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Gravettian occupation of the Beckov Gate in Western Slovakia as viewed from the interdisciplinary research of the Trenčianske Bohuslavice-Pod Tureckom site

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ABSTRACT

Trenčianske Bohuslavice-Pod Tureckom is one of the most important Gravettian open-air sites in the Slovak Republic. It is situated in Western Slovakia, in the middle course of the Váh River, in the area with abundant Upper Palaeolithic settlement. Systematic archaeological research was conducted by Juraj Bárta in 1981–1986, when 478 m^2 of the site was investigated. A small (2 m^2) amount of revisory research conducted in 2008 had an interdisciplinary character, including detailed sedimentological, stable isotope, seasonality, fired clay pellets, lithic raw materials, pollen and malacofaunal analyses. Stable isotope analyses were used for the first time in Palaeolithic research in Slovakia. Three Gravettian occupational levels in superposition were discovered at depths of 25–35 cm (layer I – ~27 ka), 55–75 cm (layer II – ~28 ka) and of 85–125 cm (layer III – 29.5 ka). The results of most analyses were similar to those obtained from other Gravettian sites in the Middle Danube region. The analyses of sediment and malacofauna indicated cooling in the studied time intervals, Stable isotope analyses indicated the mosaic character of the Gravettian palaeoenvironment. Floral and faunal analyses agreed well with the dates of all three cultural layers, which represent rather colder stadial than warmer interstadial conditions.

1. Introduction

Trenčianske Bohuslavice-Pod Tureckom represents one of the most important Upper Palaeolithic sites in Slovakia (Figs. 1 and 2). The first systematic archaeological research was conducted by Juraj Bárta (Archaeological Institute of the Slovak Academy of Sciences) in 1981–1986, when 478 m^2 of the site was studied (Bárta, 1988). During the investigation of Bárta, the research area was divided into three workplaces – A, B and C (Fig. 3). Both the findings of the lithic industry and radiocarbon dating results placed the site into the Willendorf-Kostenkian phase of the Gravettian (Verpoorte, 2002; Svoboda, 2006; Žaár, 2007).

Additional research by the Monuments Board of the Slovak Republic was conducted at the locality in September 2008. The main goal of this new research was to complete Bárta's work at this locality (which has never been published as a whole) with new results, obtained with modern methods. The research was aimed interdisciplinarily, focusing on getting the most information from the smallest (2 m^2) area. The first and most important goal was to obtain uncontaminated palaeontological material for isotope analyses ($^{87}Sr/^{86}Sr$ isotope ratio to determine migration patterns of hunted game and $^{13}C/^{12}C$ and $^{15}N/^{14}N$ ratios to determine the diet and thus the palaeoecology of reindeer and mammoth). These analyses were used for the first time in Palaeolithic research in Slovakia. Other aims of the research were detailed sedimentological, malacozoological, palynological, seasonality, lithic raw

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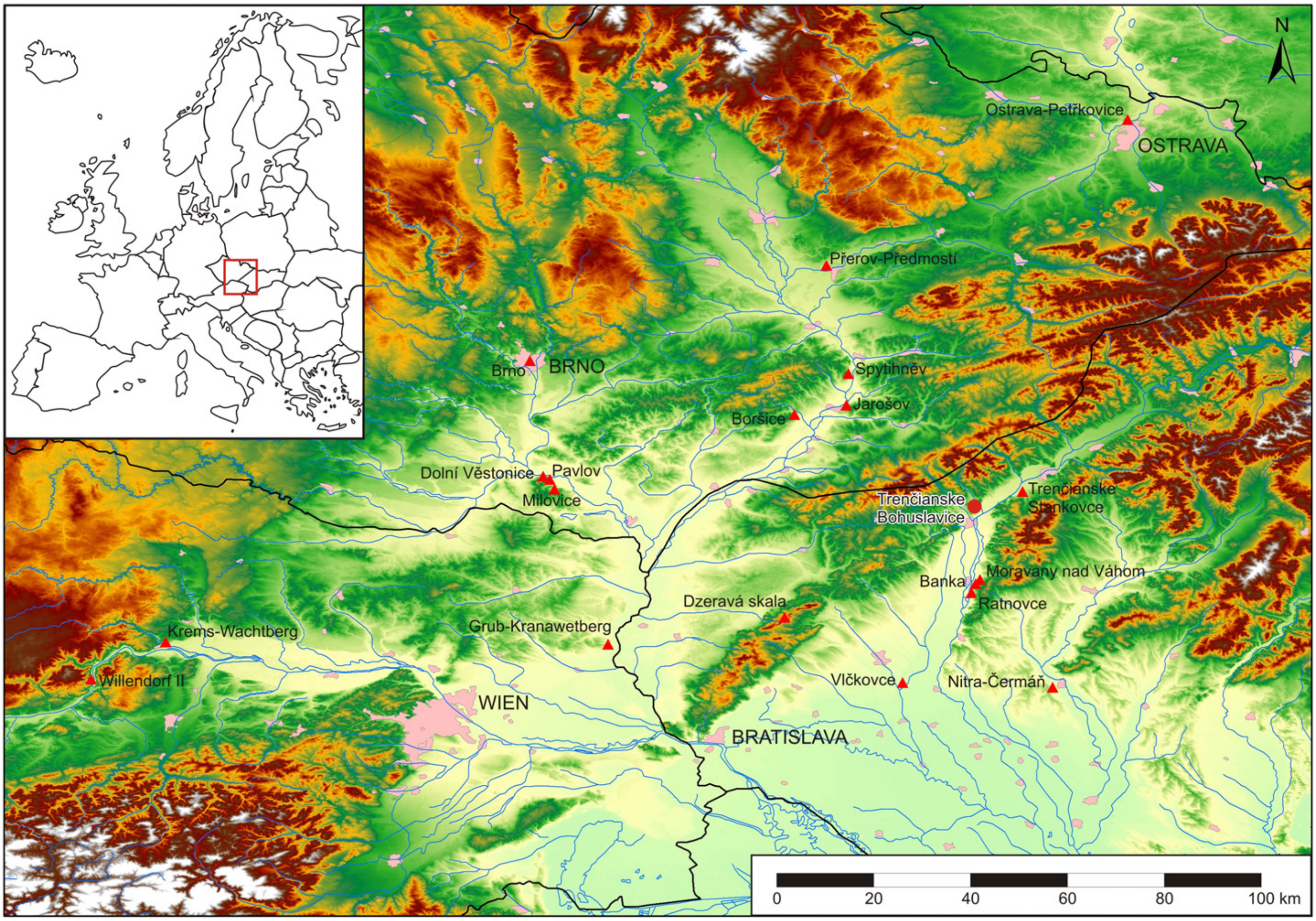

Fig. 1. Location of Trenčianske Bohuslavice site (dot) in the Middle Danube region with other important Gravettian sites from Slovakia, Moravia, Silesia and Austria. Sites are marked with triangles.

materials and fired clay pellets analyses, including radiocarbon dating of charcoals from each occupational level.

2. Location and geological setting

Trenčianske Bohuslavice is situated in Western Slovakia, about 15 km SW of Trenčín, on the right bank of the Váh River. The site is located ~350 m W of the village of Pod Tureckom on the right bank terrace of the Bošáčka Stream, covered by loess at 210–211 m a.s.l. (Bárta, 1986; 1988). The locality is situated near the entrance of the Bošácka dolina Valley, which is formed by massifs of the Turecký vrch and Hájnica Hills (Fig. 2). These two hills, together with the Beckov Castle Hill, located on the opposite side of the Váh River, define the SW edge of the Trenčín Basin, termed the Beckov Gate (Lukniš, 1946; Bárta, 1986). In terms of settlement strategy, the site is very well positioned at the narrowest point where the Váh River, the main communication route, is in contact with the foothills of Považský Inovec and White Carpathian Mountains, in a sheltered position of the lateral valley, which could also have served for passage into the present area of Moravia (Bárta, 1986).

The Trenčianske Bohuslavice-Pod Tureckom site is flanked by Mesozoic rocks of the Jablonica Nappe of the Hronicum Tectonic Unit, Upper Triassic Dachstein limestones and hauptdolomites of the Turecký vrch Hill (346.3 m a.s.l.). The northern foot is covered by Quaternary sediments – sandy gravels of the Bošáčka Stream terrace from the older part of the Last Glacial and overlain by younger loess and colluvial sediments (Salaj et al., 1987).

3. History of research

Trenčianske Bohuslavice as a Palaeolithic locality has been known since 1967 (Bárta, 1967). Systematic research of the locality begun in 1981 at workplace A (SE of the road from the village to the transformer station in the saddle between the Turecký vrch and Hradisko Hills) with trenches 1–6/81, which were dug out in terrain excavated by a bulldozer during filling up of the local brickyard mineshaft (approx. 170–180 cm of original overlying sediments were removed, so the Palaeolithic finds appeared directly below the surface). In addition, a 7 m deep stratigraphic trench was dug out in a road cut (NW of the road to the transformer station, where the surface was not lowered), and nine different sediment layers with two Palaeolithic horizons of occupation were found – the younger in the strongly calcareous loess layer C (equivalent to the main layer at the workplace A) and the older, with no palaeontological finds and raw material of radiolarite, in the underlying non-calcareous silty slightly clayey loess layer D (this layer represents PK I) (Bárta, 1986).

This stratigraphic trench was widened in 1982 and marked as workplace B (trench B1/82). In this year, research on workplace A (trenches 7–12/82) continued as well. There were two separated

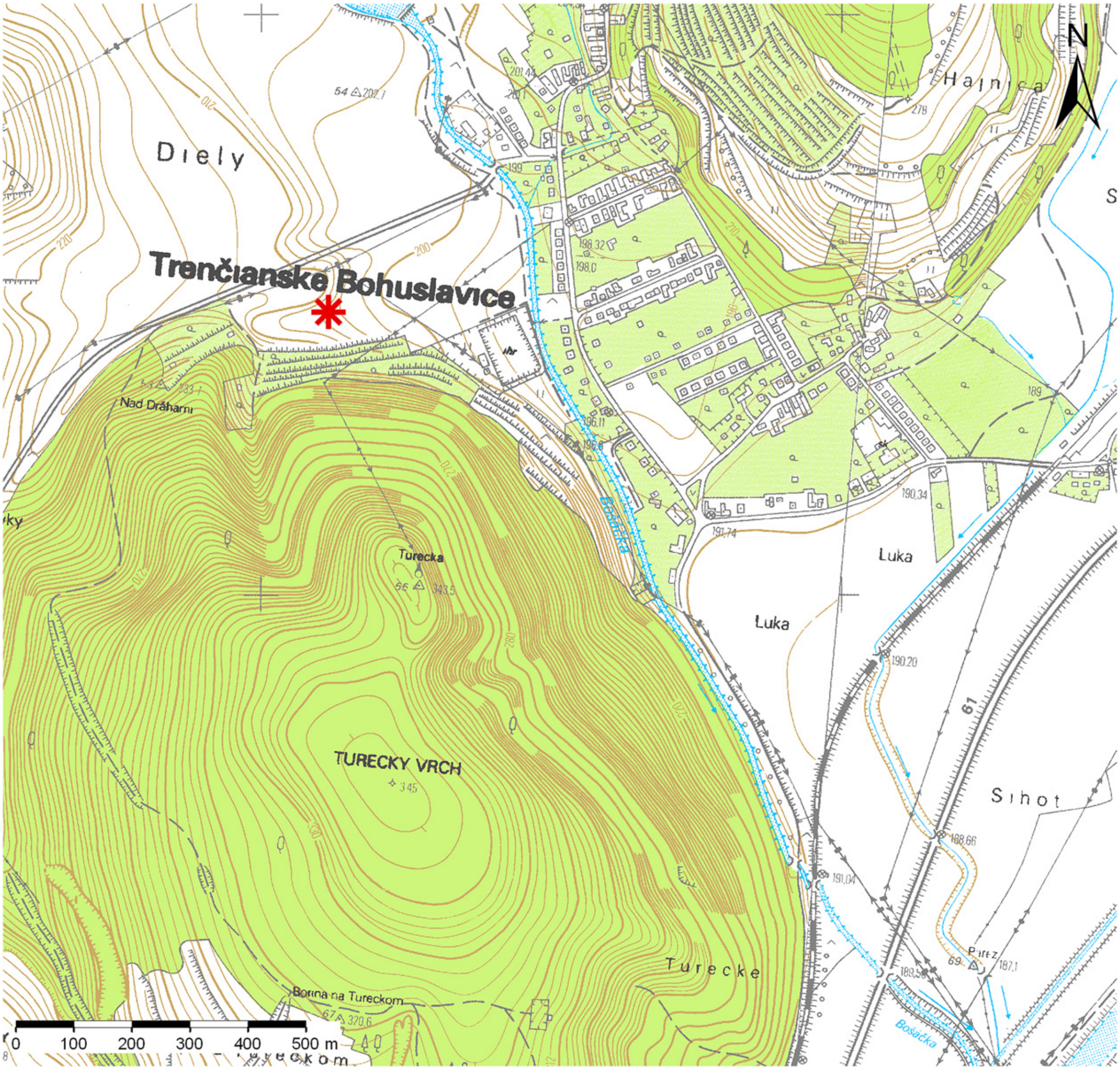

Fig. 2. Location of Trenčianske Bohuslavice-Pod Tureckom Gravettian site (asterisk). Váh River is situated in the bottom right corner of the figure.

horizons, the upper one with faunal remains, and lower older one without palaeontological finds and with industry made only from radiolarite. The lower layer was located in the sediment equivalent to layer D (PK I) in the stratigraphic trench at workplace B (Bárta, 1986).

