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Focus on the lithics: raw materials and their utilisation during the Stone Age in Central Europe

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OCCURRENCES OF NEOGENE VOLCANIC GLASS IN THE EASTERN SLOVAKIA – RAW MATERIAL SOURCE FOR THE STONE INDUSTRY

ABSTRACT: In Eastern Slovakia obsidians were used most extensively during the Late Palaeolithic and Neolithic. Natural occurrences of obsidian are linked with products of rhyolite/rhyodacite volcanism, where they associate with perlite. Viničky, Malá Bara and Brehov are the known natural occurrences. Considering the present state of knowledge, the Brehov locality is a primary source of secondary obsidian accumulations in Quaternary deluvial/fluvial deposits, partially covered by eolian sands, in the area of Brehov and Cejkov. Some of the macroscopic attributes, especially surface sculpture, of the obsidian cores from archeological sites resemble more those from the secondary accumulations. Conventional K/Ar dating of obsidians from natural occurrences and archeological sites implies multiple ages of natural sources. However, dating of obsidians at archeological sites points rather to a single source, or yet unknown source in addition to the secondary accumulations. Obsidians from at least two phases of rhyolite volcanic activity have been utilized for production of obsidian industry. Obsidians from the secondary accumulations in the area of Brehov and Cejkov apparently dominate at archeological sites and probably are equivalent to the subgroup C1a of the Carpathian obsidians.

KEY WORDS: Eastern Slovakia – Miocene rhyolites – Sources of obsidian – Isotope dating – Utilization of obsidian

INTRODUCTION

Obsidian was one of the most important raw material of superior quality for a production of stone tools in prehistory of Central Europe, including Slovakia (Biró 2006, Kaminská 1991). It incited attention of archeologists and provoked a search of its sources at least since the works of M. Roska (1934) and Š. Janšák (1935). Naturally, archeologists alone were not able to recognize natural occurrences of obsidian. This has changed when archeologists started to cooperate with geologists who knew natural and man-made outcrops with obsidian in Tokaj Mountain range and the southern part of Zemplínske vrchy Mts. (Williams-

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Thorpe *et al.* 1984, Kaminská, Ďuďa 1985). However, among glassy rhyolitic rocks in Eastern Slovakia, obsidian was not the main object of geologist's interest. Their studies concentrated especially on resources of perlite, pumice and tuffs as industrial minerals (Šalát, Ončáková 1964, Ivan 1962, 1964, Grecula, Együd 1981). Obsidian was later recognized as suitable material for a production of jewellery and ornaments (Ďuďa *a kol.* 1985). It was obvious from older geological works that the main occurrences of obsidian are those in Zemplínske vrchy Mts. and further southward in the Tokaj Mountain range. Geochemical analyses (18 elements, including REE, determined by INAA) of obsidians from natural outcrops as well as cores and artifacts at archeological sites demonstrated differences in trace element and REE contents among obsidians from localities in Zemplínske vrchy Mts. of Eastern Slovakia (Cejkov, Viničky, Streda nad Bodrogom), designated as the Carpathian 1 group (C1) and those from the Tokaj Mountain range of Northeastern Hungary (surroundings of Mád – Erdőbénye – Olaszliszka and Tolcsva – Erdőbénye-Abaujszántó), designated as the Carpathian 2 group with subgroups 2a and 2b (Williams-Thorpe *et al.* 1984). From 279 analyzed cores and artifacts 242 was assigned to the group C1 with Viničky as a probable natural source. Such the conclusion was supported by the work of Ľ. Kaminská and R. Ďuďa (1985) as well as by geological mapping for the published regional geological map in the scale 1 : 50 000 (Baňacký *et al.* 1989). Ever since, several series of analytical studies by different methods (OES, NAA, EDS, XRF, FTD, PIXE-PIGE and most recently, PGAA) confirmed that grouping and probable natural sources (Biró 2006). The first doubts about a single source of the C1 obsidians at the Viničky occurrence were brought by results of their fission track (FT) dating. While obsidian from the Viničky natural occurrence provided the age 11.1±0.5 million years (Repčok 1977), obsidian from the archeological site Hraň provided the age 14.2±0.5 million years (Repčok *et al.* 1988). FT dating of obsidians from natural outcrops and archeological sites in NE Hungary and Eastern Slovakia by G. Bigazzi *et al.* (1990) shows also two age groups of obsidians that cluster around 10 million years (Tokaj area) and 15 million years (Zemplínske vrchy Mts. and majority of artifacts from the Tokaj area), however, results do not differentiate clearly among localities in the Zemplínske vrchy Mts. area. Later a layer of reworked loamy clays with obsidian cores covered by eolian sands was discovered close to the village Brehov during technical works related to ore deposit exploration. One of the boreholes crossed glassy rhyolite and rhyolite volcanic glass underneath an andesite extrusive body (Bacsó *et al*. 1995a). These finds and a frequent surficial sculpture on obsidian artifacts lead Bačo *et al.* (2003) to conclude that the Brehov natural occurrence is another possible source of obsidian for artifacts at archeological sites beside already known Viničky locality. Based on results of the latest instrumental geochemical analyses T. Biró and Z. Kasztovszky (2013) and Z. Kasztovszky *et al.* (2014) divided the group C1 obsidians into the subgroup C1a represented by the Kašov and Cejkov workshops with yet unknown natural source and the less frequent subgroup C1b with natural source at the Viničky locality. Using results of older works (Janšák 1935, Bačo *et al.* 2003, Bačo, Bačová 2014) as well as own field work A. Přichystal and P. Škrdla (2014) came to a conclusion that secondary occurrences of obsidian in deluvial/fluvial deposits along the river Ošva among villages Brehov, Cejkov and Zemplín were the main source of obsidian for the archeological sites. Based on the work of Bacsó e*t al.* (1995a); Bačo and Bačová (2014) they considered the Brehov area also as a probable primary source of obsidian in secondary deposits.

Utilization of obsidian by Palaeolithic to Neolithic cultures in the territory of Slovakia

Obsidian artifacts with primary natural source in the Zemplínske vrchy Mts. of Eastern Slovakia have been found over most of the Central Europe (Biró 2006, Dobosi 2011, Kaminská *et al.* 2014). With increasing distance the proportion of obsidian artifacts generally decreases at the expense of local rocks of lesser quality. Extent of obsidian utilization by individual cultures of Paleolithic to Neolithic was variable. In the territory of Slovakia obsidian was not utilized until beginning of Upper Palaeolithic. In the Aurignacian culture of the Upper Palaeolithic its use was marginal. Obsidian occurrence was recorded at the archeological sites Košice-Barca I, Košice-Barca II, Kechnec I (Bánesz 1968) and Čečejovce (Kaminská 1990). Limnosilicite (fresh-water chert) was a dominant raw material of the Aurignacian in the Košice basin area (Kaminská 1991). A larger proportion of obsidian artifacts (19%) was present only at the site Tibava (Bánesz 1960), however, at this case the obsidian was of the Hungarian provenance (group 2a, Williams-Thorpe *et al.* 1984: 195). A more extensive utilization of obsidian came with the Gravettian and

Epigravettian cultures, especially in surroundings of the Zemplínske vrchy Mts. in Eastern Slovakia. Sporadic obsidian occurrences are known also from the late Gravettian in Western Slovakia – archeological sites Trenčianske Bohuslavice (Bárta 1988) and Nitra I – Čermáň (Kaminská, Kozłowski 2011) and Epigravettian at the sites Nitra III (Bárta 1980a, Kaminská, Nemergut 2014) and in the surroundings of the river Ipeľ (Bárta, Petrovský-Šichman 1962). Obsidian artifacts occur also in the Świderian sites in the Spiš area of Northern Slovakia – e.g. Veľký Slavkov (Bárta 1980b) and Lučivná/Svit (Soják 2002).

They dominated at other late Palaeolithic to Mesolithic sites in the Spiš area (Bánesz 1962, Kaminská, Javorský 1996, Soják 2002, Valde-Nowak, Soják 2009). Obsidian was present also in finds of the late Palaeolithic industry in the Orava region (Bárta 1984) and at the site Soľ in Eastern Slovakia (Šiška 1991a). Mesolithic industry from the Košice-Barca I site was completely produced from obsidian (Prošek 1959), while obsidian dominated at the site Čičarovce in the Eastern Slovakia lowland (Kaminská *et al.* 2014: 319) and its sporadic occurrence was recorded also in the Medvedia cave close to the village Ružín (Bárta 1990).

With entry of the Neolithe the proportion of obsidian among industry at archeological sites also varied. During the early stage of the Eastern Linear Pottery culture at the Moravany site in Eastern Slovakia lowland obsidian represents almost 90 % of the industry. In this case obsidian was imported in the form of unworked nodules with surface sculpture as it occurs at secondary natural sources (group 2, Tokaj Mountain range in NE Hungary) in the distance 30 – 40 km (Kaczanowska *et al.* 2015: 172). Almost 100 % utilization of obsidian was registered at other sites with the early stage of the Eastern Linear Pottery culture in the Eastern Slovakia lowland – Zbudza, Zalužice, Zemplínske Kopčany and Slavkovce (Kozłowski 1989, Kaczanowska, Kozłowski 1997: 220–221, Šiška 1989). In the proto-linear phase at the site Košice-Červený rak utilization of obsidian was subordinate to limnosilicite. The same applies to other sites in the Košice basin, e.g. Čečejovce, where obsidian represented only one third of raw material (Kaminská *et al.* 2008: 90, Tab. 1). In the following group Tiszadob utilization of obsidian increased and represented almost a half of finds (Kaminská *et al.* 2016). A complete prevalence of obsidian industry is characteristic for the following Bükk culture of Middle Neolithic. Apparently, obsidian became also a subject of trade. It occurs in the Želiezovce group in Western Slovakia and in Southern Poland (Šiška 1998). Obsidian started to expand to Western and Central Slovakia already during the younger stage of the Linear Pottery culture (along with pieces of Tiszadob ceramics) and its expansion multiplied during the Bükk culture time. According to Šiška (1995) it mirrors a reality that bearers of the Bükk culture moved westward and northward on the verge of the Middle and Late Neolithic, perhaps owing to a change in climatic conditions. Even higher demand for obsidian was recorded during Late Neolithic (following a fall of the Bükk culture), during beginning of the Lengyel culture, when thanks to a chain exchange of raw material, semiproducts and finished products obsidian has reached the central Danubian region (Šiška 1998: 77). On the verge of Neolithic and during the Eneolithic time obsidian lost its dominant status. Sporadically it occurs still during the Bronze Age.

Utilization of obsidian by Palaeolithic to Neolithic cultures in the Zemplínske vrchy Mts. region

In the Zemplínske vrchy Mts. region, with natural sources of obsidian, its utilization by Palaeolithic to Neolithic cultures was the most extensive. At the archeological site Cejkov I limnosilicite artifacts of a probable Hungarian provenance dominate over sporadic obsidian artifacts (Kaminská, Tomášková 2004). An increasing proportion of obsidian artifacts was recorded on archeological sites of the Late Gravettian – Cejkov II (Bánesz 1959: 770) Cejkov I (Kaminská, Tomášková 2004: tab. 1), Kašove – lower horizon (Bánesz 1969, Novák 2002).

