GEOLOGICAL BACKGROUND OF THE OCCURRENCES OF CARPATHIAN VOLCANIC GLASS, MAINLY OBSIDIAN, IN EASTERN SLOVAKIA •

A VULKÁNI ÜVEGEK, FŐKÉNT AZ OBSZIDIÁN FÖLDTANI VISZONYAI KELET-SZLOVÁKIÁBAN

BAČO, Pavel[1], LEXA, Jaroslav[2], BAČOVÁ, Zuzana[1], KONEČNÝ, Patrik[3] & PÉCSKAY, Zoltán.[4]

[1]State Geological Institute of D. Štúr, Jesenského 8, 040 01 Košice, Slovakia; pavel.baco@geology.sk; zuzana.bacova@geology.sk

[2]Geological Institute, Slovak Academy of Sciences, Dúbravská cesta 9, 840 05 Bratislava, Slovakia; geoljalx@savba.sk

[3]State Geological Institute of D. Štúr, Mlynská dol. 1, 817 04 Bratislava, Slovakia; patrik.konecny@geology.sk;

[4]Institute of Nuclear Research, Hungarian Academy of Sciences, Debrecen, Hungary; pecskay@namafia.atomki.hu

Abstract

Primary natural occurrences of volcanic glass in the region of Eastern Slovakia are associated with other products of silicic (rhyolite, rhyodacite) volcanism. This Upper Badenian to Lower Pannonian volcanism was a part of the bimodal andesite/rhyolite volcanic activity. Products of the silicic volcanism occur as tuffs and pumice tuffs, reworked epiclastic volcanic rocks, rare intrusions and dominantly as extrusive domes that sometimes pass into short and thick lava flows. The volcanic glass associates with intrusive and extrusive forms of silicic volcanism and occurs in massive as well as brecciated forms (e.g. in the type locality of Merník), or as perlite (Brezina, Byšta) and perlite with obsidian (Malá Bara, Viničky). Rarely the volcanic glass can occur in explosive forms of silicic volcanism (obsidian – Hermanovce, Veľká Bara). Fragments of perlite with obsidian and rare obsidian, occurring alone, are a part of reworked rhyolite/rhyodacite tuffs, epiclastic volcanic sandstones and gravels, as well as epiclastic volcanic breccias, all occurring near the municipality of Streda nad Bodrogom. In Quaternary deposits, obsidian occurs around the Cejkov and Brehov villages.

Kivonat

A vulkáni üvegek természetes előfordulása Kelet-Szlovákiában a magas SiO_2 tartalmú (savanyú) vulkanizmussal kapcsolható össze, ami a riolitos, riodácitos vulkanizmussal függ össze. A Felső Badeni időszaktól az Alsó Pannon időszakig terjedő időszakot bimodális, andezites/riolitos vulkánosság jellemezte. A savanyú vulkanizmus termékei a riolittufák és horzsaköves tufák, áthalmozott epiklasztos vulkáni kőzetek, ritkábban intrúziók formájában és uralkodóan mint extrzív kőzettestek, amelyek időnként rövid és vaskos lávakőzetekbe mennek át. Az intruzív és extruzív savanyú vulkanitokhoz kapcsolódó vulkáni üveg tömeges és breccsás formában is előfordul (pl. Merník típus-lelőhelyen),vagy mint perlit (Brezina, Byšta) és perlites obszidián (Malá Bara, Viničky). Ritkábban a vulkáni üveg a savanyú vulkanizmus explozív formájában jelenik meg (obszidián – Hermanovce, Veľká Bara). Az obszidián darabokat tartalmazó perlit és ritkábban a magában előforduló obszidián részét képezi az áthalmozott riolit és riodácit tufáknak, együtt fordul elő az epiklasztos vulkáni törmelékes kőzeteknek és breccsáknak, amelyek Bodrogszerdahely környékén fordulnak elő. A negyedkori üledékekben, másodlagos helyzetben, obszidiánt találhatunk Cejkov és Brehov falvak környezetében is.

KEYWORDS: EASTERN SLOVAKIA, SOURCES OF OBSIDIAN, FACIES POSITION, EVOLUTION OF OBSIDIAN SURFACE

KULCSSZAVAK: KELET-SZLOVÁKIA, OBSZIDIÁN FORRÁSOK, FÁCIES POZÍCIÓ, OBSZIDIÁN FELSZÍN ÉRTÉKELÉSE

• How to cite this paper: BAČO, P., LEXA, J., BAČOVÁ, Z, KONEČNÝ, P. & PÉCSKAY, Z., (2018): Geological background of the occurrences of Carpathian volcanic glass, mainly obsidian, in Eastern Slovakia, *Archeometriai Műhely* **XV/3** 157-166.

