GEOLOGY OF TOKAJ MOUNTAINS OBSIDIANS•

A TOKAJI-HEGYSÉGI OBSZIDIÁNOK GEOLÓGIÁJA

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Abstract

Tokaj Mountains (TM) is well known for the occurrence of the Carpathian Obsidian. This paper presents a general stratigraphy, geochronology and lithology framework for Miocene volcanic successions associated with obsidian formation in the area. Specific localities were chosen to show an accurate description of the geological settings. The primary occurrences are related to deposits of the Sarmatian – Lower Pannonian silicic effusive and explosive volcanism in the area of Szerencs and Erdőbénye - Erdőhorváti Caldera. The lava bodies are flow or dome like in morphology and were built-up during the several phases between 12.8±0.5 and 10.6±0.5 Ma. The Lebuj and Rókabérc localities contain obsidian marekanite (0,5-3 cm) nested in banded perlite that developed in the medial and basal, glassy part of the flow sequences. The pumice rich volcanoclastic deposits also contains fresh, angular obsidian lapilli (<cm, Meszes Hill). These clasts were incorporated from lava domes by pyroclastic flows during the caldera-related explosive eruptions. The allochthonous localities have a widespread areal distribution around the lava dome sequences with larger obsidian nodules (up to dm, Tolcsva, Erdőbénye, Olaszliszka, Mád). Due to the size range of the allochthonous obsidian fragments, the described primary occurrences cannot be considered as obsidian sources. Instead, currently unrevealed glassy parts of the latest rhyolite effusions are assumed to be the major suppliers of secondary sites.

Kivonat

A Tokaji-hegység a kárpáti obszidián jól ismert, régóta vizsgált lelőhelye. Jelen tanulmányunk átfogó összefoglalást ad a miocén vulkáni sorozat általános vulkano-sztratigráfiai, geokronológiai és a kőzettani viszonyairól. A kiválasztott előfordulások jól szemléltetik az obszidián lelőhelyek földtani jellemzőit. Az elsődleges előfordulások a szarmata-alsó pannon effuzív és explozív jellegű riolit vulkanizmus kőzetsorozataihoz kapcsolódnak a Szerencs, valamint az Erdőbénye-Erdőhorváti kaldera területén. A lávaár és lávadóm vulkáni formák több egymást követő fázisban képződtek 12.8±0.5 és 10.6±0.5 millió év között. A Lebuj és Rókabérc előfordulások fluidális perlitben megjelenő ún. marekanitokat tartalmaznak (0.5-3cm), amelyek a savanyú lávaárak belső üveges, illetve a fekü közelében kifejlődött ún. bázis övéhez kapcsolódnak. A horzsakőben gazdag vulkáni tufák szintén tartalmaznak üde, szögletes obszidián lapilliket (<cm, Meszes). Ezek a litoklasztok közeli üveges lávadómokból származtathatók, amelyeket a kaldera beszakadásokat kísérő piroklaszt árak szállítottak tovább. A másodlagos (allochton) előfordulásokat nagyobb méretű obszidián darabok jellemzik (akár dm) és ezeket jelentősebb távolságban is megtaláljuk a láva dóm sorozatok környezetében (Tolcsva, Erdőbénye, Olaszliszka, Mád). A különböző másodlagos lelőhelyekről leírt obszidiánok méretét vizsgálva megállapítható, hogy a jellemzett elsődleges előfordulások nem lehettek ezek forrásrégiói. Feltételezhető azonban, hogy az effuzív riolitos vulkanizmus jelenleg feltárásban nem vizsgálható üveges lávatestei a másodlagos előfordulások legfontosabb forrásai.

KEYWORDS: OBSIDIAN, PERLITE, RHYOLITE, CALDERA, LAVA DOME

KULCSSZAVAK: OBSZIDIÁN, PERLIT, RIOLIT, KALDERA, LÁVADÓM

• How to cite this paper: SZEPESI, J., LUKÁCS, R., T. BIRÓ, K., MARKÓ, A, PÉCSKAY, Z.& HARANGI, Sz., (2018): Geology of Tokaj Mountains obsidians, *Archeometriai Műhely* **XV/3** 167-180

Introduction

Obsidian is primary, non-hydrated volcanic glass, its formation is related to fast quenching of lavas with elevated silica content (>70%). Perlite is the hydrated variety of the silicic glass that can develop during and after solidification via water diffusion into the glass (up to 5 % H_2O). Tokaj Mountains (or Tokaj-Zemplén Mountains, Lóczy 2015) is a well-known occurrence of the Carpathian obsidians which are usually associated with perlite. The classic localities are in the famous wine region of Tokaj-Hegyalja. Its geological recognition is dated back to 18th century (Townson 1798, Esmark 1797, Beudant 1822). Szabó (1866, 1867, 1876) and Szádeczky (1886) reported the first detailed geological studies summarizing the knowledge about the geological settings and major occurrences of the obsidians. After these works, the geological and raw material research mainly focused on the volcanoclastics and hydrated, perlitic glass deposits (I. Perlaki 1972). The obsidians have received more attention in recent years due to its archaeological importance. Beside the comprehensive analytical research of them (Biró et al. 2005, Kasztovszky et al. 2008, 2014, 2018), their geological-volcanological context remain unstudied. The ongoing volcanological field survey of the MTA-ELTE Volcanology Research Group in the Tokaj Mountains (Szepesi et al. 2016 a, b 2017) also identified and described volcanic glass bearing outcrops in the southern part of TM. The mapping work recognized the primary outcrops and reworked, allochthonous materials. As a first result, the present paper gives a brief review of obsidian occurrences with their geological settings and interpretation of formation in the distinct volcanological environments. On the ground of our fieldwork-based experience we attempt to explain the processes related to the origin of secondary sources. Furthermore, we give a basic data for the further source correlation studies.