However, obsidian artifacts dominate completely at archeological sites of the Epigravettian that include majority of sites in surroundings of Zemplínske vrchy Mts., among them Cejkov (Bánesz 1993), Kašov – upper horizon (Bánesz 1969), Hrčeľ-Pivničky, Veľaty (Kaminská 1986, 1995), Kysta (Bánesz 1980: 34) and Zemplínske Jastrabie (Bánesz 1976: 241–243).

The mentioned sites rim Zemplínske vrchy Mts. at the northern and northeastern sides and closer to the sources in surroundings of Brehov and Cejkov. In older collections there are recorded also finds from the villages Zemplín and Malá Tŕňa (Andel 1955: 146). An absence of other sites at the western side of Zemplínske vrchy Mts. is probably only a result of insufficient field activities as it is demonstrated by recent finds in surroundings of villages Veľká Tŕňa and Čerhov. More favorable there is situation in the Middle Neolithic time when archeological sites of the younger Eastern Linear

Pottery culture and Bükk Culture appear, usually repeatedly, in surroundings of many villages. Malá Tŕňa and Veľká Tŕňa are the sites with numerous obsidian artifacts as mentioned by Š. Janšák (1935: 67–69) and confirmed later by sporadic surveys at several places around the villages (Kaminská, Cheben 1983, Chovanec 1999, 2005, Polla 1996). Southward they extend into the cadaster of the village Černochov with Neolithic finds including obsidian industry (Janšák 1935: 69–70). As far as density of Neolithic settlements is concerned, analogous situation is in surroundings of Malá Bara and Veľká Bara (Janšák 1935: 67–69, Čaplovič *et al.* 1977, Gašaj *et al.* 1980), Viničky (Janšák 1935: 70, Chovanec 1999), Zemplín (Janšák 1935: 57, Andel 1955: 146, Horváthová, Miroššayová 2002) and Streda nad Bodrogom (Janšák 1935: 75, Polla 1964, Šiška 1979, 1989). Similar situation is at the northeastern side of Zemplínske vrchy Mts. Here archeological sites rich in obsidian industry are in surroundings of the villages Zemplínske Jastrabie, Hraň, Novosad, Kysta and Hrčeľ (Kaminská 1987; Chovanec 2004). A rarity represents a partially explored locality of the Bükk Culture in Kašov, the site Čepegov I, where a workshop with obsidian cores has been found (Bánesz 1991; Šiška 1991b). Thirteen preserved cores are of the pyramidal form with a flat percussion plane. Raw obsidian nodules were quite large as one of the pyramidal cores shows dimnensions 148 × 59 × 50 mm and flakes are 10–12 cm long. Suchlike Neolitihic pyramidal cores (*Figure 1*), flakes and unworked obsidian nodules showing sculpturing (*Figure 2a, b*) are at the Hraň archeological site (Janšák 1935, Bačo, Bačová in Kobulský *et al.* 2014). All the obsidian nodules are bigger than 5 cm. Their sculpturing and its variability (*Figure 2a, b, 3a, b*) are identical with obsidian nodules at natural allochtonous

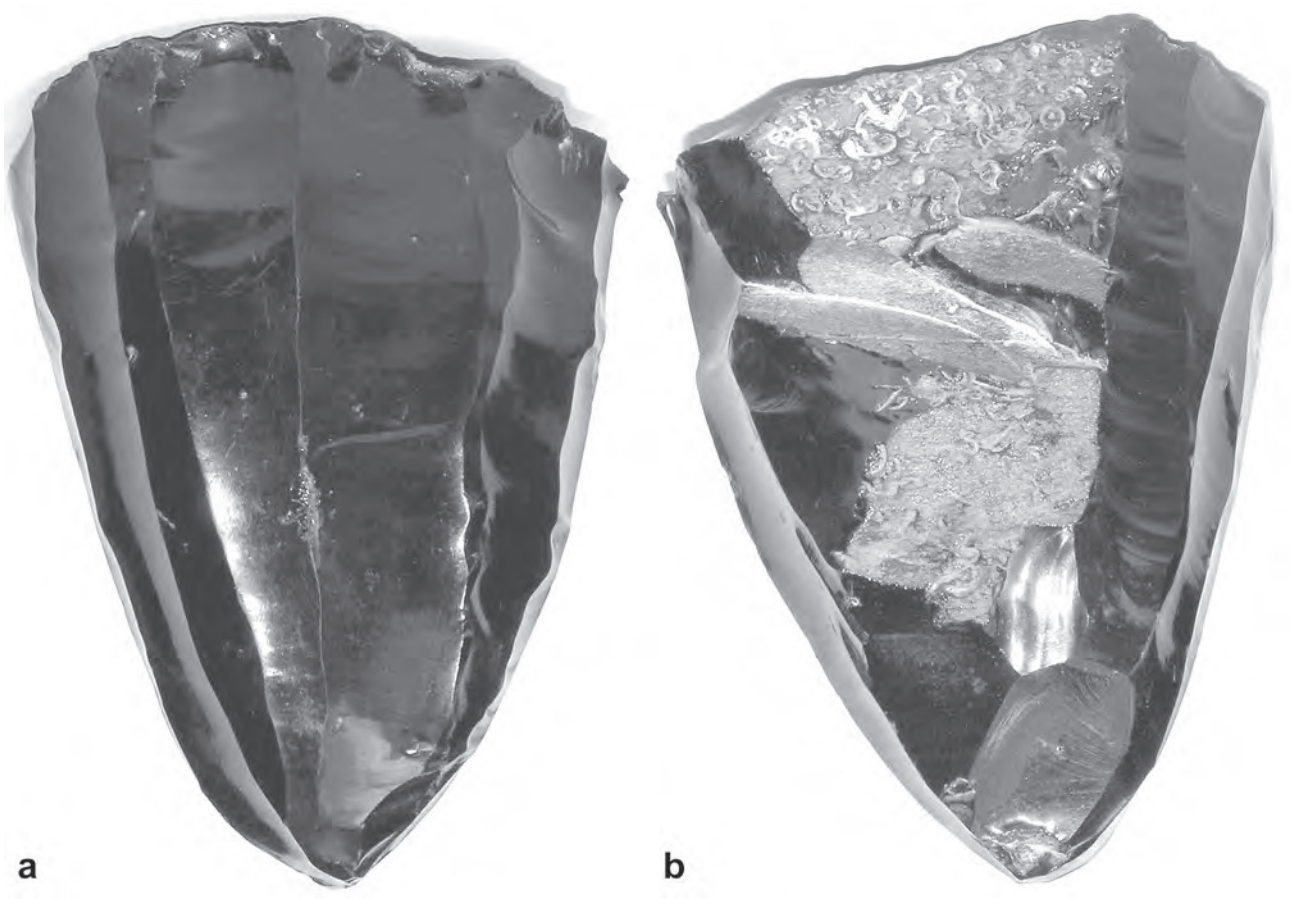

FIGURE 1. Locality Hraň – Feljarő: a pyramidal obsidian core of the Neolithic Bükk culture. Mass: 836 g, hight: 117 mm, width: 96 mm. Photo by P. Bačo.

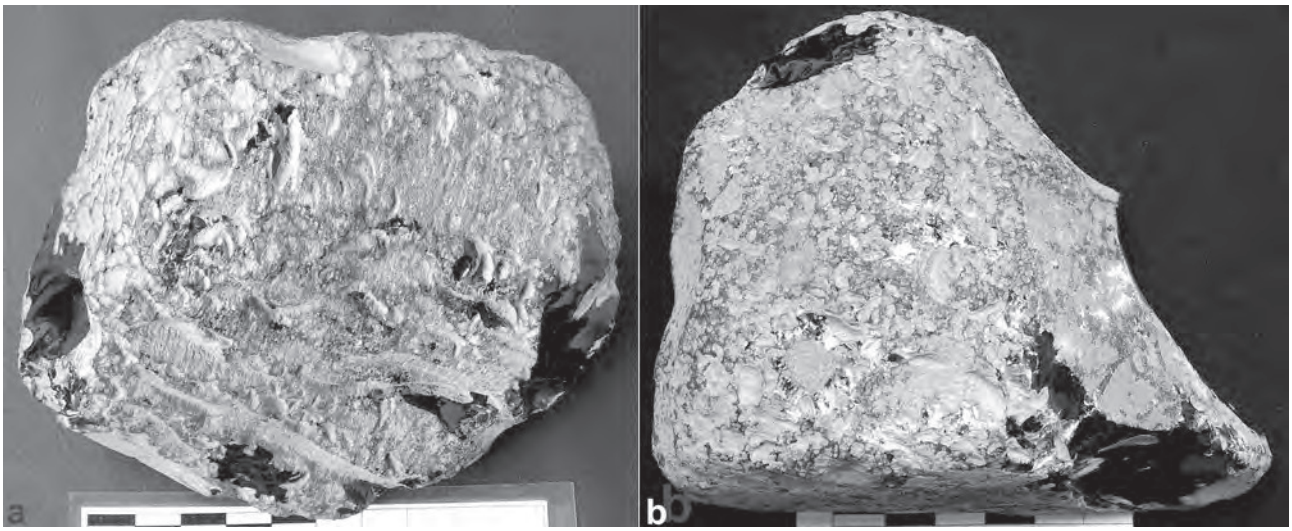

FIGURE 2. Locality Hraň – Feljarő: obsidian nodules. Mass/dimensions: a – 1,105 g / 12.6 × 10.5 × 8.1 cm; b – 735 g / 12.1 × 9.6 × 6.9 cm. Photo by P. Bačo.

occurrences and other archeological sites. Obsidian nodules with smooth surface have not been found.