Workplace B was extended northward (trench B2/83) in 1983, and trenches 13–24/83 were dug in workplace A. Beginning with trench 19/83 the probes were dug out in the intact terrain, which was not lowered by bulldozing. This allowed discovery of the youngest local Palaeolithic settlement layer in trenches 21–23/83, which was deposited relatively close to the ground surface (50–90 cm below the surface) and contained mostly industry made of radiolarite and not very plentiful palaeontological material. This season added workplace C, dug along a water pipe trench north of the municipal road. Only a few mammoth bones and stone artifacts were found at this workplace (Bárta, 1986).

Survey of trenches 23 and 24 was finished during the 1984 research season, when trenches 25 and 26/84 were investigated as well. The digging of trench 26 and the neighbouring trenches 27–29/85 were finished in 1985. The youngest layer of local Palaeolithic settlement, in which two hearths were found, played an important role. One of the hearths was unique, covered by flat pieces of sandstone (currently housed at the Nové Mesto nad Váhom Museum). Trenches 30–32/86 were uncovered in the last research year of 1986, while the trench 32/86 remained unfinished (Bárta, 1986).

4. Field and laboratory methods

The trench unearthed in 2008 with dimensions 2 × 1 m was oriented and located along a line of electrical wiring pillars. The electrical line is on the left side of the route from the village of Trenčianske Bohuslavice to the transformer station. The trench surveyed in 2008 was situated in a corner formed by Bárta's trenches 25/1984, 27/1985 and 26/1984–85. The trench was divided into eight quadrants A1–A4 and B1–B4 of 0.5 × 0.5 m dimensions. Found artifacts and bones were always left in place on elevated bases, and before removal they were located using a levelling device and photographed. J. Bárta did not use wet-sieving of the excavated sediment during his research, so the

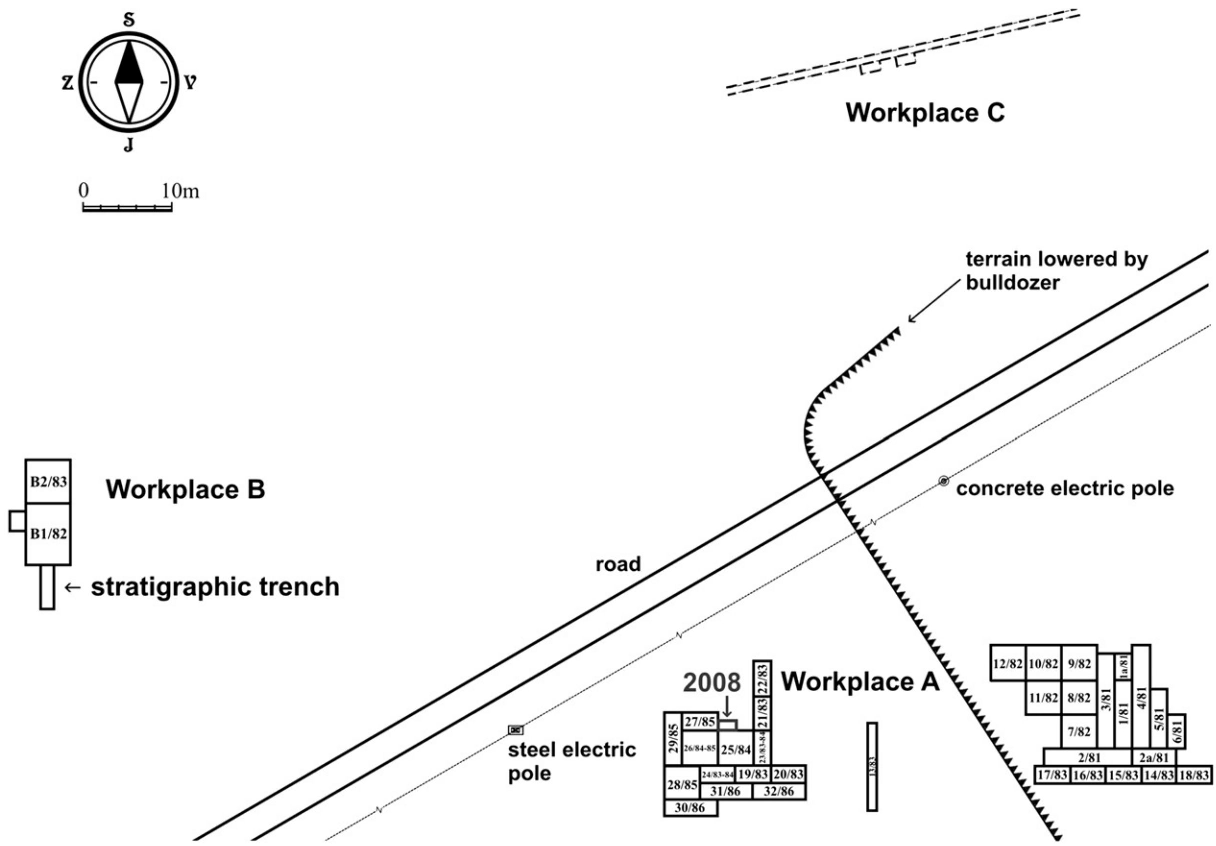

Fig. 3. Plan of archaeological research in Trenčianske Bohuslavice-Pod Tureckom. Localization of workplaces A, B, C and the trench from 2008 (modified from Žaár, 2007).

majority of small finds remained undiscovered. In the new research in 2008 the sediment was wet-washed in two plastic containers through sieves with 2 mm mesh size, so that even the smallest fragments of artifacts and bones could be captured.

4.1. Sedimentology

Lithostratigraphical logging was done on the B4 section of the northern wall. Individual lithostratigraphical units were described. Samples for magnetic susceptibility measurements were taken at 3 cm intervals from the B4 section. Five samples from individual units were taken for laser grain-size measurements. Charcoals from all three cultural layers were sampled for radiocarbon dating. Depths of dated cultural layers were used to calculate the average depositional rates for individual intervals of the late MIS 3.

Environmental magnetic susceptibility (MS) of unconsolidated samples was measured in plastic boxes as mass susceptibility (χ) in 10^{-9} m^3 kg^{-1} using an MFK1-FA Kappabridge at three different frequencies (kf1 = 976; kf2 = 3904 and kf3 = 15,616 Hz) in the AGICO, Ltd. The low-frequency (kf1) susceptibility was used as the standard. Frequency-dependent magnetic susceptibility (kFD) is given in standardised form kFD = (100.(kf1−kf3).kf1^{-1}) as proposed by Dearing et al. (1996) using the low- (kf1) and high-frequency (kf3) magnetic susceptibilities. For further summary of magnetic parameters and terminology, see Evans and Heller (2003).

Grain size was measured by laser diffraction methods using a Cilas 1064 granulometer for the 0.0004–0.5 mm fraction. Ultrasonic dispersion and washing in sodium polyphosphate were used prior to grain size analyses to avoid flocculation of analysed particles. The basic grain size characteristics are demonstrated by the graphic mean (Mz; Folk and Ward, 1957) and by the sand/clay ratio.

4.2. Radiocarbon dating

Accelerated Mass Spectrometry (AMS) radiocarbon analysis at the University of Groningen was used to date the three cultural layers. The dates were calibrated using the IntCal09 calibration curve (Reimer et al., 2009) and are given in years before present (conventionally before the year 1950 AD). Also calibrated were 11 radiocarbon dates from Trenčianske Bohuslavice-Pod Tureckom known from older literature (Bárta, 1988; Verpoorte, 2002).

4.3. Lithic raw materials of the Gravettian chipped industry

The excavation at the locality by Juraj Bárta in 1981–1986 revealed more than 8000 chipped artifacts, and their evaluation from the raw material point of view was carried out macroscopically (Žaár, 2007). A new collection obtained during the 2008 field research was inspected using a stereomicroscope. Magnetic susceptibility of hematite was measured by a KT-6 portable kappameter.

4.4. Fired clay pellets

As at other Central European Gravettian sites (e.g. Klíma, 1957, 1959; Králík et al., 2008; Svoboda et al., 2009), a sample of 85 small pellets of fired clay was obtained from wet-sieving. Given that the pieces of fired clay from Palaeolithic sites sometimes bear various imprints and traces such as fingerprints (see Králík and Novotný, 2005, for review), imprints of textiles (Adovasio et al., 1996), plant leaves (Králík, 2008), and animal hair traces (Králík et al., 2008), the sample of pellets was examined under the stereomicroscope.

4.5. Faunal remains

For the determination of faunal remains, the osteological atlases were used (Hue, 1907; Pales and Lambert, 1971; Schmid, 1972; Prat, 1987a, 1987b) Frequencies of skeletal elements were measured in terms of the Number of Identified Specimens (NISP) and Minimum Number of Individuals (MNI) (Klein and Cruz-Uribe, 1984; Lyman, 1994). All bones were examined closely in order to find all possible modifications, namely traces of processes caused by humans, animals and the abiotic environment (Wojtal, 2007). Specifically, all palaeontological material was carefully inspected using strong directional light to detect the presence of cut marks (Binford, 1981). For burned bones, the colour-based scheme of Dokládal (1999) was used to determine the burning temperature.

4.6. Analyses of the increment of tooth cement

It is not a complicated process to prepare a tooth thin section, and the same methods are used as are applied in other scientific disciplines such as geology or pedology (Fancy, 1980; Beasley et al., 1992; Nývltová Fišáková, 2007; Nývltová Fišáková, 2013). A thin-section of the tooth is made in the first third of the root. As the tooth enamel is hard yet fragile, the tooth needs to be cast in resin. The cross-section has to be covered by a protective slide, as a small percentage of air humidity can crack or otherwise damage the section. The cross-sections are studied under a polarising microscope using crossed nicols. For this study, 4–10× enlargement lenses are used and the resulting image is shot and recorded on a digital camera (Burke, 1993; Ábelová, 2005, 2008). The cementum analyses were done on a Nikon Eclipse LV 100 POL polarising microscope (Institute of Archaeology AS CR).