HU ISSN 1786-271X; urn: nbn: hu-4106 © by the author(s)

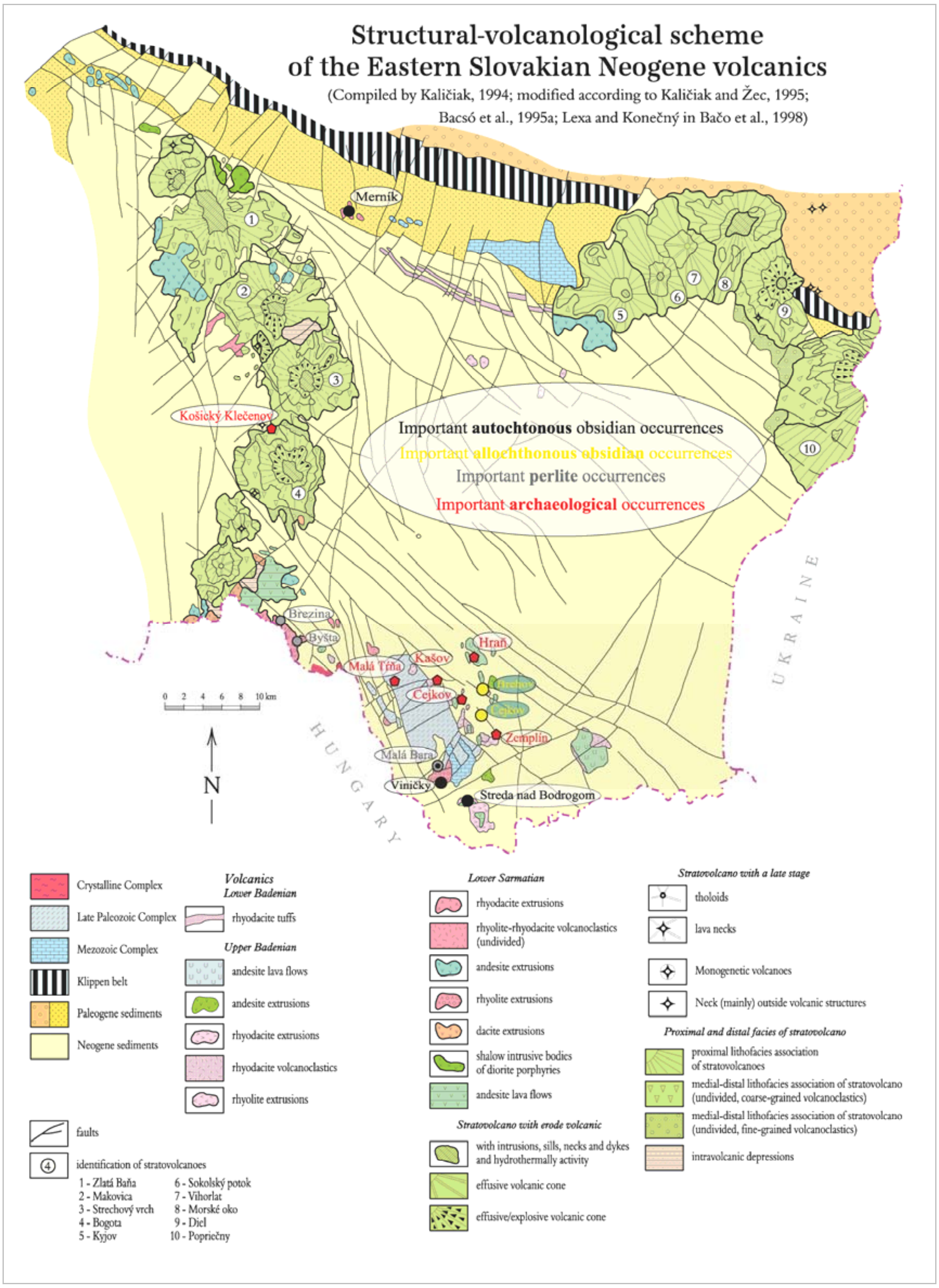

Fig. 1.: Natural obsidian and perlite occurrences in Eastern Slovakia, including the most important archeological sites with obsidian industry. According Bačo et al., 2017, Fig. 4, p. 212. (structural-volcanological scheme compiled by Kaličiak (1994), modified by Kaličiak & Žec (1995), Bacsó et al. (1995), Lexa & Konečný in Bačo et al. (1998).

1. ábra: Természetes obszidián és perlit előfordulások Kelet-Szlovákiában, a legfontosabb obszidián-kőiparral rendelkező régészeti lelőhelyek feltüntetésével. Bačo et al., 2017, Fig. 4, p. 212. nyomán (a szerkezeti vázlatot Kaličiak (1994), állította össze, majd a következő tanulmányok alapján módosítottuk: Kaličiak & Žec (1995), Bacsó et al. (1995), Lexa & Konečný in Bačo et al. (1998).

Introduction

Occurrences of the volcanic glass in the Eastern Slovakia are mainly associated with products of acidic volcanism. It is a part of bimodal andesite-rhyolite volcanism of the Late Badenian to Early Pannonian age (Lexa & Kaličiak, 2000; Pécskay et al., 2006). Rhyolite and rhyodacite volcanism is characterized by pyroclastic rocks in the form of tuffs and pumice tuffs, in minor extent with juvenile and lithic lapilli. Volcanic complex contains also various forms of intrusive, but mainly extrusive bodies with rare transition to lava flows. Previous works about geological position of the obsidian in the area of Eastern Slovakia provided only general information. More detail work, but focused on perlite, is by Šalát & Offčáková (1964). Later works (Kaminská & Ďuďa, 1995; Baňacký et al., 1989) did not describe a detail geological position of the obsidians. The description of obsidian allochthonous occurrences near Cejkov was published only recently (Přichystal & Škrdla, 2014). Various facies positions of obsidians, either primary or secondary, was reported in work by Bačo et al. (2017).