Geological settings

TM is located in north-eastern part of the Carpathian Pannonian Region and is the southern part of the Tokaj-Slanske Mts. which is roughly perpendicular to the orogenic belt of the Carpathians. The TM extends until the Hungarian-Slovakian border. It is a composite volcanic area that is bounded by the Hernád, Bodrog and Ronyva tectonic lines (**Fig. 1.**) that created its 15-25 km wide, faults aligned graben-like structure (Gyarmati, 1977, Kaličiak and Žec 1995, Gyarmati and Szepesi 2007, Zelenka et al. 2012). The volcanic formations continue towards western and eastern direction under the sedimentary cover of Bodrogköz and Hernád valley. The region evolved at the eastern part ALCAPA microplate (Horváth 1995) as part of the Central Parathetys realm and is connected to the Eastern Slovakian Basin of the Transcarpathian Depression (Vass et al. 1988, Kováč et al. 2007).

The calc-alkaline volcanic activity occurred between the Late Badenian and Early Pannonian period in the TM (15-9.4 Ma Pécskay et al. 1987, 2006, Pécskay & Molnár 2002; Lexa et al. 2010). While the Slanskè Mountains is dominated by andesitic volcanism, the TM and the neighbouring Zemplín Hills (Bačo et al. 2017, 2019 in this volume) represent coeval intermediate to silicic volcanic activity. The latest palaeovolcanic reconstruction (Zelenka et al. 2012) is based on detailed volcanological, petrological geochemical and geophysical investigations and defined the major evolutionary stages and eruptive centres of the succession. The volcanism involved explosive and effusive activity and the palaeovolcanic environment gradually changed from submarine to subaerial.

The first Badenian explosive eruptions were phreatomagmatic, they produced extensive rhyo-dacitic and rhyolitic ignimbrite sheets that covered large areas (Lexa et al. 2010, Zelenka et al. 2012). The following, widespread Sarmatian ignimbrites and related lava dome edifices are the most frequent obsidian sources. The associated large eruptive centres are at the northern (Hegyköz, Perlaky 1972), middle (Erdőbénye - Erdőhorváti) and the southern part (Szerencs Caldera, Zelenka et al. 2012) of the mountains. The accompanying lava dome building extrusions (blue coloured, **Fig. 1.**) occurred at the early and late stage of the eruptive cycles (Telkibánya, Kishuta, Erdőhorváti, Mád, Bodrogkeresztúr).

Coeval andesitic composite volcanoes with eroded/collapsed calderas occur in the northern (Hollóháza), central (Regéc-Baskó) and southern (Mád) segments of the TM. Several subvolcanic bodies (andesite-dacite) intruded into the volcanoclastic succession (Tállya-Kopasz Hill, Gönc-Hársas). The youngest ignimbrite horizon (Vizsoly Tuff) is bounded to a N-S striking fracture zone along the Hernád Through (Zelenka et al. 2012). The volcanic activity terminated by pyroxene-dacite cones (Tokaj, Szegi), olivine bearing andesite domes (Erdőbénye) and a basaltic dike (Sárospatak).