4.7. Stable isotope analyses

All isotope analyses in this work were performed in geochemical laboratories of the Czech Geological Survey. In order to determine the diet and thus the palaeoecology of reindeer and mammoth, the composition of carbon ($^{13}C/^{12}C$) and nitrogen ($^{15}N/^{14}N$) isotopes was used. Samples of dentine of one mammoth tusk and four reindeer teeth from layer III were used for analyses. For credible isotope analyses, it is important to maintain the original composition of isotopes of organic carbon and nitrogen and to remove alien and inorganic material. A well-proved methodology, used also for radiocarbon dating (Stafford et al., 1988), was employed. Determination of $^{13}C/^{12}C$ ratios used the methodology of McCrea (1950). The analyses were carried out by means of the procedure standard for this type of material. After combustion of the collagen in the elemental analysis (Fisons 1108), the products were chromatographically separated to nitrogen and carbon dioxide and analysed in a MAT 251 Finnigan mass spectrometer by comparison with reference gases of known isotopic composition. The whole procedure was controlled by means of international reference materials NBS 22 (NIST USA, $\delta^{13}C$ −29.75‰) and NZ1, NZ2 (IAEA Vienna $\delta^{15}N$ 0‰ and 20‰). The size of the sample was optimised so that the measurement error could not exceed 0.15‰ (Smrčka et al., 2004, 2006, 2008).

The $^{87}Sr/^{86}Sr$ ratio was used to reconstruct animal migration patterns. Except for one arctic fox humerus, the first molars of four reindeer were analysed, all from cultural layer III. The first molars are established during the prenatal development phase and their strontium ratio reflects the geological sub-soil their mothers lived on during pregnancy (Červený et al., 1999; Komárek et al., 2001). The shells of gastropods from the cultural layer were used to determine the ratio of strontium isotopes in the sub-soil. Strontium for determination of $^{87}Sr/^{86}Sr$ ratios from bone and tooth enamel samples was isolated using cation-exchange chromatography columns filled with Eichrom's Sr-spec resin. Isotopic analyses were performed using a Finnigan MAT 262 TIMS system. Samples were loaded onto a single tantalum filament, and measured in peak jumping mode. Further analytical details are specified in Míková and Denková (2007). The $^{87}Sr/^{86}Sr$ ratios were corrected for mass fractionation using the $^{86}Sr/^{88}Sr$ value of 0.1194 as an internal standard. External reproducibility is given by the results of repeated analyses of the NBS 987 reference material yielding an average $^{87}Sr/^{86}Sr$ value of 0.710246 ± 0.000022 (2 sigma), $n = 16$. The fossil bone composite reference material (Chavagnac et al., 2007) yields the $^{87}Sr/^{86}Sr$ value of 0.707750 ± 0.000028 (2 sigma), $n = 15$.

4.8. Pollen analysis

The sediment was analysed in the laboratory using the standard Erdtmann's method (Erdtman, 1960). The mineral bearing sediment was treated with HF and HCl, which removed the silicate and carbonate sediment matrix. An acetolysis solution ($H_2SO_4 + (CH_3CO)_2O$) and KOH were then applied to the samples. Acetolysis dissolves the organic particles. A secondary effect of the procedure is darkening of the pollen grains, which permits the identification of aperturation aspects and surface patterns. To obtain at least the minimum number of pollen grains, heavy liquid $ZnCl_2$ was used in addition to the common maceration methods. Due to the expected low concentration of sporomorphs, the maceration was not finished and the grains observed microscopically in the heavy liquid. The pollen spectra for every sample were examined on 5 slides. For identification, publications of Erdtman (1957); Erdtman et al. (1961); Rybníčková (1974); Moore et al. (1991) and Reille (1995) were used.

4.9. Malacological remains

The malacological examinations at the Trenčianske Bohuslavice-Pod Tureckom site were carried out using 6 samples obtained from the section in the middle of the northern wall of the 2008 trench. All the obtained samples were cut from profile with palette-knife and then divided into two equal parts, both about 2 kg. One collection of samples was examined by J. Kovanda and the second by K. Péková. Kovanda wet-sieved the sediment using an 0.5 mm mesh sieve, and Péková used 0.365 mm mesh. Undamaged shells of snails and identifiable fragments were then selected and counted. Standard malacological methods described by Ložek (1964), Alexandrowicz (1987) and Kernátsová (2001) were used. Quantitative palaeoclimatic values were calculated, using Gastropoda taxa, for which the optimum temperatures and resistance ranges were determined (Sümegi, 1989; Hertelendi et al., 1992; Sólymos and Sümegi, 1999), using the equation of Skoflek (1990) for calculating the July mean temperature of the investigated level.

5. Results and interpretations

5.1. Lithostratigraphy, grain size and magnetic properties of the studied profile

Three different lithostratigraphical units were differentiated in the B4 section; they are described in Fig. 4. The topmost unit (A) is described as ploughed soil with a sharp plough boundary, which delineates the topsoil from the underlying loess. It is a ∼26 cm thick humic A-horizon of a luvic chernozem or greysol, which contains common vertical fissures and small carbonate, Fe and Mn oxide mottles, carbonate concretions and plentiful organic remains and roots, often with carbonate incrustations. Strong

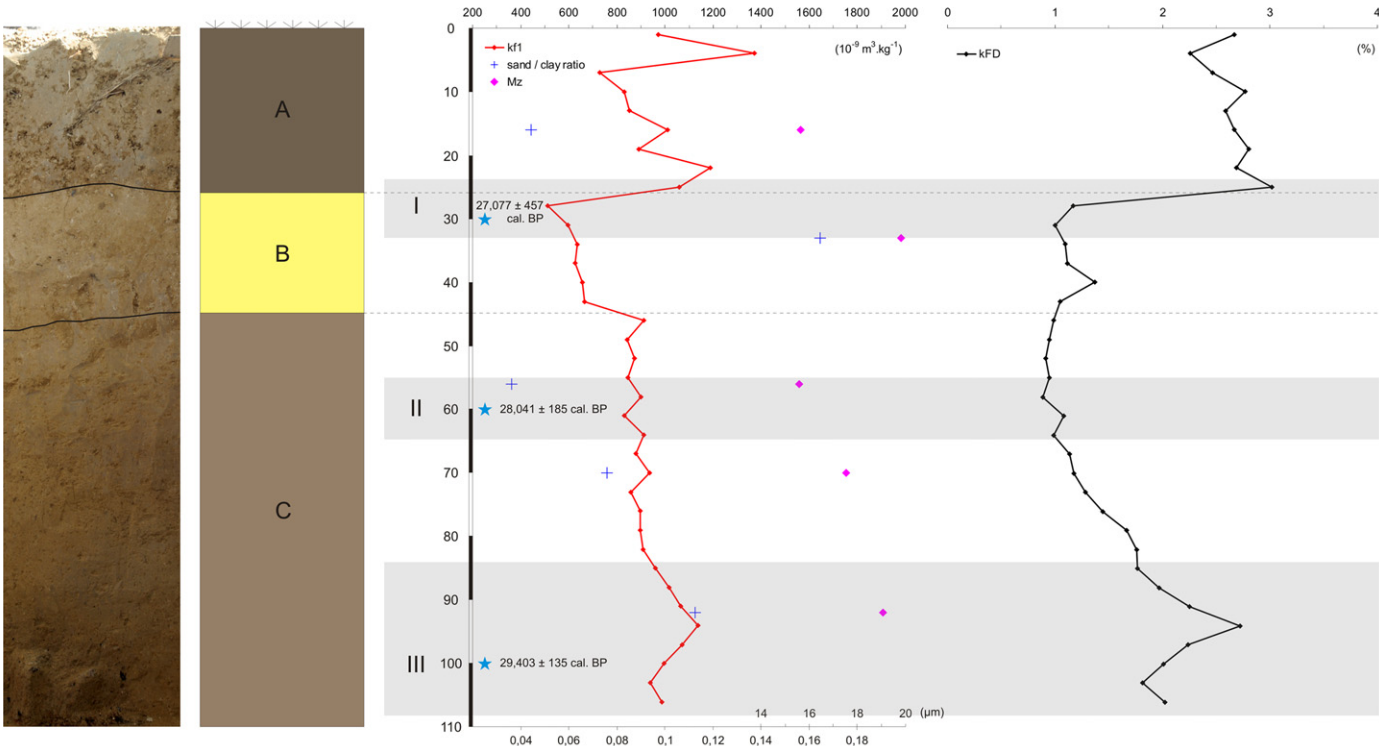

Fig. 4. Lithostratigraphical log of the studied section in the B4 sector of the 2008 trench at Trenčianske Bohuslavice-Pod Tureckom site. From left to right profile photo, basic lithostratigraphical log with units boundaries, graphs in the right reflect low-field magnetic susceptibility (kf1) in 10^{-9} m^3 kg^{-1}; sand/clay ratio; sediment graphic mean size (Mz) in μm; frequency-dependent magnetic susceptibility (kFD = 100*(Kf1−Kf3)/Kf3) in %. Shaded layers correspond to cultural layers I, II and III. Depth scale is in cm.

anthropogenic influence also is indicated by common brick pieces. The topsoil has very high magnetic susceptibility (kf1) values (>700.10^{-9} m^3 kg^{-1}), but reveals large vertical differences, frequency-dependent susceptibility (kFD) values shows also the highest values (2.3–3.0%) of the whole profile. The material is very poorly sorted with the mean size in the fine silt fraction (15.6 μm) and highest clay content (nearly 23%).

The underlying loess (B) is only ~20 cm thick and is typically light ochre-coloured with common small (up to few mm) calcareous concretions, infiltrations, Fe and Mn mottles and crotovinas (1–2 cm in diameter) filled by material from the overlying soil. Subvertical fissures mostly up to 10 cm long filled by carbonates continue from the overlying soil, and some make rim-like structures. The upper part of the loess represents illuvial horizon, where carbonates and clay are concentrated. The uppermost cultural layer (I) with some artifacts and charcoals were found in the upper part of the loess. In terms of magnetic properties, the loess unit has the lowest magnetic susceptibility (kf1) values of the whole profile studied (510–670.10^{-9} m^3 kg^{-1}). Frequency-dependent susceptibility (kFD) is also very low (1.0–1.4%) with a marked peak at 40 cm (Fig. 4). The loess unit is the coarsest unit of the whole studied profile. It contains ~3% very fine sand and <19% clay, and the mean size is 19.8 μm.

The underlying light brown calcareous clayey silts start at the depth of 46 cm and continue down to the base of the profile (110 cm). Fining upward was seen in the profile, which was subsequently supported by grain-size measurements (Fig. 4). These are interpreted as geliflucted colluvial deposits, with diverse proportions of reworked soil material (soil sediment), especially in the lower part of the studied profile. Subvertical calcareous infiltrations continue from the overlying loess. Two major sets of charcoals and artifacts, mostly from erratic flint and radiolarite, are concentrated at the depths of 55–65 cm and 84–108 cm. They are described as cultural layers and denoted as layer II (depth 55–65 cm) and layer III (depth 84–108 cm). The magnetic susceptibility (kf1) is rather uniform from the top of the unit C to the depth of ~85 cm, where values of ~850–950.10^{-9} m^3 kg^{-1} were measured; but is higher in the lowermost cultural layer (III), where it rises to ~1140.10^{-9} m^3 kg^{-1} at 94 cm (Fig. 4). Frequency-dependent susceptibility (kFD) may also be divided into two different parts. In the upper part of unit C (depth 46–64 cm) it is very low (0.9–1.1%), with a small peak at 61 cm, but it increases with depth with a maximum value at 94 cm reaching 2.7%. A fining upward trend was supported by grain-size measurements, where the coarsest material was found in the cultural layer III (depth 92 cm), where ~2% very fine sand and only ~17% clay was present. At the top of this unit, <1% very fine sand and nearly 22% clay was found. This fining upward trend is also supported by poor sorting and by decrease of the mean size from 19.1 μm to 15.6 μm.

5.2. Radiocarbon dating

All three cultural layers found during the 2008 research were dated. Individual charcoal samples were taken from the following depths: 30, 60 and 100 cm. Radiocarbon dates and their calibrated ages using the IntCal09 calibration curve (Reimer et al., 2009) are given in Table 1. All three ages lie at the end of the MIS 3. The calibrated ages from previous publications are also given in Table 1.

