THE NEOLITHIC OBSIDIANS FROM SOUTHEASTERN UKRAINE: FIRST CHARACTERIZATION AND PROVENANCE DETERMINATION

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Keywords: *Obsidian • Neolithic • Semenovka 1 • Lysa Gora • Göllüdağ*

Abstract: This paper discusses the results obtained from the characterization of six obsidian samples from the Neolithic sites of Lysa Gora and one from Semenovka 1, in southeastern Ukraine. They show that obsidians of different sources were utilized by the inhabitants of Lysa Gora, among which are Baksan (Russian Federation), Sjunik (Armenia) and another undefined source, while the provenance of the bladelet fragment from Semenovka 1 is of particular interest since it comes from one of the Göllüdağ outcrops in Central Anatolia. The first characterization of Ukrainian specimens fills a gap in our knowledge in the distribution of the archaeological obsidians in a wide region delimited by the Carpathians, in the west, and the Caucasus, in the east. They contribute to the interpretation of the models of their procurement and circulation in the steppe region northwest of the Azov Sea during the Neolithic.

GÜNEYDOĞU UKRAYNA'DA BULUNAN NEOLİTİK OBSİDİYENLER: İLK TANIMLAMA VE KAYNAK TAYİNİ

Anahtar Kelimeler: *Obsidiyen • Neolitik • Semenovka 1• Lysa Gora • Göllüdağ*

Öz: Bu makale, Ukrayna'nın güneydoğusunda yer alan Lysa Gora Neolitik yerleşiminden altı, Semenovka 1 Neolitik yerleşiminden bir obsidiyen örneğin tanımlanmasından elde edilen sonuçları tartışır. Onlar Lysa Gora sakinleri tarafından kullanılmış farklı kaynaklardan obsidiyenleri gösterir, bunlar arasında Baksan (Rusya Federasyonu), Sjunik (Ermenistan) ve tanımsız başka bir kaynak vardır. Oysa Semenovka 1'de bulunan dilgicik parçasının menşei, Orta Anadolu'daki Göllüdağ kaynaklarından biri olduğu için özellikle ilgi çekicidir. Ukraynalı örneklerin ilk tanımlaması, doğuda Kafkaslar, batıda Karpatlar tarafından sınırlanmış geniş bir bölgede arkeolojik obsidiyenlerin dağılımı konusundaki bilgilerimizde bir boşluğu doldurur. Onlar Neolitik süresince Azak Denizi'nin kuzeybatısındaki step (bozkır) bölgede obsidiyenlerin tedarik edilme ve dolaşım modellerinin yorumlanmasına katkıda bulunur.

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Introduction

The scope of this paper is to describe the results of the first characterizations of seven obsidian samples from two Neolithic sites of southeastern Ukraine, and to frame them into the general pattern of circulation of archaeological obsidians within the territory comprised between the Carpathians, in the west, and the Caucasus, in the east.

Given that Neolithic obsidian artefacts from this region have never been analyzed before with this method, the results are expected to clarify some of the complex aspects of the Neolithization of the south steppe zones of Ukraine and Russia, a topic still much debated[1].

The recent analysis of archaeological obsidian from the Balkans[2] and the Caucasus[3] have greatly contributed to the interpretation of the models of exploitation and distribution of the Carpathian, Melian[4] and Caucasian sources, and the definition of the mechanisms of circulation of different tool types, leaving the steppe zone north of the Black and Azov Seas an empty quarter still open to investigation.

History of the research on Ukrainian obsidians

In the Soviet era obsidian was recognized as a raw material exploited in prehistory for making tools even from the beginning of archaeological research[5]. M. Rudinskiy[6] was one of the first to report archaeological obsidians from Eastern Ukraine. Since then several specimens have been recovered from contexts of different periods, from the Palaeolithic to the Chalcolithic. However, the problem of obsidian provenance started to attract the attention of archaeologists only in the 1960's, when V. F. Petrun (or Petrougne) pointed out the importance of chemical characterization, although his research was based mainly on thin section analysis and optical refraction measurement. His studies were centered on obsidian from both archaeological and raw material sources of the Carpathians[7] and Soviet Far East. Nevertheless his papers, mainly published in local journals, had little impact on the archaeology of the country that remained often uninterested in scientific techniques aimed at the definition of provenance of volcanic glasses[8].

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1 See for instance Telegin 1988; Kotova 2003; Tovkailo 2005; Tsibriy 2008.

2 Williams Thorpe *et al.* 1984; Biagi *et al.* 2007.

3 Badalyan 2010; Chataigner – Gratuze 2013a; 2013b.

4 Torrence 1986; Gratuze 1999; Perlès *et al.* 2011.

5 Gorodtsov 1923, 23.

6 Rudinskiy 1931, 164.

7 Petrun 1972; Petrugne 1986.

8 Petrun 1960.

In contrast the approach by V. Nasedkin and A. A. Formosov was utilized for a long time. Analyzing the obsidians from Kuban by optical technique, on the basis of refraction index similarities, they concluded that some samples were from Zayukov, others from Transcaucasia[9].

Probably influenced by their work, L. Matskevoy started a similar study on a circular scraper from his excavations at the Neolithic site of Frontove, in Eastern Crimea[10]. The petrographer N. Makarov defined its refraction index, similar to those published by V. Nasedkin and A. A. Formosov for the Armenian and Kabardino-Balkaria obsidians, although he could not define its precise provenance.

