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‘Looking for the tombs of dragons’: preliminary results of archaeo-geochemical prospecting studies at Tirinkatar - Karmir Sar area, southern slopes of Mt Aragats, Armenia*

Arshavir Hovhannisyan, Dmitri Arakelyan, Harald von der Osten, Pavol Hnila, Alessandra Gilibert, Varduhi Siradeghyan and Arsen Bobokhyan

Abstract: An interdisciplinary archaeogeochemical research on vishaps (stone stelae also known as dragon stones) has been carried out for the first time in Armenia. The survey area is situated in the neighborhood of Tirinkatar and Karmir Sar volcanoes on southern slopes of Mt. Aragats. The geochemical prospecting studies have been realised on a high mountain meadow (2850 m asl) with 12 vishaps and numerous circular stone structures known as cromlechs. Five cromlechs excavated until now did not yield any human remains and the main aim of the geochemical prospection was to check whether other cromlechs detected by archaeological surface survey and by ground-penetrating radar contained burials. The geochemical haloes of some chemical elements indicate their anthropogenic character and a very high probability that some of the cromlechs were tombs.

Keywords: Aragats, Tirinkatar, Karmir Sar, vishap, archaeo-geochemical prospecting, interdisciplinary studies, geochemical anomaly of phosphorus

Introduction

Modernity and novelty of the project. In view of great amounts of archaeological fieldwork, there arises the question of choosing the most effective (informative) archaeological sites so as not to conduct massive excavations and damage the ancient landscape. It goes about the selection of certain sites (rich in archaeological material) among burial grounds occupying large areas, ancient settlements, where the availability of copper, bronze, lead, iron, silver, gold jewelry, tools, weapons, human and animal bones and other findings are supposed, since these are the most informative objects from the perspective of archaeological studies.

Practical significance. In the present study we have used the method of lithogeochemical prospecting, discovering and estimation, which have already been tested in the area of Artanish Peninsula (Artanish 23 and 29 cemeteries) and have proved its reliability.[1]

* The 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.

This method is an adapted version of lithogeochemical prospecting and exploration methods of metallic ore bodies and deposits.[2] In geochemistry, it is referred to as the Mobile Metal Ion (MMI) method, thanks to which a number of mineral deposits have been discovered.

The MMI method is based on the fact that secondary geochemical haloes are formed above and around the metallic ore bodies. In just the same way the anthropogenic geochemical haloes are formed above and around the metal objects and bones, buried in the archaeological buried-covered sites. The source of 'nutrition' of haloes, in the first case is the ore body, and in the second one - an artefact or a bone.

The core principle is as follows: all metal objects which have been produced and used by human beings, as well as human and animal bones, are more or less chemically active. Being once buried, they interact with an aggressive environment, including the ones with water rich in atmospheric oxygen. Thus, they form chemical compounds, which spread in soils due to surface tension forces,[3] producing their own anthropogenic geochemical haloes reaching up to the soil surface.

The basic tracer elements for the assessment of geochemical haloes are Cu, Sn, As, Pb, Zn, Ag, Fe, Ni, Co, Mo, Mn and gold, which form part of the archaeological findings of the Bronze and Iron Ages, as well as phosphorus (P), which forms part of human and animal bones. The formed geochemical haloes of those elements contain quantitative and qualitative information and are expressed (reflected) on the earth surface in soils. Some researchers have already begun implementing that kind of assessment work for ancient Roman settlements and obtained reliable results.[4]

The chemical content of the haloes is the same as that of the buried artefact, so mapping the haloes on the soil surface by means of geochemical studies shows the areas under which metal findings or bones are present, without the need of excavating them. This result enables the researcher to 'read' and qualitatively evaluate the archaeological site using a non-destructive method that can considerably integrate more familiar techniques, such as geoprospection and the like. As mentioned above some researchers have already begun implementing that kind of assessment in Roman settlements and we tested it in the area of Artanish Peninsula.

In short, the MMI method applied to archaelogical sites enables to:

a) reveal metallic objects, human and animal bones at a depth of up to some meters;
b) determine the types of metals which were applied in alloys of buried objects;
c) contribute to reducing financial expenses and time investment during archaeological excavations;
d) facilitate the identification of the boundaries of a given archaeological site, and has a significance from a palaeoecological point of view.

[1] Hovhannisyan *et al.* 2020a.
[2] Hovhannisyan *et al.* 2017. Cf. Solovov 1990; Grigorian 1992.
[3] Mann *et al.* 2005.
[4] Cook *et al.* 2005; Oonk *et al.* 2012; Sylvester *et al.* 2017.

Purpose, nature and area of the work. From the beginning of the studies the purpose of our work was to reveal and evaluate the expected geochemical haloes in the soil layer above the presumable buried archaeological monuments singled out by the archaeologists identified by archaeological surface surveys and by the prospections with ground-penitrating radar.

The 'Areguni' Project research successfully showed[5] that the geochemical haloes emerge in the outcome of decaying and corrosion of artefacts as well as human and animal bones, then moving to the surface through capillary forces.

The survey area of this study is a surface of about 1 sq km situated near the Tirinkatar and Karmir Sar volcanoes, on the southern slope of Mount Aragats, hypsometrically at an average height of 2850 m asl. This area, of course, has not been selected randomly. Archaeological scientific research has been carried out here since 2012.[6] The site is known as the place with the highest concentration of vishaps, prehistoric stelae 12 of which have been identified until now.[7]

Apart from the vishaps, the site is replete with archaeological features, including cromlechs and other burial mounds, which might be contemporary to the vishaps. Four cromlechs dating to the Middle Bronze Age were previously excavated in other parts of the site. They did not yield a single bone. It is not clear whether the bones were never present or whether they disappeared due to the harsh climatic conditions persisting over millennia. Geophysical survey of the area by Harald von der Osten brought evidence of further dispersed cromlechs and cromlech clusters.[8] In order to identify the time period and historical situation those newly attested cromlechs need to be additionally investigated. Besides, we need to obtain an answer to the question whether the local cromlechs are real tombs that once contained burials or whether they were fake tombs distracting the tomb robbers, or, maybe they have another, symbolic or unknown significance. The geochemical prospection has great potential to offer some chronological and functional answers without excavating the cromlechs – a tempting option given the tight financial and temporal constraints of most archaeological projects. In this contribution, we show that geochemical prospection works as a critical integration to it.

Geological structure of Aragats volcano massif and its geomorphology

For people who carved dragons out of volcanic rocks the geological environment should have played an essential role in shaping the sacred landscape; Mount Aragats in general, and Tirinkatar with its environment in particular, strictly correspond to this idea. With this in mind the vishap architects chose the place – the fluvioglacial plateau as such perhaps coming out just of its geological features.

[5] Hovhannisyan *et al.* 2017.
[6] Gilibert *et al.* 2012; Bobokhyan *et al.* 2018.
[7] Hovhanisyan *et al*. 2020b (forthcoming).
[8] Cf. von der Osten *et al.* 2018.

The Aragats volcano massif was formed as a result of repeated manifestations of volcanic activity for a long period of time. Many researchers have studied the geology of the Aragats massif. Starting from G. Abich (second half of the 19th century) and to date the works of more than one generation of researchers have been dedicated to investigation of the geological structure of the massif, its tectonic position, the stratigraphy of individual components of volcanogenic and fluvioglacial formations, petrochemistry, genesis of individual lava flows and many other issues.

The rocks of the ancient foundation, occurring at the base of the volcano massif are represented by intensively dislocated deposits of Eopalaeozoic, Upper Cretaceous, Palaeocene-Middle Eocene, and in the periphery – of Oligocene and Miocene. Foothill areas of the Aragats massif are large depressions – Ararat, Shirak, Aparan, filled with Neogene and Quaternary deposits (Figure 1).

The Aragats volcano massif has a shape of a huge convex shield with four peaks in the middle. The thickness of volcanogenic formations, forming the massif reaches 1.5 km: they are represented by diverse lavas of andesite-basalts, andesites, andesite-dacites, rhyolites, etc., their tuffs and tuff breccias, which are 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 above the sea level. The four jagged peaks are the remains of volcanic cone. They surround the crater extended by water-glacial erosion to the diameter of 2 km and at a depth of 300-400 m.[9] In the near of the peak there are ca. 10 glacial circuses, which are 3-4 km long and 1-2 km wide. The centre of modern glaciation of Armenia is also there, with an area up to 2-3 km^2. The ice is firn, which shows that the glacier is in retreat. In orohydrography of the Aragats massif a significant place, besides the rivers originating from the summit, is occupied by lakes, the number of which approaches 100.[10]

Geological structure of Mount Tirinkatar and its surroundings

Along the right bank of the Amberd River, at the base of geological section, are situated the most ancient Upper Pliocene formations of the site, represented by andesites, andesite-dacites and dacites of the Upper Aragats subsuite (Figure 2). The surface of lavas is eroded, knobby and uneven. Andesite-dacites are thin plate-like with giant concentrically-conchoidal joint of light grey ground mass.