5.3. Archaeology

Three individual cultural horizons lying in superposition were found. Spatial distribution of artifacts and other finds in the three layers can be seen in Figs. 5 and 6. The most plentiful archaeological material (57 identified artifacts) from the lower cultural layer (III)

Table 1
Radiocarbon dates from the Trenčianske Bohuslavice-Pod Tureckom site (Bárta, 1988; Verpoorte, 2002; Žaár, 2007; Vlačiky, 2009). All ^{14}C dates were made on charcoal. Laboratory codes: Gd – Gliwice radiocarbon laboratory, GrA – Groningen AMS facility. Lab. nr. – laboratory number, Meas. – year of measurement.

Lab. nr.	Author	Meas.	Radiocarbon date (^{14}C years BP)	Calibrated age (years BP)	Trench/year/sector	Depth (cm)	Cultural layer
Gd-2490	Bárta	1986	23700 ± 500	28570 ± 548	28/1985	180	III
Gd-4009	Bárta	1986	22500 ± 600	27074 ± 773	B2/1983	260–290	III (B)
Gd-4010	Bárta	1986	23000 ± 1300	27649 ± 1540	23/1983–84	165 ?	III
Gd-4011	Bárta	1986	20300 ± 500	24286 ± 610	27/1985	58–60? 70	II
Gd-4014	Bárta	1986	23400 ± 700	28127 ± 1046	29/1985	90	II
Gd-4016	Bárta	1986	22800 ± 600	27461 ± 754	B1/1982	180	II (B)
GrA-6126	Verpoorte	2000	23100 ± 150	27946 ± 207	27/1985	70	II
GrA-6139	Verpoorte	2000	29910 ± 260	34688 ± 229	18/1983	120	IV ?
GrA-6161	Verpoorte	2000	23280 ± 140	28124 ± 200	B2/1983	270	III (B)
GrA-6162	Verpoorte	2000	25650 ± 160	30476 ± 172	24/1983–84	180	III
GrA-6163	Verpoorte	2000	25130 ± 170	29976 ± 245	20/1983	140	III
GrA-2311	Vlačiky	2009	22330 ± 110	27077 ± 457	2008/B1	30	I
GrA-2312	Vlačiky	2009	24540 ± 130	29403 ± 135	2008/A3	100	III
GrA-44244	Vlačiky	2009	23210 ± 100	28041 ± 185	2008/B3	60	II

can be described clearly as Gravettian in origin. Predominance of backed bladelets (13), coming mainly from wet-sieving (9 pieces of total 13) and presence of several retouched blades (5), pointed retouched blade and two burins (dihedral and burin on blade) represent the usual content of Gravettian lithic industries in Moravian and west-Slovakian sites (e.g. Svoboda (ed.), 2002). This layer was characterised by the rich presence of charcoals, which formed in the northern part of the trench (sectors B2 and B4) concentrations and continuous layers with burned sediment underneath.

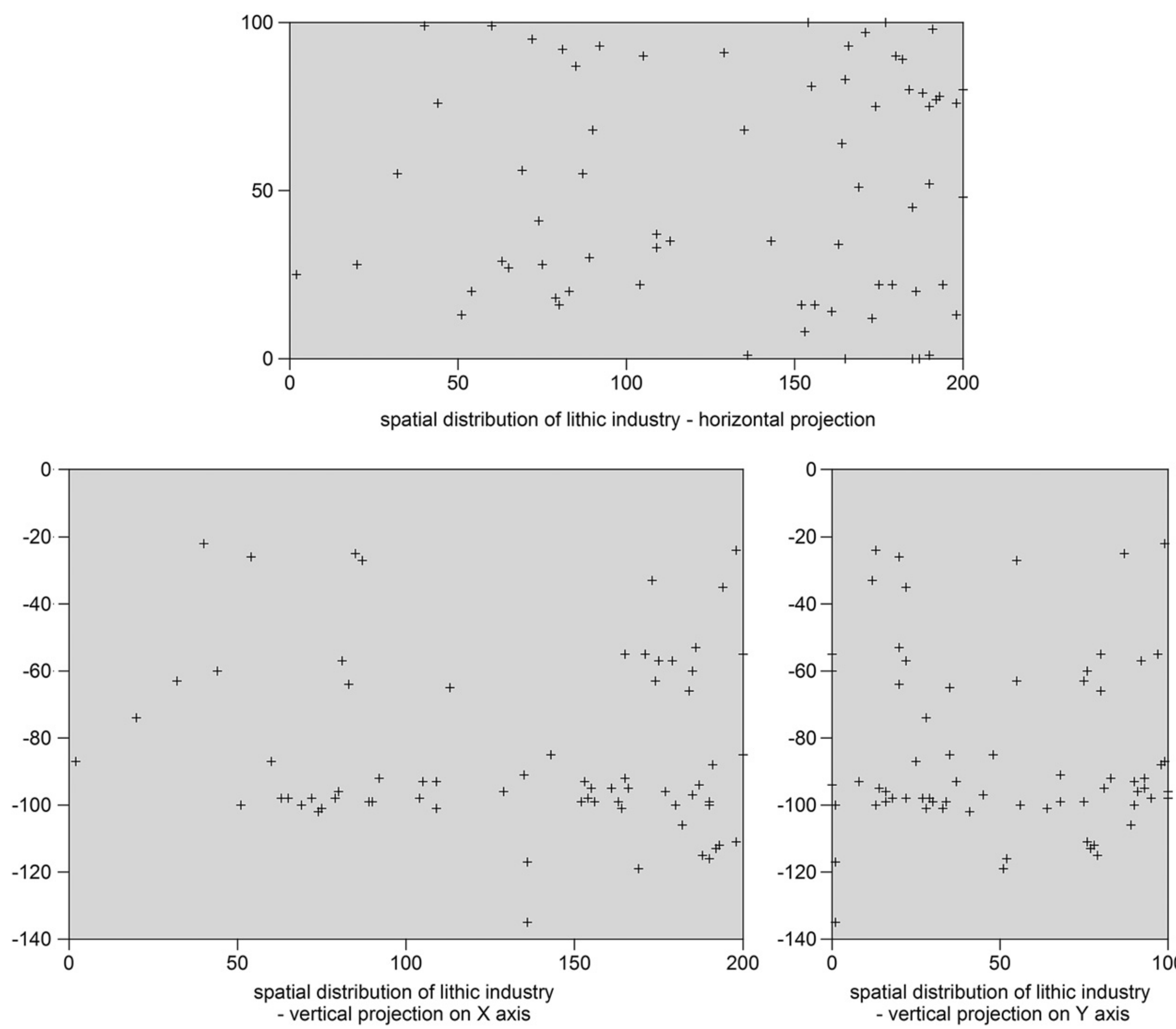

Fig. 5. Trenčianske Bohuslavice-Pod Tureckom, 2008 trench: spatial distribution of chipped lithic artifacts.

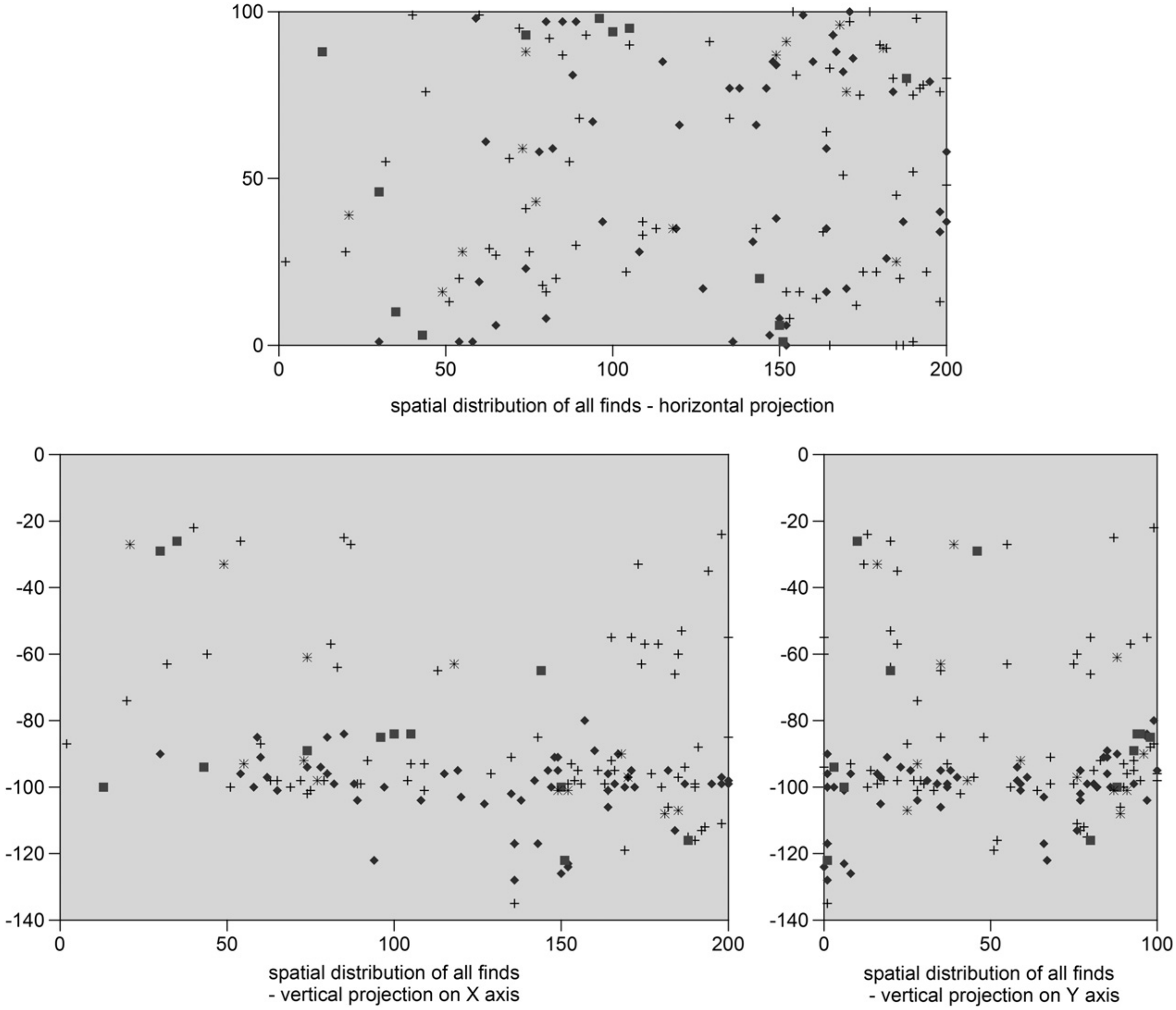

Fig. 6. Trenčianske Bohuslavice-Pod Tureckom, 2008 trench: spatial distribution of all finds. Annotations: + – chipped lithic artifacts, ■ – stones, ◆ – bones, * – charcoals.

The middle layer (II) was less numerous in finds (16 identified artifacts), but it also provided one combination of dihedral burin and single-blow burin on bilaterally retouched blade, made of erratic flint, one combination of endscraper and dihedral burin, made of erratic flint, and one backed bladelet from the wet-sieving, made also of erratic flint. This layer can also be described as Gravettian based on the lithic industry found. In the upper layer (I), except for 7 debitage pieces, only one tool, a truncated blade made of red-brown radiolarite, was found. The archaeological affiliation of the material found in cultural layer I and also from layers II and III to the Gravettian is supported by the radiocarbon ages of these layers (Table 1). In total, 406 artifacts were recovered from wet-sieving. Most (312 pieces) are fragments and chips with the greatest dimension <10 mm, and only 94 pieces have one dimension >10 mm. Also found were 104 small pieces of hematite.