Later, when L. Matskevoy moved to Western Ukraine, he started to work on local archaeological obsidians, which were more common in this region than in Eastern Ukraine, focused on specimens of different ages from the Upper Palaeolithic to the Neolithic. Both methods, refraction index and thin section analysis, were later applied by several mineralogists and petrographers, although in most cases with controversial results because of the absence of chemical characterization of the reference samples from the different outcrops.

The sites

Semenovka 1

Semenovka 1 is located on the right (northern) terrace of the Molochna River at the northern outskirts of Melitopol (Zaporizhzhya region). Its approximate location is 46°52'08"N - 35°25'59"E (fig. 1, n. 1; fig. 2). It was discovered and test trenched by B. D. Mikhailov and later excavated by N. S. Kotova and O. V. Tuboltsev in 1991-1992[11].

Semenovka 1 yielded evidence of two main cultural layers: 1) the lower, attributed to the Surska culture with some Azov-Dnieper ceramic fragments, was found at the depth of 1.4-1.8 m in an undisturbed part of the site. It produced many chipped stone artefacts, among which are 154 tools, and more than 200 potsherds attributed to at least 22 vessels; 2) the upper layer belongs to a later aspect of the Azov-Dnieper culture, from which come fragments of at least 9 vessels containing sand and shell inclusions. The chipped stone tools consist mainly of blades with semi-abrupt, convergent retouch, and different types of end scrapers.

The proximal edge of an obsidian bladelet (fig. 6, n. 6) was recovered from the loam layer of Trench 2, in square 19[12].

Five radiocarbon dates have been obtained from unidentified animal bones collected from Trench 2, attributed to the Early Neolithic Surska culture, from the horizon just below the obsidian specimen: 7285±70 BP (Ki-7679), 7125±60 BP (Ki-6689), 7110±60 BP (Ki-7677), 6980±65 BP (Ki-6688) and 6850±70 BP (Ki-7678)[13]. The upper layer, containing Azov-Dnieper pottery,

9 Nasedkin – Formosov 1965.
10 Matskevoy 1977.
11 Kotova – Tuboltsev 1996.
12 Kotova – Tuboltsev 1996, 30.
13 Kotova – Tuboltsev 1996; Kotova 2011.

was radiocarbon dated to 6360±70 BP (Ki-7675) from unidentified animal bones[14].

Lysa Gora

Lysa Gora is a low hill partly eroded by the eastern bank of the Dnieper River, c. 2 km northwest of Vasylivka (Zaporizhzhya region) (fig. 1, n. 2). The site was discovered by A. V. Bodyanskiy in 1961 and repeatedly visited by S. N. Kravchenko in the 1980's[15]. This latter author collected mainly cores, blades and retouched implements covered by a bluish patina obtained from a flint variety of grey and dark grey colour[16].

At present the area, flooded in 1955 due to the construction of a dam along the Dnieper, is absolutely different from the marshy landscape rich in small islands, called Velyky Lug[17] that until the 1950's characterized the confluence between the Konska and the Dnieper. Many archaeological sites of different ages have been discovered on the promontory (fig. 3), one of which has been attributed to the Late Palaeolithic[18].

Since the 1960's this region has been systematically surveyed by the Institute of Archaeology of the Academy of Sciences of the USSR, the Zaporizhzhya Regional History Museum, the Zaporizhzhya University, and local amateurs. In 1999 V. A. Busel and O. V. Tuboltsev drew a detailed map of the find spots in order to link the surface finds to the archaeological sites with the material culture finds (fig. 4).

Fragments of six obsidian bladelets were recovered from the beach of Ruchey 2 (Stream 2) during the 1988 survey, which also yielded a few potsherds of the Azov-Dnieper culture. The area is located just to the northeast of a Neolithic cemetery[19] at c. 47°27'27"N - 35°14'13"E. All the obsidian specimens from Ruchey 2 are weathered, with rounded surfaces and small *concassage* breaks along the sides (fig. 6, nn. 1-5). Other specimens were collected later, a few of which were precisely mapped (see fig. 4). Another sample was recovered by V. A. Busel from the mouth of Progon gully, a beach of Ruchey 2. It is a partly corticated flakelet, in "fresh" condition, without any *concassage* detachment, obtained by hard percussion (fig. 6, n. 7).

Ruchey 2 is an eroded beach, c. 1 km long, from which a larger number of chipped stone tools of different periods, from the Palaeolithic to the Chalcolithic, has been recorded (fig. 5)[20]. Here the coastline is still being eroded away close to a bend of an old course of the Konska River. More recently, another local amateur, B. V. Mazko, collected one more obsidian bladelet from this spot.

All together six samples have been analyzed from Lysa Gora. They consist of five finished products, more precisely medial or proximal fragments of

14 Kotova 2003.
15 Kravchenko 1988.
16 Olenkovskiy, 1991, 68.
17 Busel – Tubolzev 1999.
18 Olenkovskiy 1991.

19 Bodyanskiy 1959.
20 The finds from Lysa Gora, Ruchey 2 are currently being studied by O. V. Tubolzev and Z. H. Popandopulo.

unretouched, heavily weathered bladelets (fig. 6, nn. 1-5) and one complete, partly corticated, unretouched flakelet detached by hard percussion, the traces of which are clearly visible on both faces (fig. 6, n. 7).

LA-ICP-MS analyzes

The obsidian artefacts reported above were analyzed at the Centre Ernest -Babelon, IRAMAT (CNRS/Université d'Orléans) using Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS) with an Element XR mass spectrometer from Thermofisher Instrument and a VG UV microprobe ablation device[21].

