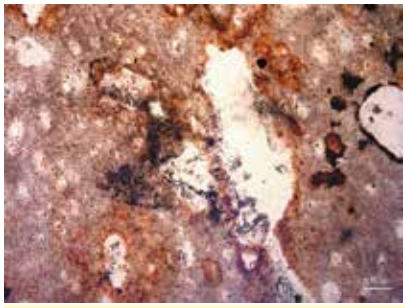
V 6c	**V 6c**. *Brown-greyish-brown volcanic glass with numerous microlites of plagioclase; without analyser* **V 6c'**; *with analyser*
V 6 fragment	**V 6 fr**. *Brownish gray volcanic glass with perlitic texture; without analyser;* **V 6 fr'** *with analyser*
V 7a	*Vesicular texture of brownish-brown and greyish volcanic glass; without analyser*
V 7b	*Perlitic, vesicular texture of the ground mass. The areas with limonitization changes; without analyser*
V 7c	*Hyaline structure of the ground mass; without analyser*
V 8	**V 8** *Pylotaxitic structure of the ground mass; without analyser;* **V 8'** *with analyser* **V 8''**. *The large crystals of plagioclase contain microinclusions of volcanic glass; without analyser*
V 8 fragment	**V 8 fr**. *Perlitic, fine vesicular texture of the ground mass. Crystals of clinopyroxene;* **V 8 fr'** *without analyser*

Thin Sections

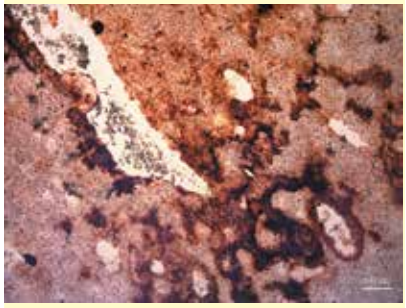
V 09a



V 09b

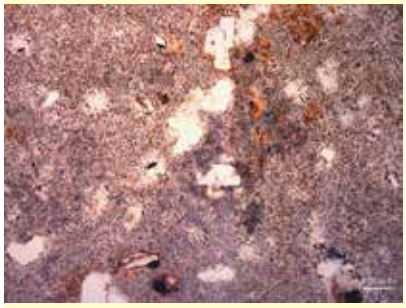


V 09c

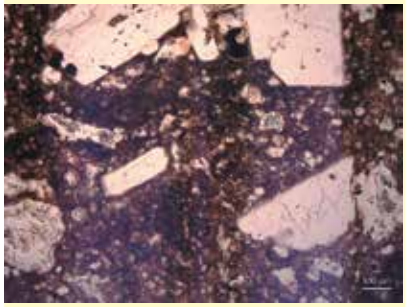


V 09d

V 10

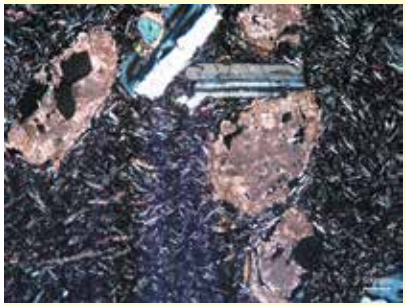


V 011



V 012

L 01



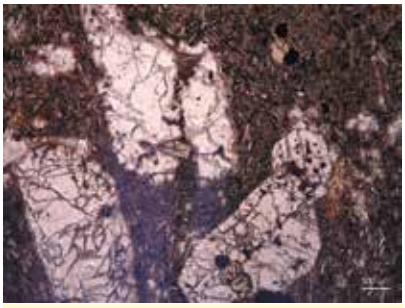
L 01'

L 02

L 02'