Main sources of obsidian and its origin

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). Products of the silicic volcanism occur as tuffs and pumice tuffs, reworked epiclastic volcanic rocks, rare intrusions

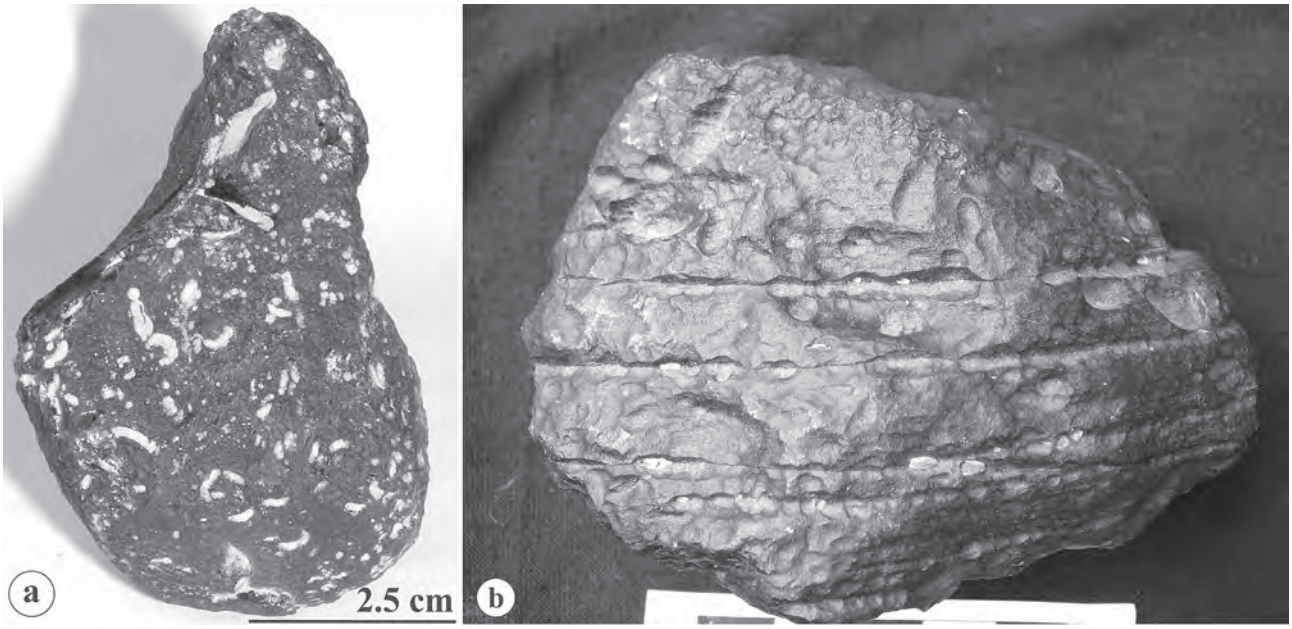

FIGURE 3. Locality Hraň – Feljarő: obsidian nodules with two essential types of surface sculpturing that reflects internal fabric. Parallel sculpturing (b) mirrors fluidal texture of obsidian. Mass/dimensions: a – 170 g / 5.7 × 4.3 × 7.7 cm; b – 310 g / 9.1 × 8.3 × 5.3 cm. Photo by P. Bačo.

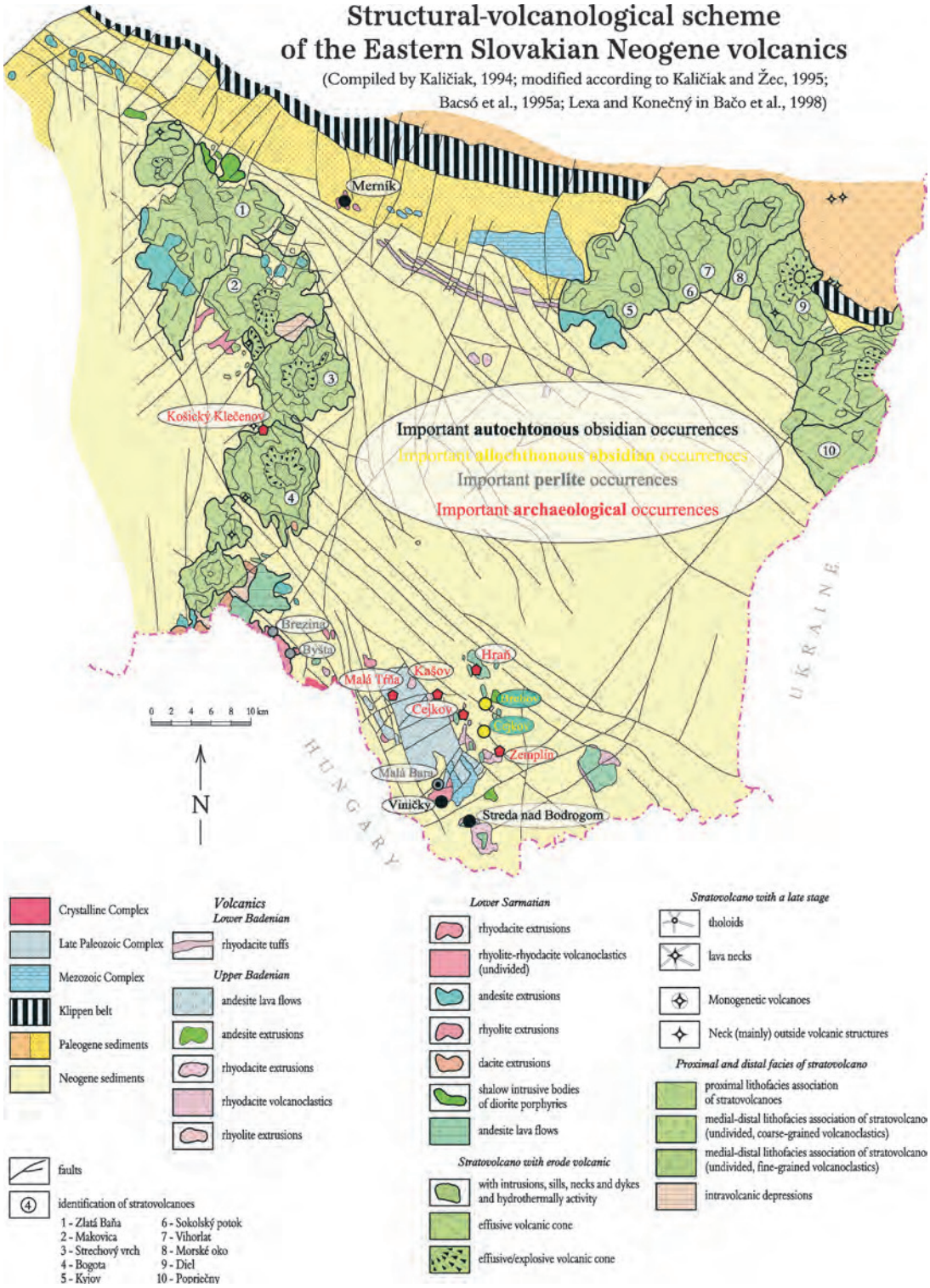

FIGURE 4. Natural obsidian and perlite occurrences in Eastern Slovakia, including the most important archeological sites with obsidian industry (structural-volcanological scheme compiled by Kaličiak 1994, modified by Kaličiak and Žec 1995, Bacsó *et al*. 1995a, Lexa and Konečný in Bačo *et al*. 1998).

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 (*Figure 4*).

Autochtonous (primary) occurrences of volcanic glass

Rhyolite intrusions next to the village Merník – the northern part of the East Slovakian Lowland

At this locality volcanic glass forms marginal parts of various small rhyolite intrusions and dykes at a cinabarite deposit (Bačo *et al.* 1986). 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. The glass is not obsidian. It is of a dark gray color with variable tints (*Figure 5a, b*), 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. Glass could be collected at outcrops. However, it lacks proper physical properties and has never been found at archeological sites.

Rhyolite extrusive domes and intrusions in surroundings of Byšta and Brezina

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 (*Figure 4*) (Bačo *et al.* 1998). However, in this case perlite does not include obsidian nodules that could be used for a production of obsidian industry. Obsidian occurring in broader surroundings at the surface in the form of sculptured nodules, cores (*Figure 6a, b, c*) and various types of obsidian industry, sometimes in association with fragments of perlite, are of the anthropogenic origin.

FIGURE 5. Locality Merník, northern side of the Lipová hora Hill, a trench wall: a, volcanic glass; b, detail of glass jointing. Photo by P. Bačo.

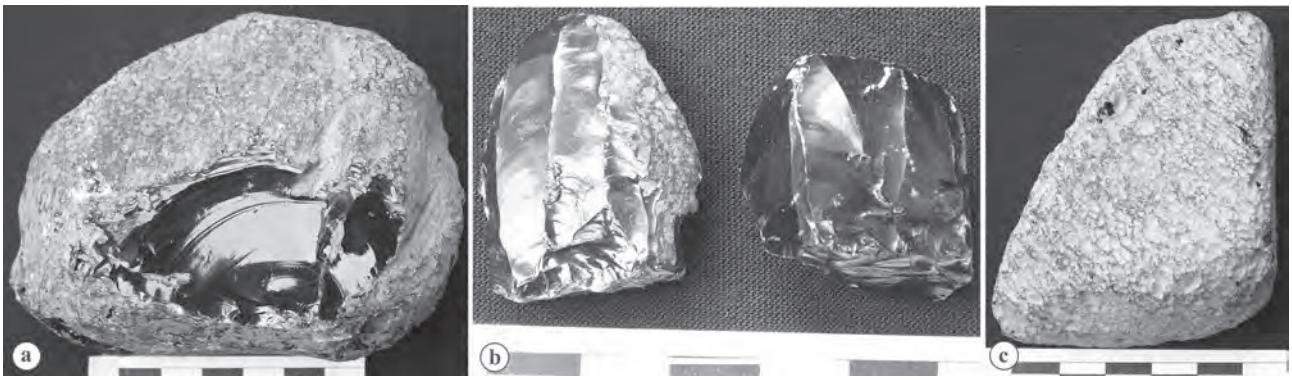

FIGURE 6. Locality Kuzmice-Dancov potok: a, c, obsidian nodules showing surface sculpturing; locality Kuzmice: b, obsidian cores, Neolithic. Photo by P. Bačo.

Rhyolite extrusive dome/flow and intrusion – Viničky and Malá Bara

Marginal parts of the extrusive dome/flow Borsuk close to the village Malá Bara, but especially in surroundings of the village Viničky (*Figure 7*) 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 figure 7. Obsidians always occur along with perlite, usually as obsidian nodules in perlite environment.

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. winecellars. 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, including a direct continuation of the intrusion shown at the figure 6a with all attributes of obsidian occurrence. The same type of setting could occur elsewhere in

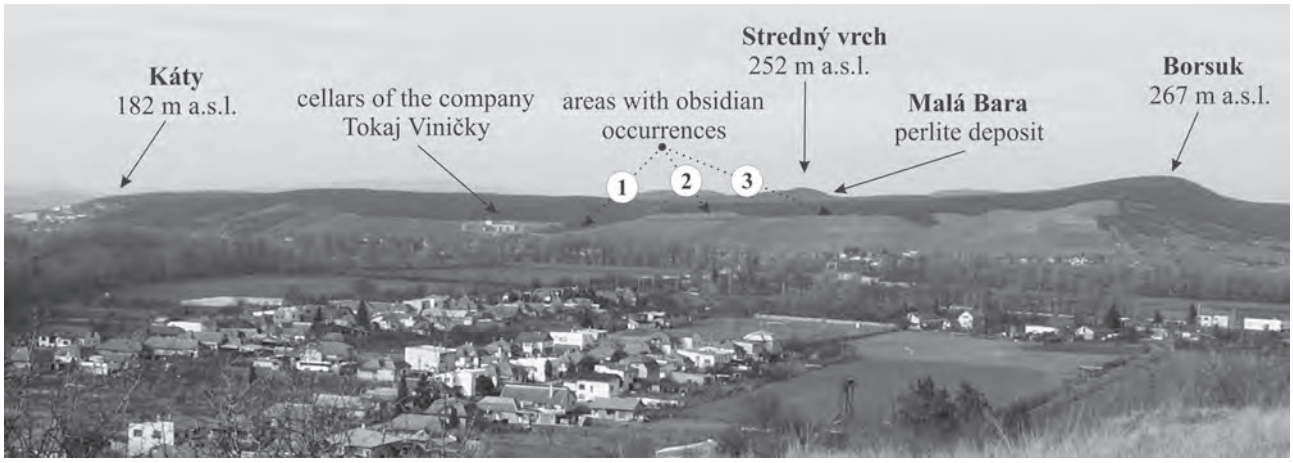

FIGURE 7. Panorama of the SW side of the Borsuk rhyolite dome/flow next to the village Viničky with obsidian and perlite occurrences, including the Tokaj Viničky ltd. winecellars, 1–3, obsidian occurrences. View from the southeast. Photo by P. Bačo.