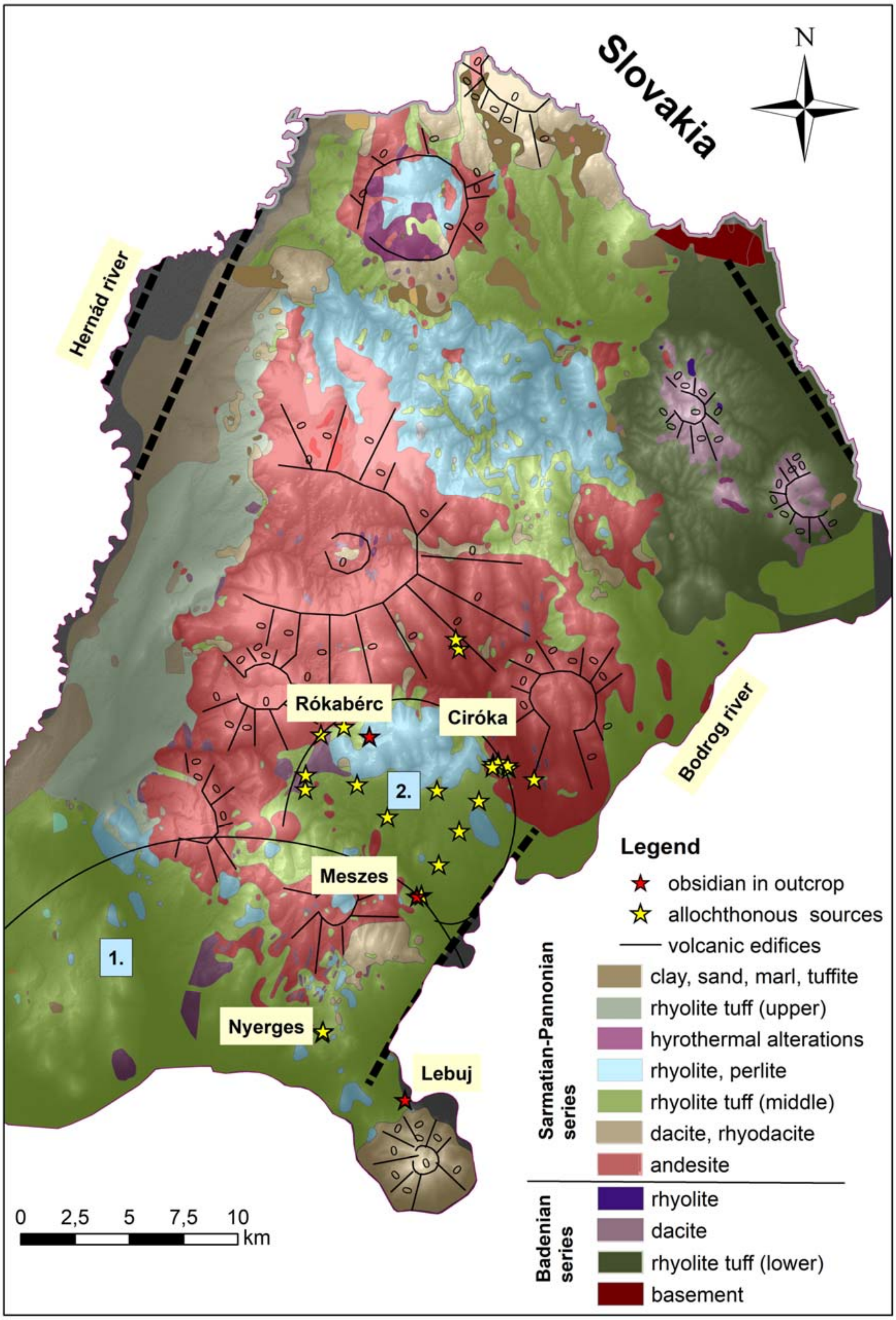

Fig. 1.: Geological scheme of the Tokaj Mountains with the major volcanic centres, Based on Gyarmati 1977, Lexa et al. 2010, Zelenka et al. 2012, 1. Szerencs Caldera, 2. Erdőbénye-Erdőhorváti Caldera

1. ábra: A Tokaji-hegység földtani térképe a legfontosabb vulkáni központokkal, Gyarmati 1977, Lexa et al. 2010, Zelenka et al. 2012 alapján módosítva, 1. Szerencs kaldera, 2. Erdőbénye-Erdőhorváti kaldera

Methods

The current investigation involved detailed fieldwork sampling and compilation of geochronology database to establish a general stratigraphic framework for the obsidian occurrences. Fieldwork was carried out using 1:10 000 scale topographic and the 1:25 000 geologic maps (Erhardt et al. 1964, Gyarmati 1971, Gyarmati et al. 1968, Gyarmati & Zelenka 1968, 1970, Pentelényi 1968). The lithologic (e.g. glassy/microcrystalline texture) and volcano-sedimentology (e.g., massive/bedded lapilli tuff) features were used to distinguish lithofacies units. The obsidian bearing lithofacies zones investigated in detail (**Fig. 1.**). Collected samples were cut to document macroscopic scale features and then thin sections were made from their particular parts. Petrographic descriptions were made using combined optical microscopy observations and back scattered electron imaging (AMRAY 1830, EDAX PV9800 spectrometer) at the Dept. Petrology and Geochemistry, Eötvös University using 20 kV voltage. The K-Ar geochronology data were compiled from literature (Pécskay et al. 1987, 2006, Pécskay and Molnár 2002) and linked to previously described volcanic forms (Zelenka et al. 2012).

Results

The former TM fieldworks (I. Perlaki 1972, Szepesi et al. 2016, 2017) predicted and identified obsidian sources only in the southern part of the mountains. The current research identified 22 obsidian sites (**Fig. 1.**) from the southern TM, in the area of the Szerencs and Erdőbénye-Erdőhorváti Caldera. Based on previous works (Zelenka 1964, Gyarmati and Zelenka 1968) the general stratigraphic profile was compiled for both successions (**Fig. 2.**). The registered elevations of the outcrops varied between 90-400 m above sea level and are related to different stratigraphic segments of the caldera successions (**Fig. 2.**). The previous radiometric dating sampled the rhyolites from the surroundings of the obsidian localities (**Table 1., Fig. 2.**). The Szerencs Caldera rhyolites formed between 12.8-11.6±0.5 Ma, while the slightly younger and smaller volcanic centre of Erdőhorváti-Erdőbénye Caldera evolved between 11.8-10.6±0,5 million years.

According to Szádeczky (1886) two types of occurrences can be distinguished in the area: primary outcrops containing obsidians and secondary, allochthonous sources where the obsidian was found in the deluvial sediments or soil. The localities from northern part of TM were reported as primary sources by Szádeczky (1886) and recognized to variably hydrated perlite deposits. The following part describes five localities which are representative for the TM obsidians.