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

An andesite-dacite cover occurs on all of the above lavas and tuffs, overlying all mentioned areas in the section formations and widespread in the western part of the site; its thickness in some areas reaches 15 m.

[9] Amaryan 1972.
[10] Lichkov 1931.

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. Eruption centres 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 (Figure 2).

The western slope of Mount Tirinkatar is covered by Upper Quaternary glacial and water-glacial loamy sands, loams, as well as boulder-blocky deposits. In the valley of the river Ampur 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.

The interstream area of Ampur and Amberd rivers marked by elevations of Tirinkatar and Karmir Sar is predominantly composed of Middle Quaternary lava formations,[11] 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 (Figures 2; 3/1).

Geochemical prospecting-assessment of works at archaeological site Karmir Sar

The following issues have been resolved for the goal achievement: site reconnaissance and topographical adjustments, determination of sampling network for each single archaeological object, geochemical sampling, sample drying, sieving, crushing in laboratory conditions up to the dimensions, intended for the analysis, spectral semi-quantitative analysis for 38 chemical elements, geochemical interpretation and preparation of maps in GIS format.

Geochemical soil sampling of six archaeological objects (cromlechs) was carried out during the geochemical prospecting-assessment work in the area of Tirinkatar-Karmir Sar (Operation A_Cromlech 5; Operation G_Cromlech 1; Operation J_CromlechVishap 7; Cromlech Cluster 1 - Cromlech 1; Cromlech Cluster 1 - Cromlech 2; Cromlech Cluster 2 - Cromlech 3) (Figure 4/1). On the whole 123 samples were taken (Table 1). The sampling selection carried out by an archaeological-geological interdisciplinary group. The sampling loci were first georeferenced by a handheld GPS navigation device. Later, the location of the sampling points was more accurately measured by total station. The sampling network was adapted on the specific feature size (Table 1). The number of samples could, of course, have been greater, but the financial means were limited. Sampling was carried out at a depth of 15-20 cm, after removing the topsoil with a hand shovel. The weight of samples varied between 150-250 g, depending on degree of humidity and presence of gravel. Each single sample was given its own index number and its coordinates were recorded in UTM system.

[11] Zavaritskiy 1944; *idem* 1947; Aslanyan 1950; *idem* 1956; Amaryan 1972; Meliksetian 2012.

	Archaeological Object	Quantity of Samples	Sampling Network Size*	Approximate Surface of Sampling Area, m^2
1	Operation A_Cromlech 5	16	4 × 4 m	140
2	Operation G_Cromlech 1	15	3 × 3 m	225
3	Operation J_Cromlech of Vishap 7	11	3 × 3.5 m	80
4	Cromlech Cluster 1- Cromlech 1	16	4 × 4 m	225
5	Cromlech Cluster 1- Cromlech 2	36	10 × 10 m	3600
6	Cromlech Cluster 2- Cromlech 3	29	10 × 5 m	1130
Total 123				5400

** Network size has up to 20% deviation in some places, depending on surface location of archaeological objects and clusters*

Table 1

Sample processing was carried out in the Laboratory of Mineralogy of the Institute of Geological Sciences of NAS RA. Duplicates were taken for all samples to carry out further checkup analysis. Semi-quantitative analysis was carried out in the specialised geochemical laboratory (Geochemical laboratory of JSC 'Exploration Association', Aleksandrov, Russia).

It should be noted that for the archaeological objects at such elevations (more than 2500 m above sea level), where negative temperatures last for six months or more, geochemical prospecting-assessment explorations have been made for the first time all over the world.

Geochemical prospecting (exploration): results and discussions

When conducting geochemical prospection studies, the chemical elements Cu, Sn, Pb, Zn, Ag, As, Ni and Co are usually the centre of attention, which in our case are indicators of artefacts. The logic of such a choice is as follows: these elements are included in the composition of assumed metal artefact, and actually they are present in the composition of all artefacts of Bronze and Iron Ages in the territory of the Republic of Armenia, or they are the main component. Particular attention was also paid to phosphorus, an element present in the composition of human and animal bones, having the highest geochemical migration feature while decaying in nature. As the results of 'Areguni' Project have shown,[12] phosphorus is a primary indicator for the presence of tombs.

The studies conducted by us on the cromlechs of Tirinkatar-Karmir Sar area confirm that actually it is only phosphorus that works, and it is the sole reliable

[12] Hovhannisyan *et al.* 2020a.

element in this landscape for prospecting the presence of tombs. Real information has been mainly obtained during the interpretation of this element.

The passive role of metallic elements is presumably connected with the low temperature (braking or sharp deceleration of chemical processes in soils), short vegetation period of plants (which leads to a reduction in destructive chemical processes by the plant's root system), as well as the fact that in the most part of the year, at these altitudes, the water is frozen, then the processes of leaching and capillary transfer to the surface of the soil stop.

It should be noted that the occurrence form of chemical elements in soils is very important, since they often have a significant impact on migration features of chemical elements, therefore they can promote the formation of geochemical anomalies or on the contrary, prevent it. But this type of research requires additional time and financial resources, so it is left for the future.

Operation A_Cromlech 5. It is located in the central part of the study area. 16 geochemical samples were taken. The sampling area is about 140 m^2. Data for 19 elements were obtained through the spectral analysis made for 38 chemical elements. Geochemical maps in GIS format were prepared for the latter. No definite anomalies of base metal elements which could be present in the composition of possible metal artefacts were recorded on the site. Here, normally, the difference between their background and highest values is measured by a coefficient of 1.2-1.5, which naturally cannot be of particular interest. The picture is quite indistinct for these metals and no contrast of contents is observed. Phosphorus demonstrates a different picture. In the SW corner of the site it has formed rather a contrast anomaly (according to the results of N 4 and N 8 sampling points), where the values compared to the background ones are rather high - 6 to 10 times (Figure 4/2).

It is clear that in the depth of SW corner there is a source (sources) generating anomaly of phosphorus and there is high probability that they are human or animal bones since although animal urine contains phosphorus compounds, however, they cannot generate such contrast anomalies because of their extremely low contents.

As regards the phosphorus fertilizers, it is clear that crops have never been grown at these altitudes; therefore the matter of fertilizers is completely irrelevant. Whether the phosphorus source is old or recent, perhaps the answer to this question will be given by further excavations. In any case, it is a fact that to form a contrast and permanent geochemical haloes we need to have a permanent source for those haloes: a source which has been decaying and moving to the daylight surface during centuries and millennia.

Although the metals in the site behave rather inert, however, there is one striking and worth mentioning fact. The matter concerns copper and barium. Barium has a contrast anomaly in the same sample no. 4, and as for copper – though it did not produce contrast anomaly, however, the highest background value is exactly in the same sample no. 4 (Figure 5/1-2), in the very sample where the content of phosphorus is also the highest.

If at least a slight increase in copper content in the SW corner can be explained by linking it with the assumed burial (joint manifestation of phosphorus and copper), then the relatively high barium content in the same SW corner so far does not follow any logic and needs further study.

Operation G_Cromlech 1. It is located in the NW part of the study area. 15 geochemical samples were taken here. The sampling area is about 225 m^2. Data for 18 elements were obtained through the spectral analysis made for 38 chemical elements. Geochemical maps in GIS format were prepared for the latter.

All elements of this site almost identically display inert behavior; at best the background values are exceeded 1.2-1.5 times (Figure 6). There are some exceptions for rare elements; however, this is probably the subject of further research, since no work is known in archaeological-geochemical prospecting sphere regarding the latter ones.

Operation J_Cromlech of Vishap 7. It is located in the eastern part of the study area. 11 geochemical samples were taken here. The sampling area is about 80 m^2. Data for 20 elements were obtained through the spectral analysis made for 38 chemical elements.

Sampling was carried out around the vishap partially excavated. Sampling includes southern, eastern and western wings of the archaeological trench. One individual sample - no. 11 was taken from the section of south-eastern corner of the archaeological object, just above the top of the pile of heavily burnt bones (Figure 7/1-2).