FIGURE 8. Locality Viničky: obsidian nodules from the site no. 2 in the fig. 7. Photo by P. Bačo.

surroundings, especially eastward and southeastward at localities 2 and 3 (*Figure 7*). 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.

Obsidian in perlitized parts of rhyolite intrusions – Viničky

Here denudation has reached one or several small rhyolite intrusions and/or dykes affected by extensive perlitization with remnants of preserved obsidian (*Figure 8*). Intrusions with perlite and obsidian are covered by a thin veneer of eluvial deposits, sometimes as thin as 0.5 m – e.g. localities 2 and 3 (*Figure 7*), or by a thicker layer of polymict eluvial/deluvial deposits with thickness up to 5 m – e.g. locality 1 (*Figure* 7) and area of the Tokaj Viničky Ltd. winecellars (*Figures 7 and 9*) (Bačo *et al.* 2011). Gradual weathering of perlite frees enclosed obsidian nodules 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 (*Figure 8*). Not often, however, more frequently as generally assumed, there are present cores 10 cm or more in diameter (*Figure 10a, b*). Form of obsidian pieces is irregular. Their surface id 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. That is proved by observation of initial stages of obsidian sculpturing in a section of eluvial deposits directly above the primary source (*Figure 11a, b, c*). Extent of sculpturing depends on the position of obsidian pieces in the section (*Figure 9*). Obsidian in the figure 11a from the top of weathered perlite shows the same type of surface attributes as obsidian nodules in fresh perlite – remnants of perlite can be seen in the upper right corner of the figure. Obsidian nodule in the figure 11b 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 11c 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.

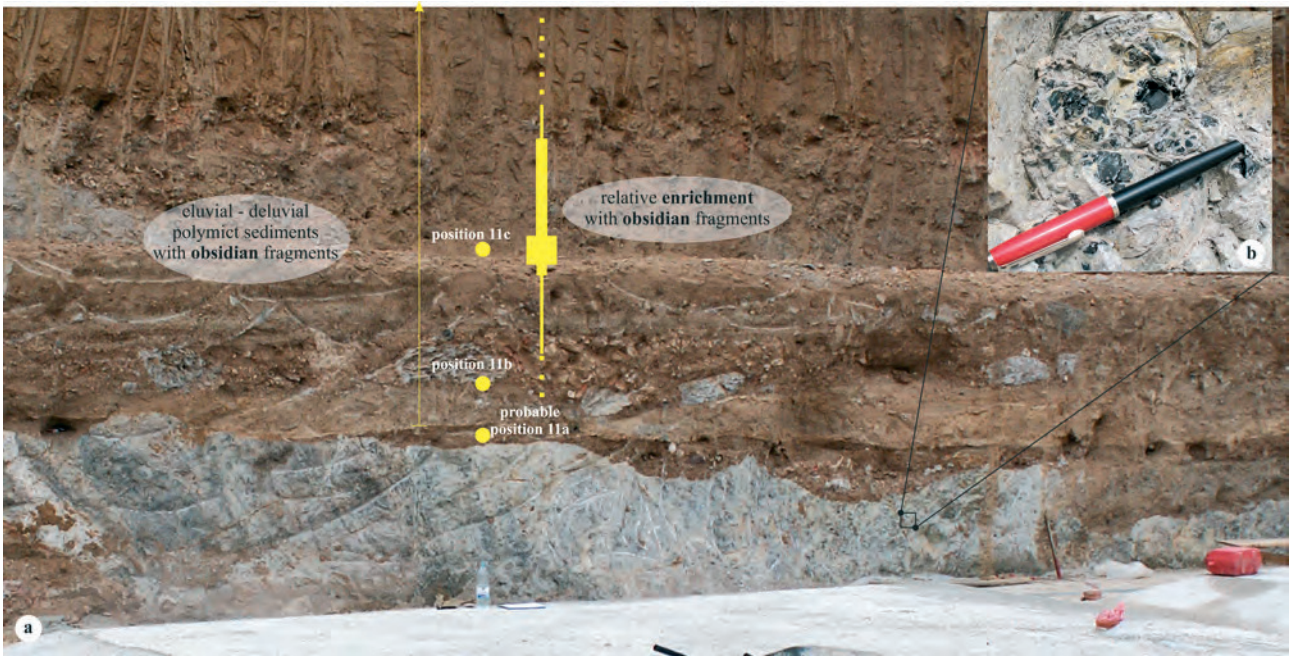

FIGURE 9. Locality Viničky, groundwork section of the Tokaj Viničky ltd. buiding: a, eroded top of the perlitized glassy rhyolite intrusion; b, detail of preserved obsidian nodules. Obsidian occurs in the central part of the perlitized intrusion in the width 5–7 m. Yellow column indicates relative abundance of obsidian nodules in eluvial/deluvial deposits. Yellow dots indicate finding positions of obsidian nodules in the fig. 11. Photo by P. Bačo.

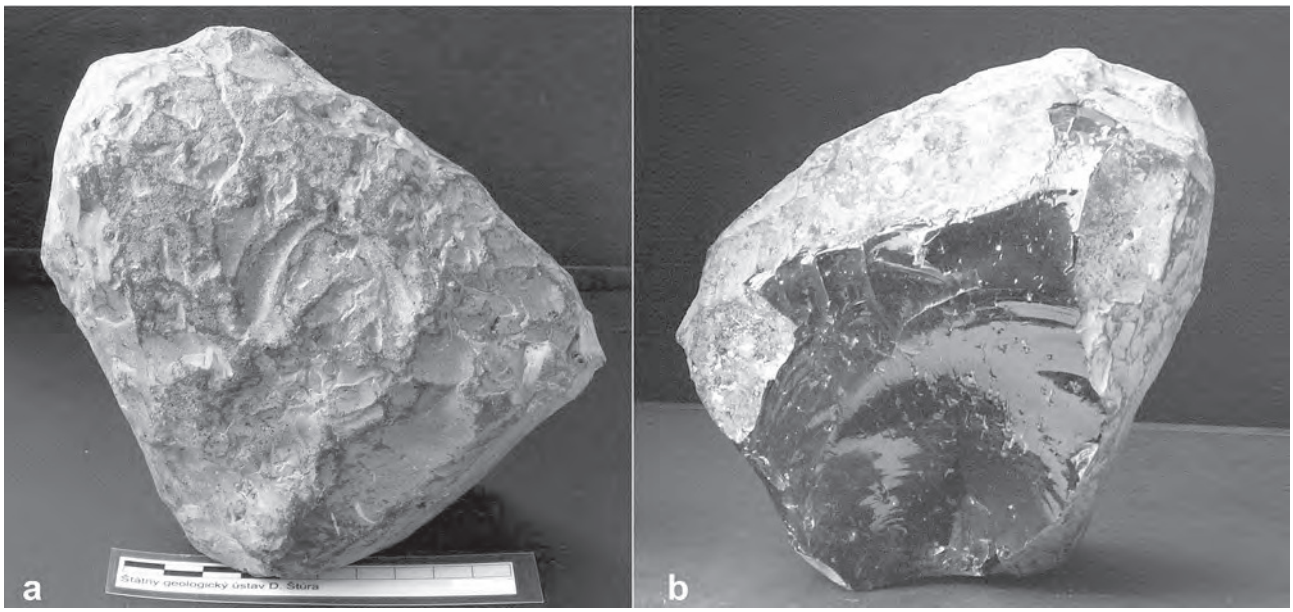

FIGURE 10. Locality Viničky, a large obsidian nodule: a, initial stage of sculpturing with remnants of original contact planes with perlite shell; b, typical conchoidal fracture of obsidian. Mass: 1,735 g; dimensions: 14.5 × 11.5 × 9.5 cm. Photo by P. Bačo.

Obsidian in perlitic breccias – Viničky, Malá Bara

Most of the obsidian nodules observed in the Tokaj Viničky Ltd. winecellars occurs in perlitic breccias (*Figure 12a, 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 in Kobulský e*t al.* 2014, Lexa *et al.* 2014). 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. Planes of obsidian fragments are variably convex or concave, smooth and glossy (*Figure 13b*). At freshly broken surface they are black or pitch black with

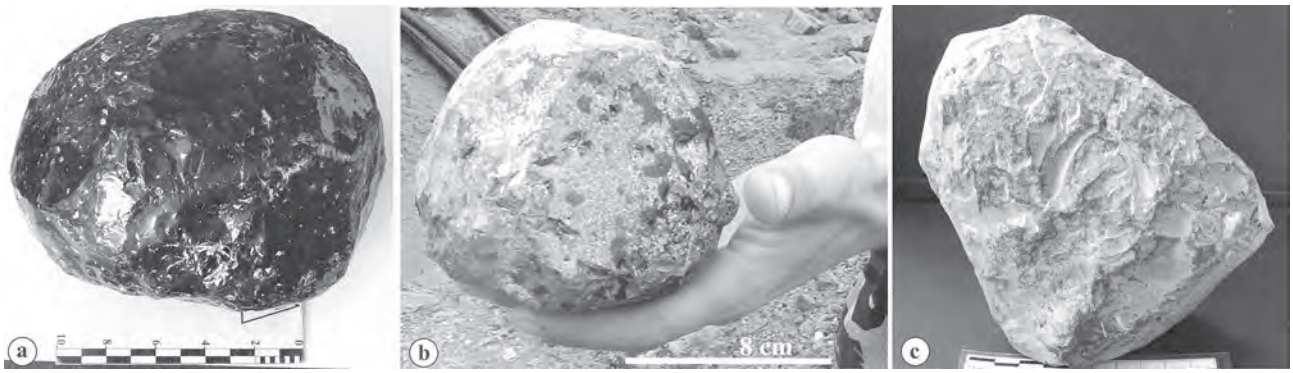

FIGURE 11. Locality Viničky, obsidian nodules from the site no. 2 in the fig. 4 showing a progressive evolution of their surface as a function of their position (compare the fig. 9): a, obsidian nodule from the weathered top of perlitized intrusion; b, obsidian nodule from eluvial deposits; c, obsidian nodule with initial surface sculpturing from eluvial/deluvial deposits. Photo by P. Bačo.