Table 1.: Geochronology data of Szerencs Caldera and Erdőbénye lava domes/flows, for lithostratigraphy correlation see **Fig. 2.**

1. táblázat: A Szerencs és Erdőbénye-Erdőhorváti kaldera lávadóm/lávaár előfordulásainak geokronológiai adatai, rétegtani korreláció a **2. ábra** alapján

Volcanological unit	**Locality**	**rock type**	**Age**	**±1σ**	**Reference**
Erdőbénye-Erdőhorváti Caldera lava domes	Szokolya	rhyolite	10.6	0.5	unpublished
	Nagy-Páca	rhyolite	11.2	0.5	Pécskay et al. 1987
	Bh. Eh-13 106-114.8	rhyolite	11.0	0.4	Pécskay et al. 1987
	Fenyves road	rhyolite	11.5	0.5	Pécskay et al. 1987
	Vörös peak	rhyolite	11.8	0.4	Kiss et al. 2010
Szerencs Caldera lava domes	Harcsa Hill	rhyolite	10.8	0.8	Pécskay & Molnár 2002
	Király Hill	rhyolite	11.6	0.6	unpublished
	Lebuj, Tokaj Hill	rhyolite	11.6	0.6	Pécskay et al. 1987
	Terézia Hill	rhyolite	12.1	0.5	Pécskay et al. 1987
	Kakas Hill	rhyolite	12.8	0.5	Pécskay & Molnár 2002
	Tállya 15 borehole 518-556 m	rhyolite	12.0	0.8	Pécskay et al. 1987

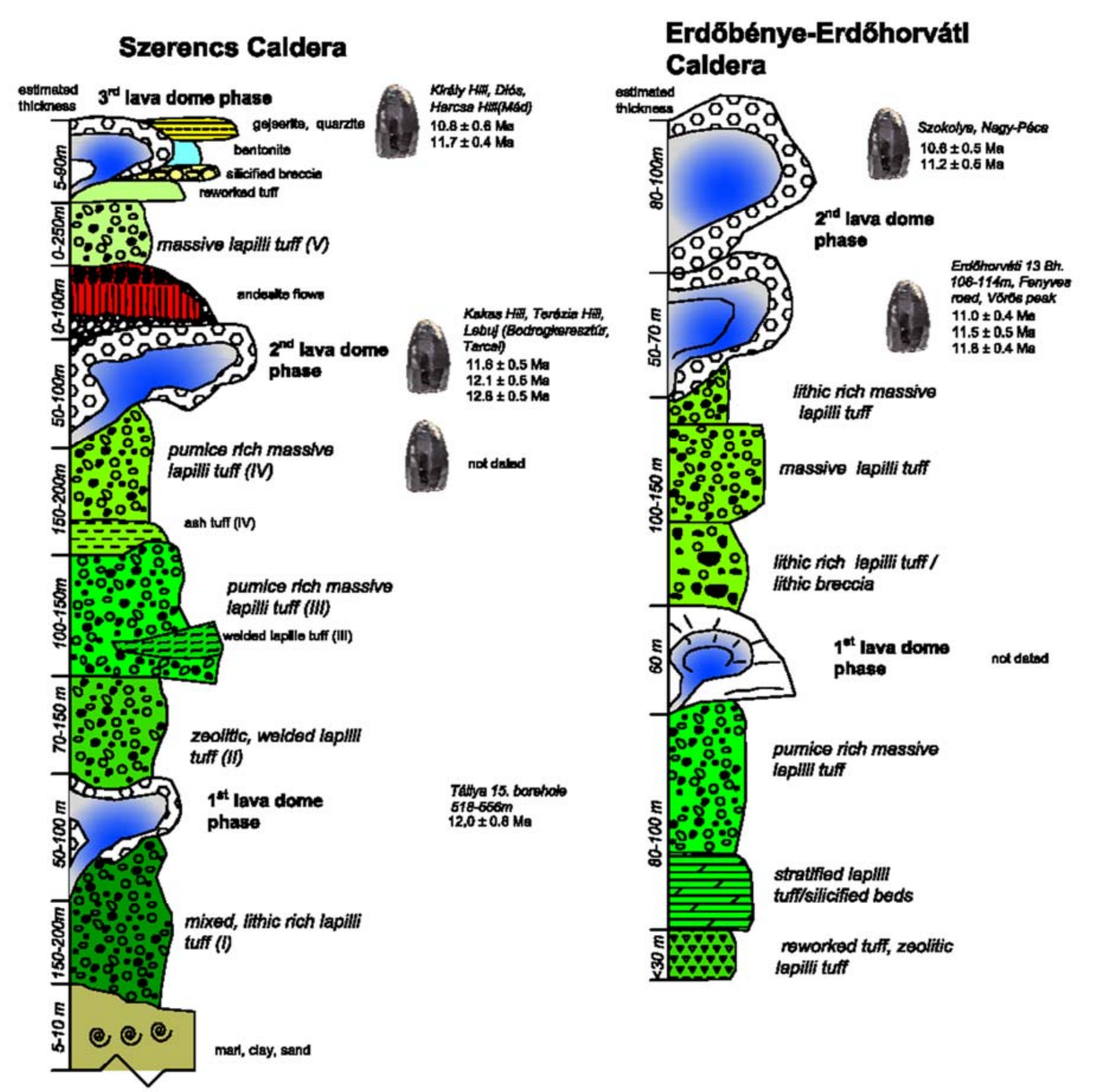

Fig. 2.: Schematic sketch of Szerencs and Erdőbénye-Erdőhorváti Caldera succession based on Zelenka (1964) and borehole documentary (Eh.13, Gyarmati 1981). Obsidian symbols indicate primary localities in the stratigraphy.

2. ábra: A Szerencs és Erdőbénye-Erdőhorváti kaldera vulkáni kőzetsorozatának vázlata Zelenka (1964) és az Erdőhorváti 13. fúrás rétegsora alapján (Gyarmati 1981. Az obszidián szimbólumok az elsődleges előfordulások rétegtani helyzetét rögzítik.