That sample had a reference value for us, since it was the only case when sampling was carried out not by ‘blind network’, but from the soil above the bones of apparently old origin, in which the abnormal content of phosphorus would be the most striking proof not only of the fact that phosphorus ‘works’, but it would also testify to the correct selection and accuracy of the method of laboratory analysis.

Later it turned out that this little experiment was a success. The analysis results justified the expectations. Contrast anomaly of phosphorus was obtained in that site, based on the contents of samples nos 2 and 11. It is noteworthy that the background values are exceeded 5 and 10 times, accordingly.

So we can state not only the fact that we have anomaly of phosphorus formed in the soil layer, but also see the source of that anomaly – the pile of sacrificed (?) bones at the bottom and in the section of the archaeological trench.

Interesting values were also obtained for silver (Figure 8/1). The sample no. 9 showed the result of 0.5 ppm, which is a rather high value and it needs checking during the further excavations. It should be noted that the higher contents of silver are recorded for only one other sampling area - Cromlech Cluster 2 - Cromlech 3 (Figure 11/2): there are no traces of silver in the other sites. The other elements showed values near the background ones and they are of no interest at the moment.

Cromlech Cluster 1 - Cromlech 1. It is located in the western part of the study area. 16 geochemical samples were taken. The sampling area is about 225 m^2. Data for 20 elements were obtained through the spectral analysis made for 38 chemical elements. In this site the sample no. 6 showed not so big contrast anomaly of phosphorus: the background value is exceeded twice (Figure 8/2). All the other basic elements have values close to the background ones. This may be viewed as an indication of absence of metals and bones in this particular cromlech.

Cromlech Cluster 1 - Cromlech 2. It is located in the western part of the study area. 36 geochemical samples were taken here. The sampling area is about 3600 m^2. Data for 21 elements were obtained through the spectral analysis made for 38 chemical elements. Geochemical maps in GIS format have been prepared. Geochemical sampling in this case was carried out not on a separate cromlech, but all over the cromlech cluster.

Phosphorus has formed anomalies exceeding the background 2.5 times in the eastern part of the site: samples nos 27 and 32 (Figure 9/1).

Visually these anomalies are not connected with any particular archaeological object. It should be noted that in this site, as in Operation A_Cromlech 5, barium again produced a contrast anomaly, and only in this case the position of barium anomalies does not exactly coincide with phosphorus, but it occupies the western part of the site (Figure 9/2).

The other elements do not contain information for geochemical interpretation.

Cromlech Cluster 2 - Cromlech 3. It is located in the eastern part of the study area. 29 geochemical samples were taken here. The sampling area is about 1130 m^2. Data for 21 elements were obtained through the spectral analysis made for 38 chemical elements.

This is the most promising site, because the most contrasting anomalies of phosphorus are located here (Figure 10/1), more contrasting even in comparison to *Operation J_Cromlech of Vishap 7* (above the pile of sacrificed bones).

The maximum values reach up to 20 000 ppm. That sample was taken from the point which was located in the centre of the circle similar to a cromlech (sample no. 19 - 2500 ppm and sample no. 20 - 20 000 ppm are taken outside the sampling network, visually from cromlech-like construction).

Such values, especially for sample no. 20, with high probability, indicate the presence of bones below the surface. This conclusion is also complemented by the abnormal contents of samples no. 11 (10 000 ppm) and no. 12 (10 000 ppm) in the immediate vicinity of the sample no. 20.

The element barium, as in the previous two cases, also generates contrast anomalies (Figure 10/2). Moreover, this anomaly coincides completely with the anomaly of phosphorus, showing the close correlation of these two elements. Thus, we can state that barium at least in two cases - Operation A_Cromlech 5 (Figures 4/2; 5/2) as well as Cromlech Cluster 2 - Cromlech 3 (Figure 10/1-2) forms a close spatial correlation with phosphorus. If anthropogenic origin of barium anomaly is confirmed, it will be possible to study the use of correlation relations of phosphorus and barium as prospecting criteria of geochemical anomalies of anthropogenic origin.

It is noteworthy that tin shows minimum values in the area of phosphorus and barium anomalies (Figure 11/1). This phenomenon has never been considered in similar activities by exploration and prospecting geochemists. This requires additional research.

The element silver also generates more or less contrast anomalies. The most contrast ratios are several times higher than the background one (Figure 11/2). In this site the samples nos 9-10; 21-23 showed the result of 0.07-0.1 ppm, which is a rather high value and it needs further checking during future excavations. But the anomaly of silver has no spatial correlations with other elements. The behavior of silver in the area of Cromlech Cluster 2 - Cromlech 3 requires new studies.

Interestingly the mentioned positive data gained from geochemical prospection (see Figures 10/1-2) nicely correlate with the results of geophysical radar survey realised by H. von der Osten in 2019 (Area 23), which supposes the presence of a rectangular chamber of *ca.* 3 x 2.6 m in the same location (Figure 12/1-2). Geochemical survey shows positive anomalies of P and Ba, as well as negative anomaly of Sn in the soils above the geophysical anomaly (Figure 13).

Conclusions

While describing the archaeological objects under the study we discussed the geochemical features of the haloes formed above them and the connection of the geochemical features with the assumed objects of anthropogenic origin located under the soil, as well as their localisation.

We have an actual fact when the phosphorus anomalies of already excavated area of Operation J_Cromlech of Vishap 7 are in proven spatial and visual connection with the pile of bones at a depth of 15-20 cm. This fact is the strongest argument, which gives reason to believe that there are also piles of bones under the phosphorus anomalies formed in Operation A_Cromlech 5 and especially in Cromlech Cluster 2 - Cromlech 3.

The use of geochemical method allows us to identify the areas in which phosphorus, copper and barium anomalies are integrated. The role of barium has not yet been fully clarified. Copper and phosphorus integration make it possible to assume the possible existence of bones and copper (bronze) objects in the SW corner of Operation A_Cromlech 5 at a certain depth. Cromlech Cluster 2 - Cromlech 3 deserves a special attention: here, together with phosphorus anomalies with the highest abnormal values, the barium anomaly is again integrated. They are located inside the cromlech circle, which gives reason to assume the existence of an ancient burial.

For the further work, we recommended to carry out excavations in the SW corner of Operation A_Cromlech 5 and in the area of samples nos 20, 11 and 12 of Cromlech Cluster 2 - Cromlech 3.

We think that, in the future, the study of material composition of metal artefacts excavated in the area will enable using the presumable prospecting-assessment potential of chemical elements in the upcoming archaeological activities.