Geological settings

The Middle Miocene Tokaj-Zemplín-Beregovo-Oas field of monogenetic rhyolite volcanoes is an integral part of the Middle/Late Miocene bimodal andesite-rhyolite volcanics associated with a system of horsts and grabens south of the Transcarpathian Basin – a segment in the Carpathian volcanic arc (Lexa et al., 2010). Episodes of rhyolite volcanic activity alternated with activity of andesites and dacites that have given rise to mostly solitary small stratovolcanoes, effusive complexes and extrusive domes. K/Ar ages of andesites, dacites and rhyolites overlap in the interval 13.8 – 9.5 Ma (Pécskay et al., 2006).

The formation of the horst and grabens as well as the volcanism were related to the interplay of subduction, delamination and back-arc extension (Seghedi & Downes 2011). The bimodal andesite-rhyolite volcanic association is interpreted as contemporaneous partial melting of metasomatized lithospheric mantle and crustal source materials as a result of the related tectono-thermal reactivation. Peraluminous rhyolites are of anatectic origin, later affected to various extent by mixing with mafic mantle source magmas and lower pressure AFC *(Assimilation and Fractional Crystallization)* processes (Konečný et al., 2010, Kohút et al., 2017).

Primary natural occurrences of obsidian in the region of Eastern Slovakia associate with other products of silicic (rhyolite, rhyodacite) volcanism that was a part of the bimodal andesite/rhyolite volcanic activity during the Upper Badenian to Lower Pannonian time (Lexa & Kaličiak 2000, Pécskay et al., 2006). Products of the silicic volcanism occur as tuffs and pumice tuffs, reworked epiclastic volcanic rocks, rare intrusions and dominantly as extrusive domes that sometimes pass into short and thick lava flows (dome flows, coulées). Massive as well as brecciated forms of volcanic glass, perlite and obsidian, associate especially with intrusive and extrusive forms of silicic volcanism (Bačo et al. 2017, Fig. 1).

Main sources of volcanic glass

At the Merník locality (**Fig. 1.**) volcanic glass forms marginal parts of various small rhyolite intrusions and dykes at a cinnabar deposit. Directly at the surface it crops out at the northwestern side of the hill Lipová hora, where it forms margin of a rhyolite intrusion as well as several purely glassy dykes. It is of a dark gray color with variable tints, contains xenoliths of surrounding rocks (mostly claystone and sandstones) and is highly fractured. That prevents utilization of the glass for a production of chipped artifacts, though rare massive parts have been identified.

Hydrated volcanic glass – perlite occurs at marginal parts of the extrusive dome Harsas next to the village Byšta and it forms also separate dykes in surroundings of Byšta and Brezina (**Fig. 1.**). However, in this case perlite does not include obsidian cores that could be used for a production of obsidian industry.

Marginal parts of the extrusive dome/flow Borsuk close to the village Malá Bara, but especially in surroundings of the village Viničky host the most important primary occurrences of obsidian in Slovakia. First of all they crop out at the southeastern side of the dome/flow at localities marked as 1, 2 and 3 in the **Fig. 2.** Obsidians always occur along with perlite, usually as obsidian cores in perlite environment.

Lithological setting of the autochthonous obsidian occurrences

The form of obsidian occurrence in the perlite environment could be observed in newly driven (years 2006 – 2007) underground galleries of the Tokaj Viničky ltd. (PROMACO SA) wine cellars. Clearly, obsidian occurs in two types of geological/lithological setting.

The first type of setting is represented by perlitized parts of small rhyolite intrusions and/or dykes (**Fig. 3.**), including a direct continuation of the intrusion with all attributes of obsidian occurrence. The same type of setting could occur elsewhere in surroundings, especially eastward and southeastward at localities 2 and 3 (**Fig. 2.**).

Fig. 2.: Panorama of the SW side of the Borsuk rhyolite dome/flow (rhyolite volcano) next to the village Viničky with obsidian and perlite occurrences, including the Tokaj Viničky ltd.(PROMACO AS) Winecellars, 1,2,3 – obsidian occurrences. View from the southeast. Photo by P. Bačo. According Bačo et al. (2017), Fig. 7, p. 214.

2. ábra: A Borsuk riolit kőzettest (riolit vulkán) DNY oldaláról nyíló kilátás Szőlőske (Viničky) határában, a perlit és obszidián előfordulási helyekkel, a Tokaj Viničky Ltd. (PROMACO AS) 1,2,3 borospincékkel, DK felől. P. Bačo felvétele. Bačo et al. (2017), Fig. 7, p. 214. nyomán.