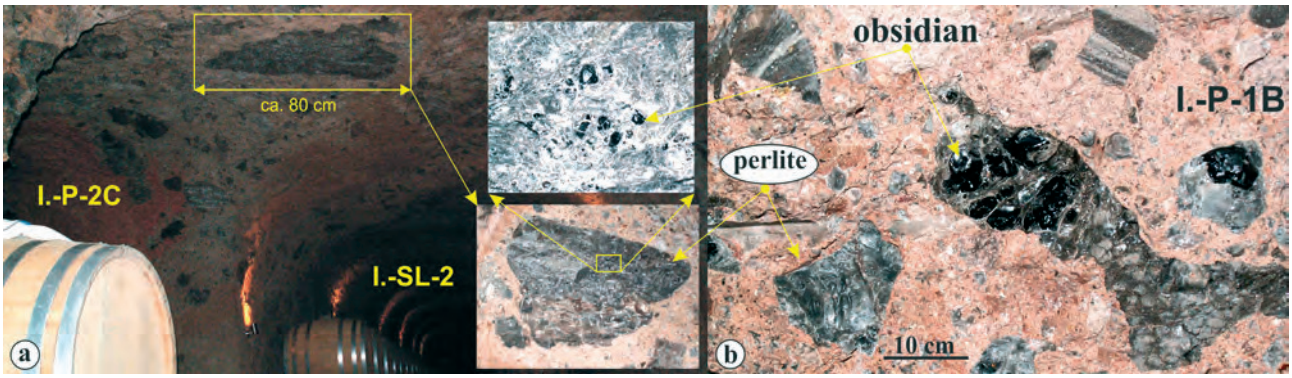

FIGURE 12. Locality Viničky, Tokaj Viničky ltd. winecellars: a, b, autochtonous occurrence of obsidian nodules in perlitic breccias at the base of the Borsuk dome/flow. Photo by P. Bačo.

FIGURE 13. Locality Viničky, Tokaj Viničky Ltd. winecellars, gallery I-II/UP3: obsidian fragment and nodule from autochtonous perlitic breccias at the base of the Borsuk dome/flow. Mass/dimensions: a, 98 g / 6.5 × 6.1 × 3.1 cm; b, 187 g / 8.0 × 5.8 × 3.2 cm. Photo by P. Bačo.

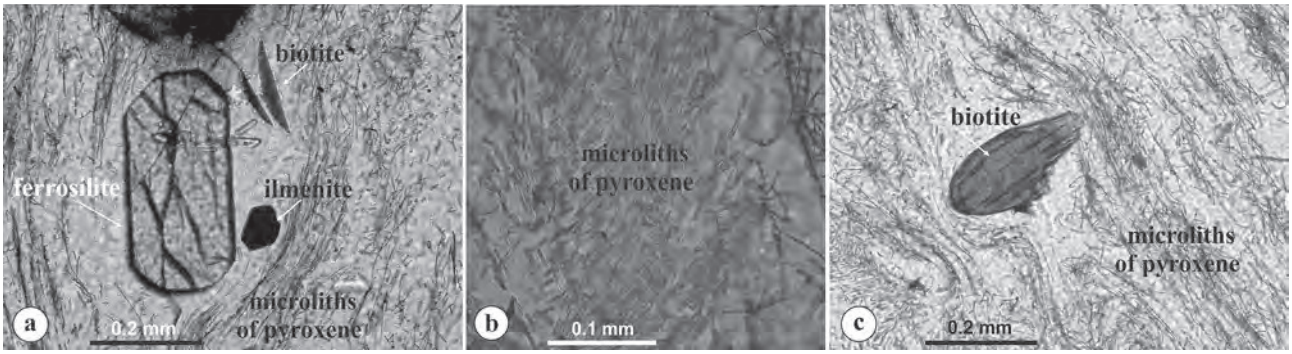

FIGURE 14. Locality Viničky: microphotographs of obsidian thin-section (transmitted light, one nicol). Photo by P. Bačo.

a pronounced conchoidal fracture (*Figure 13a*). Using a microscope one can observe in obsidian rare microphenocrysts of biotite, plagioclase, rare Fe-orthopyroxene (ferosilite) and ilmenite (*Figure 14a, c*). Frequently observed banded texture or alternation of dark and pale streaks is caused by flow oriented minute crystals – microlites and trichytes (*Figure 14b*), mostly of pyroxene composition. This internal fabric of obsidian glass is a probable cause of sculpturing if the glass is exposed to weathering.

Rare and generally small nodules 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 nodules prevented its utilization for a production of obsidian industry.

Allochtonous (secondary) occurrences of volcanic glass

Reworked volcaniclastic rocks with perlite and obsidian – Streda nad Bodrogom

Perlite with nodules of obsidian, known also under the name "marekanite" (Šalát, Ončáková 1964) occurs in an abandoned quarry north of the city Streda nad Bodrogom (*Figure 4*). 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 nodules varies in the range 0.5–5 cm with the average size around 2.5 cm (*Figure 15a, b*). Obsidian nodules at this locality show many attributes that are characteristic of obsidians at the locality Viničky, as there are occurrences in the form of cores in perlite, color, luster and conchoidal fracture. The Viničky locality was generally accepted as probable source (Baňacký e*t al.* 1989, Bačo, Bačová 2014: 8). However, results of K/Ar dating (see bellow) point to a different age and yet unknow primary source. Could be this locality one of the sources for obsidian industry at archeological sites? The horizon of obsidian-bearing rocks is up to 30 m thick and laterally extends for 500 m in the steep northern slope of the Šibeničný vrch hill. Before opening of the horizon by the quarry it was exposed in natural outcrops or covered by a thin veneer of deluvial deposits only. Theoretically, weathered out obsidian cores could be collected and utilized by Palaeolithic/Neolithic cultures, including finds directly on the Šibeničný vrch (Janšák 1935, Chovanec 2004). On the other side, obsidian cores are generally too small, we lack a proper evidence and ages of dated obsidians from archeological sites are not identical with the age of volcanic glasses at this locality. Also, majority of obsidian nodules from this locality shows irisation of tumble finished pieces, an attribute that has not been observed neither with obsidians at the Viničky locality, nor with obsidians at archeological sites of Eastern Slovakia.

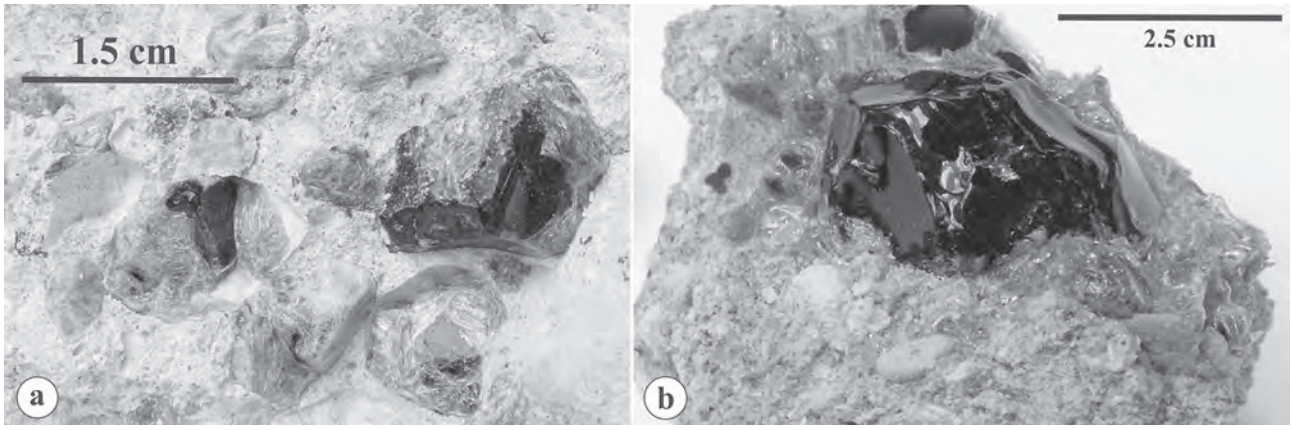

FIGURE 15. Locality Streda nad Bodrogom, abandoned quarry: a, b, obsidian in perlite shell (marekanite) occurring as fragments in reworked polimict rhyolite volcanoclastic rocks. Photo by P. Bačo.

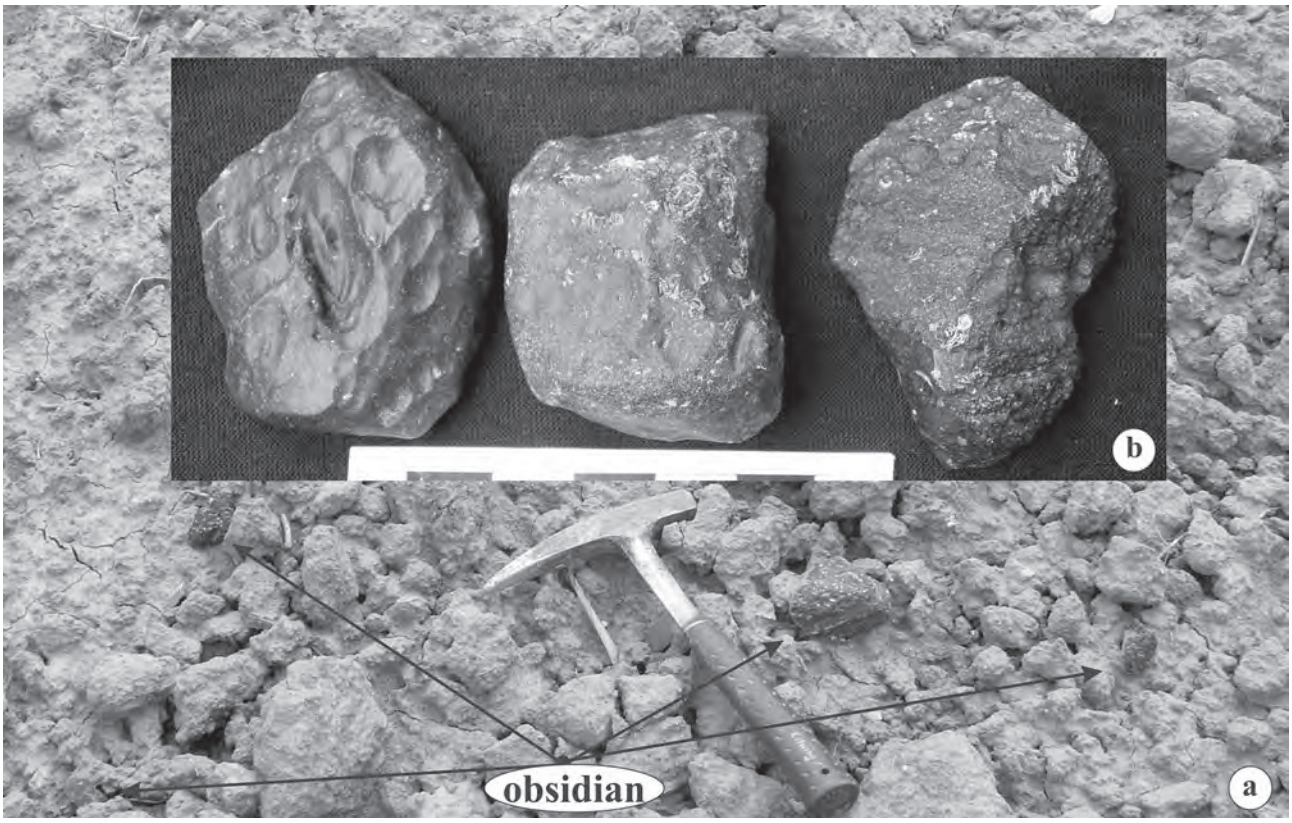

FIGURE 16. Locality Cejkov – Malé lúky-Žihľavník: a, finding position of obsidian nodules; b, dominant types of their surface sculpturing. Photo by P. Bačo.