Lebuj locality (Bodrogkeresztúr)

The outcrop is located at eastern edge of Tokaj-Nagy Hill (**Fig. 1.**), its name is connected to the famous, centuries-old Lebuj pub in Bodrogkeresztúr. The outcrop wall (**Fig. 3.**) was created during a road construction in the 18th century. The significance of this outcrop is demonstrated by historical perspectives (Townson 1793, Beudant 1822, Ricthofen 1860). Esmark (1798) applied the perlite geological term at the first time in Hungary referring the Lebuj locality. Szabó (1866) recognized the genetic relationship between obsidian and perlite. The 100 meter long, 15 meter high wall (**Fig. 3.**) contains obsidian grains nested in perlite which is called traditionally as “marekanite”. The name came from Pallas, who described almost the same formation from Okhotsk, Russia (Pallas 1771).

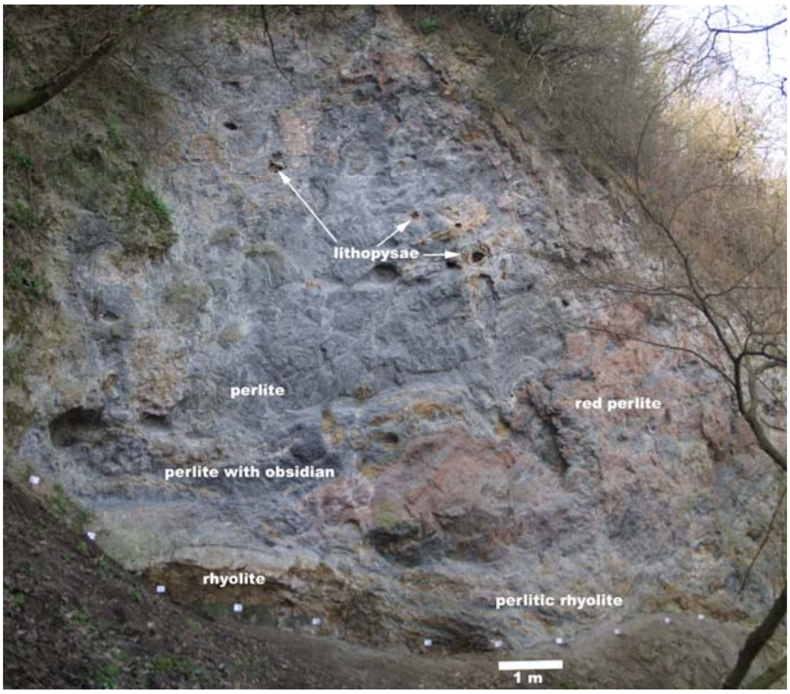

Fig. 3.: Lithofacies zonation of western wall of Lebuj outcrop (Photo by J. Szepesi, 2009)

3. ábra: A Lebuj-feltárás nyugati falának litofáciesei (Fotó: Szepesi J., 2009)

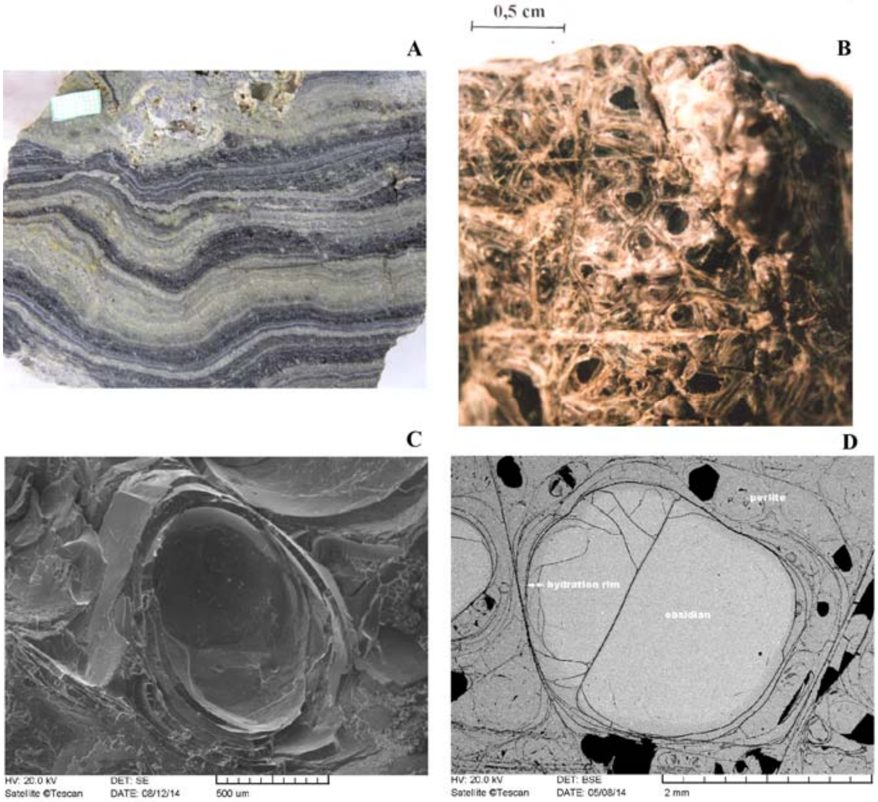

Fig. 4.: Close-up and SEM imaging of the Lebuj samples, a, banded perlite with obsidians (scale=1cm), b, close up view of the textures with rounded to subangular obsidian grains, c, rounded surface of the obsidian grain bounded by dense perlitic cracking (SEM image), d, Backscattered image of an obsidian grain in thin section, a darker hydration rim can be clearly identified at the grain boundary

4 ábra: A Lebuj-feltárás mintáinak makro- és pásztázó elektronmikroszkópos felvételei. a, fluidális perlit obszidián szemcsékkel (lépték=1 cm), b, makroszkópos szöveti felvétel, az obszidián szemcsék alakja a gömbölyded és szögletes között változhat, c, kerekded obszidián szemcse körül kialakult sűrű perlites repedés rendszer (pásztázó elektronmikroszkópos felvétel) d, Obszidián szemcse vékonycsiszolatban (visszaszórt elektron kép): a sötétebb hidratációs szegély jól azonosítható a szemcse határfelületén.