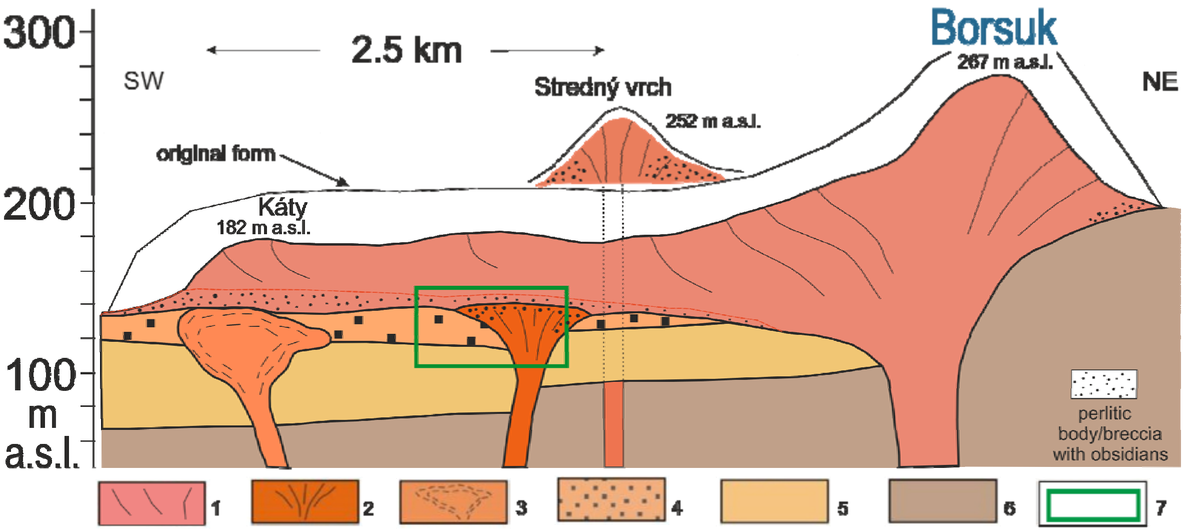

Fig. 3.: Structural cross section of the Viničky rhyolite volcanoes. (modified after Lexa et al. (2014); Fig. 1B, p. 237). 1-Late rhyolite dome and couleé (dome flow), 2-Early rhyolite extrusive dome, 3-Dacite/rhyodacite cryptodome, 4-Coarse proximal facies dacite/rhyodacite phreatic/phreatomagmatic pyroclastic rocks, 5-Distal facies rhyolite tuffs and pumice tuffs, 6-Permian and Triassic basement rocks, 7-Area well documented in walls of the wine-cellar

3. ábra: A szőlőskei (Viničky) riolit vulkánok szerkezeti metszete (Lexa et al. (2014); Fig. 1B, p. 237 nyomán, módosítva). 1 – késői riolit kőzettest és láva, 2 – korai riolit extruzív kőzettest, 3 – dácit / riodácit kőzettest, 4 – durva proximális fáciesű dácit / riodácit freatikus / freato magmatikus piroklasztikus kőzet, 5 – távoli fácieshez tartozó riolit tufák és horzsaköves tufák, 6 – perm és triász korú alapkőzet, 7 – a borpince falában jól dokumentált terület

Fig. 4a, b, c.: Locality Viničky, obsidian nodules showing a progressive evolution of their surface as a function of their position (compare the fig. 6): a – obsidian nodule from the weathered top of perlitized intrusion; b – obsidian nodule from eluvial deposits; c – obsidian nodule with initial surface sculpturing from eluvial/deluvial deposits. Photo by P. Bačo.

4a, b, c. ábra: Szőlőske (Viničky) lelőhely, obszidián gumók felszíne a környezet hatásainak függvényében (v.ö., 6. ábra): a – obszidián gumó a perlitesedett intrúzió felső, mállott részéből; b – obszidián gumó eluviális környezetből; c – obszidián gumó a felszín barázdálódásának kezdeti szakaszából, eluviális / deluviális környezetből. P. Bačo felvétele.

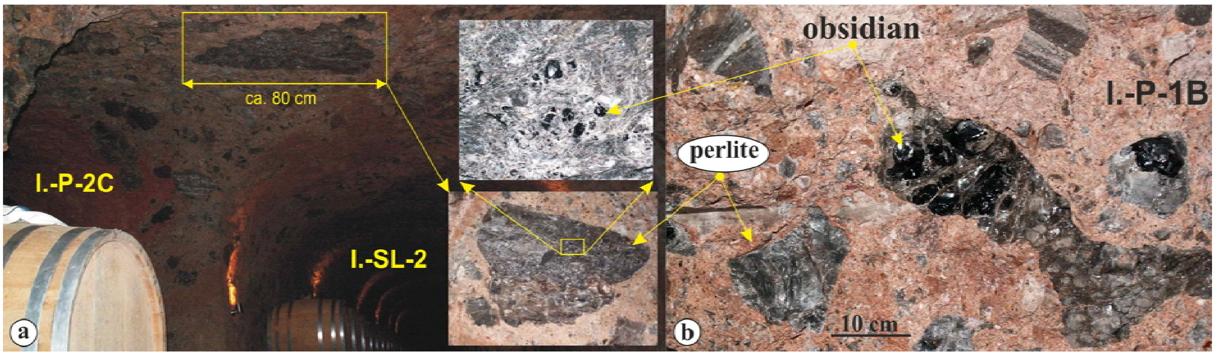

Fig. 5a, b,. Locality Viničky, Tokaj Viničky ltd. winecellars: a, b – autochtonous occurrence of obsidian nodules in perlitic breccias at the base of the Borsuk dome/flow. Photo by P. Bačo.