LA-ICP-MS is widely used to determine the elemental composition of obsidian and causes minimal damage to the specimen[22]. LA-ICP-MS operates as follows. The object placed in the ablation cell is sampled by the laser beam, which is generated by an Nd YAG pulsed laser. Its frequency is quadrupled allowing it to operate in the ultraviolet region at 266 nm. The diameter of the ablation crater ranges from 60 to 100 μm, and its depth is around 250 μm. An argon gas flow carries the ablated aerosol to the injector inlet of the plasma torch, where the matter is dissociated, atomized and ionized. Ions are then injected into the vacuum chamber of a double focusing magnetic sector field, which filters the ions depending upon their mass-to-charge ratio. Ions are then collected by a dual mode secondary electron multiplier (SEM), associated with a Faraday detector. This combination allows to increase the linear dynamic range of the mass spectrometer by an additional three orders of magnitude, when compared to single SEM.

Standard reference materials Glass SRM 610 from the National Institute for Standards and Technology, and glasses B and D from the Corning Glass Laboratory are used for external standardization. Isotope 28Si is used as an internal standard to normalize the measured signal.

The concentration of thirty-eight elements is determined for each sample, including zirconium, yttrium, niobium, barium, strontium, cerium, lanthanum and titanium, which in our experience are the most useful elements for discriminating between obsidian outcrops[23]. Attribution to a source is determined by comparing the composition of archaeological obsidian with the composition of the reference source outcrops dataset.

Results

According to the results obtained from the above analyzes (tables 1 and 2), four Lysa Gora bladelet fragments (fig. 6, n. 1-3, 5) come from the Armenian source of Sjunik (fig. 7, composition group Sjunik 3, Mets Sevkar and Pokr Sevkar)[24], while another medial bladelet fragment (fig. 6, n. 4), which is characterized by high lithium, rubidium and cesium contents, has a chemical composition which is similar to the one

[21] Chataigner – Gratuze 2013a.
[22] Barca *et al.* 2007; Giussani *et al.* 2009.
[23] Gratuze 1998.
[24] Cherry *et al.* 2010, 149-151; Chataigner – Gratuze 2013, 14.

published by J. Keller *et al.*[25] for the Russian source of Baksan (Kabardino-Balkar Republic) (fig. 8).

The complete, corticated flakelet from Lysa Gora, Progon (fig. 6, n. 7), does not match for several elements with any composition present in our database from Turkish, Armenian, Slovakian, Hungarian or Mediterranean obsidian sources. The composition of this obsidian is characterized by low values of niobium, tantalum and uranium and a high barium concentration (tables 1, 2). Only a few obsidian outcrops located at Melos, in the Carpathian and on the Süphan Dağı show a similar trend. The rare earth elements profile of the Lysa Gora Progon flakelet does not match with those of the above sources although it looks close to the Carpathian C1 group (Cejkov, fig. 9 below). However the composition and aspect (opaque black) of this obsidian remain significantly different from the one around Cejkov. A recent paper published by C. N. Rosania *et al.*[26] has identified a new Carpathian obsidian group, referred as C3, around Rokosovo (Malyj Rakovets) in Ukraine. Although the composition of the Lysa Gora Progon flakelet does not match with that of this new obsidian source, it is possible that this obsidian comes from an undocumented source, possibly located in Transcarpathian Ukraine.

The proximal bladelet fragment from Semenovka (fig. 6, n. 6) is to be attributed to the Cappadocian source of Göllüdağ (fig. 10: composition group Göllüdağ 5, Kaletepe-Eriklidere)[27].

Discussion

The results of the first characterizations of the southeast Ukrainian obsidian artefacts show that materials from different long distance sources were available to the first farmers who settled in the steppe zones north of the Azov Sea in different periods of the Neolithic. In this respect an important role is played by a fragment of obsidian bladelet from an Early Neolithic stratified context at Semenovka, radiocarbon dated between the end of the 8th and the beginning of the 7th millennium BP. The site location is also interesting since it lies some 45 km from the present-day Azov Sea coast, and c. 20 km from the northern edge of the Molochny Liman.

The east Göllüdağ obsidian source was already known a few years ago for its wide distribution radius[28]. More recent analyzes have shown that the Göllüdağ 5, Kaletepe-Eriklidere obsidian[29] has excellent technological qualities, among which are flexibility and low fragility[30]. Already during the PPN period it was traded or exchanged further south, for instance to Shillourokambos in Cyprus[31].

Although the recovery of a Göllüdağ 5 obsidian bladelet from a site close to the northwestern shore of the Azov Sea is so far unique, it suggests a complex pattern of trade or exchange or

25 Keller *et al.* 1996, 80.
26 Rosania *et al.* 2008.

27 Binder *et al.* 2011, Fig. 1, table 2 ; Balkan-Atlı – Binder 2012.
28 Chataigner *et al.* 1998, 525.
29 Balkan-Atlı *et al.* 2011.
30 Binder *et al.* 2011, 3182.
31 Briois *et al.* 1997.

transmission within a "contact zone"[32] extending much farther north than previously suggested.

Also, the samples from Lysa Gora yielded unexpected results. Although they come from two different areas of the site close to each other (Ruchey 2: five broken bladelets, and Progon: one complete flakelet), their characterization indicates three different provenance sources. In effect four bladelets are from Sjunik, in southeastern Armenia, one bladelet is from Baksan (Russian Federation), while the corticated flakelet from Progon is from an unknown source that shows similarities with the Carpathians. Although still undefined, its probable provenance from a western source can be suggested.