Obsidians at secondary natural occurrences

Obsidians in Quaternary deposits east of the villge Cejkov – area "Malé lúky-Žihľavník"

The area with obsidian fragments and nodules extends SW of the village Brehov, nowadays in cadastre of the village Cejkov. Š. Janšák (1935: 56) 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, often identical with remnants of sculpturing on worked obsidian nodules at archeological localities. That lead A. Přichystal and 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). Character of the locality, as it was described by Janšák (1935: 57), remains unchanged (*Figures 16a, b, 17*).

Obsidians in Quaternary deposits northwest of the village Brehov – area "Za alejou"

This area represents a second concentrated occurrence of obsidian in surroundings of Brehov. It was discovered during exploration for base metal ores (Bacsó *et al.* 1995b) that included trenching. In this case obsidian fragments and nodules (*Figure 18*) 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 (*Figure 18*, middle piece) are present too. Form of obsidian fragments and nodules is irregular, dominantly isometric (*Figure 18*). 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 (*Figure 19*), 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) allochtonous occurrence as in the case of the Cejkov locality described first by Š. Janšák (1935) and recently in a greater detail by A. Přichystal and P. Škrdla (2014).

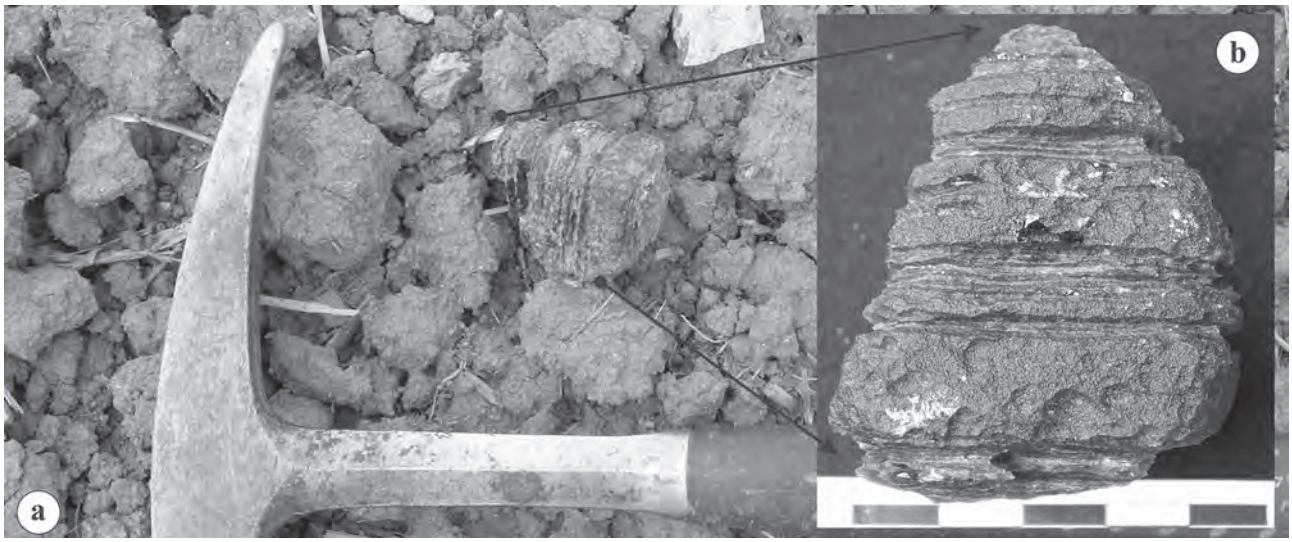

FIGURE 17. Locality Cejkov – Malé lúky-Žihľavník: a – finding position of obsidian nodule; b –surface sculpturing reflecting its fluidal texture. Dimensions: 5.1 × 4.6 × 4.0 cm. Photo by P. Bačo.

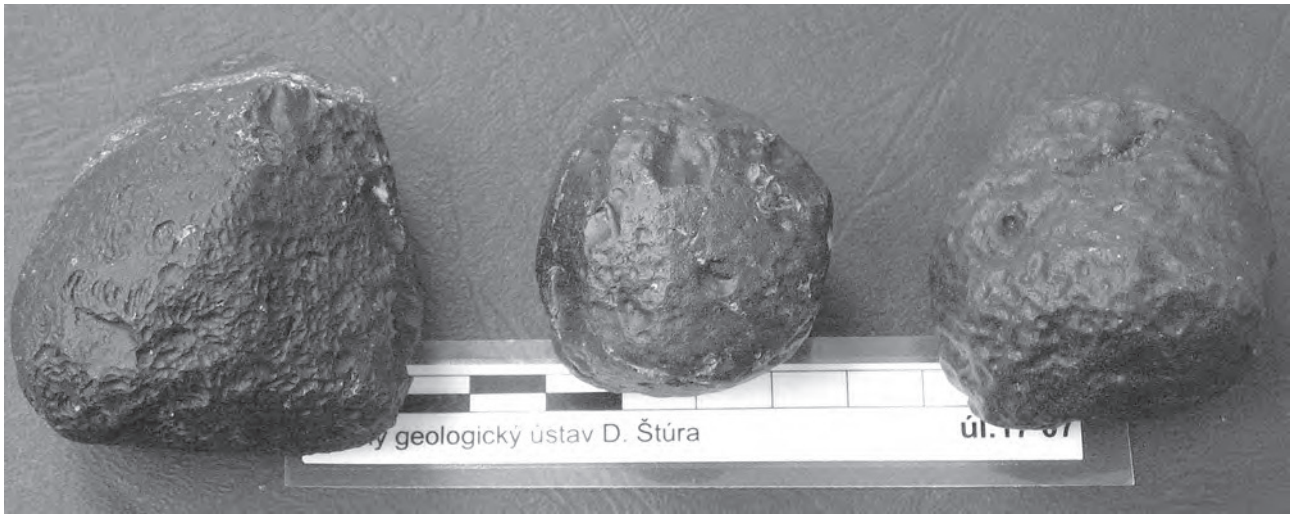

FIGURE 18. Locality Brehov – Za alejou: isometric, moderately sculptured obsidian nodules. Mass/dimensions: 128 g / 3.9 × 5.2 × 5.4 cm; 68 g / 3.3 × 3.9 × 4.0 cm; 76 g / 3.9 × 4.3 × 4.6 cm . Photo by P. Bačo.

Preliminary results of K/Ar dating of obsidians and perlites from natural occurrences and archeological sites

Conventional K/Ar dating has been carried out in the framework a complex investigation of rhyolite volcanism in the region of Zemplínske vrchy Mts. and northern part of the Tokaj Mountain range. K/Ar dating was carried out on whole rock samples. The radiogenic argon content was measured with a magnetic mass spectrometer incorporating an argon extraction line developed in the Institute of Nuclear Research of the Hungarian Academy of Sciences (ATOMKI, Debrecen). K content was measured with a digital flame photometer. Li internal standard and Na buffer was added to the dissolved sample (see details on the experimental method in K. Balogh 1985). Atomic constants suggested by R. H. Steiger and E. Jägger (1977) were used for calculating the K/Ar age. Analytical error is given at 68% confidence level (1σ), using the equation of A. V. Cox and G. B. Dalrymple (1967). We have dated samples of obsidian and associated perlite from two types of their primary occurrence, obsidian and associated perlite from the allochtonous occurrence, obsidian nodules from natural allochtonous occurrences and obsidian nodules from archeological sites.

Primary volcanic glasses, obsidian and perlite, are those at the locality Viničky. Samples number 1, 2 and 3 (*Figure 20, Table 1*) represent obsidian and perlite from perlitic breccias at the base of the Borsuk dome/flow. Samples number 4 and 5 (*Figure 20, Table 1*) represent obsidian and perlite from perlitized marginal parts of small intrusions. Sample number 6 dated by FT method (Repčok 1977) represents obsidian from the same source as samples number 4 and 5, however it was collected as fragment in overlying deluvial deposits.

The first type of allochtonous volcanic glasses occurs at the locality Streda nad Bodrogom. Samples number 7 to 12 represent obsidian and perlite (*Figure 20, Table 1*) from reworked rhyolite/rhyodacite tuffs and epiclastic volcanic rocks.

The second type of allochtonous volcanic glasses, in this case obsidian only, occurs as reworked pieces in

TABLE 1. Localization, geological position and age of dated obsidians and associated perlites.

Location and geology			Rock	Signature		Colour of the point	M.a.
				in the chart	on the map	on the map	
Viničky area autochthonos occurrences (autcrop and vine cellar)		Perlitic breccia with obsidian	mixed perlite/obsidian	V-32+33^{+}	1		11.58±0.46
				V-32+33^{-}	2		12.12±0.47
			obsidian	V-2	3		13.52±0.81
		Dike and surface occurrence	perlite	V-34b^{-}	4		11.19±0.53
			obsidian	Viničky - wall	5		11.04±0.34
			obsidian	Viničky - FT	6		11.10±0.80
Streda nad Bodrogom area „autochthonous“ occurrence (quarry in reworked tuffs and EVB)		fragments in reworked tuffs/epiclastic volcanic breccias	obsidian	TO-109^{+}	7		14.69±0.45
			obsidian	TO-109^{-}	8		14.47±0.56
			obsidian	TO-134a	9		14.35±0.69
			perlite	TO-134b	10		14.95±0.65
			obsidian	64/12	11		14.49±0.65
			perlite	65/12	12		14.32±0.58
Areas with allochthonous occurrences	**Brehov**	**Quarternary** Pleistocene	obsidian	Cejkov	13		12.45±0.92
	Cejkov		obsidian	Brehov	14		13.48±0.72
	Kašov	**“Archaeological“** Neolite	obsidian	Kašov	15		12.03±0.61
	Hraň		obsidian	Hraň	16		13.51±0.78
			obsidian	Hraň - FT	17		14.20±0.50
	Košice - Šaca		obsidian	Košice-Šaca			12.97±0.62

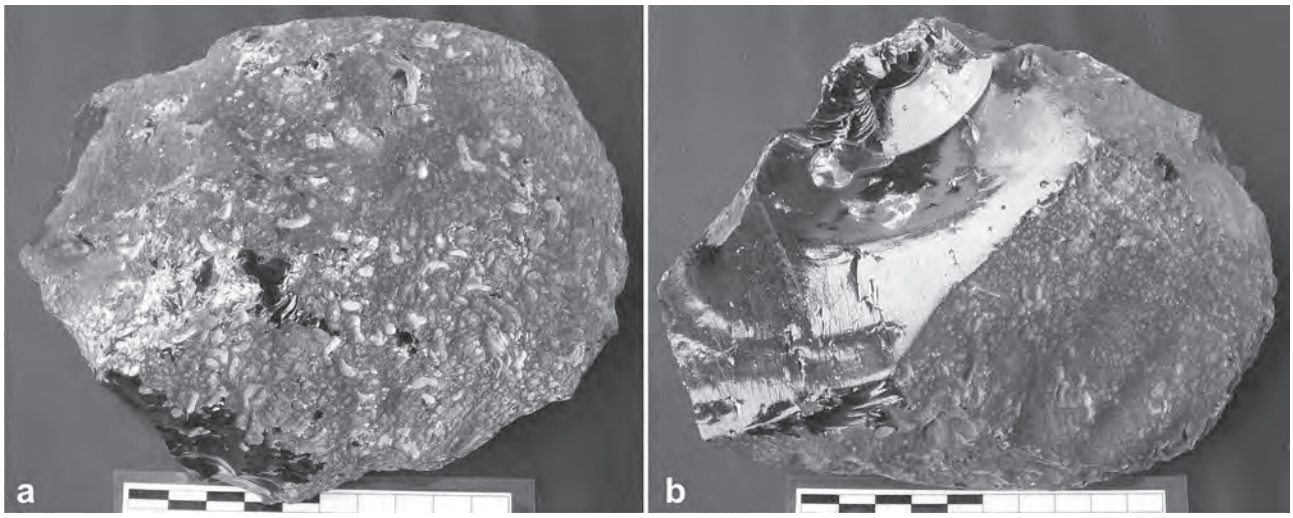

FIGURE 19. Locality Brehov – Konopiská: a, b, obsidian nodule showing natural surface sculpturing and conchoidal fracture. Mass/dimensions: 1,345 g / 16.3 × 12.8 × 6.7 cm. Photo by P. Bačo.

quaternary eluvial/deluvial/fluvial deposits. Sample 13 is from the locality Cejkov – Malé lúky-Žihľavník, sample number 14 is from the locality Brehov – Za alejou (*Figure 20, Table* 1).