5a, b. ábra: Szőlőske (Viničky), Tokaj Viničky Ltd. borpincéje lelőhely: a, b – obszidián gumók autochton előfordulása perlit-breccsában a Borsuk kőzettest / lávaár találkozásánál. P. Bačo felvétele.

Intrusions with perlite and obsidian are covered by a thin veneer of eluvial deposits. Gradual weathering of perlite frees enclosed obsidian cores into these eluvial/deluvial deposits. Size of individual obsidian pieces varies in the range 2 mm – 14 cm, with the average size 3 – 5 cm. Not often, however, more frequently as generally assumed, there are present cores 10 cm or more in diameter. Form of obsidian pieces is irregular. Their surface is mostly smooth, patinated, sometimes with rare remnants of perlite. Sculpture of the type, as it is known from the surface of obsidians at archeological sites, is absent (has not been observed). Apparently, the residence time of obsidians in eluvial/deluvial deposits is too short to develop full scale sculpturing. Obsidian in the figure 4a from the top of weathered perlite shows the same type of surface attributes as obsidian cores in fresh perlite. Obsidian nodule in the figure 4b from a higher position shows patinated surface with a minimal rounding of edges and planes that are characteristic of bigger obsidians in perlite. Obsidian nodule in the figure **4c** from the highest position in the section (and the longest expected residence time) shows an initial stage of sculpturing in the form of roughness and small pits.

The second type of setting is represented by perlitic breccias at the base of the Borsuk dome/flow. This type of setting applies also to the locality Malá Bara (**Fig. 1, 2**). Most of the obsidian cores observed in the Tokaj Viničky Ltd. (PROMACO SA) wine cellars occurs in perlitic breccias (**Fig. 5a, b**) that represent base of a thick and extensive rhyolite lava flow with a source at the extrusive dome of Borsuk hill NE of the village Viničky (Bačo e*t al.* 2012). Perlitic breccias are formed of angular blocks of dark to pale perlites up to 3 m in diameter, often with pronounced flow banding, in pinkish matrix of grounded perlitic material. Rarely they include fragments of underlying pyroclastic rocks. In these breccias obsidian occurs as fragments up to 10 – 15 cm in diameter, much smaller on the average.

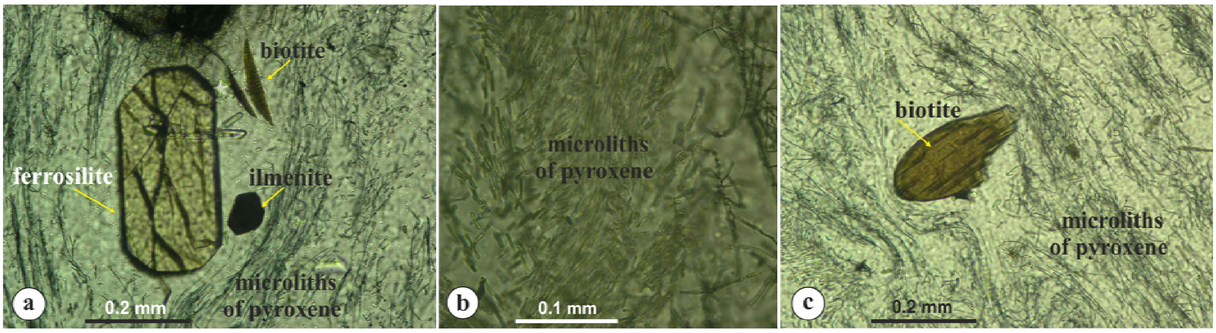

Fig. 6a, b, c.: Locality Viničky: microphotographs of obsidian thin-section (transmitted light, one nicol). Photo by P. Bačo.

6a, b, c. ábra: Szőlőske (Viničky) lelőhely: obszidián vékonycsiszolata (áteső fényben, 1 Nikol). P. Bačo felvétele.

Planes of obsidian fragments are variably convex or concave, smooth and glossy. At freshly broken surface they are black or pitch black with a pronounced conchoidal fracture.

Using a microscope one can observe in obsidian rare microphenocrysts of biotite, plagioclase, rare Fe-orthopyroxene (ferosilite) and ilmenite (**Fig. 6a, c**). Frequently observed banded texture or alternation of dark and pale streaks is caused by flow oriented minute crystals – microlites and trichytes (**Fig. 6b**), mostly of pyroxene composition. This internal fabric of obsidian glass is a probable cause of sculpturing if the glass is exposed to weathering.