Most of the Neolithic surface finds from Lysa Gora come from sources located in the Caucasian mountains. This result is quite unexpected given that obsidian artefacts from the south Armenian source of Sjunik are known to have been traded mainly toward the south and southeast down to Lake Urmia in Iran and the Caspian Sea[33]. Little is known of their northern distribution, which is suggested as just beyond Lake Sevan in the northeast[34]. Even less is known of the distribution radius of the Baksan obsidian that outcrops from the eastern Elbrus massive[35].

To sum up, the first characterizations of a few southeast Ukrainian obsidians have yielded quite interesting results, which fill a gap in our knowledge of the distribution of the archaeological obsidian along the southern steppe belt of the Black and Azov Seas. They suggest that the Neolithic communities settled in the study region had some kind of contact or had established trade or exchange activities with the Caucasus and further south with Central Anatolia.

Although so far we know very little of these activities in the study area during the Neolithic, we can suggest that obsidian artefacts were imported or exchanged from distant sources, as finished products in the form of bladelets, as is the case for both Semenovka 1 and Lysa Gora, Ruchey 2. The only exception is represented by the corticated flakelet from Lysa Gora, Progon, which was most probably manufactured on the spot. It provenance source, although at present still undefined, is probably to be found farther to the west in the Carpathian region of southeast Europe.

In a wider perspective, the obsidian artefacts analyzed fall into the complex problem of the origin of the FTN societies in the steppe zones of southeastern Europe[36], which took place during a period of climatic changes and regional landscape variations that probably favoured the spread of the first Neolithic communities over a wide region[37], whose settlement pattern,

32 Renfrew *et al.* 1966.
33 Arimura *et al.* 2010, Fig. 7.
34 Chataigner – Barge 2010, Fig. 12.
35 Keller *et al.* 1996, 73.
36 Nandris, 2007, 12.
37 Dolukhanov *et al.* 2009, 38; see also Nicholas *et al.* 2011; Pashkevych 2012.

economy and population behaviour are nevertheless still far too poorly known.

List of Figures and Tables

Figure 1. Location of the two Neolithic southeastern Ukrainian sites mentioned in the text: Semenovka 1 (1) and Lysa Gora (2) (drawing by P. Biagi).

Figure 2. The site of Semenovka 1 (green rectangle) along the right, northern, bank of the Molochna River (Google satellite image with modifications by O. V. Tubolzev).

Figure 3. The marshy area northwest of Vasylivka (Vasil'evka on the map) at the confluence between the Karachokrak and Konska (Konskaya on the map) Rivers in the 1950's. The marshy landscape of Velyky Lug is at the top, left corner, where Lake Kom'ish'evatoe is located (Ordinance Survey Map of the Russian Empire 1864).

Figure 4. Satellite image of the area surrounding the city of Vasylivka with the location of the sites mentioned in the text: Lysa Gora, Neolithic cemetery (1) and Lysa Gora, Ruchey 2 (2) and Lysa Gora, Progon (3). The black dots are obsidian finds collected in 2012 and as yet uncharacterised. The light blue line marks the bank of the ancient Konska riverbed and the red one the terraces (map by O. V. Tubolzev).

Figure 5. The beach of Lysa Gora, Ruchey 2 where most of the obsidian artefacts have been collected, from the northwest (photograph by O. V. Tubolzev).

Figure 6. Obsidian artefacts from Lysa Gora, Ruchey 2 (nn. 1-5), Lysa Gora, Progon (n. 7) and Semenovka 1 (n. 6) (drawings by P. Biagi, inking by E. Starnini).

Figure 7. Normalized abundance of extended rare-earth elements to the Earth's continental crust for the obsidian samples Lysa Gora 1-3 and 5 compared to that of Sjunik 3 (Mets Sevkar-Pork Sevkar) obsidian groups. The normalizing constants are from K. H. Wedepohl (1995) (drawing by B. Gratuze).

Figure 8. Normalized abundance of extended rare-earth elements to the Earth's continental crust for the obsidian sample Lysa Gora 4 compared to that from Baksan. The normalizing constants are from K. H. Wedepohl (1995) (drawing by B. Gratuze).

Figure 9. Normalized abundance of extended rare-earth elements to the Earth's continental crust for the Lysa Progon 7 artefact compared to that of obsidian chemical groups characterized by low niobium and high barium content: Melos, Süphan Dağı, Mad and Tolcsva (above), Cejkov, Kasov and Vinicky, Carpathian 1 group (below). The normalizing constants are from K. H. Wedepohl (1995) (drawing by B. Gratuze).

Figure 10. Normalized abundance of extended rare-earth elements to the Earth's continental crust for the obsidian sample Semenovka 1 compared to that from Göllüdağ 5 obsidian group. The normalizing constants are from K. H. Wedepohl (1995) (drawing by B. Gratuze).

Table 1. Chemical composition of the studied artefacts, major and minor elements (Si, Al, Na, K, Fe, Ca, Mg, Ti and Mn) are expressed as weight % of oxide; other elements are given in part per million (1ppm = 0.0001%). When more than one analysis has been made, average values and their standard deviation are given.

Table 2. Chemical composition of the studied artefacts, elements are given in part per million (1ppm = 0.0001%). When more than one analysis has been made, average values and their standard deviation are given.