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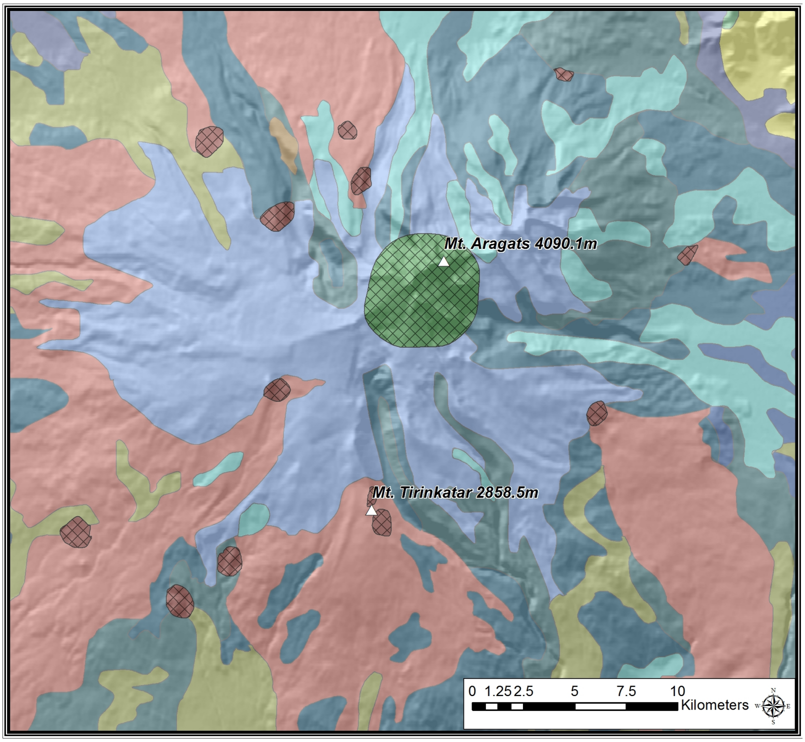
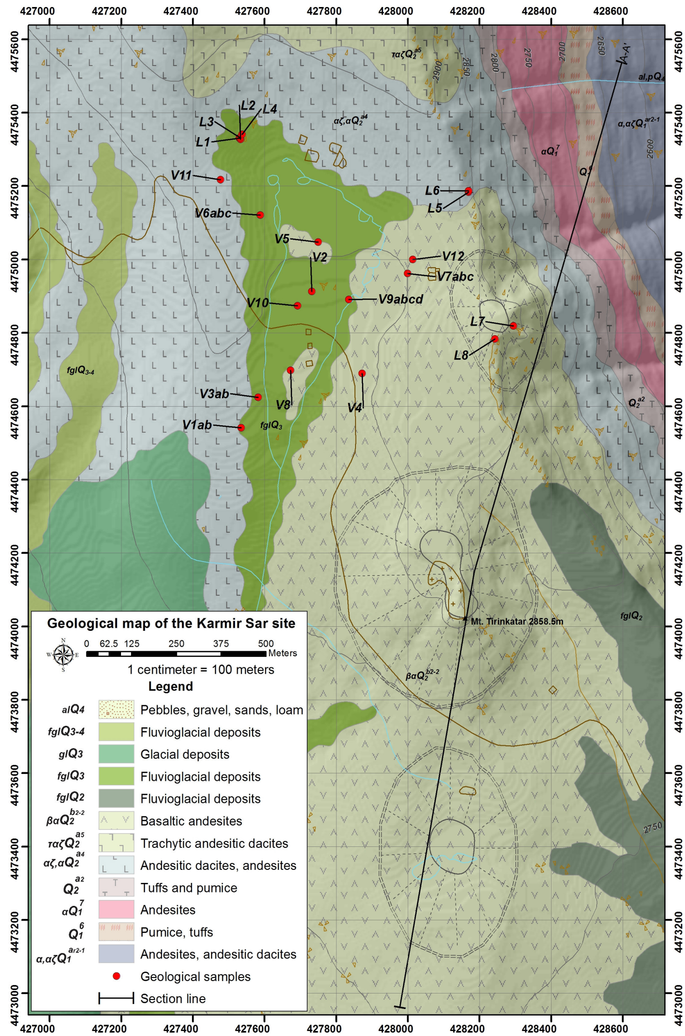


Legend

- **Q4** Eluvial, alluvial slop sediment, pebbles, sands, sandsoils, sand loams
- **Q4** Alluvial sediments of Shirak, Aparan, Araratian, sands, clays, pebbles
- **Q3** Glacifluvial, slope and flood block-pebbles and breccia, formations
- **Q3** Ignimbrit tuffs of Yerevan, Ani, Artik, Byurakan types
- **Q3** Volcanic lava flows, basalts, andesitebasalts, andesites, and andesitedacits
- **Q2** Basalts, andesitebasalts, andesites, andesitedacites, dacites
- **Q2** Upper whitish subsuite, riolites, obsidians, pearlite, their piroclasters
- **Q1** Basalts, andesitebasalts, andesites, andesitedacites, and dacites
- **Q1** Andesitebasalts, andesitadacites, dacites
- **K1** Sandstones, limestones, marls, alevrolites, tuffalevrolites, layers of tuffsandstones
- The central craters of upper pliocene Aragats ploygenetic volcano.
- Centres of quartenary volcano
- Volcanoes

Figure 1. Geological scheme of Aragats volcano, by Dmitri Arakelyan.



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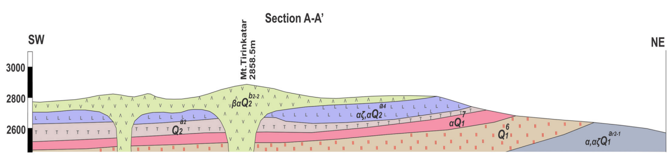

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Figure 2. 1. Geological map (Scale 1:10 000) of Tirinkatar volcano and its surroundings with sampling points from vishaps (index V) and lava flows (index L), by Arshavir Hovhannisyan and Dmitri Arakelyan. 2. Geological section along the A-A′ line,
by Arshavir Hovhannisyan and Dmitri Arakelyan.

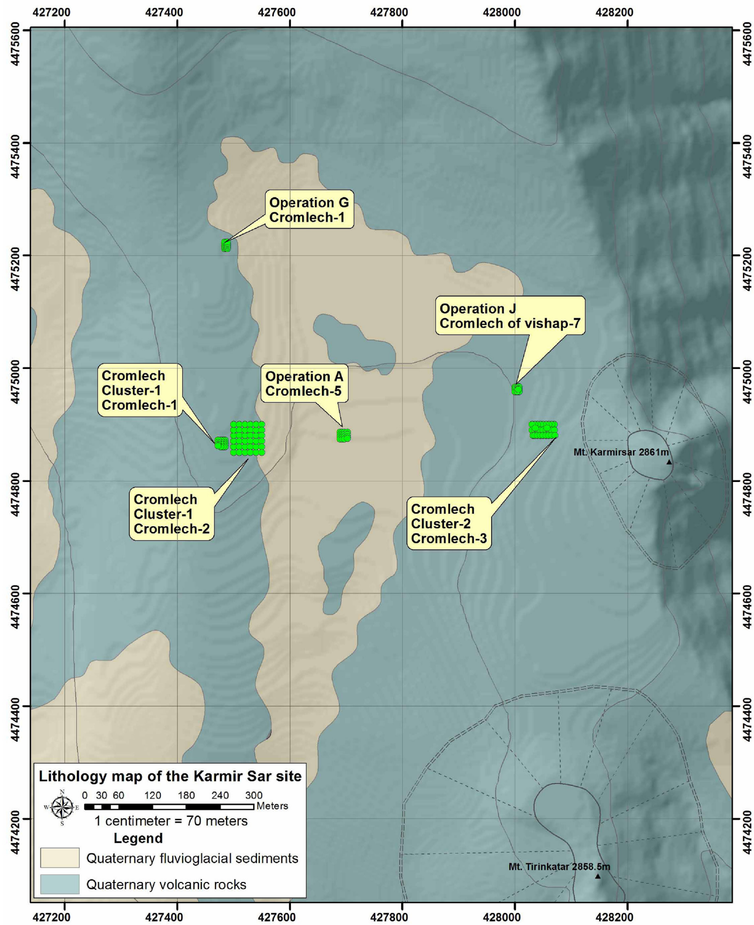

Figure 3. General area of geochemical sampling, by Arshavir Hovhannisyan and Dmitri Arakelyan.

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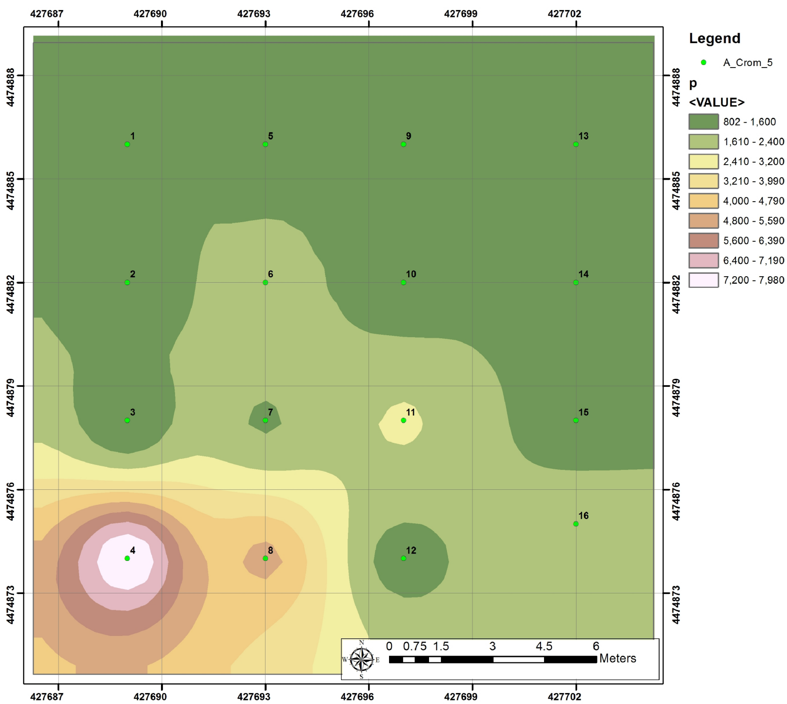