Samples number 15 and 16 and sample number 17 dated by FT method (Repčok *et al.* 1988) represent obsidian cores from archeological sites Kašov and Hraň (*Figure 20, Table 1*). Sample Košice–Šaca (not on the map, *Table 1*) represents obsidian nodule from the archeological site. Results of K/Ar dating and available FT data are in the table 1.

DISCUSSION

Surroundings of Viničky, respectively southern slopes of the hills Borsuk and Káty, is the most important autochtonous occurrence of obsidian in the Zemplínske vrchy Mts. area and for a long time it was considered in archeological literature as a sole primary source of obsidian in Eastern Slovakia (Williams-Thorpe *et al.* 1984, Kaminská, Duďa 1985).

Based on observations in the Tokaj Viničky Ltd. winecellars 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 wineyards. Their past exploitation has not been confirmed. Those related to perlitized parts of small intrusions were most probably a source for obsidian nodules that occur in recent eluvial/deluvial Quaternary deposits and thus could be collected. The problem, whether the Viničky locality was or could be a sole source of obsidian in the Zemplínske vrchy Mts. area for obsidian industry at archeological sites remains open (Bačo *et al.* 2003, Přichystal 2009). There is increasing evidence that the locality Viničky was rather a supplementary source than a dominant source. It is evident that obsidian nodules in Viničky were available for a surface collection during the Palaeolithic and Neolithic time. 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 Zemplínske vrchy Mts. provenance at archeological sites (Přichystal, Škrdla 2014). 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. However, such the 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, Bacsó *et al.* 1995a, b, Bačo *et al.* 2003, Přichystal, Škrdla 2014). A. Přichystal and P. Škrdla (2014) studied in a great

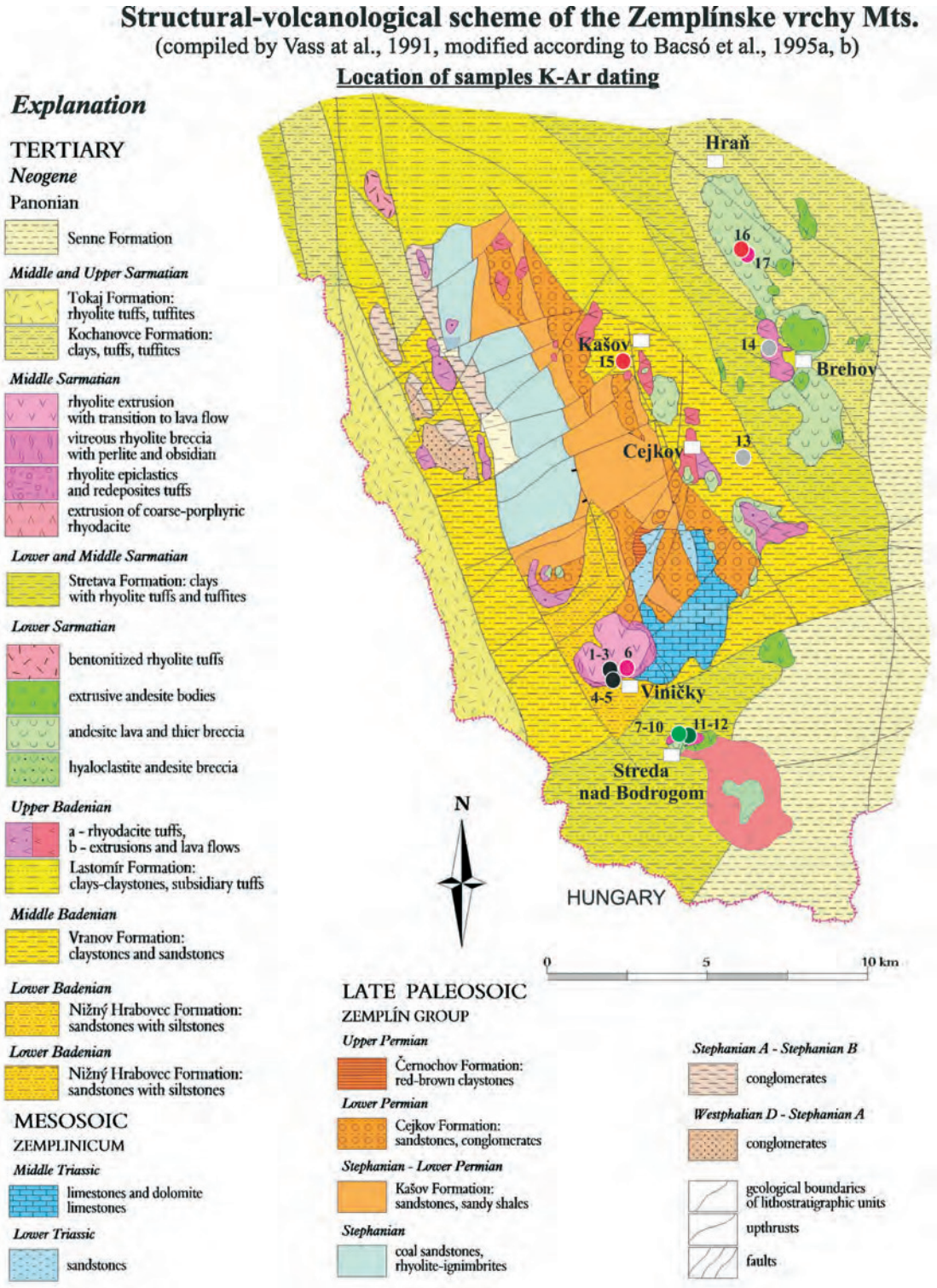

FIGURE 20. Localization of isotope dated volcanic glasses in the Zemplínske vrchy Mts. region. Color coding of localities, reflecting the type of occurrence, is identical with the table 1 (structural-volcanological scheme compiled by Vass at al. 1991, modified according to Bacsó *et al.* 1995a, b).

detail allochtonous natural occurrences of obsidian around Cejkov and concluded that these occurrences were a possible principal source of obsidian for the obsidian industry at the Palaeolithic/Neolithic archeological sites of Central Europe. Apparently, the same applies also to the second allochtonous secondary occurrence northwest of Brehov. However, primary source of obsidians at both allochtonous localities remains unknown. East of these localities, underneath andesite extrusive dome of the Veľký vrch hill north of Brehov, an exploration borehole has crossed locally perlitized glassy rhyodacite, including also domains of pure black glass. Though obsidian that we could compare with described allochtonous occurrences has not been observed, other parts of the rhyodacite body with perlite and obsidian at its margin could be exposed at the surface and provide obsidian fragments/nodules to secondary allochtonous accumulations in Quaternary deposits. On the basis of these data we can conclude that beside the already known primary source of raw obsidian in Viničky (Williams-Thorpe *et al*. 1984, Kaminská, Ďuďa 1985, Kaminská 1991) there was another primary source at surroundings of Brehov (Bacsó *et al.* 1995a, Bačo *et al.* 2003, Bačo, Bačová 2014: 8, Přichystal, Škrdla 2014).

Results of K/Ar dating also point to two groups of volcanic glasses at the locality Viničky. The first older group (samples V-2, V-32+33^{+} and V-32+33^{-}) represents obsidian and perlite from perlitic breccia at the base of the Borsuk dome/flow and shows ages in the range 13,52 ± 0.81 – 11.58 ± 0.46 Ma (Ma = million years). The second younger group (samples V-34b^{-}, Viničky-wall and Viničky FT) represents obsidian and perlite related to small intrusions and shows ages in the range 11.19 ± 0.53 – 11.04 ± 0.34 Ma. K/Ar dating of obsidians and associated perlites (marekanites) from reworked rhyolite/rhyodacite tuffs, epiclastic volcanic rocks at the locality Streda nad Bodrogom (samples TO-109^{+}; TO-109^{-}; TO-134a, TO-134b and 64/12) provided ages in the range 14.95 ± 0.56 – 14.32 ± 0.58 Ma. This age interval points to yet unknown source. Nearby, at the Tarbucka hill next to the villages Malý Kamenec and Veľký Kamenec, there is a rhyodacite extrusive dome of the same age (unpublished dating of Z. Pécskay). However, the rhyodacite is coarse porphyritic while the dated volcanic glasses are aphanitic. No other occurrences of obsidian and/or perlite of this age are known in the region of Eastern Slovakia and Northeastern Hungary. K/Ar dating of obsidian nodules from allochtonous natural occurrences provided ages 12.45 ± 0.92 Ma (Cejkov) and 13.48 ± 0.72 Ma (Brehov). Dating of obsidian cores (or nodules) from archeological sites provided ages 13.51 ± 0.78 Ma and 14.20 ± 0.50 Ma (Hraň), 12.03 ± 0.61 Ma (Kašov) and 12.97 ± 0.62 Ma (Košice-Šaca). The range of results from archeological sites is rather wide, but it overlaps with ages of volcanic glasses from autochtonous and allochtonous natural occurrences in Eastern Slovakia.

Ages of obsidians from archeological sites do not overlap with the ages of the younger group from Viničky and ages of the group from Streda nad Bodrogom (*Figure 21*). While in the case of obsidians from the locality Streda nad Bodrogon it confirms their absence at archeological sites, in the case of obsidians from the younger source in Viničky an interpretation is different. As there is geochemical evidence that obsidians from this source are among obsidian artifacts at archeological sites (Williams-Thorpe *et al.* 1984, Biró, Kasztovszky 2013) in this case we have to conclude that dating has not confirmed their presence yet. On the other side ages of obsidians from archeological sites overlap with the ages of the older group from Viničky as well as with the ages of allochtonous obsidians in surroundings of Cejkov and Brehov (*Figure 21*). Results of dating alone do not differentiate among these two possible sources and other attributes must be used (e.g. sculpturing, color, trace element contents, etc.). A rather wide range of results, in the case of obsidian nodules from natural allochtonous occurrences as well as in the case of obsidian cores (and nodules) from archeological sites can indicate more than one primary natural source.