Fig. 5.: Rókabérc locality, a, brownish perlite with small obsidian grains in the Zsivány-valley road cut (400 m a.s.l.) b Larger obsidian grains in rhyolite debris (375 m a.s.l.)

5 ábra: Rókabérc lelőhely, barna perlit kisméretű obszidián szemcsékkel, Zsivány-völgy út bevágás (400 m t.sz.f.) b nagyobb méretű obszidián szemcsék vörös riolit törmelékben (375 t.sz.f.)

From a volcanological point of view the Lebuj represents an older lava dome occurrence (**Fig. 2.**) at the eastern margin of the Szerencs Caldera (**Fig. 1.**). The field survey identified 6 major lithofacies zones (**Fig. 3.**) which follow each other upwards: rhyolite, welded lapilli tuff, red and black perlite breccia, obsidian rich perlite, reddish perlite, lithophysae-rich perlite.

The obsidian-rich zone is identified only at the central-lower perlitic part of the outcrop (**Fig. 3.**) in a thickness of 2-4 meters. The small (<1cm), rounded to subangular grains are nested in gray perlite. The perlitic lava texture is generally flow banded, which is defined by strong fluidal alignment of white-gray bands (**Fig. 4a, b**).

Two feldspars (sanidine and plagioclase), quartz, biotite and rare ilmenite are observed as phenocrysts. The perlitic texture is defined by an onion skin-like foliation around the obsidian cores (**Fig. 4c**). The density of perlitic fracturing is varied between 50-250 µm, rare fractures cut through the obsidian cores (**Fig. 4d**). The macroscopically black obsidian shows light-gray colour on backscattered images, while the perlitic matrix is dark gray. A hydration rim can be seen at the margin of obsidian cores (**Fig. 4d**). The surrounding glass is variably felsitic in certain bands and sometimes contains small spherulites. Under the glassy zone a devitrified rhyolite lithofacies is identified with a thickness of 1-2 m (**Fig. 3.**) which disappear from the central part of the outcrop wall and occurs in the eastern edge. Common hollow cavities (lithopysae, 1-10 cm) developed with concentric crystallized rims most frequently in the upper part of central wall (**Fig. 3.**). Occasionally, a reddish coloured perlite breccia zone crops out at the partly soil covered western part. A welded lapilli tuff and the lowermost rhyolite at the base of the succession make the volcanological interpretation even more complicated.

Rókabérc

The Rókabérc (530 m a.s.l.) is situated at the centre of the Erdőbénye-Erdőhorváti Caldera and expose obsidians in two different outcrops (**Fig. 1.**). The Zsivány-valley section (400 m a.s.l.) is a 250 m long road cut which reveals rhyolite, perlitic rhyolite-perlite lithofacies zonation in upward direction. The prominent obsidian grains (3-5 mm, **Fig. 5a**) are embedded in perlite in comprising a 2-5 meter thick layer. The colour of perlitic matrix is brownish and cut through by vertical, shiny shrinkage joints. The other outcrop is located behind the Rókabérc hunting lodge. The dense debris of the reddish rhyolite mixed with fresh, black coloured obsidians. Here, the grain size of the obsidian clasts is slightly larger (0,5-2 cm, **Fig. 5b**).Their shape is varied from angular to rounded. The surface of the obsidians are very irregular and are dissected by cracks and conchoidal fractures. As phenocryst, beside the most frequent plagioclase, sanidine, quartz and biotite small grains of magnetite and pyroxenes were also identified (Rózsa et al. 2003).

Meszes section

The Meszes Hill (254 m a.s.l.) is located at north-eastern part of the Szerencs Caldera. A 200 meter deep borehole (Eb-163) revealed the complete lithostratigraphic section of the hill. This is consistent with the upper part of caldera succession (**Fig. 2.**). The unaltered, pumice enriched massive lapilli tuff (80 m) at the bottom represents the 4th major, explosive event of the caldera (**Fig. 2.**). In the middle part, a 40 meter thick andesite flow sequence is embedded in layers of mixed (andesitic-rhyolitic) lapilli tuff (50m).

Fig. 6.: Meszes locality, a, Pumice rich, obsidian bearing lapilli tuff (147 m a.s.l.) b, Larger obsidian grains around the tuff locality from the ditch (150-135 m a.s.l.)