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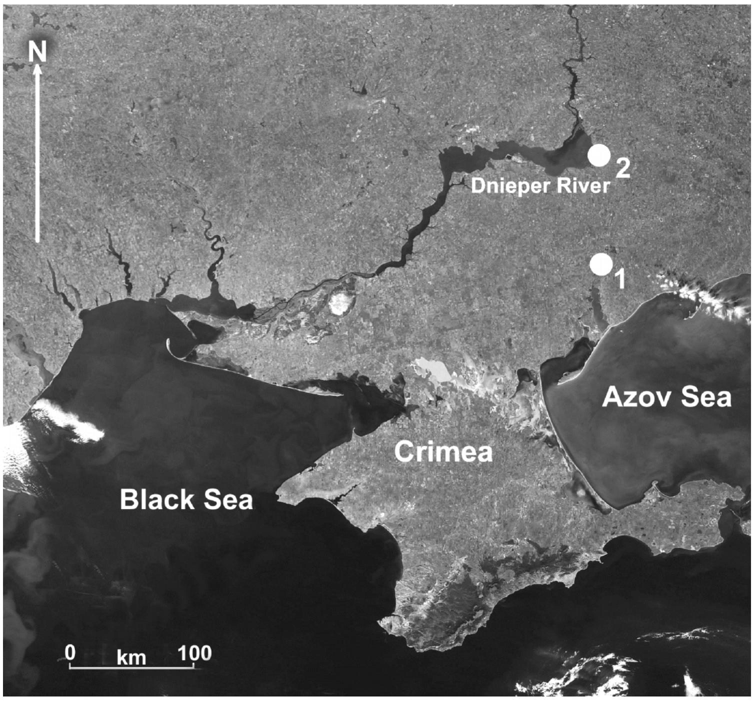
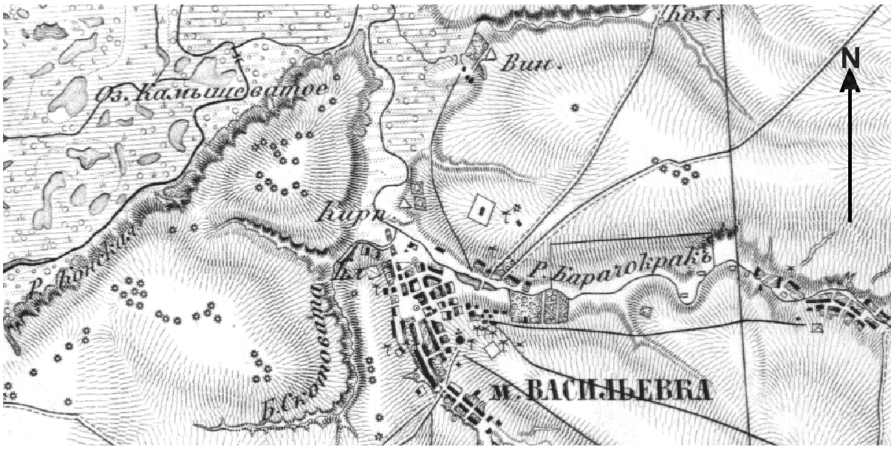


Figure 1

Figure 2



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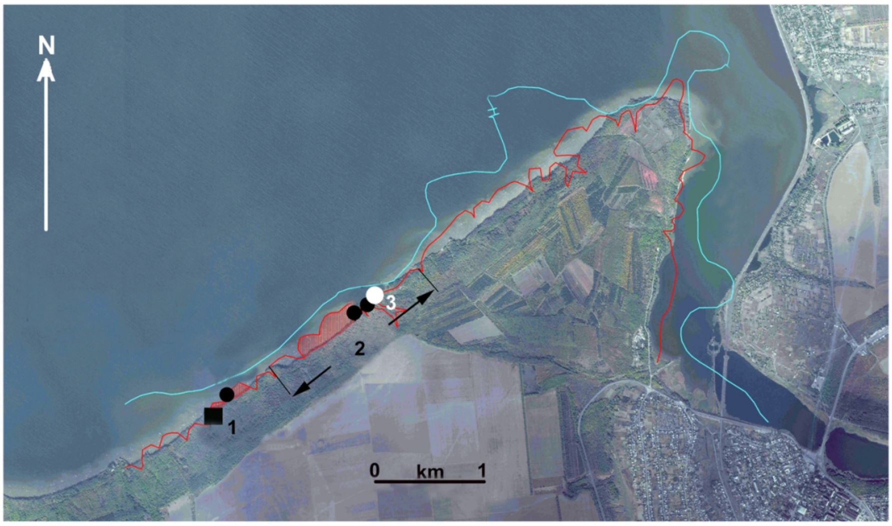
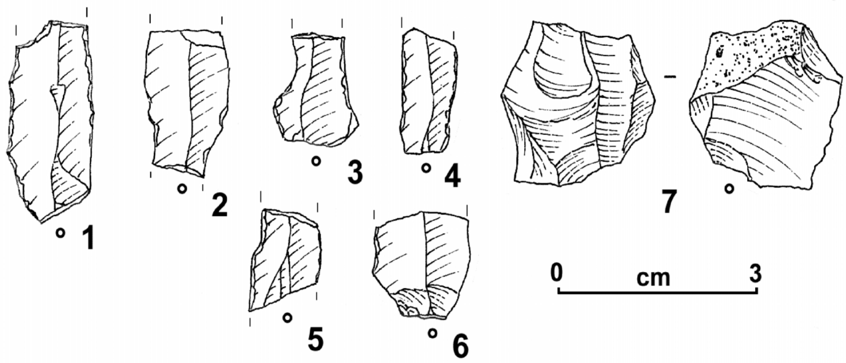