Lithological setting of the allochthonous obsidian occurrences

Rare and generally small cores of obsidian enclosed in perlite fragments (marekanites) of breccias at the base of the same rhyolite lava flow occur also on its northern side, south of the village Malá Bara. However, in this case the small size of obsidian cores prevented its utilization for a production of obsidian industry.

Perlite with cores of obsidian, known also under the name "marekanite" (**Fig. 7a, b**) occurs in an abandoned quarry north of the city Streda nad Bodrogom. Fragments of perlite with obsidian as well as obsidian alone are a part of reworked rhyolite/rhyodacite tuffs, epiclastic volcanic sandstones and gravels and epiclastic volcanic breccias laid down as a submarine landslide. So the perlite and obsidian fragments are not at the place of their origin. Size of obsidian cores varies in the range 0.5 – 5 cm with the average size around 2.5 cm. Obsidian cores at this locality show many attributes that are characteristic of obsidians at the locality Viničky, as there are occurrence in the form of cores in perlite, color, luster and conchoidal fracture. The Viničky locality was generally accepted as probable source. However, results of K/Ar dating point to a different age and yet unknow primary source (Bačo et al., 2017).

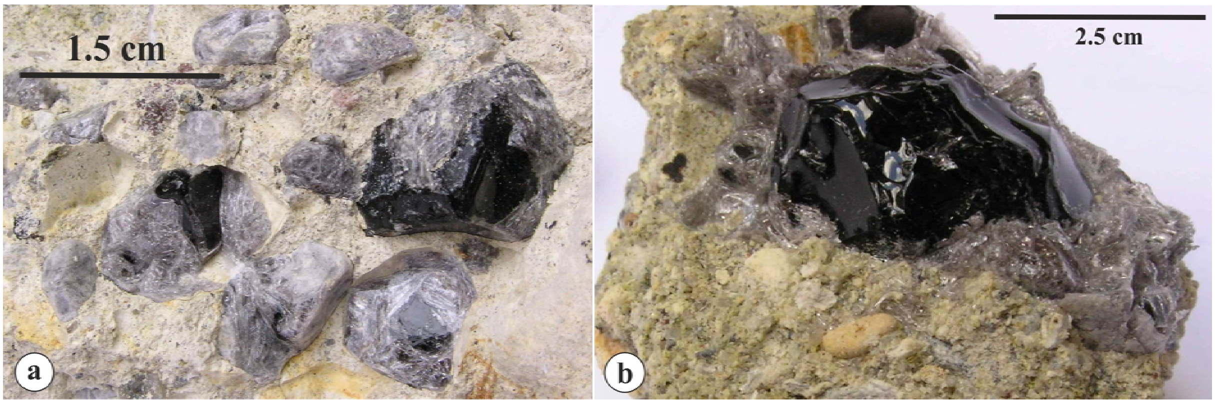

Fig. 7a,b.: Locality Streda nad Bodrogom, abandoned quarry: a, b – obsidian in perlite shell (marekanite) occurring as fragments in reworked polimict rhyolite volcanoclastic rocks. Photo by P. Bačo.

7a, b ábra: Bodrogszerdahely (Streda nad Bodrogom), felhagyott bánya: a, b – perlitben előforduló obszidián szemek (marekanit) törmelékként az áthalmozott polimikt rioltos vulkanoklaszt kőzetben. P. Bačo felvétele.

HU ISSN 1786-271X; urn: nbn: hu-4106 © by the author(s)

Fig. 8a,b.: Locality Cejkov – Malé lúky-Žihľavník: a – finding position of obsidian nodule; b – surface sculpturing reflecting its fluidal texture. Dimensions: 5.1 x 4.6 x 4.0 cm. Photo by P. Bačo.

8a, b ábra: Céke (Cejkov) – Malé lúky-Žihľavník lelőhely: a – obszidián gumó lelőkörülmények; b – felszíni barázdáltság a fluidális szövet nyomaival. Méretek: 5.1 x 4.6 x 4.0 cm. P. Bačo felvétele.

Fig. 9.: Locality Brehov – Za alejou: isometric, moderately sculptured obsidian nodules. Mass/dimensions: 128 g / 3.9 x 5.2 x 5.4 cm; 68 g / 3.3 x 3.9 x 4.0 cm; 76 g / 3.9 x 4.3 x 4.6 cm . Photo by P. Bačo.

9. ábra: Imreg (Brehov) – Za alejou lelőhely: izometrikus, kevéssé barázdált felszínű obszidián gumók. Tömeg / méretek: 128 g / 3.9 x 5.2 x 5.4 cm; 68 g / 3.3 x 3.9 x 4.0 cm; 76 g / 3.9 x 4.3 x 4.6 cm . P. Bačo felvétele.