5.4. Lithic raw materials of the Gravettian chipped industry

There is no doubt that the prevalent raw material from the Trenčianske Bohuslavice-Pod Tureckom site is represented by radiolarite of various colours (reddish brown, green to greenish grey, green with reddish brown spots, brown) (Fig. 7). Reddish brown or green colours are caused by iron oxide pigments in various stages of oxidation being dispersed in siliceous cement of the rock. According to the determination of O. Žaár, the radiolarite forms >50% of the chipped industry, more than 4000 artifacts (Žaár,

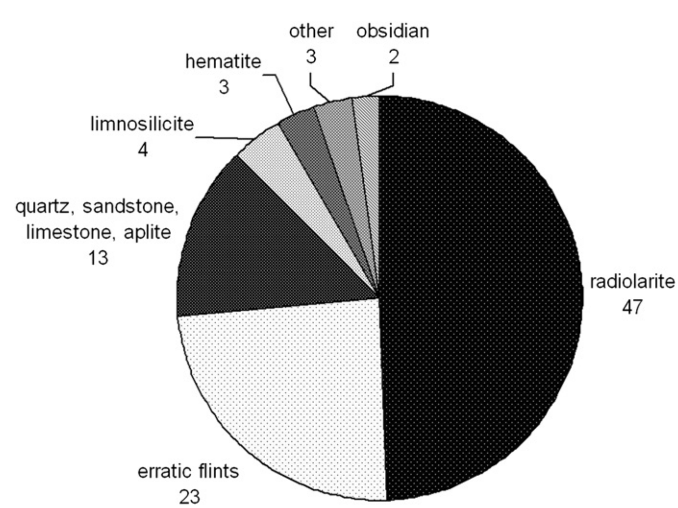

Fig. 7. Lithic raw materials of the Gravettian chipped industry from the Trenčianske Bohuslavice-Pod Tureckom site, 2008 trench, all three cultural layers together.

2007). In the new smaller collection (95 stone artifacts including limestone and sandstone pebbles, 81 pieces from the 2008 trench directly and 14 pieces from surface survey) it is 49.5% (47 items).

Silicites (erratic flints) from glacial sediments are the second most used raw material making about 40% in the collection of Bárta and only 24.2% (23 pieces) in the 2008 research. The estimation of their exact share at the locality is rather difficult because of the very intensive patina of the artifacts. In addition, the spectrum of siliceous rocks in glacial sediments is very wide, but generally the siliceous rocks of Danian age prevail over typical Maastrichtian flints. In spite of the patina, numerous relics of Bryozoa could be observed in some artifacts as a typical sign of silicites of Danian age (Gába and Pek, 1999) originating from glacial sediments.

Other raw materials appeared only sporadically. Volcanic obsidian was used in 56 artifacts, i.e. 0.7% in Bárta's collection (Žaár, 2007). The new excavation revealed 2 obsidian artifacts (2.1%). Probably, only a few artefacts (4 pieces; 4.2%) were made of limnic silicite, a very popular raw material in the Slovak Palaeolithic with deposits in central and eastern Slovakia. Besides typical chipped artifacts mentioned above, pebbles or parts made of calcareous or non-calcareous quartz sandstones, glauconite, dark limestone and tourmaline aplite were found (13 pieces; 13.7%). They represent local raw material collected in gravel of the Váh River or its tributaries. Special comment is devoted to finds of natural colouring pigment containing hematite. A few (3 pieces; 3.2%) small irregular pieces of the pigment have a typical red streak and magnetic susceptibility in the range of $0.09–0.22.10^{-3}$ SI. Traces after crushing have been also found on one piece of calcareous sandstone.

5.5. Fired clay pellets

The size of the pellets (the largest length/measurement) ranges from 2.7 mm to 32.4 mm, the average value is 6.0 mm and median 5.3 mm. These parameters exclude a group of nine objects, which apparently originated from recent disintegration/breakage of a larger piece. The objects are rounded or irregular and they have different hardness, but most of them are poorly fired (some not at all) and they can be easily rubbed on paper. These pellets and fragments can be divided into several categories by colour: light ochre, tan, orange, grey-brown, grey, and grey-black. Brighter orange colours reflect oxidizing environments, while darker colours reflect reducing environments.

Unfortunately, as in findings from other sites, the sizes of most of the objects and/or state of preservation of their original surfaces are insufficient to capture interpretable traces. No fingerprints or other distinct traces have been found. The exception is the largest object, an irregular fired clay piece 32.4 mm in size, which bears several recognizable traces/hits caused by hard objects (wood? bone?). One has a regular oval shape with sharp edges; the other is narrow and jagged. In addition to the described traces, a substantial number of the pellets (in 54 of 85 cases) possess small circular or oval cavities/holes. Frequently, several of these features were present on a piece. The shortest diameter measured in these cavities varied between 80 and 350 μm, with a mean of 152 μm.

5.6. Faunal spectrum

The spatial distribution of faunal remains from the 2008 trench can be seen in Fig. 8. No bones were found in layer I, and only small unidentifiable fragments of burned bones after wet-sieving were discovered in layer II. Unlike the other two layers, the lower layer (III) was rich in palaeontological material. Eighty pieces of various faunal remains were stratified and numerous fragments of bones were found during wet-sieving of the sediment. The total number of stratified faunal elements identified to taxon (NISP) is 41. The remains of mammoth (NISP: 8), reindeer (7), arctic fox (11) and hare (15) were recognized in the material. Another reindeer bone, 6 bones from arctic fox and a hare incisivus and phalanx were identified during wet-sieving of the sediment. Minimum number of individuals (MNI) of animals from the 2008 trench is one for each species. Interesting finds were an almost complete left hind autopodials of the arctic fox (quadrant A4) and the young hare (quadrant B3, in the hollow with a piece of hematite and the backed bladelet), found partly in anatomical position. No direct traces of intentional activity (such as cut marks) were found on the material. However, some of the bones from wet-washing showed signs of burning (they were grey-black to white-grey), namely the second phalanx of hare (A3, depth 90–100 cm), the distal epiphysis of left radius (A1, depth 70–80 cm) and the first phalanx of arctic fox (B4, depth 90–100 cm). According to the colour of these three burned bones, they must have been burned at 500–600 °C.

The hunted game from the Gravettian site in Trenčianske Bohuslavice-Pod Tureckom, from Bárta's and 2008 research together, belonged to the following species and genera: *Rangifer tarandus* (reindeer), *Equus germanicus* (horse), *Mammuthus primigenius* (mammoth), *Vulpes lagopus* (arctic fox), *Bos/Bison* sp. (aurochs/steppe wisent), *Ursus arctos* (brown bear), *Canis lupus* (wolf), *Castor fiber* (beaver), *Coelodonta antiquitatis* (woolly rhinoceros), *Lepus* sp. (hare), and *Cervus elaphus* (red deer). Based on the number of bones and teeth found, reindeer dominated, followed by horse and those of mammoth and arctic fox. Other mammal species were rare (Fig. 9).

5.7. Analyses of the tooth cement microstructure

A total of 9 thin-sections of reindeer teeth were studied (Table 2). Four reindeer teeth do not have preserved cement increments. On the molar from trench 25/85, the summer increment is not fully complete and the winter increment had not yet begun to grow. This means that the animal must have been hunted between September and November. The other reindeers were hunted in spring (April to June), as the winter increment on their teeth is complete, but the summer accretion had not begun to form.

5.8. Stable isotope analyses

5.8.1. Faunal diet and palaeoecology

The $\delta^{13}C$ values of the reindeers studied from Trenčianske Bohuslavice site ranged from −19.5‰ to −20.7‰, and the $\delta^{15}N$ values from the same reindeers varied from 5.1‰ to 6.9‰ (Table 3). The $\delta^{13}C$ values from studied mammoth tusk dentine (trench 20/83) ranged from −10.8‰ to −8.3‰ (Table 4). The $\delta^{13}C$ values of the food consumed by the mammoth ranged from −24.9‰ to −22.4‰. This indicates that there were changes in dietary intake during the life of this animal.

5.8.2. Faunal migration

The strontium ratios of arctic fox, four reindeer and gastropods from Trenčianske Bohuslavice-Pod Tureckom site are shown in Table 5. From Fig. 10, the $^{87}Sr/^{86}Sr$ values of the reindeer and arctic fox are different and higher than that of the snails.

5.9. Evaluation of malacofauna

The flotation of sieved sediment yielded 13 (Kovanda) or 16 (Péková) taxa of mollusca (Tables 6 and 7). Four (*Vertigo parcedentata*, *Columella columella*, *Pupilla loessica* and *Vallonia tenuilabris*) pertained to species of so-called collumelar faunas during the glacial maximum. Another 8 species sporadically occurred in

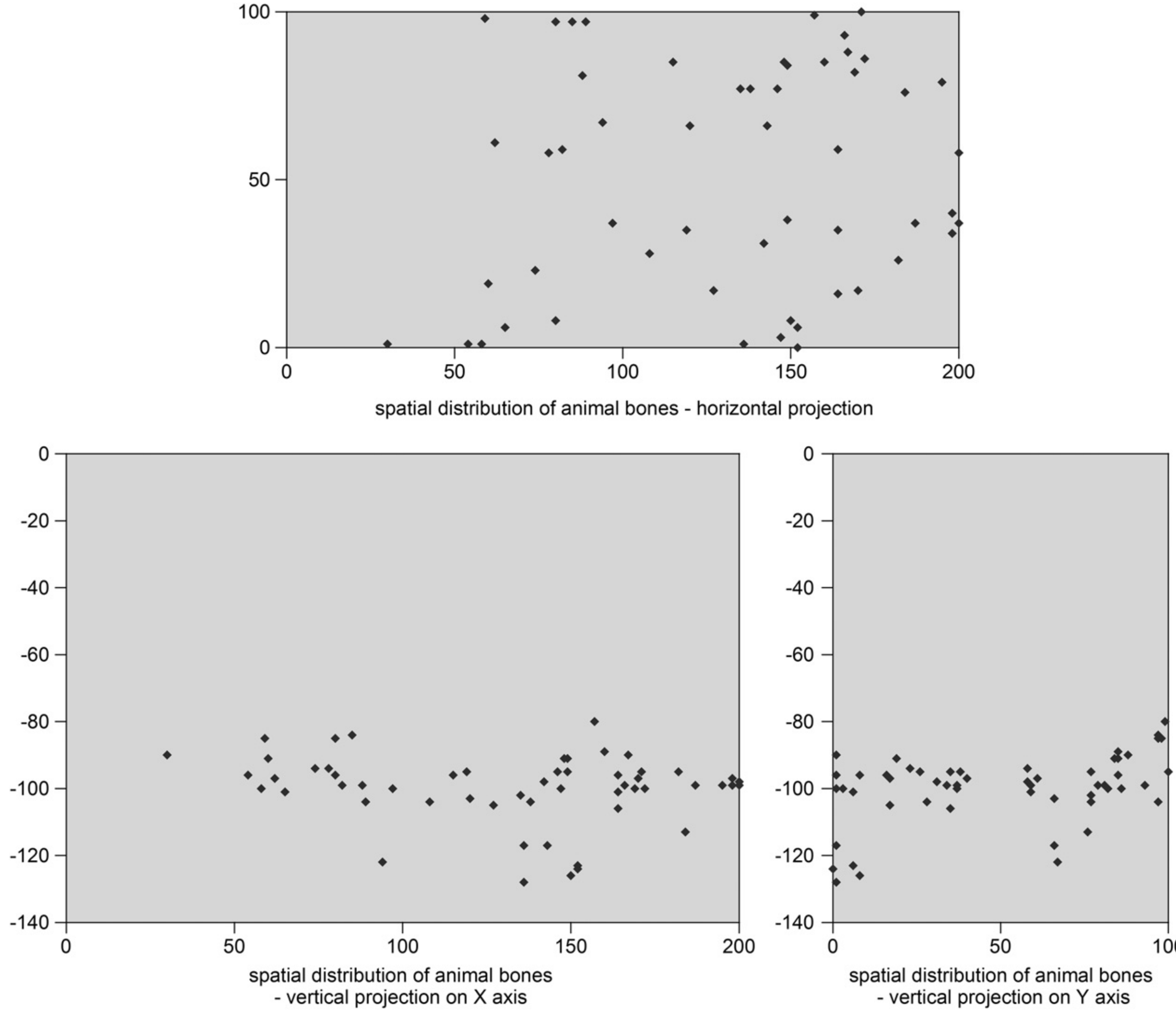

Fig. 8. Trenčianske Bohuslavice-Pod Tureckom, 2008 trench: spatial distribution of bones.

loess, but they palaeoclimatically correspond to the so-called transition periods between stadials and interstadials (*Pupilla triplicata*, *Pupilla muscorum*, *Vallonia costata*, *Trochulus hispidus*, *Clausilia dubia*, *Succinella oblonga* with its subspecies *S. o. elongata*). These are mostly the representatives of open (grassed) areas, and the taxa are fully independent from biotope types. There is one steppe species, *Pupilla triplicata,* and one hygrophilous species (*S. oblonga* and *S. o. elongata*). Quantitative palaeoclimatic values for taxa identified and counted by Péková are given in Table 7.