Figure 4

Figure 5



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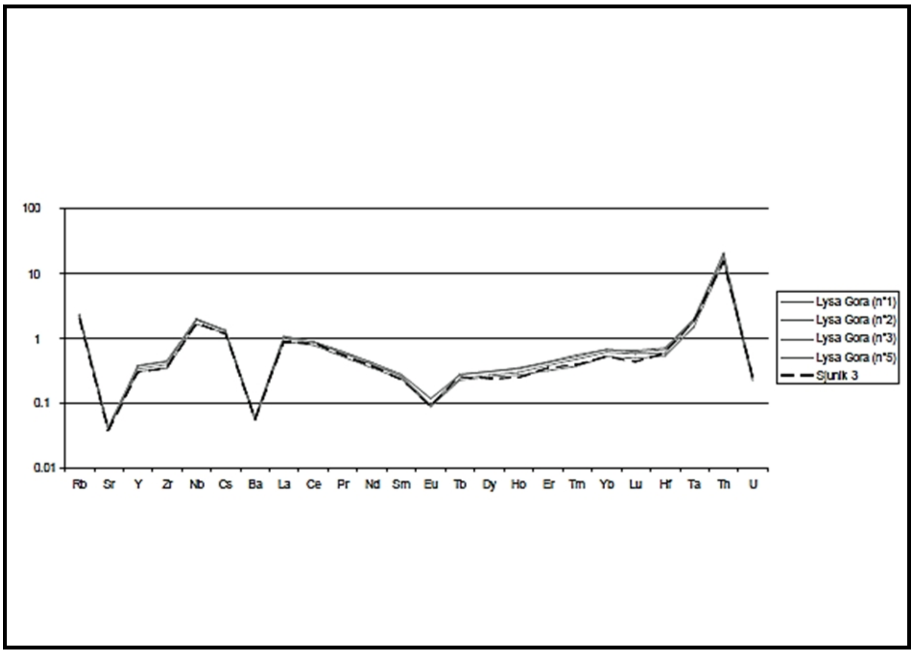

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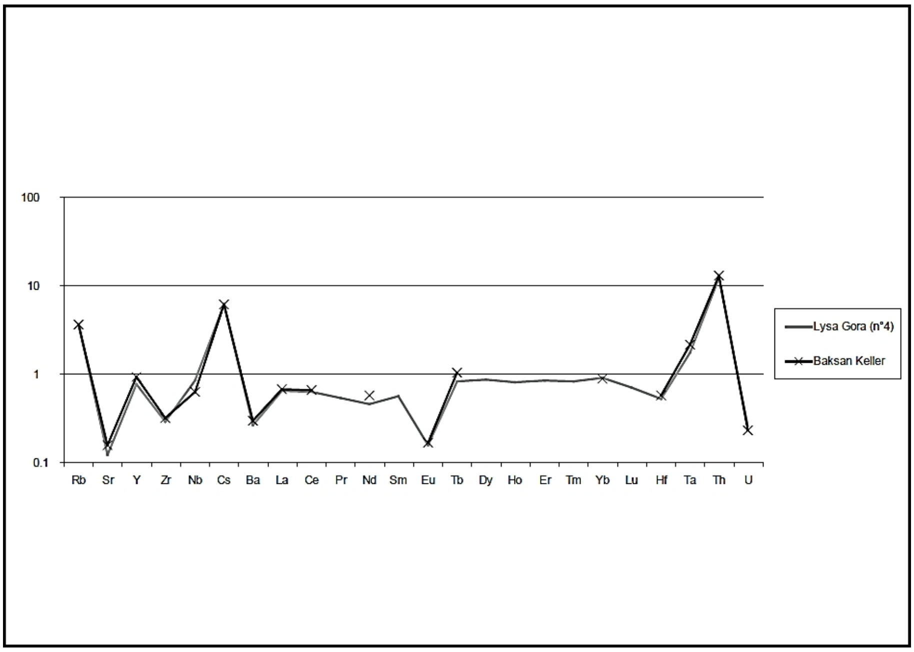

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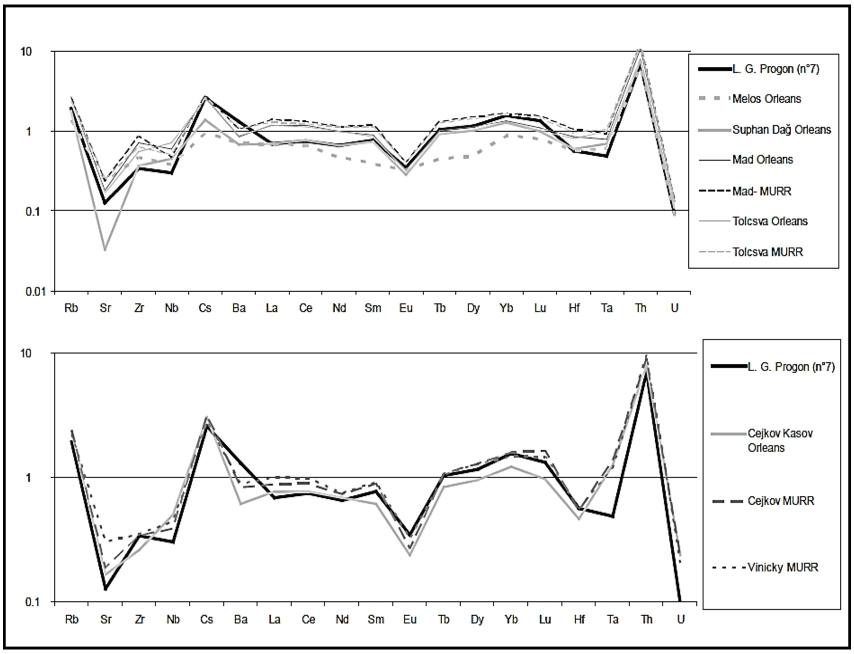