6. ábra: Meszes előfordulás, a horzsakőben gazdag obszidiánt tartalmazó lapilli tufa (147 m t.sz.f.) b, Nagyobb obszidián szemcse a lapilli tufa előfordulás környezetében kialakult árokból 150-135 m t.sz.f)

At the top, the sequence terminates with rhyolitic lavas (10 metre) in which a perlitic layer developed at the base. The obsidian was identified in two primary sources. First one was revealed by drilling and found at basal part of the rhyolite flow (5-9 m), where the obsidian forms marekanite in perlitic rhyolite and pumiceous perlite. Unfortunately, the borehole documentary did not provide data on its grain size. The other primary source is the pumice rich lapilli tuff (**Fig. 6a**) which is available in outcrops, too. The logged outcrops were in a small quarry around the vineyards, 2 large gorges and smaller ditches. The lithofacies lacks internal stratification and comprises high amount of rounded pumice (<cm) and subordinate angular obsidian and rhyolite lapilli (~cm, **Fig. 6a**) in a fine ash size matrix (Fig. 6a). The matrix (30-45%) consists of glass shards and crystal fragments (5-10%), mainly feldspars (sanidine and plagioclase), quartz and biotite.

Allochthonous sources

There are localities where obsidian is found in the deluvial sediments and soil (brown forest soil, Raman forest soil) and therefore they are termed as secondary allochthonous sources (**Fig. 1.**). Generally, the common black coloured type (**Fig. 6d, 7a, c, d**) can be collected from the vineyards of the foothill regions with moderately steep slopes between 250-110 m elevations. The grain size is highly variable and range between 1-10 cm (Mád, Olaszliszka, Erdőbénye, Tolcsva). The largest obsidians (up to 5 kg) were reported in historical studies (Olaszliszka, Szádeczky 1886). A broad number of collected obsidian nodules are available in museums (**Fig. 7.**) or private collections (e.g. Encsy György, Tállya) but currently the source areas are hidden in the field.

Accumulations of rounded obsidian grains are observed at Meszes on the gentle slopes (150 m a.s.l) and foots of the Meszes hill (110 m a.s.l.). Here, the largest size was about 5-8 cm in diameter, and the average around 3 cm (**Fig. 6b.**). The obsidian surface is smooth and curvy and has brown-gray crust while the fresh fracture surface is black.

A more dense debris of the black angular fragments (1-3 cm) was found in Nyerges (**Fig. 1.**, 229 m. a.s.l) between Mád and Bodrogkeresztúr. The obsidian mixed with slightly larger fragments of hydrothermally altered rhyolite and lapilli tuff (**Fig. 7a**). The unusual abundance of the obsidian is nearly equal with other clast types. The larger individual grains collected from Erdőbénye, Tolcsva region where well defined flow banding texture can be observed (**Fig. 7c**). Another, rare, reddish coloured type (**Fig. 7b**) obsidian was collected from a very small area around Tolcsva (Gyopáros-Ciróka, 205 m a.s.l. **Fig. 1.**).

Fig. 7.: Secondary obsidian sources, a, Nyerges (229 m a.s.l.) Dense obsidian debris (black)with rhyolite tuff (white) and rhyolite (light brown-pink) fragments in forest soil. b, Tolcsva, Mahogany obsidian (Ciróka, 200 m a.s.l.) Note the irregular reddish surface of glass (Hungarian National Museum collection, photo by J. Antoni), c, Flow-banded obsidian from Erdőbénye (Hungarian National Museum collection photo by J. Antoni), d, One of the largest obsidian nodule from Mád, Kakas Hill (photo by J. Antoni)

7 ábra: Másodlagos obszidián lelőhelyek a, Nyerges (229 m t.sz.f) Sűrű obszidián törmelék (fekete), riolittufával (fehér) és riolittal barna erdőtalajban. b, Tolcsva, mahagóni obszidián (200 m t.sz.f.) jellegzetes szabálytalan bemélyedésekkel a felszínén (Magyar Nemzeti Múzeum gyűjteménye Fotó: Antoni J.). c, fluidális szövetű obszidián Erdőbényéről (Magyar Nemzeti Múzeum gyűjteménye, Fotó: Antoni J.), d, a legnagyobb obszidián példányok egyike (Mád, Kakas-hegy, Magyar Nemzeti Múzeum gyűjteménye. Fotó: Antoni J.)

This variety occurs together with the black variant, but its frequency is much lower. This special TM obsidian is referred as “mahogany” subtype (Biró et al. 2005, Kasztovszky et al. 2018) using the terminology from the historical descriptions (Szabó, 1867, 1876). The grains size is usually smaller (1-5 cm) and flow banding is also typical. The surface is highly irregular showing gas bubble originated cavities.

Discussion

The Tokaj Mountains is recognized as a classic locality of the Carpathian obsidian (Biró 1984, Williams-Thorpe et al. 1984, Kasztovszky et al. 2018). Generally, this is a non-transparent, black silicic glass variety (Carpathian 2 type) but macroscopically different types were distinguished by archaeological and geochemical studies (Biró et al. 1984, 1986, Williams-Thorpe et al. 1984.). The early workers have classified the sources using their primary (in outcrop) or secondary (reworked) occurrence (Szabó 1867, 1876, Szádeczky 1886). We found that the reported northern primary localities contain variably hydrated perlite and cannot be taken as obsidian sources. The fieldwork confirmed that obsidian of TM is related to two major rhyolitic volcanic centres, the Szerencs and Erdőbénye - Erdőhorváti Caldera (**Fig. 1.**) at the southern part of the mountains. Only three primary natural sources are identified in specific outcrops. Some boreholes also drilled obsidian rich layers but usually they are not revealed in the surface. All the other occurrence localities could be interpreted as allochthonous sources and are in reworked deluvial deposits or soils. The size range of TM obsidians is considerably smaller than the Zemplín Hills samples. The size in the primary sources range between 0.5-3 cm in the TM while the fragments from the perlitic breccias of Viničky can reach dimensions up to 10-15cm (Bačo et al. 2017, 2019 in this volume).