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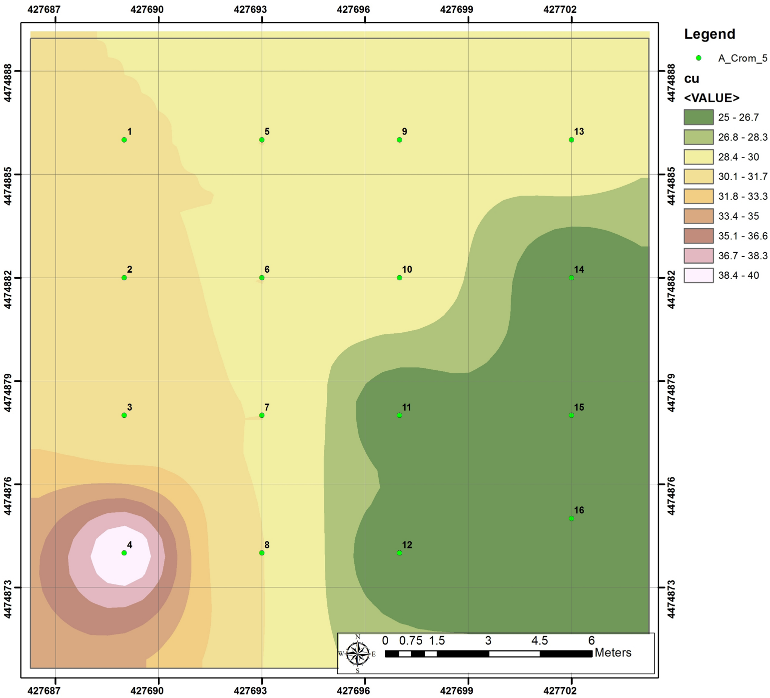
Figure 4. 1. View on Tirinkatar and KarmirSar. Vishaps located on the plateau, photo by Arsen Bobokhyan. 2. Operation A_Cromlech 5. Geochemical anomaly of phosphorus, by Arshavir Hovhannisyan and Dmitri Arakelyan.



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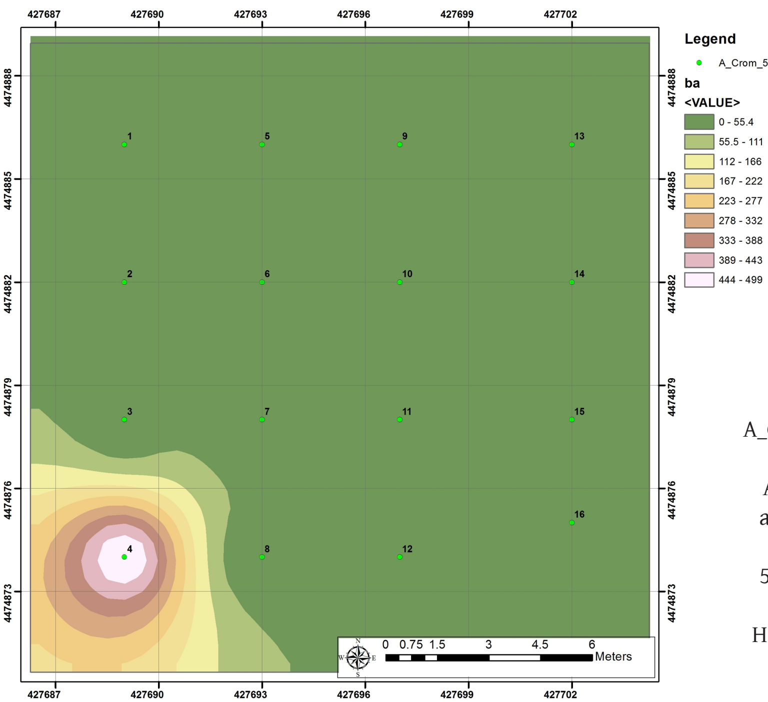

Figure 5. 1. Operation A_Cromlech 5. Geochemical anomaly of copper, by Arshavir Hovhannisyan and Dmitri Arakelyan. 2. Operation A_Cromlech 5. Geochemical anomaly of barium, by Arshavir Hovhannisyan and Dmitri Arakelyan.

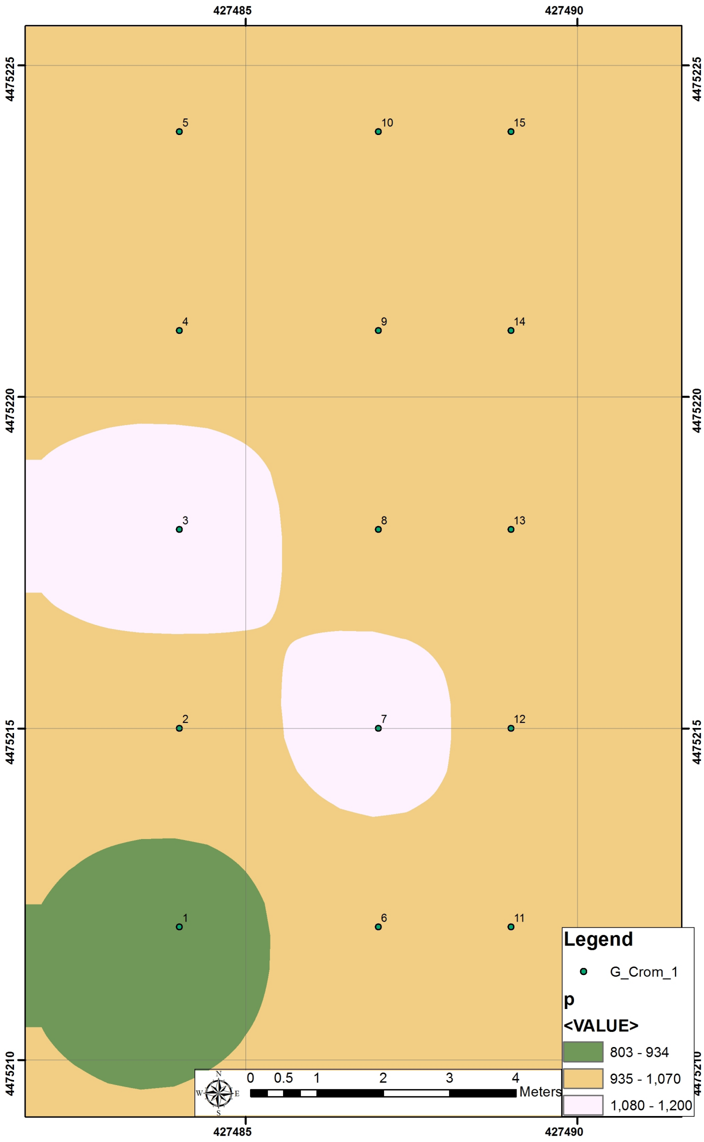

Figure 6. Operation G_Cromlech 1. Geochemical anomaly of phosphorus, by Arshavir Hovhannisyan and Dmitri Arakelyan.