Obsidian at secondary natural occurrences

The area with obsidian fragments and nodules at secondary naturally position extends SW of the village Brehov, nowadays in cadaster of the village Cejkov. Š. Janšák (1935) recognized the locality „as one of the richest finding places in Eastern Slovakia“. Raw, unworked obsidian occurs as grains/nodules of variable size from tiny gains 0.5 – 1 mm in diameter to nodules 8 cm in diameter, rarely with mass over 1 kg. Their surface shows a variety of sculpturing (**Fig. 8.**), often identical with remnants of sculpturing on worked obsidian nodules at archeological localities. That lead A. Přichystal & P. Škrdla (2014), who have studied this locality in a great detail, to consider this locality as a possible principal source of obsidian for the obsidian industry at the Palaeolithic/Neolithic archeological sites of Central Europe (C1a subgroup of Biró & Kasztovszky (2013) and Kasztovszky et al. (2014).

Obsidians in Quaternary deposits northwest of the village Brehov – area „Za alejou“ represents a second concentrated occurrence of obsidian in surroundings of Brehov. It was discovered during exploration for base metal ores (Bacsó et al. 1995) that included trenching. In this case obsidian fragments and nodules (**Fig. 9.**) occur in loamy weathered and argillized

rhyodacites and their breccias. These are covered by eolian sands in thickness up to 2 m. Size of obsidian fragments and nodules varies in the range 5 mm to 10 cm, around 5 cm on the average. Their surface shows usually sculpturing. Obsidians with less developed sculpturing (**Fig. 9**., middle piece) are present too. Form of obsidian fragments and nodules is irregular, dominantly isometric (**Fig. 9.**). Sculpturing is less pronounced than on obsidians at archeological sites. Important there is an absence of flakes in the horizon with obsidian, though at the surface they are present. Areal extend of the occurrence is several hectares and we can't exclude other ones in close surroundings. Obsidian in the form of sculptured fragments/nodules is quite frequent, often of relatively large size. Brehov is the locality with the largest fragments/nodules of sculptured obsidians. Geological setting, amount and size distribution of obsidian fragments/nodules at the Brehov locality points to an analogical (not similar) allochthonous occurrence as in the case of the Cejkov locality.

Discussion

Surroundings of Viničky, respectively southern slopes of the hills Borsuk and Katy, is the most important autochthonous occurrence of obsidian in the Zemplinske vrchy Mts. area.

Based on observations in the Tokaj Viničky Ltd. wine cellars obsidian nodules occur in two

geological/lithological settings. Those related to perlite breccias at the base of the rhyolite lava flow could be more widespread. Their possible exposures are nowadays obscured by vineyards.

The problem, whether the Viničky locality was or could be a sole source of obsidian in the Zemplinske vrchy Mts. area for obsidian industry at archaeological sites remains open (Bačo et al. 2003, Přichystal 2009, Bačo et al., 2017).

However, owing to a short residence time of obsidian nodules in eluvial/delluvial deposits above the primary source there was not enough time to develop sculpturing that is characteristic for majority of obsidian raw material pieces with the Zemplinske vrchy Mts. provenance at archaeological sites. Sculpturing originated in the secondary environment where obsidian is exposed to long lasting weathering. In Viničky we can't exclude entirely a possibility of repeated reworking of the weathered out obsidian nodules during the Late Sarmatian and Pannonian time and in that case also evolution of sculpturing. These deposits have not been observed. Also, reworking could not bring obsidians to the area of Cejkov and Brehov where the two most extensive secondary occurrences of obsidian are present (Janšák 1935, Bacso et al. 1995a, b, Bačo et al. 2003, Přichystal & Škrdla 2014). Primary source of obsidians at both allochthonous localities remains unknown.

Conclusions

Careful description of primary and secondary natural occurrences of volcanic glasses allows for following conclusions:

There are two primary sources of obsidian nodules at the Viničky locality related to two phases of rhyolite volcanic activity. Perlitic breccias with obsidian nodules at the base of the Borsuk dome/flow represent the older source. Perlitized margins of small intrusions with obsidian nodules represent the younger source. Absence or rudimentary development of sculpturing on the surface of obsidian nodules is characteristic for both sources.

Allochthonous obsidians and associated perlite (marekanites) at the locality Streda nad Bodrogom are older than obsidians and perlites at other natural and archeological localities. They do not have equivalents among obsidians at archeological sites and we do not know their source.

There are two known allochthonous occurrences of obsidian nodules in Quaternary deposits around Cejkov and Brehov: Cejkov – Malé lúky-Žihľavník and Brehov – Za alejou. Theirs, at the moment hypothetical, primary source was in the Brehov area.

Evolution of rhyolite volcanic activity in the region of Zemplín Hills is more complex as previously assumed. Owing to changing paleogeography it could create secondary obsidian accumulations in an unexpected way. We can't exclude surprise findings in future, including new, yet unknown sources of volcanic glasses.

References

BACSÓ Z., KALIČIAKOVÁ E., KOŠARKOVÁ M., SELIGA J., KOMOŇ J., STAŇA Š., ZEMAN I., VELICH R., ZLINSKÁ A., (1995a): Subvulkanické telesá východného Slovenska, polymetalické, drahokovové, vzácnokovové a ortuťové rudy. [Sub-volcanic bodies of Eastern Slovakia, polymetallic, precious and mercury ores. Open file report, in Slovak] Záverečná správa. Geologický ústav Dionýza Štúra. Bratislava. 239s.