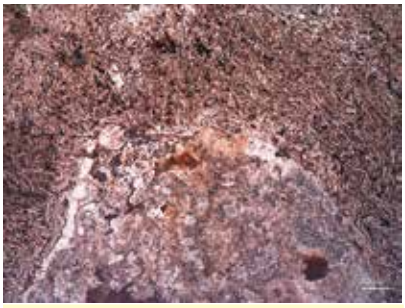
V 9a	*Very fine vesicular volcanic glass. Agglomerate crystals of plagioclase and clinopyroxene; without analyser*
V 9b	*Areas of limonitized very fine vesicular volcanic glass; without analyser*
V 9c	*Areas of limonitized brownish volcanic glass. The walls of some vesicles are filled with iron hydroxides; without analyser*
V 9d	*Areas of limonitized brownish volcanic glass; without analyser*
V 10	*Phenocrysts of plagioclase and clinopyroxene with ore mineral; without analyser*
V 11	*The rare vesicles are filled with radiolith isotropic mineral; without analyser*
V 12	*The binder mass is black-greyish-brown and structureless; without analyser*
L 1	**L 1**. *Fragments of carbonized and replaced by clayey material rock; without analyser;* **L 1'** *with analyser*
L 2	**L 2** *without analyser* **L 2'**. *The pylotaxitic structure of the ground mass; with analyser*

Thin Sections



L03

L03'

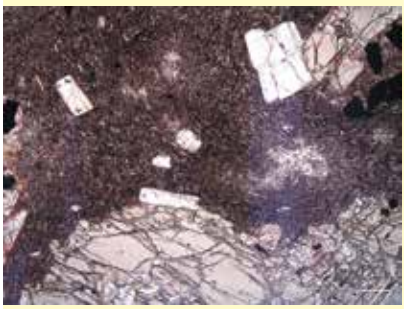


L04

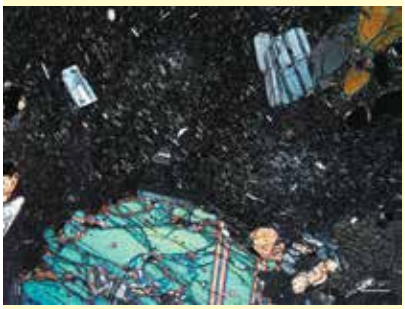
L04'

L05

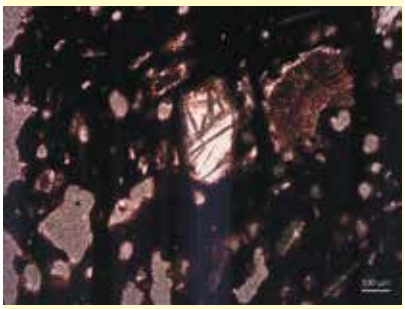
L05'



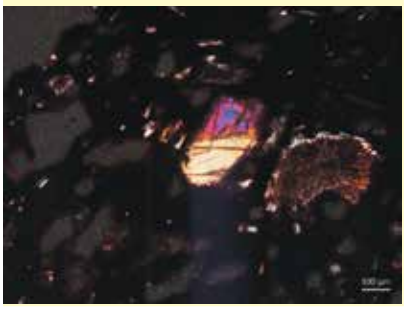
L06



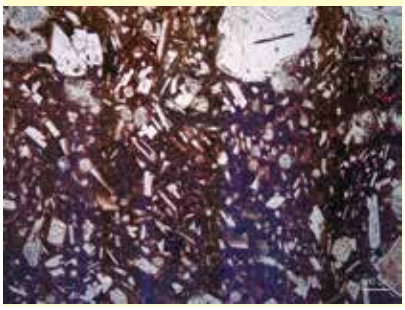
L06'



L07



L07'



L08

L08'

L3	**L3** *Crystals of plagioclase with micro-impregnation of ore mineral; without analyser;* **L3'** *without analyser*
L4	**L4** *Vesicles with colorless isotropic mineral; without analyser;* **L4'** *with analyser*
L5	**L5** *without analyser;* **L5'**. *Cryptocrystalline structure of the ground mass; with analyser*
L6	**L6** *Agglomerate prismatic crystals of pyroxene; without analyser;* **L6'** *with analyser*
L7	**L7** *Smaller grains of brownish clinopyroxene; without analyser;* **L7'** *with analyser*
L8	**L8** *Very fine vesicular volcanic glass with microlites of plagioclase and micro-grains of clinopyroxene; without analyser;* **L8'** *with analyser*

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