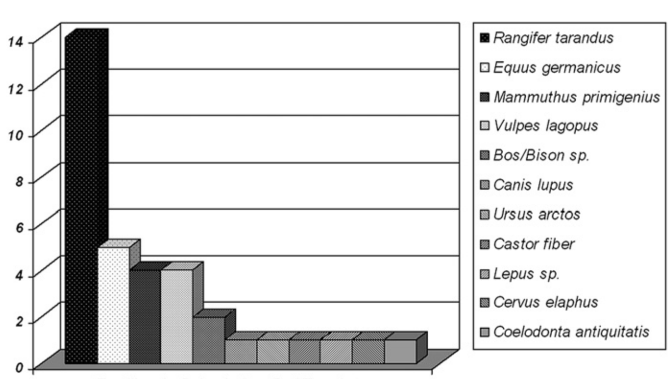

Fig. 9. Minimum number of individuals for the identified taxa (from Bárta's research and 2008 trench together) from the Trenčianske Bohuslavice-Pod Tureckom site.

5.10. Pollen analysis

A total of 6 samples were processed. Under the microscope, the samples contain undissolved mineral admixture and lesser amount of organics (destroyed plant tissues). The sample from the depth

Table 2
Localisation, tooth type and death season of reindeers from the Trenčianske Bohuslavice-Pod Tureckom site.

Localisation	Species	Tooth type	Tooth age	Hunting season
26/85	*Rangifer tarandus*	molar-M_3	–	–
19–20/83	*Rangifer tarandus*	molar-M^1	3	IV–VI
Surface collection	*Rangifer tarandus*	premolar-P_3	2	IV–VI
Cultural layer III	*Rangifer tarandus*	molar-M_3	–	–
Cultural layer III	*Rangifer tarandus*	molar-M_1	–	–
Cultural layer III	*Rangifer tarandus*	premolar-P_4	–	–
25/85	*Rangifer tarandus*	molar-M_1	3	IX–XI
24/84	*Rangifer tarandus*	premolar-P^2	2?	IV–VI
30/86	*Rangifer tarandus*	premolar-P^2	2?	IV–VI

Table 3
Carbon and nitrogen isotope ratios of reindeers from the Trenčianske Bohuslavice-Pod Tureckom site.

Species	$\Delta^{13}C$ (‰)	$\Delta^{15}N$ (‰)	N%	C/N	C%
Rangifer tarandus, dens	−19.5	5.1	8.0	3.0	23.6
Rangifer tarandus, dens	−20.4	5.8	13.7	2.9	39.3
Rangifer tarandus, dens	−20.3	5.3	10.2	2.9	29.9
Rangifer tarandus, dens	−20.7	6.9	13.6	2.9	39.7

105 cm (cultural layer III) contained greater amounts of separated organics. Almost all of the samples were sterile, and therefore pollen diagrams cannot be constructed. Only in three cases palynomorphs were present, unfortunately of limited value (Table 8).

6. Discussion

6.1. Lithostratigraphy, grain size and magnetic properties of the studied profile

Magnetic susceptibility variations have been successfully used to reconstruct palaeoclimatic trends in loess-palaeosol sequences worldwide (Heller et al., 1991; Muhs et al., 1999; Evans et al., 2003). Numerous studies indicate that the carriers of the magnetic susceptibility signal in loess-palaeosol sequences are ultrafine and fine superparamagnetic minerals produced by in situ pedogenetical biological processes (Maher and Thompson, 1992, 1995), this is true for Chinese loess plateau (Zhou et al., 1990; Heller et al., 1991), as well as for European loess sequences (Antoine et al., 2001). On the other hand, the wind-vigour model, where higher magnetic susceptibility values are connected with loess layers deposited by stronger winds, which transported dense iron oxide particles, was found to be typical for more continental climate conditions in Siberia (Evans et al., 2003) and Alaska (Begét and Hawkins, 1989). Kletetschka and Banarjee (1995) showed that the magnetic signal in loess may be produced by heating and cooling and thus can be a human-made phenomenon at archaeological sites (Crowther and Barker, 1995). However, higher values of magnetic susceptibility can also be found for large detrital clay grains (>1 μm), as was shown by Maher and Thompson (1995).

The magnitude of the magnetic susceptibility cannot be used as the direct indicator of pedogenic intensity (Chen et al., 1999), as the magnetic signal is influenced mainly by concentrations of diamagnetic and paramagnetic minerals (Evans and Heller, 2003). For that reason, the frequency-dependent magnetic susceptibility (kFD) is used, as it shows the proportional contribution of superparamagnetic minerals to the magnetic susceptibility record and can thus be used as a more reliable indicator of the pedogenesis (Chen et al., 1999).

Ultrafine and fine grains (<0.05 μm) as defined by Maher and Thompson (1995) are not present in the grain-size analyses. The highest enrichment of the humic A-horizon (A) compared to its parent metarial (the underlying loess, unit B) is in the coarse clay to fine silt fractions (2–8 μm), peaking around 4 μm. This is

Table 4
$\delta^{13}C$ and calculated $\delta\ ^{13}C_{food}$ values from studied mammoth tusk dentine from the Trenčianske Bohuslavice-Pod Tureckom site (trench 20/83). MP TB – *Mammuthus primigenius*, Trenčianske Bohuslavice.

	MP TB 1 (external part of the tusk)	MP TB 2	MP TB 3	MP TB 4	MP TB 5 (internal part of the tusk)
$\Delta^{13}C$ (‰ PDB)	−8.8	−8.7	−8.3	−9.2	−10.8
$\Delta^{13}C_{food}$(‰ PDB)	22.9	22.8	22.4	23.3	24.9

Table 5
Strontium isotope ratio of arctic fox, four reindeers and gastropods from the Trenčianske Bohuslavice-Pod Tureckom site.

$^{87/86}Sr$	2σ error	Species
0.709731	0.000015	*Vulpes lagopus*
0.70987	0.000019	*Rangifer tarandus*
0.709518	0.00002	*Rangifer tarandus*
0.709577	0.000018	*Rangifer tarandus*
0.709464	0.000015	*Rangifer tarandus*
0.708584	0.000004	snail

accompanied by lower shares of the coarsest fractions (>36 μm). The enrichment of the topsoil is caused by the presence of decomposed organic matter and by chemical weathering of larger particles. Higher kf1 and kFD values of the topsoil (A) comparing to the underlying loess (B) correlates with increased intensity of pedogenetic processes during warmer and especially wetter conditions, with higher supply of organic matter and Fe and a rather well-drained soil above the loess, which produce higher magnetic susceptibility (by higher concentrations of magnetite and maghemite) during a greater number of wetting and drying cycles (Maher and Thompson, 1995). The same is true for the lower part of colluvial unit (C) with soil sediment admixture, where the lowermost cultural layer (III) is present. No clear magnetic changes could be found for the middle cultural layer (II). Lower kf1 values of the loess unit (B) reflect rather dry conditions, when Fe oxides are more oxidised forming more hematite and goethite (Maher and Thompson, 1995). The rapid increase of magnetic parameters in the upper part of the loess (B) is affected by pedogenic processes connected with the overlying topsoil.The fining upward trend in colluvial sediments may be seen in enrichment in the fine to medium clay (<2 μm) and in a slighter increase in the fine silt fraction (5–8 μm) and in depletion of the coarsest fraction (>40 μm), and is accompanied especially by the decrease of kFD.

6.2. Radiocarbon dating

From the Trenčianske Bohuslavice-Pod Tureckom Gravettian site, there are now 14 radiocarbon dates, including three new dates from the 2008 trench (Table 1). The first three of dates (Gd-4009, Gd-4010 and Gd-4011) were published by Bárta (1988). Verpoorte (2002) dated another five charcoals from Bárta's research, and incorrectly stated the place of origin of the GrN-16139 sample. Verpoorte in his paper also mentioned the first three dates and one unpublished (Gd-2490), but he located them incorrectly or incompletely. This paper corrects these errors by using Bárta's

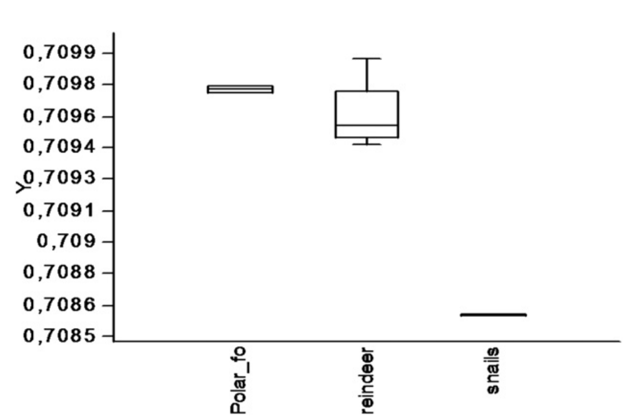

Fig. 10. Box plots of strontium isotope ratios of arctic fox, the group of four reindeers and husk of snails from the Trenčianske Bohuslavice-Pod Tureckom site.

Table 6
Malacofauna from the Trenčianske Bohuslavice-Pod Tureckom site, 2008 trench (Kovanda). Annotations: X – abundant; x – rare; (x) – uncertain determination.

Taxon/depth	25 cm	45 cm	65 cm	85 cm	105 cm	125 cm
Succinella oblonga Drap.	X		x			
Succinella oblonga elongata Sndb.	X	X	x	x	x	
Vertigo parcedentata (Br.)		x				
Pupilla muscorum (L.)	X	X	X	X	X	X
Pupilla loessica Ložek	X		X	x	x	
Pupilla triplicata (Stud.)	x	x	X	X	X	X
Pupilla sterrii (Voith)			x	x		
Columella columella (Mart.)	x	x				
Vallonia tenuilabris (Br.)	x	X	x		x	
Vallonia cf. *costata* (Müll.) frgm.						x
Clausilia dubia Drap.	x			x	x	
Trochulus hispidus (L.)	(x)	x	(x)		(x)	x
Limacidae sp.						x

original documentation, and an overview of places of origin of all dates (Bárta, 1986) is offered for clarity.

From the main layer at workplace B (260–290 cm) came two dates, 27,074 ± 773 and 28,124 ± 200 cal. BP. Despite the availability of original documentation of the research, the location of the date 27,461 ± 754 cal. BP (Gd-4016) remains problematic. A depth of 180 cm is mentioned, but the initial findings from workplace B during both years of research (1982 and 1983) were located at a depth of >200 cm. Furthermore, this workplace was dug to180 cm depth using an excavator in 1983. Therefore, it is assumed that the dated sample could come from the original stratigraphic trench in this workplace, about the depth of the shallower deposited cultural layer with charcoals and isolated artifacts made of radiolarite. Due to the distance between workplaces A and B (about 100 m or more), correlation between cultural layers on these workplaces is very speculative, if at all possible.

The youngest phase of Gravettian settlement in workplace A (by Bárta, 1986; 1988, according the situation in the 2008 trench it is cultural layer II) is represented by three dates. Two originate from the same solifluction-breached hearth on the boundaries of trenches 26/84–85 and 27/85: 24,286 ± 610 cal. BP (Gd-4011) and 27,946 ± 207 cal. BP (GrN-16126). The difference in dating the same hearth between the Gliwice and Groningen laboratories is >3500 calendar years. The third date of 28,127 ± 1046 cal. BP (Gd-4014) comes from organic material on flat pieces of sandstone-covered hearth from trench 29/85. Workplace A provided a further four dates, three from the main archaeological layer (by Bárta, 1986; 1988; according the situation in the 2008 trench it is cultural layer III) in the group of trenches situated more to the west: 28,570 ± 548 cal. BP (Gd-2490), 29,976 ± 245 cal. BP (GrN-16163) and 30,476 ± 172 cal. BP (GrN-16162). The last date, 34,688 ± 229 cal. BP (GrN-16139), is problematic. Verpoorte (2002) incorrectly stated the place of origin of this date as trench IB/18, but according to the original documentation a trench with this designation did not exist. Therefore, Žaár (2007) believes this date came from trench 18/83, as in this trench at the depth of 120 cm a large cluster of charcoals was found.