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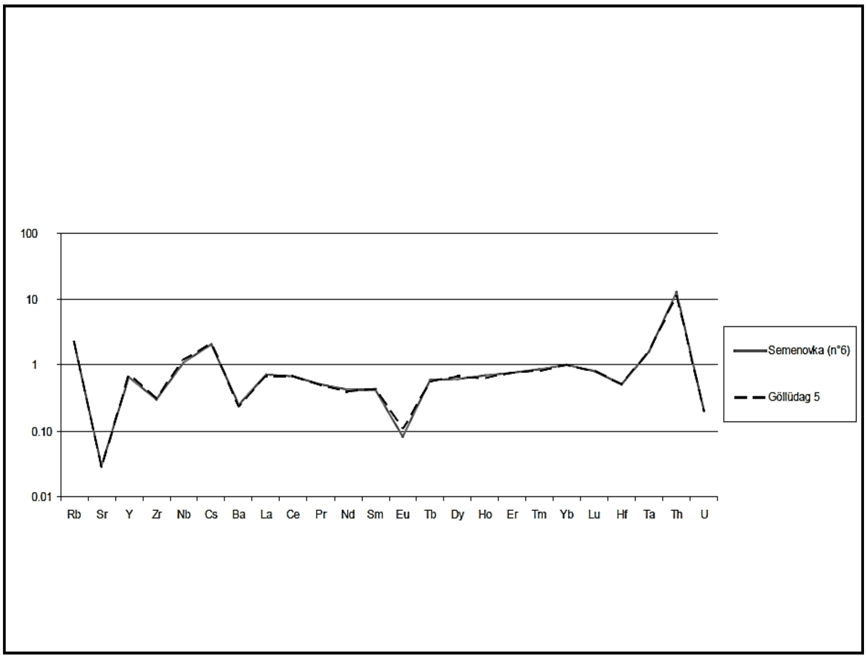

Figure 10

Provenance	Sample ref. fig. 6		Li	B	Na_2O	MgO	Al_2O_3	SiO_2	K_2O	CaO	Sc	TiO_2	MnO	Fe_2O_3	Zn	Rb	Sr	Y	Zr	Nb
Sjunik 3	Lysa Gora (n°1)		48	19	4.06%	0.05%	14.2%	75.9%	4.41%	0.49%	2	0.09%	0.05%	0.71%	33	164	13	7.3	70	31
	Lysa Gora (n°2)	avr. (2)	53	14	4.23%	0.048%	12.5%	76.9%	4.88%	0.45%	4	0.097%	0.058%	0.69%	30	176	13	8	81	37
		std	*4*	*0.6*	*0.07%*	*0.001%*	*0.07%*	*0.1%*	*0.03%*	*0.001%*	*0.1*	*0.0003%*	*0.001%*	*0.003%*	*0.3*	*0.4*	*0.08*	*0.05*	*0.6*	*0.3*
	Lysa Gora (n°3)		53	14	4.25%	0.049%	13.1%	76.3%	4.88%	0.47%	4	0.098%	0.060%	0.70%	30	180	13	9.1	90	38
	Lysa Gora (n°5)		54	14	4.24%	0.050%	12.9%	76.5%	4.91%	0.48%	4	0.101%	0.059%	0.69%	29	176	14	9.0	89	37
Golludag 5	Semenovka (n°6)	avr. (3)	46	34	3.72%	0.034%	14.7%	76.0%	4.07%	0.46%	8	0.060%	0.056%	0.77%	20	174	10	16	60	21
		std	*0.7*	*1*	*0.02%*	*0.001%*	*0.2%*	*0.2%*	*0.05%*	*0.03%*	*2*	*0.001%*	*0.002%*	*0.05%*	*1*	*1*	*0.08*	*0.6*	*2*	*0.2*
Baksan	Lysa Gora (n°4)	avr. (2)	112	60	4.18%	0.060%	13.6%	75.6%	4.62%	0.70%	5	0.044%	0.068%	0.91%	40	284	40	19	59	16
		std	*5*	*2*	*0.07%*	*0.0005%*	*0.2%*	*0.33%*	*0.004%*	*0.003%*	*0.2*	*0.0008%*	*0.001%*	*0.41%*	*4.6*	*2.1*	*0.1*	*0.1*	*0.05*	*0.2*
Unknown	L. G. Progon (n°7)	avr. (3)	49	23	4.09%	0.04%	13.3%	76.3%	4.28%	0.68%	7	0.05%	0.04%	1.07%	37	151	42	26	69	6
		std	*2*	*2*	*0.16%*	*0.005%*	*0.09%*	*0.09%*	*0.08%*	*0.04%*	*1*	*0.001%*	*0.001%*	*0.11%*	*7*	*7*	*2*	*1*	*4*	*0.2*
	Source values		Li	B	Na_2O	MgO	Al_2O_3	SiO_2	K_2O	CaO	Sc	TiO_2	MnO	Fe_2O_3	Zn	Rb	Sr	Y	Zr	Nb
	Göllüdag 5	avr. (198)	54	36	3.7%	0.040%	13.2%	75.7%	4.1%	0.6%	5	0.058%	0.060%	0.78%	23	181	9	17	62	23
		std	*6*	*2*	*0.5%*	*0.007%*	*1.8%*	*7.7%*	*0.7%*	*0.1%*	*1*	*0.003%*	*0.003%*	*0.06%*	*3*	*9*	*1*	*3*	*9*	*3*
	Sjunik 3	avr. (15)	56	25	3.77%	0.05%	13.9%	76.6%	4.22%	0.50%	12	0.09%	0.06%	0.67%	31	166	12	7	68	31
		std	*5*	*4*	*0.04%*	*0.005%*	*0.14%*	*0.01%*	*0.10%*	*0.01%*	*0.3*	*0.002%*	*0.001%*	*0.006%*	*6*	*8*	*3*	*1*	*11*	*2*
	Sjunik 3 Keller														29	169	15	12	99	32
	Sjunik 3 Keller														25	170	19	10	85	32
	Baksan Keller														43	280	53	22	65	12