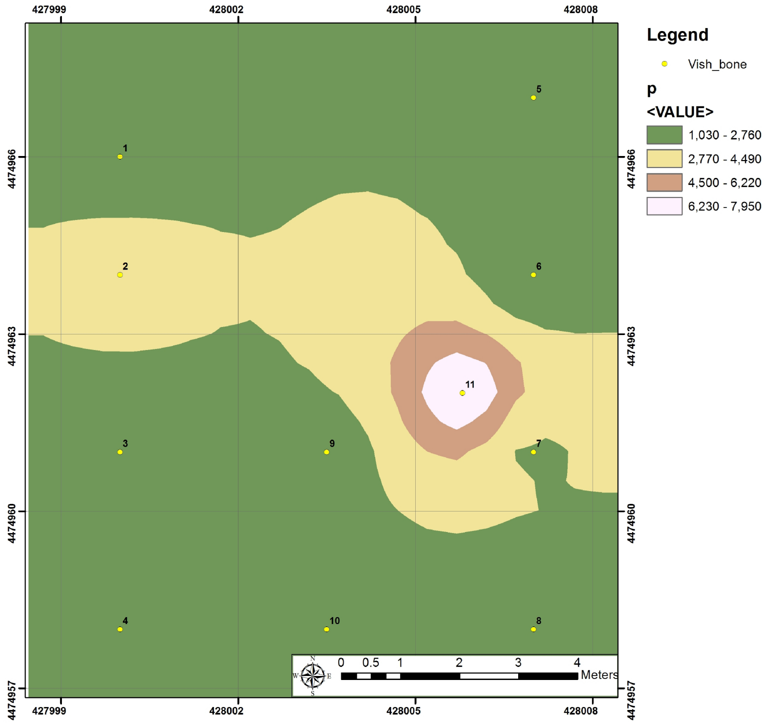

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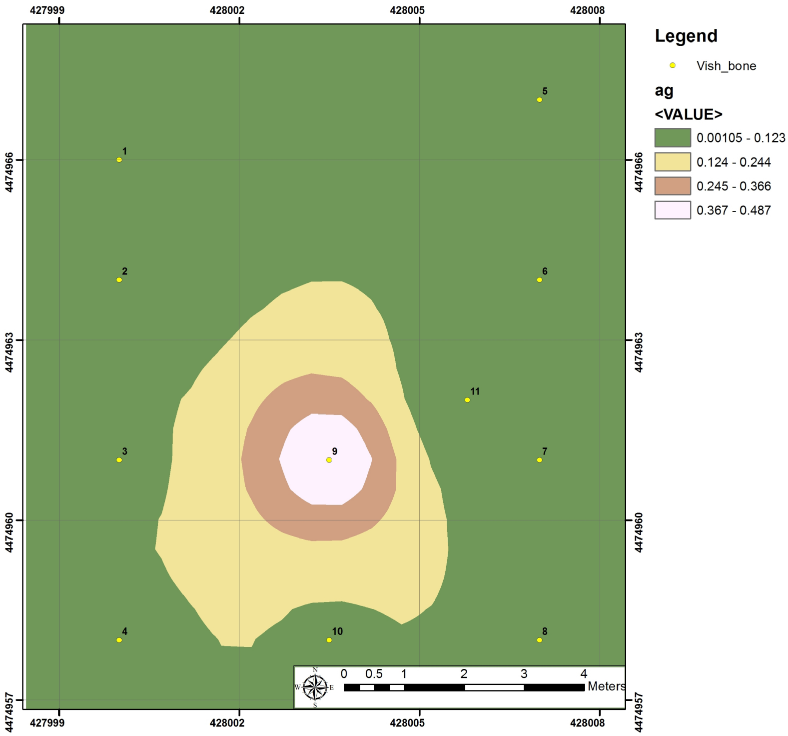
Figure 7. 1. Operation J_Cromlech of Vishap 7. Geochemical anomaly of phosphorus, by Arshavir Hovhannisyan and Dmitri Arakelyan. 2. Operation J at the end of excavations. Drone photo by Pavol Hnila.



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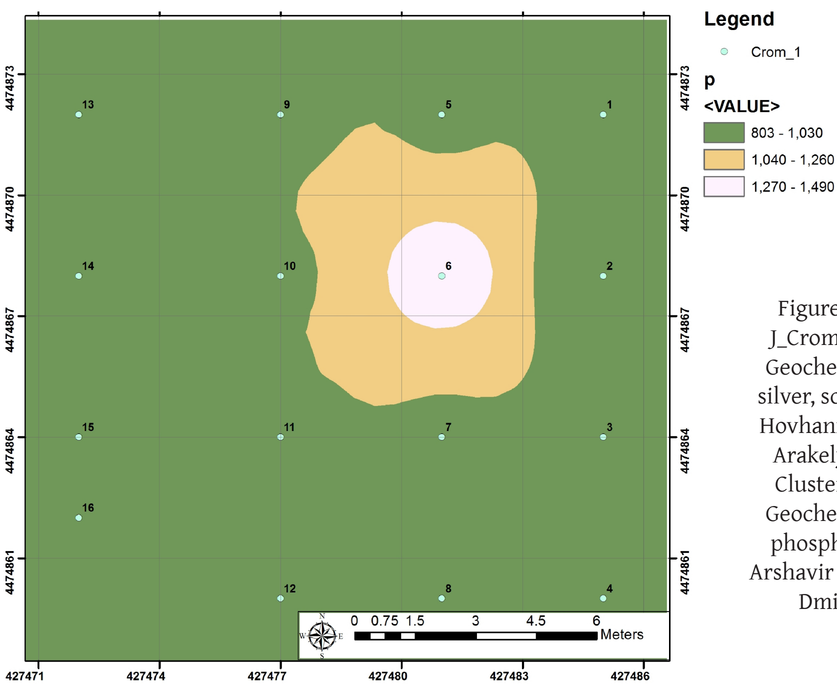
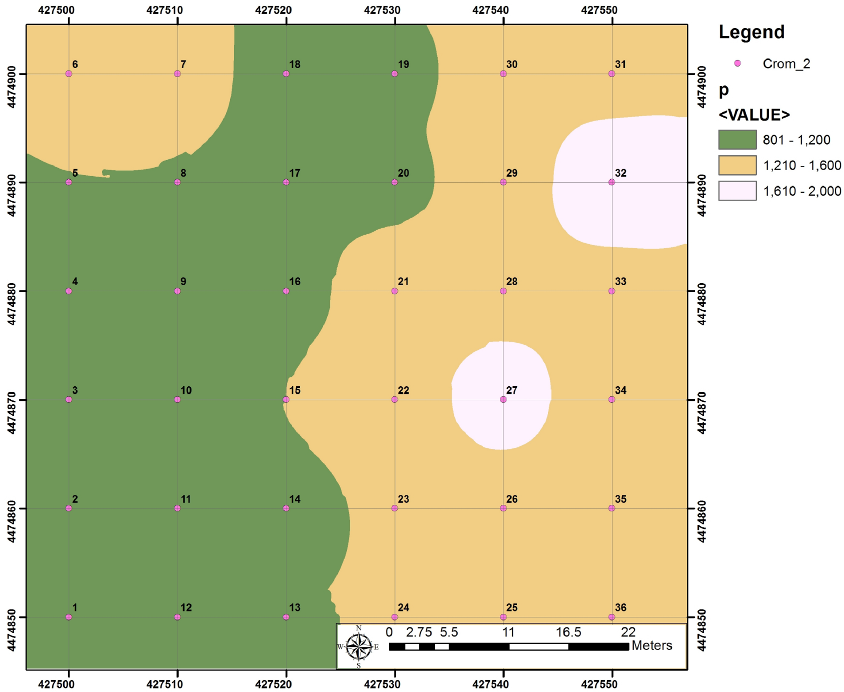


Figure 8. 1. Operation J_Cromlech of Vishap 7. Geochemical anomaly of silver, scheme by Arshavir Hovhannisyan and Dmitri Arakelyan. 2. Cromlech Cluster 1 - Cromlech 1. Geochemical anomaly of phosphorus, scheme by Arshavir Hovhannisyan and Dmitri Arakelyan.