The K-Ar radiometric ages of the volcanic deposits related to the obsidian clasts scatter between 12.8±0.5 and 10.6±0.5 million years. The ages suggest that the activity of Erdőbénye - Erdőhorváti Caldera succession is s slightly younger than the Szerencs Caldera. Comparing the TM volcanism with those of Zemplin Hills (Bačo et al. 2017, 2019 in this volume) the activity is older in the area of Streda and Bodrogom (from 15.0±0.7 to 14.3±0.6, Bačo et al. 2017) but the other localities (Viničky, Brehov) developed in the same time span (from 12.1±0.5 to 11.0±0.4).

Primary obsidian localities

The primary outcrops are located at various altitude levels (100-400 a.s.l.) and the obsidian is dominantly associated with rhyolite lavas and hydrated perlite deposits. This relationship was first described by Pallas (1771) and indicates that formation of obsidian is connected to the basal or upper glassy layers around the microcrystalline rhyolitic core of the rhyolitic lava dome sequences (Manley & Fink 1987, McPhie et al. 1993, Szepesi et al. 2016a). The primary volcanic glass suffered partial syn and /or post-emplacement hydration, so the unaffected obsidian grains vary in size and are nested in perlitic matrix. These lava dome edifices are associated with both caldera successions in different stratigraphic level (**Fig. 2.**).

The Lebuj obsidian developed at the lowest stratigraphic position and is related to 2nd lava dome phase of the Szerencs Caldera (**Fig. 2.**). The obsidian rich perlite lithofacies characterizes the basal section of a rhyolite lava flow (Szepesi and Kozák 2014, Szepesi et al. 2016b). The Rókabérc outcrops (400 m a.s.l.) reveal the topmost section of the Erdőbénye Caldera related volcanic deposits (**Fig. 2.**). The obsidian is identified in perlite which represents the upper and basal glassy layers of a rhyolite flow, where the size of marekanite is slightly larger at the basal settings (**Fig. 5.**). Fresh angular lapilli sized obsidian grains are also identified in volcanoclastic layers (**Fig. 2., 6.**) of the caldera-forming explosive eruptions. The Meszes site reveals the pumice rich lapilli tuff which probably represents the 4th major rhyolite tuff layer (**Fig. 2.**) of the Szerencs Caldera eruptions. The angular lapilli can be interpreted as juvenile clasts of the massive lapilli tuff (ignimbrite) that deposited from pyroclastic density currents during large explosive eruptions. They show no signs of successive reworking as reported from Streda and Bodrogom (Zemplín Hills, Bačo et al. 2017, 2018 in this volume).

Allochthonous sources

The allochthonous sources are the most widespread localities in Tokaj Mountains (**Fig. 1.**) and represent reworked occurrences of primary obsidian formations. The altitude conditions are highly variable but are usually lower than 300 meter in elevation. Large obsidian nodules (3-8 cm, **Fig. 6b**) can be found in the foothill of Meszes, and we have only indirect evidences about their origin. The obsidian bearing pumice rich lapilli tuff outcrops directly above on the slopes, but its obsidian lapilli size (cm, **Fig. 6a**) is below the range of those from the reworked deposit. The Eb-163 borehole drilled a marekanite bearing layer below Meszes top that represents the topmost rhyolite flow units of the Szerencs Caldera (**Fig. 1., 2.**) succession. This layer is assumed as the potential source for the slope material (**Fig. 6b**). In this case, the altitude difference is about 180 meter and suggest long (~km) erosional transport on the slope. This scenario could also be applicable in the Nyerges case where obsidian debris mixed with lapilli tuff and hydrothermally affected rhyolite deposits (**Fig. 7a**). The angular shape of glass fragments indicates nearby source with shorter deluvial transport distance.

The thickest rhyolitic lava dome sequence developed in the Erdőbénye-Erdőhorváti Caldera succession (over 100 m, **Fig. 2.**), where obsidians were reported from also the basal and medial sections. Accordingly, the largest number of allochthonous sources is identified around this lava dome field (**Fig. 1.**) including the special mahogany (red) type (**Fig. 7b**). The primary lava dome localities suggest that they were formed during the last evolutional stage of the silicic volcanism. The following long-continuous (10 million years) denudation exposed and partly eroded the glassy parts of the rhyolite flows. The obsidians clasts detached from the easily disintegrable perlite and were carried by slope transport processes and were distributed widespread around the lava dome field in deluvial deposits.

Conclusions

This study summarizes our present knowledge on the geological setting of the Carpathian C2 obsidian. We demonstrated that the primary origin of the obsidian is related to the quenched glassy (mainly basal) carapace part of the silicic lava domes or flows in the TM. We also showed that beside the primary lava dome originated obsidian fragments, obsidian clast can be found as lithic clasts in primary pyroclastic flow deposits. Our results provide compelling evidence for the connection between rhyolitic lava dome sequences and the allochthonous obsidian occurrences. Although, the Zemplín Hills obsidian fragments developed at similar settings, their grain size is usually in larger order. However, historical obsidian studies of the TM reported quite large grains, but unfortunately we could not find these occurrences so far. Therefore, future work should include more detailed field studies of rhyolite lavas and tuffs where we would expect new occurrences. Detailed volcanological and geochemical studies are also important ways to better understand the formation and archaeological correlation of the Carpathian obsidian.

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