BACSÓ, Z., MALACHOVSKÝ, P., HRINKOS. V., REPČIAK M., KALIČIAKOVÁ E., KOŠARKOVÁ M., SELIGA J., KOMOŇ J., STAŇA Š. & ZLINSKÁ A. (1995b): Brehov – západ. [Brehov - west - polymetalic ores, a search survey as of 15.4.1995. Open file report, in Slovak] Záverečná správa. Geologický ústav Dionýza Štúra. Bratislava. 206s.

BAČO, P., BAČOVÁ, Z., KONEČNÝ, P. & KONEČNÝ, V. (2012): Extruzívne teleso ryolitu Borsuk pri Viničkách, Banské diela. [Rhyolite extrusive body Borsuk close to village Viničky, mining works. Open file report, in Slovak] *Čiastková záverečná práca,* Geofond, ŠGÚDŠ, Bratislava, 1–82.

BAČO, P., KAMINSKÁ, Ľ., LEXA, J., PÉCSKAY, Z., BAČOVÁ, Z. & KONEČNÝ, V. (2017): Occurrences of Neogene Volcanic Glass in the Eastern Slovakia – Raw Material source for the Stone Industry. *Anthropologie* **LV/1-2** 207–230.

BAŇACKÝ, V., ELEČKO, M., KALIČIAK, M., STRAKA, P., ŠKVARKA, L., ŠUCHA, P., VASS, D., VOZÁROVÁ, A. & VOZÁR, J. (1989): *Vysvetlivky ku geologickej mape južnej časti Východoslovenskej nížiny a Zemplínskych vrchov* 1:50 000. Vydavateľstvo GÚDŠ, Bratislava, 143s.

BIRÓ, K. T. & KASZTOVSZKY, Zs. (2013): Obsidian Studies Using Nuclear Techniques in Hungary. *Science for Heritage. Newslette*r No.**1** December. Zagreb 2013: 6–9.

JANŠÁK Š. (1935): *Praveké sídlisk*á *s obsidiánovou industriou na východnom Slovensku.* [Prehistoric settlements with obsidian industry in Eastern Slovakia, in Slovak] Bratislava 1935. Jan Pociska et al., Bratislava, 330s.

KASZTOVSZKY. Zs., BIRÓ, K. T. & KIS Z. (2014): Prompt Gamma Activation Analysis of the Nyírlugos obsidian core depot find. *Journal of Lithic Studies* **1/1** 151–163.

KOHÚT, M., MIKUŠ, T., MILOVSKÁ, S., ŠURKA, J., KONEČNÝ, P., HOLICKÝ, I., KOLLÁROVÁ, V., JESENÁK, K., DRÁBIK, M. & BAČO, P. (2017): Geochémia obsidiánov Východného Slovenska - časť 2.: Odlišnosti v zložení skla a horniny, [Geochemistry of the obsidians from the Eastern Slovakia - Part 2: Differences in composition of glass and rock, in Slovak] *Konferencia Geochémia* ŠGÚDŠ 79–82.

KONEČNÝ, P., BAČO, P. & KONEČNÝ, V. (2010): Acid Miocene volcanism in the Eastern Slovakia, variable sources and magma forming processes: constraints from petrology and geochemistry. In CHATZIPEROS, A. et al. (eds.), XIX CBGA congress abstract volume, *Geologica Balcanica* **39** 199–200.

LEXA, J. & KALIČIAK, M. (2000): Geotectonic aspects of the Neogene volcanism in Eastern Slovakia, *Mineralia Slovaca* **32/3** 205–210.

LEXA, J., SEGHEDI, I., NÉMETH, K., SZAKÁCS, A., KONEČNÝ, V., PÉCSKAY, Z., FÜLÖP, A. & KOVACS, M. (2010): Neogene-Quaternary Volcanic forms in the Carpathian-Pannonian Region: a review. Central European *Journal of Geosciences* **2** 207–270.

PÉCSKAY, Z., LEXA, J., SZAKÁCS, A., SEGHEDI, I., BALOGH, K., KONEČNÝ, V., ZELENKA, T., KOVACS, M., PÓKA, T., FÜLÖP, A., MÁRTON, E., PANAIOTU, C. & CVETKOVIC, V. (2006): Geochronology of Neogene magmatism in the Carpathian arc and intra-Carpathian area. *Geol. Carpathica* **57/6** 511–530.

PŘICHYSTAL, A. & ŠKRDLA, P. (2014): Kde ležel hlavní zdroj obsidiánu v pravěku střední Evropy?, (Where was situated the principal source of obsidian in prehistory of Central Europe?) *Slovenská archeológia* **62** 215–226.

SEGHEDI, I. & DOWNES, H. (2011): Geochemistry and tectonic development of Cenozoic magmatism in the Carpathian-Pannonian region. *Gondwana Research* **20** 655–672.

ŠALÁT, J. & ONČÁKOVÁ P. (1964): *Perlity, ich výskyt, petrochémia a praktické využitie.* GÚ SAV, Bratislava. 147s.

HU ISSN 1786-271X; urn: nbn: hu-4106 © by the author(s)