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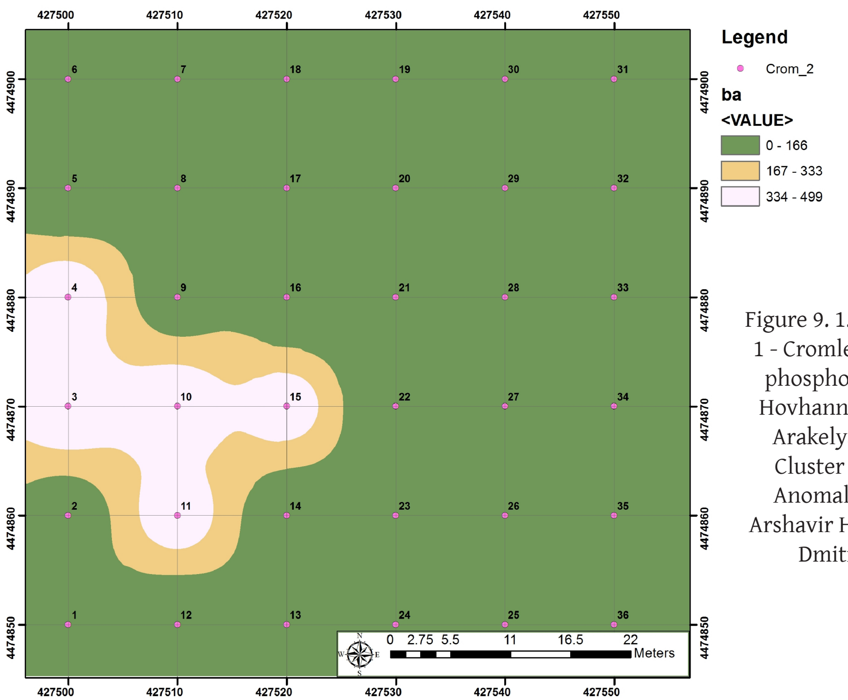
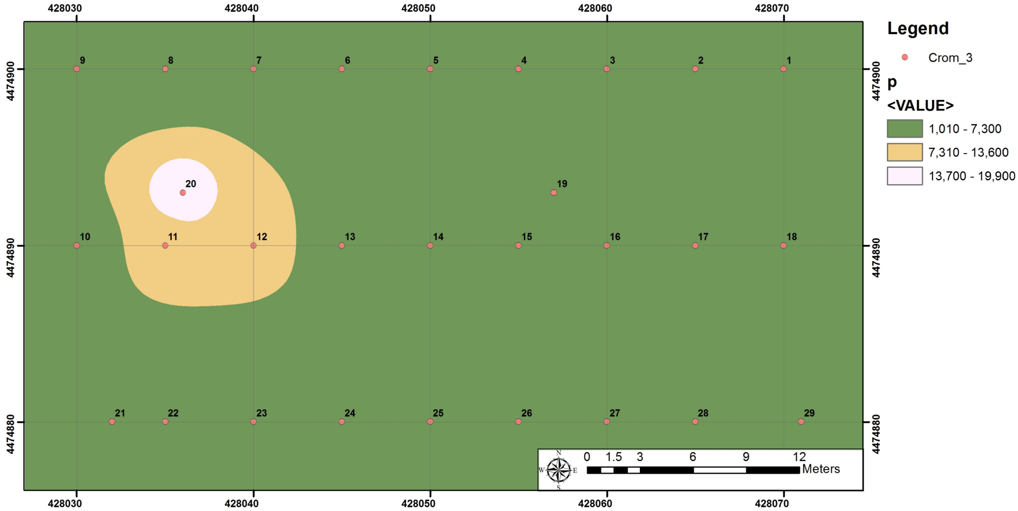


Figure 9. 1. Cromlech Cluster 1 - Cromlech 2. Anomaly of phosphorus, by Arshavir Hovhannisyan and Dmitri Arakelyan. 2. Cromlech Cluster 1 - Cromlech 2. Anomaly of barium, by Arshavir Hovhannisyan and Dmitri Arakelyan.



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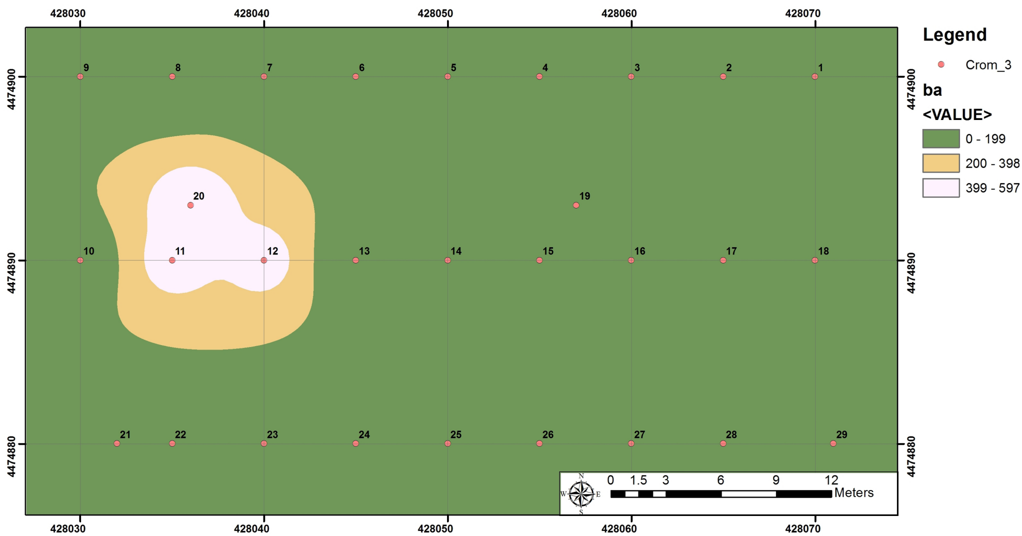

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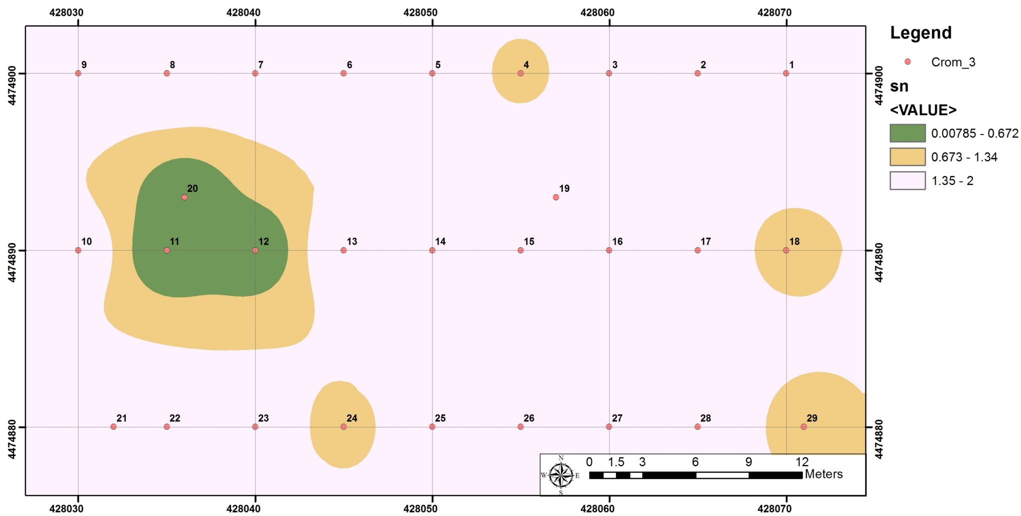
Figure 10. 1. Cromlech Cluster 2 - Cromlech 3. Anomaly of phosphorus, by Arshavir Hovhannisyan and Dmitri Arakelyan. 2. Cromlech Cluster 2 - Cromlech 3. Anomaly of barium, by Arshavir Hovhannisyan and Dmitri Arakelyan.



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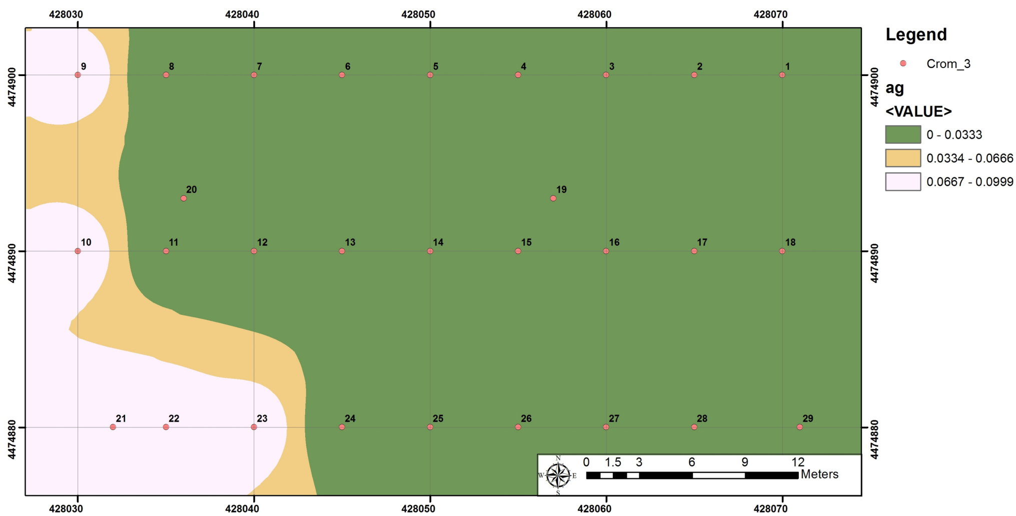