Table 1

Provenance	Sample ref. fig. 6		Cs	Ba	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	Hf	Ta	Th	U
Sjunik 3	Lysa Gora (n°1)		4.2	35	27	46	3.5	9.4	1.27	0.12	1.33	0.14	0.96	0.22	0.66	0.11	1.04	0.17	2.59	1.63	25.7	9.20
	Lysa Gora (n°2)	avr. (2)	4.5	33	30	52	3.9	10.6	1.34	0.13	0.91	0.16	1.07	0.24	0.82	0.15	1.23	0.20	3.0	1.99	31.1	10.5
		std	*0.03*	*0.6*	*0.3*	*0.4*	*0.002*	*0.2*	*0.02*	*0.012*	*0.1*	*0.006*	*0.04*	*0.002*	*0.02*	*0.010*	*0.01*	*0.005*	*0.1*	*0.03*	*1.3*	*0.3*
	Lysa Gora (n°3)		4.5	32	32	52	4.1	11.4	1.41	0.12	1.01	0.18	1.16	0.28	0.91	0.17	1.35	0.23	3.48	2.15	35.3	10.7
	Lysa Gora (n°5)		4.4	36	32	53	4.2	11.3	1.50	0.15	1.04	0.17	1.18	0.27	0.88	0.16	1.34	0.22	3.31	2.08	33.3	10.3
Baksan	Lysa Gora (n°4)	avr. (2)	21	155	19	37	3.6	12.5	2.97	0.21	2.61	0.53	3.34	0.64	1.74	0.25	1.77	0.24	2.59	1.94	20.5	10.8
		std	*0.04*	*1.8*	*0.1*	*0.5*	*0.05*	*0.02*	*0.05*	*0.001*	*0.05*	*0.004*	*0.03*	*0.004*	*0.03*	*0.001*	*0.06*	*0.003*	*0.02*	*0.01*	*0.2*	*0.1*
Golludag 5	Semenovka (n°6)	avr. (3)	7.0	144	21	40	3.5	11.3	2.19	0.12	2.01	0.39	2.4	0.53	1.59	0.25	1.91	0.28	2.5	1.77	20.9	8.2
		std	*0.09*	*2*	*0.9*	*0.9*	*0.06*	*0.2*	*0.07*	*0.02*	*0.15*	*0.01*	*0.1*	*0.02*	*0.04*	*0.02*	*0.07*	*0.01*	*0.1*	*0.03*	*1.0*	*0.1*
Unknown	L. G. Progon (n°7)	avr. (3)	9	761	21	45	4.6	17.8	4.1	0.45	3.8	0.67	4.4	0.95	2.7	0.41	3.1	0.47	2.8	0.54	11.8	4.00
		std	*0.5*	*32*	*1*	*2*	*0.3*	*1*	*0.3*	*0.05*	*0.4*	*0.03*	*0.2*	*0.05*	*0.2*	*0.03*	*0.2*	*0.02*	*0.1*	*0.05*	*0.8*	*0.01*
	Source values		Cs	Ba	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	Hf	Ta	Th	U
	Göllüdag 5	avr. (198)	7.2	132	20	40	3.3	10.7	2.3	0.13	2.1	0.37	2.5	0.51	1.60	0.24	1.96	0.28	2.47	1.77	19	8.0
		std	*0.4*	*10*	*3*	*3*	*0.3*	*1.0*	*0.2*	*0.01*	*0.2*	*0.03*	*0.2*	*0.04*	*0.1*	*0.02*	*0.2*	*0.02*	*0.3*	*0.2*	*2*	*0.7*
	Sjunik 3	avr. (15)	4.3	34	26	48	3.6	10.1	1.7	0.18	1.3	0.21	1.31	0.31	0.97	0.17	1.47	0.22	2.97	1.74	25	10.8
		std	*0.4*	*7*	*5*	*5*	*0.8*	*2.4*	*0.1*	*0.01*	*0.1*	*0.005*	*0.09*	*0.002*	*0.1*	*0.002*	*0.05*	*0.002*	*0.6*	*0.3*	*4*	*1.3*
	Sjunik 3 Keller		4.9	45	33	54		14.8	2.56	0.18		0.19					1.39	0.24	3.45	2.58	34.4	10.2
	Sjunik 3 Keller		4.8	41	34	58		14.0	2.70	0.18		0.15					1.33	0.22	3.64	2.79	35.3	10.2
	Baksan Keller		21	173	20	40		15.7	6.99	0.22		0.68					1.79	0.47	2.81	2.37	22.0	9.6

Table 2