Table 7
Malacofauna and calculated mean July palaeotempereature from the Trenčianske Bohuslavice-Pod Tureckom site, 2008 trench (Péková). Bolded are species used for mean July palaeotempereature calculation.

Taxon/depth	25 cm	45 cm	65 cm	85 cm	105 cm	125 cm	Σ
***Vitrea crystallina* (Müll.)**		14					14
***Pupilla muscorum* (L.)**	124	140	52	69	25	4	414
Pupilla muscorum elongata (Ložek)		2					2
Pupilla muscorum densegyrata (Ložek)	73	90	15	16	3	1	198
Pupilla sterrii (Voith)	1	43	2	12	7		65
Pupilla loessica Ložek	38	43	7	10	2		100
***Pupilla triplicata* (Stud.)**		1	4	36	11	2	54
***Vallonia tenuilabris* (Br.)**	52	49	4				105
***Clausilia dubia* Drap.**	1	3					4
***Succinella oblonga* Drap.**	58	59	1	1		1	120
Succinella oblonga elongata Sndb.	48	42					90
***Trochulus hispidus* (L.)**	11	19					30
Cochlicopa lubrica (Müll.)		1					1
Vallonia enniensis (Gred.)	4	4					8
Cochlicopa nitens Gall.		1					1
Sphaerium corneum (L.)		1					1
Pupilla sp.	125	269	68	61	16	4	543
Trichia sp.	2	3					5
Clausilidae sp.	1	1		1	2		5
Σ	538	785	153	206	66	12	1760
Mean July palaeotemperature (°C)	**14.5**	**14.7**	**15.8**	**17.4**	**17.2**	**17.1**	

Table 8
Found sporomorphs from the Trenčianske Bohuslavice-Pod Tureckom site, 2008 trench.

Taxon/depth	25 cm	45 cm	65 cm	85 cm	105 cm	125 cm
Abies (fir)	0	1	0	0	0	0
Betula (birch)	1	0	0	0	0	0
Pinus (pine)	1	0	1	0	0	0
Asteraceae	1	0	0	0	0	0
Poaceae	1	0	1	0	0	0
Rosaceae	1	0	0	0	0	0
undetermined Algae	2	0	0	0	0	0

All three newly dated charcoal samples fall in the range of 26,000–30,000 cal. BP (see Table 1 and Fig. 11). They may be compared with the standard palaeoclimatic records, such as the NGRIP $\delta^{18}O$ (NGRIP, 2004; Andersen et al., 2006). Two Greenland interstadials (GI, formerly Dansgaard-Oeschger events; e.g., Johnsen et al., 1992; Andersen et al., 2006) fall in this time period (see Fig. 11). All the three dates from individual archaeological layers fall in stadial conditions. Similar stadial ages were found for other Gravettian sites in the Danube region of Moravia: Dolní Věstonice I–III (Svoboda, 2002), Pavlov VI (Svoboda et al., 2009), Milovice (Oliva, 2009), Boršice, Jarošov (Škrdla, 2005; Škrdla et al., 2006), Spytihněv (Škrdla et al., 2008b) and Austria: Willendorf II (Nigst et al., 2008). This may help, together with the seasonality and raw material and typology of artifacts, to trace the migration of individual groups of Palaeolithic people in the Middle Danube region. However, more dated sites are needed to reveal details.

6.3. Archaeology

Due to the extent of the field research in Trenčianske Bohuslavice in 2008 (2 m^2), the material unearthed here is very limited, but can be compared with the enormous amount of lithic industry excavated by J. Bárta during his research in the 1980s. Generally, the new observations are similar to the analysis of Bárta's lithic material made by Žaár (2007). The Trenčianske Bohuslavice site is known as the representative of the stratified west-Slovakian sites from the younger phase of the Gravettian, the "shouldered points horizon" (Bárta, 1988). Other names given to this phase (Willendorfian-Kostienkian, etc.) are sometimes used as synonyms. The main methodological problem is that the shouldered point, *fossile directeur,* was never discovered at this site. On the other hand, the site provided a nice collection of leaf points, almost all made of radiolarite, mainly red (Bárta, 1988; Žaár, 2007). What is

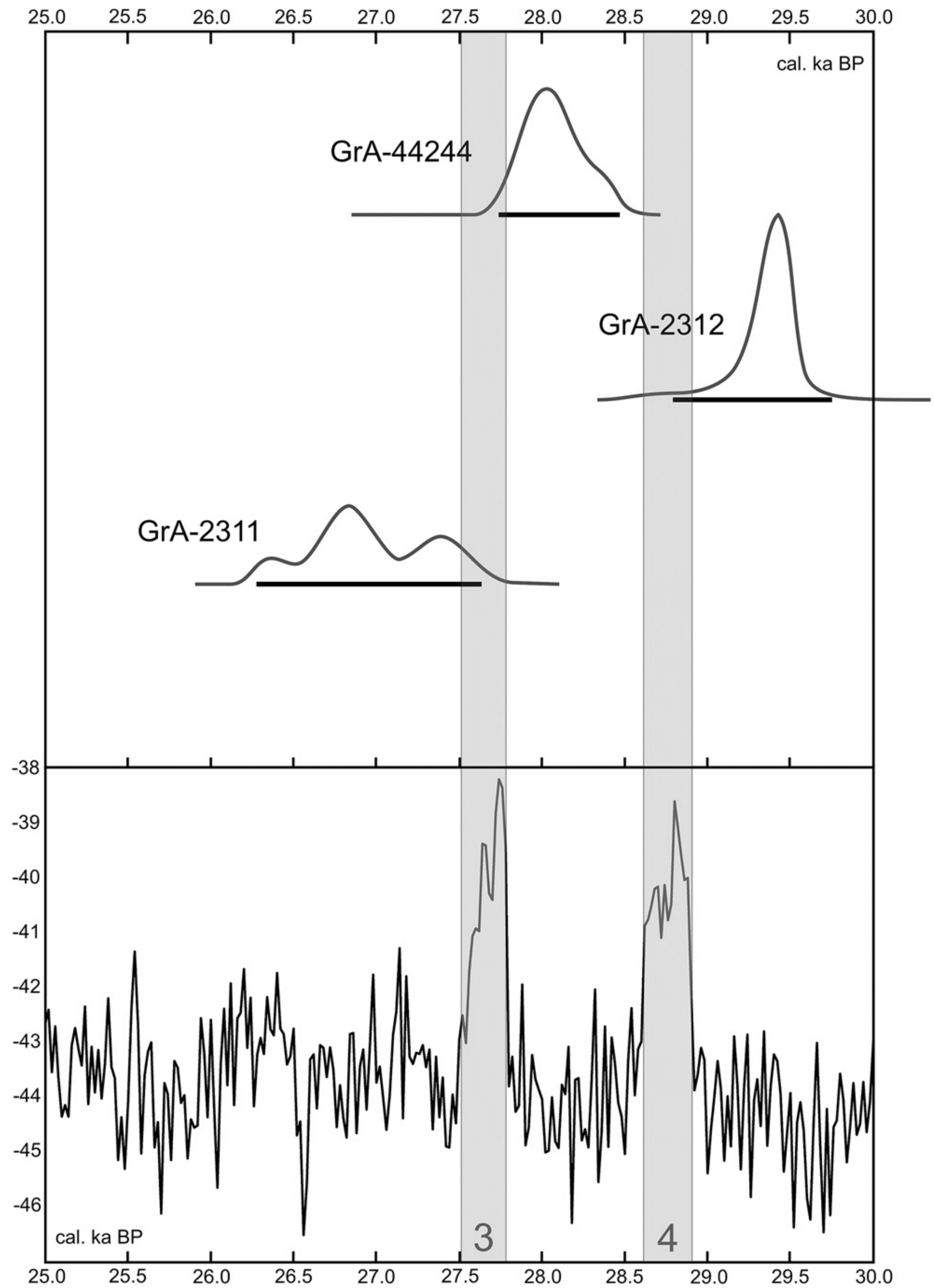

Fig. 11. Probability plots of calibrated radiocarbon ages with horizontal bars representing 2 sigma values from the cultural layers I, II and III of the Trenčianske Bohuslavice-Pod Tureckom site compared with $\delta^{18}O$ (in ‰) values from the NGRIP Greenland core (NGRIP, 2004) with Greenland interstadials 3 and 4 marked in grey.

exceptionally important is the evidence of drilling of hard materials (siliceous pebbles) from the stratified context.

The Pavlovian as a typically Moravian culture (except some localities in southern Poland – Wójcice (Ginter, 1966), and potentionally in Lower Austria) did not penetrate the Lesser Carpathians and White Carpathian mountain chains, although there are some traces of sporadic Pavlovian settlement in the Dzeravá skala Cave (Kaminská et al., 2005) The top of the Gravettian settlement of Western Slovakia comes from the shouldered points horizon, when the Gravettian settlement in the territory of Moravia was much sparser than in “classical” Pavlovian time. Lithic industry of recently published research of the Milovice site from the 1980s (Oliva, 2009) is characterized by the use of radiolarites and by the presence of the typical small points. According to Oliva (2009) it represents a heterogeneous element in the assumed Pavlovian settlement in the Dolní Věstonice–Pavlov–Milovice region, and it shows links to some Mediterranean industries. Due to the research techniques used since the 1880s in the famous Předmostí site near Přerov, it is now not clear, if the Gravettian settlement in this (probably most important Central European Gravettian) site comes only from the Pavlovian or whether it could also originate from the shouldered points horizon. Shouldered points are typical for the famous Polish site in Kraków-Spadzista street (Kozłowski and Sobczyk, 1987).

Local Gravettian settlement in the Váh River valley has been known for decades. One area with extensive shouldered points horizon settlement is the region with hot springs near Piešťany, the territories of Moravany nad Váhom, Banka, Ratnovce, Sokolovce municipalities and others (Hromada and Kozlowski, 1995; Hromada, 1998, 2000; Kozlowski, 1998, 2000). Recently another area with extensive Palaeolithic settlement (i.e. not only Gravettian, there are also some sites from the EUP and others) was discovered in the Trenčín Basin, which is much closer to the Trenčianske Bohuslavice site. Unfortunately, the vast majority of lithic industry comes from surface surveys, but due to the technological, typological and raw material analyses, it is clear that the most important local shouldered points horizon settlement is concentrated in the Trenčianske Stankovce site cluster (Kozłowski, 2008; Michalík, 2010). There are also some other Gravettian surface sites (Trenčianska Turná I, Trenčianska Turná II, Trenčianska Turná V, Mníchova Lehota I, Beckov I, old finds from Trenčín-Zamarovce) from the Trenčín Basin, but at present they cannot be assigned to the shouldered points horizon expressly (Kaminská et al., 2008). The use of the local radiolarite is one of the most characteristic features of the Gravettian in the Váh Valley.