For archeology there is important to know connection among natural sources of obsidian nodules and their utilization by prehistoric cultures. The archeological site Čerhov with the first obsidian finds of Aurignacian is at the western side of Zemplínske vrchy Mts., while the late Palaeolithic archeological sites of Epigravettian are at their northern and northeastern side. Neolithic archeological sites are confirmed in whole surroundings of Zemplínske vrchy Mts. From the above description of obsidian and associated perlite occurrences related to Neogene rhyolite volcanic activity in Eastern Slovakia it is evident that as primary sources of obsidians at archeological sites we should consider locality Viničky and not unquestionably verified locality Brehov. Indeed, just the primary obsidian occurrence at Brehov should be a source of known secondary obsidian accumulations in Quaternary deposits around Cejkov and Brehov that in turn served as a source for obsidian

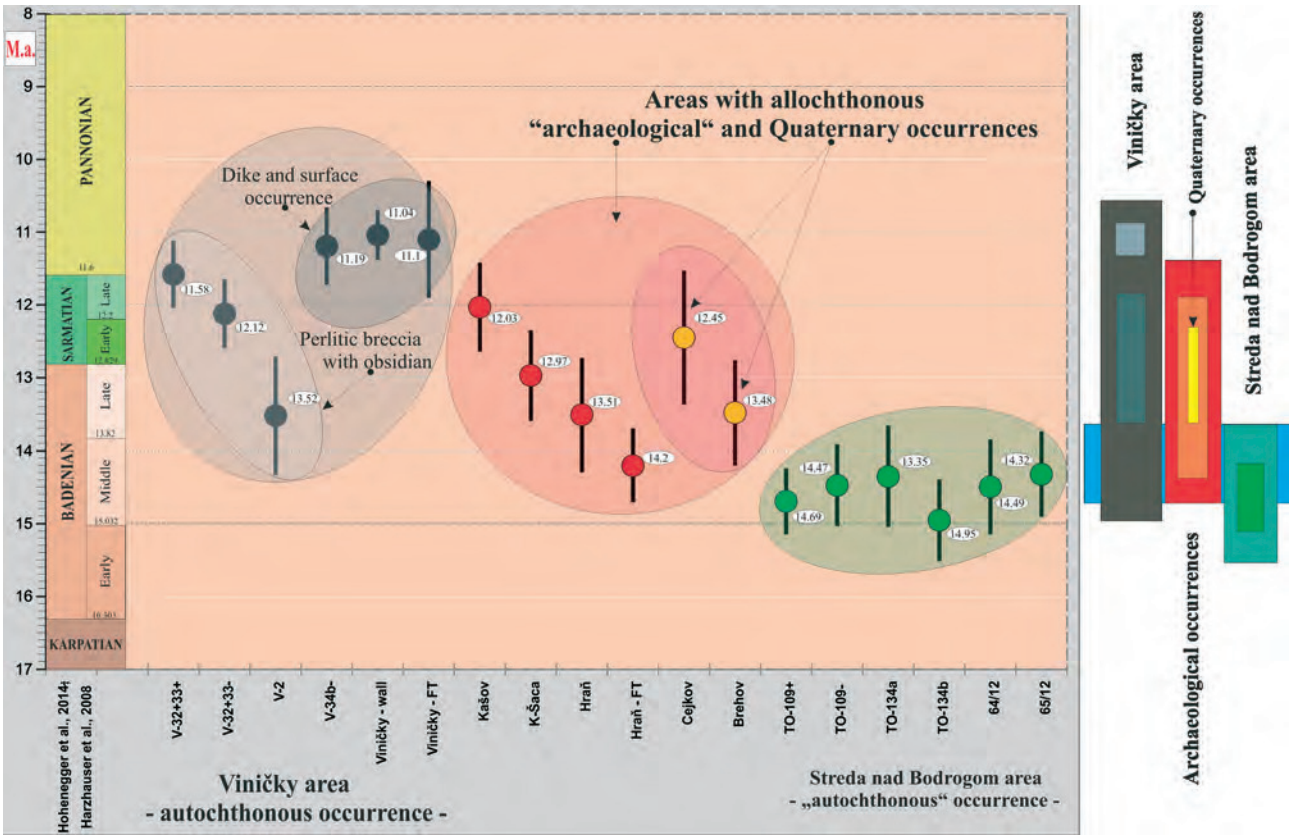

FIGURE 21. Results of isotope dating of volcanic glasses in the Zemplínske vrchy Mts. region grouped in accordance with localities and the type of occurrence. Localization of individual samples and their geological position is given in the text as well as in the Table 1.

industry at archeological sites (Přichystal, Škrdla 2014). An overlap of relevant ages (*Figure 21*) indicates that the obsidian accumulations in surroundings of Cejkov and Brehov could be a source of dated obsidian nodules at the archeological sites Hraň and Košice-Šaca. Age of the obsidian nodule from the Neolithic archeological site Kašov overlaps with younger ages of the older group from Viničky (*Figure 21*). If considering results of dating only, that would indicate a presence of obsidian from Viničky at one of the archeological sites on the northeastern side of Zemplínske vrchy Mts., where otherwise obsidians from Cejkov and Brehov dominate. However, the dated obsidian core (and nodules) shows sculpturing and therefore its origin at the locality Viničky is doubtful.

Size of obsidian nodules at individual primary and secondary occurrences (Viničky a Brehov/Cejkov) is comparable. At primary occurrences smaller nodules (under 3 cm in diameter) dominate. The same is valid for secondary occurrences. Generally speaking, count of obsidian nodules at primary as well as secondary occurrences is inversely proportional to their size. A relatively higher abundance of bigger nodules (8 to 15 cm) at secondary occurrences is caused by their secondary enrichment during transport and deposition. The biggest obsidian nodules (e.g. those with mass > 2 kg) come from secondary occurrences only. As far as size of obsidian industry is concerned, most of obsidian cores and artifacts is smaller, rarely reaching length 10 cm. So, smaller obsidian nodules could be used for their production that could be found at several sources. Majority of obsidians from natural occurrences shows upon macroscopic/microscopic observation an alternation of pale and dark streaks, so called fluidal texture. This is caused by uneven distribution of microlites in bands owing to a flow orientation. A degree, to which streaks are observable, depends on a mutual orientation of the observed surface and flow

banding in the glass. Most of artifacts at archeological sites show fluidal texture. Sculpturing is the most pronounced macroscopically observable attribute of obsidian nodules that is no related to the quality of raw material. It is characteristic for obsidian nodules at secondary accumulations in surroundings of Cejkov and Brehov and it is almost absent or rudimentary developed on obsidian nodules from Viničky owing to their primary geological position. At archeological sites there are obsidian cores and/or artifacts showing sculpturing. However, their proportion is small. Most of the artifacts there are tools and flakes without remnants of the former nodule surface. So, we do not know, whether they have been produced from a nodule with or without sculpturing. Merely in the upper horizon at the Kašov archeological site there is 43,540 of artifacts. Can we exclude safely that stone-knappers have utilized obsidian nodules without sculpturing coming from the Viničky source? Where actually was the main source of obsidian nodules? Were secondary accumulations of obsidian nodules in Quaternary deposits around Cejkov the main source of obsidian at archeological sites as claimed by A. Přichystal and P. Škrdla (2014)? During the last years there was identified also another secondary source of obsidian nodules northwest of Brehov (Bacsó *et al.* 1995a). Their physical attributes and similarity with obsidian nodules in surroundings of Cejkov indicate that they could represent a source of equal value (Bačo *et al.* 2003, Bačo, Bačová 2014). Apparently, both secondary accumulations of obsidian nodules were a crucial source of obsidians at archeological sites. While they were a dominant source for many of the studied archeological sites, it is not enough data available to claim that Cejkov and Brehov have been dominant sources of obsidian nodules for all archeological sites in the Zemplínske vrchy Mts. region. The Carpathian group 1 (C1) obsidians dominate among artifacts at archeological sites of Central Europe (Willams-Thorpe *et al.* 1984, Biró 2006). At first it was assigned to the primary source at the locality Viničky (Willams-Thorpe *et al.* 1984, Kaminská, Duďa 1985). Later the C1 group was on the basis of the latest instrumental geochemical analyses (Biró, Kasztovszky 2013, Kasztovszky *et al.* 2014) divided into the dominant subgroup C1a at the Kašov and Cejkov workshops, while the less frequent subgroup C1b was assigned to the Viničky source. A. Přichystal and P. Škrdla (2014) concluded that natural secondary obsidian nodule accumulations in surroundings of Cejkov and Brehov were a possible principal source of obsidian for the obsidian industry at Palaeolithic/Neolithic archeological sites. It follows that we can correlate obsidians from the yet hypothetical Brehov primary source and their secondary accumulations in Quaternary deposits around Cejkov and Brehov with the C1a subgroup of the Carpathian obsidians.

A period since the first appearance of obsidian artifacts in the region of Zemplínske vrchy Mts. during Aurignacian till its last utilization (Eneolite, Bronze Age?) lasted for about 30,000 years.

Utilization of individual natural sources depended upon many factors, including how localities with obsidian nodules were made accessible for surface collection by natural processes, as picking was the most frequent mode of "exploitation". During such the long time the secondary accumulations could be repeatedly reworked, flooded, covered by eolian sands and vice versa exposed by erosion.

CONCLUSIONS

Careful description of primary and secondary natural occurrences of volcanic glasses, K/Ar dating of obsidian and associated perlites from natural occurrences and obsidian artifacts from archeological sites and interpretation of results in the framework of archeological data allows for following conclusions:

1. 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.
2. The locality Viničky was only a subordinate source of obsidians at most of the Palaeolithic/Neolithic archeological sites in the region of Zemplínske vrchy Mts. (and elsewhere in Central Europe).
3. Allochtonous 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.
4. There are two known allochtonous 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. These allochtonous obsidian nodule occurrences were a principal source of the obsidian industry at the Palaeolithic/Neolithic archeological sites in the region of Zemplín Hills (Bačo, Bačová 2014, Přichystal, Škrdla 2014) and elsewhere in Central Europe (Přichystal, Škrdla 2014).

5. Likely we can correlate the C1a subgroup of Carpathian obsidians (Biró, Kasztovszky 2013, Kasztovszky *et al.* 2014) with the allochtonous sources in surroundings of Cejkov and Brehov. These sources covered probably most of the obsidian consumption during Palaeolithic and Neolithic in central Europe.
6. As ages of the dated obsidian artifacts overlap with ages of obsidians at allochtonous occurrences as well as the older source in Viničky, on the basis of K/Ar dating alone we can't differentiate among these sources.
7. A rather wide range of results, in the case of obsidian nodules from natural allochtonous occurrences as well as in the case of obsidian cores from archeological sites indicate propably more than one primary natural source. Evolution of rhyolite volcanic activity in the region of Zemplínske vrchy Mts. 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.
8. A further investigation by a complex of methods at natural occurrences as well as archeological sites is needed to confirm assumptions and clarify remaining questions.

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