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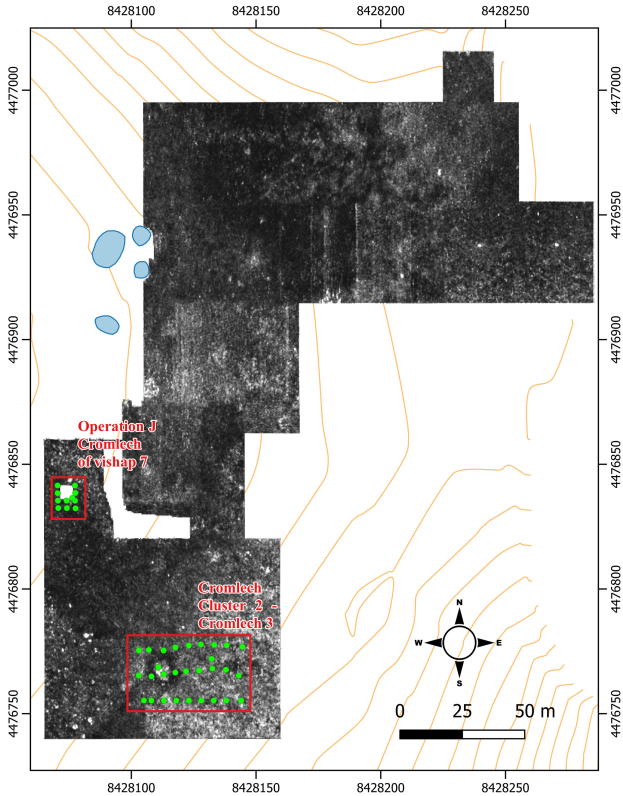
Figure 11. 1. Cromlech Cluster 2 - Cromlech 3. Anomaly of tin, by Arshavir Hovhannisyan and Dmitri Arakelyan. 2. Cromlech Cluster 2 - Cromlech 3. Anomaly of silver, by Arshavir Hovhannisyan and Dmitri Arakelyan.



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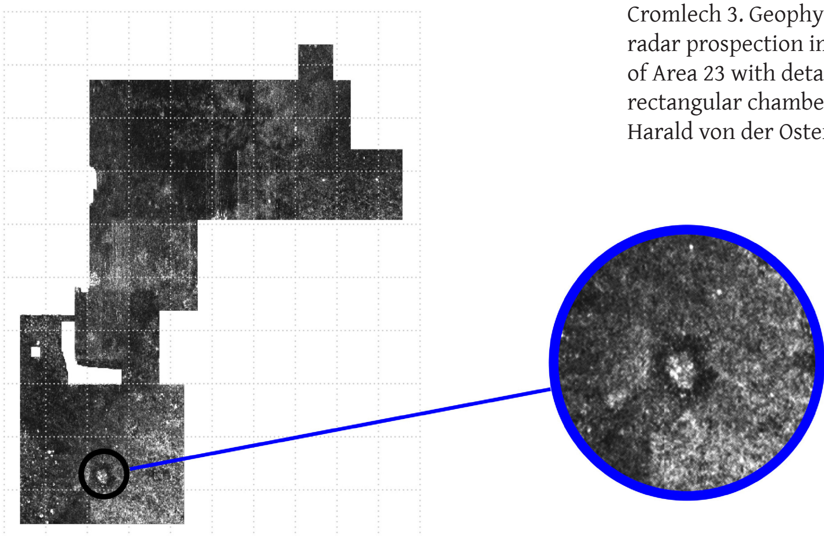

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Figure 12. 1. Cromlech Cluster 2 - Cromlech 3. Geophysical radar prospection image and geochemical sampling points of Area 23 with detail of rectangular chamber, by Harald von der Osten and Pavol Hnila (excavation grid in Gauss-Krüger zone 8 coordinates).
2. Cromlech Cluster 2 - Cromlech 3. Geophysical radar prospection image of Area 23 with detail of rectangular chamber, by Harald von der Osten.

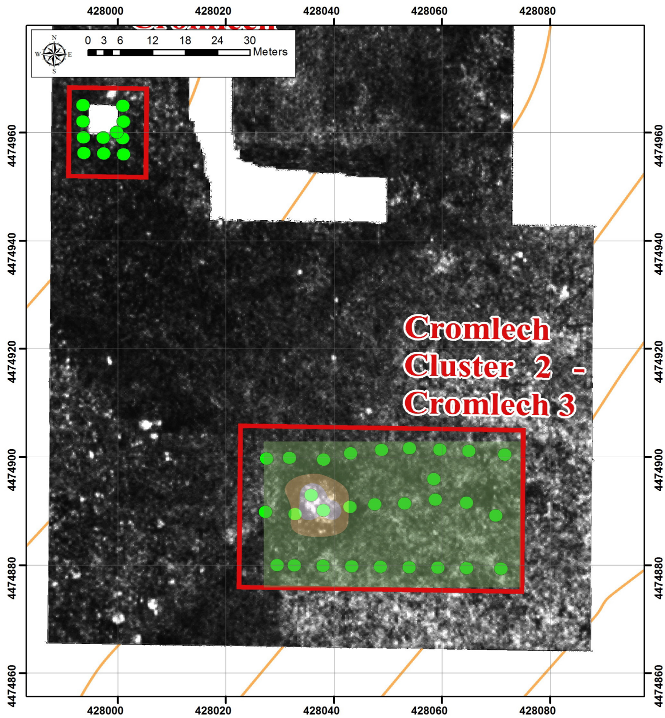

Figure 13. Spatial coincidence of the geophysical (the light grey background stain and geochemical anomalies), by Harald von der Osten and Dmitri Arakelyan (UTM 38 coordinates grid).

Abbreviations

AA	Archäologischer Anzeiger, Berlin
AAAR	Arctic, Antarctic and Alpine Research, Colorado
AAE	Arabian Archaeology and Epigraphy, Copenhague
ACSS	Ancient Civilizations from Scythia to Siberia, Leiden
ADAJ	Annual of the Department of Antiquities of Jordan, Amman
AI	Acta Iranica, Leiden
AJA	American Journal of Archaeology, Boston, Mass.
AJNES	Aramazd: Armenian Journal of Near Eastern Studies, Oxford
AMI	Archäologische Mitteilungen aus Iran, Neue Folge, Berlin
AMIT	Archäologische Mitteilungen aus Iran und Turan, Berlin
AnAn	Anatolia Antiqua, İstanbul Paris
AnAr	Anadolu Araştırmaları (JKlF Jahrbuch für Kleinasiatische Forschungen), İstanbul
AN	Arxitekturnoe nasledstvo (Architectural Legacy), Moscow
ANES	Ancient Near Eastern Studies, Louvain
AnSt	Anatolian Studies. Journal of the British Institute at Ankara, London
AOAT	Alter Orient und Altes Testament, Kevelaer / Neukirchen-Vluyn
AoF	Altorientalische Forschungen, Berlin
AST	Araştırma Sonuçları Toplantısı, Ankara
AWE	Ancient West & East, Leuven
BAR–IS	British Archaeological Reports. International Series, Oxford
BASOR	Bulletin of the American Schools of Oriental Research, New Haven
BAVA	Beiträge zur Allgemeinen und Vergleichenden Archäologie, München
BEH	Banber Erevani hamalsarani. Hasarakakan gitut‘yunner, Yerevan
BSOAS	Bulletin of the School of Oriental and African Research, Oxford/Cambridge
CA	Current Anthropology, Chicago
CHANE	Culture and History of the Ancient Near East, Leiden
CollAn	Colloquium Anatolicum, İstanbul
DHAA	Hayastani Hanrapetut‘yunum daštayin hnagitakan ašxatank‘neri ardyunk‘nerin nvirvac gitakan nstašrǰan. Zekuc‘umneri t‘ezisner (Conference Devoted to Archaeological Fieldwork Results in the Republic of Armenia, Abstracts of Reports), Yerevan
DocAs	Documenta Asiana, Roma
HHM	Hin Hayastani mšakuyt‘ə (The Culture of Ancient Armenia), Yerevan
IA	Iranica Antiqua, Leiden
IEJ	Israel Exploration Journal, Jerusalem
IF	Indogermanische Forschungen. Zeitschrift für Indogermansitik und allgemeine Sprachwissenschaft, Straßburg/Leipzig/Berlin
IstM(itt.)	Istanbuler Mitteilungen, Istanbul / Tübingen
JAMT	Journal of Archaeological Method and Theory, Berlin
JAOS	Journal of the American Oriental Society, Boston
JAS	Journal of Archaeological Science, Amsterdam
JFA	Journal of Field Archaeology, Boston
JGA	Journal of Glacial Archaeology, Sheffield
JIES	Journal of Indo-European Studies, Hattiesburg
JNES	Journal of Near Eastern Studies, Chicago
JPOS	Journal of the Palestine Oriental Society, Jerusalem
JRAS	Journal of the Royal Asiatic Society, London