6.4. Lithic raw materials of the Gravettian chipped industry

The high occurrence of such an attractive raw material as radiolarite is not surprising. It was very popular among the Gravettian hunters in the western part of Slovakia (especially in the Váh River valley; Bárta, 1989), because one of its most important sources lies close to the valley. Radiolarite can be found among pebbles of the Váh River, but its original source is connected with the Pieniny Klippen Belt (Krobicki et al., 2003). This narrow, but very long belt at the border between the Outer and Central West Carpathians contains at a few places klippes of Jurassic limestones with layers and nodules of radiolarite. The nearest source of radiolarite for the Trenčianske Bohuslavice Gravettian site can be found at the village of Podbranč about 30 km to the WSW, but there is no evidence of its prehistoric use. On the other hand, in the 20th century (Skutil, 1947) it has been generally known that large prehistoric exploitation of radiolarite occurred around the village of Vršatské Podhradie, close to the important Vlára Pass connecting Western Slovakia and southern Moravia (about 40 km NE from Trenčianske Bohuslavice). The Vlára Pass is built of Paleogene clastic flysh sediments (Krejčí, 1992), but in its area there are situated prehistoric workshops based on radiolarite imported from the area of Vršatské Podhradie (Přichystal, 2009). Therefore, it is highly probable that the provenance of radiolarite at the Gravettian site Trenčianske Bohuslavice-Pod Tureckom is the area of Vršatské Podhradie.

The continental glacier never reached the territory of Slovakia. Silicites (erratic flints) were collected from glacial sediments of northern Moravia or Silesia (Nývlt et al., 2011) similarly as the Gravettian people from the famous Gravettian (Pavlovian) settlements of Dolní Věstonice and Pavlov in southern Moravia did (Zapletal, 1945). Prehistoric hunters from Trenčianske Bohuslavice could reach deposits of glacial sediments via the Vlára Pass or any other pass to southern Moravia and then follow the Morava River and the Moravian Gate depression between the Bohemian Massif and West Carpathians. Another possibility was to navigate by the Váh River and walk along it to the area of Žilina and then through the Kysuca Gate to reach the glacial deposits in the Ostrava Basin. In any case, the erratic silicites had to be transported a distance of >150 km. Obsidian natural occurrences have been described within Central Europe only in the Zemplín–Tokaj Mountains at the border of SE Slovakia and NE Hungary (Janšák, 1935; Williams-Thorpe et al., 1984). This unique rock in the Trenčianske Bohuslavice-Pod Tureckom site is the raw material from the most distant source (about 300 km). A similar hematite as found in Trenčianske Bohuslavice was also used at the Gravettian (Pavlovian) sites in southern Moravia (Přichystal, 2002) for colouring human bodies (especially heads) in graves. Unfortunately, the hematite from Trenčianske Bohuslavice is of unknown provenance.

In spite of its location in Western Slovakia, the raw material basis of Gravettian hunters from Trenčianske Bohuslavice-Pod Tureckom is very similar to those from Gravettian (Pavlovian) sites in southern Moravia. Of course, the substantial influence of the nearby radiolarite source is evident. However, large Gravettian sites in southern and central Moravia (Pavlov I – NW, Dolní Věstonice I, Přerov-Předmostí III) have workshops based on imported radiolarite (e.g. Svoboda, 1997). The Gravettian locality at Milovice shows a prevalence of radiolarite (Oliva, 2009) coming very probably from the area of Vršatské Podhradie. The distance between Milovice and the radiolarite source is about 120 km, and the locality of Milovice is believed to be a heterogeneous part in the Gravettian settlement below the Pavlov Hills, probably with direct connection to Western Slovakia.

6.5. Fired clay pellets

Comparing with samples from other Palaeolithic sites, the Trenčianske Bohuslavice pellets are smaller (Fig. 12), but the reasons for that are not clear. It may be a consequence of different properties of loess or conditions of firing, different fragmentation, different way of flotation, or a different approach to the fraction of small pellets in various archaeological excavations. The small size of pieces from Trenčianske Bohuslavice, however, is largely not due to

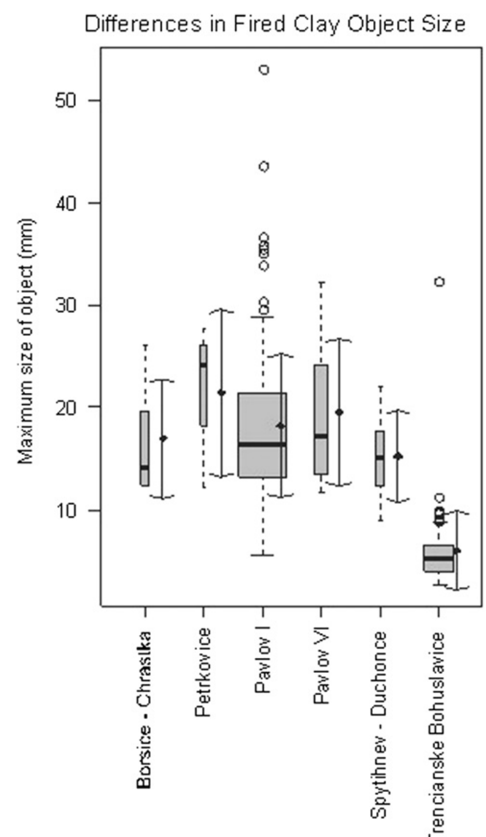

Fig. 12. Box-and-whisker plot of maximum size of clay pellets from different Central European Gravettian Sites: Pavlov VI, Boršice-Chrástka, and Spytihněv-Duchonce (Králík et al., 2008; Svoboda et al., 2009), Petřkovice (Králík, 2008), Pavlov I (unpublished data), and Trenčianske Bohuslavice (present study). Thick line - median, box - upper and lower hinges, whiskers - one times the interquartile range, white circles - outliers and extremes, black points - non-robust mean, arrows - +/− 1 sigma range. Widths of boxes are proportional to the square-roots of the number of observations in the groups (R Development Core Team, 2010).

recent fragmentation because many are still partly covered with sinter (calcium carbonate) layer. In addition, one case has confirmed that the presence of a large piece is not excluded. Therefore, the size distribution of fired clay pellets of Trenčianske Bohuslavice seems plausible.

The material of fired clay pellets from the site is probably local loess. On some pellets, colour gradients were recorded which correspond to findings from the Boršice-Chrástka site (Králík et al., 2008). Impact features on the largest object, an irregular fired clay piece, resemble some of the cases present on the clay fragments from Pavlov I and could be a trace of intentional human activity (Králík and Novotný, 2005). Their interpretation is hindered by a layer of sinter. Small cavities/holes found on the pellets are probably elongated in shape (fine tubes), but more advanced imaging techniques will be necessary to show their direction in pellets and to accurately determine their origins. Small cavities could be a natural part of the structure of loess. However, there is also a certain similarity with cavities from animal hairs that have been found on two clay objects from the site of Pavlov VI (Králík et al., 2008).

6.6. Faunal spectrum

The first limited information about rich palaeontological material of hunting game and the results of evaluation of malacofauna from Bárta's research in Trenčianske Bohuslavice were published by Holec and Kernátsová (1997). More detailed studies of the material of selected mammal species from this locality were made by Karol (2005), Pošvancová (2005) and Vlačiky (2005). Human modifications, such as cut marks and intentional breakage mainly on the reindeer and mammoth bones were published by Vlačiky (2008a, 2008b). A vast concentration of faunal remains situated in trenches 19/83, 24/83–84, 25/84, 26/84–85 and 31/86 was interpreted as bone dump Vlačiky (2008a, b).

Described animals from the 2008 trench had clearly been prey of Gravettian hunters, although no direct traces of intentional activity (cut marks – Wojtal, 2007) were found on the material. The extremely rare occurrence of cut marks is not uncommon, and was seen at other open-air sites with human artifacts, which are certainly accumulated by hunters as well (Wojtal, 2007). The only direct trace of intentional activity on the faunal material represents three burned bones. The high occurrence of autopodial bones (notably if they were found in anatomical position, such as the bones of arctic fox and hare) indicated the presence of animal fur, because the lower parts of the extremities, metapodials and phalanges, were brought to the sites together with the skin (Ďurišová, 2005). Similar spectra of hunting game as in the Trenčianske Bohuslavice-Pod Tureckom site were also described at many other Gravettian sites in Middle Danube region, e.g. Moravany nad Váhom-Lopata II (Lipecki and Wojtal, 1998), Banka-Horné farské role (Ďurišová, 2000), Boršice-Chrástka (Škrdla et al., 2008b) and Spytihněv-Duchonce (Škrdla et al., 2008a).

6.7. Analyses of the tooth cement microstructure

Analyses of the increments of tooth cement were used to determine settlement seasonality. The annual increment comprises the light summer and dark winter growth, the different shades being the result of the varying action of cementoblasts, which is influenced by the relative percentage of the mineral and organic elements (Carlson, 1991; Debeljak, 2000; Ábelová, 2005; Hillson, 2005; Nývltová Fišáková, 2007). For the analysis it is also necessary to determine the thickness of the winter and summer layer and thus determine the amount of time which passed from when the increment began to form (from May or November) in that particular species of mammal (Lieberman et al., 1990; Carlson, 1991; Lakota-Moskalewska, 1997; Debeljak, 2000; Ábelová, 2005; Nývltová Fišáková, 2007). In order to calculate the age of the tooth using the cement increment method, it is necessary to add the length of time that passed between the birth of the animal and the eruption of that specific permanent tooth (Debeljak, 1997; Červený et al., 1999; Komárek et al., 2001). However, efflorescence destroys the surface of the tooth, which also adversely affects the cement, so in some cases the age of the animal and the season in which it died cannot be determined (Ábelová, 2005), as in four cases from this research.

Analyses of the tooth cement microstructure of another five reindeers from Trenčianske Bohuslavice-Pod Tureckom indicates that the site was seasonal, and probably related to spring and autumn migrations. There were similar seasonal localities during the Gravettian in Moravia (Jarošov, Spytihněv), where they existed together with sites that were inhabited all year round, such as Dolní Věstonice-Pavlov and Přerov-Předmostí (Nývltová Fišáková, 2007, 2013). This result can also be caused by the fact that only five reindeer teeth and no carnivore tooth were analysed. For example, from the Moravany nad Váhom-Lopata II site, in addition to three reindeer teeth, also one canine each from brown bear, wolf and red fox were analyzed, and the result was year-round inhabitancy of this site (Nývltová Fišáková, 2008; 2013; Vlačiky, 2009). Furbearers were generally hunted at the time of their greatest abundance, and when their pelts were in optimal condition. This suggests that winter could be the optimal season for hunting (Soffer, 1985). Unfortunately, there is a lack of carnivore teeth from this site.

6.8. Stable isotope analyses

6.8.1. Faunal diet and palaeoecology

Stable isotopes provide a way of identifying palaeoenvironment (migration, food strategies) without relying on the archaeological proxies of animal bones – this means it is immune to the factors, which can affect a bone assemblage at a site, upon which more traditional dietary analyses are based. Bone assemblages at sites represent "a biased average of the dietary refuse of the group" (Bocherens et al., 2005). The isotope composition of tooth and bone tissue is proportional to the environment and nutritional intake during the formation of this tissue (Bryant et al., 1994; Balasse et al., 2002; Smrčka, 2005; Smrčka et al., 2006). Tooth enamel practically does not change at all once it has formed (Smrčka, 2005; Smrčka et al., 2006) and therefore the isotope ratio reflects the nutrition available and the location and climate in which the tooth grew and mineralised.

The studied reindeer from the Trenčianske Bohuslavice site, on the basis of the carbon and nitrogen isotope ratios ($^{13}C/^{12}C$ and $^{15}N/^{14}N$), lived in a relatively varied environment, and ranged partly through park-type landscape as well as through regions with tundra vegetation and lichens and in grassy steppes (Fig. 13) This corroborates with the theory that reindeer passed through a variety of different environments on their migration paths. This is also indicated by the $\delta^{15}N$ values, which indicate a diversity of environments and also that the reindeer predominantly inhabited tundra regions. In plants, the relative isotope ratio of nitrogen (^{15}N) depends primarily on its origin. The values are also influenced by the climate. In regions with a very warm climate, the $\delta^{15}N$ values are demonstrably higher than in regions with a mild climate (Marriotti et al., 1980; Michelsen et al., 1996; Rodiére et al., 1996). The $\delta^{15}N$ values distinguish the trophic level of the organism in question ($\delta^{15}N$ increases by 2–3‰ for each level of the food pyramid:Bocherens and Marriotti, 2002; Bocherens and Drucker, 2003). This means that plants contain around 3‰ ^{15}N, herbivores living on plants have 6‰, and predators have a ^{15}N content of

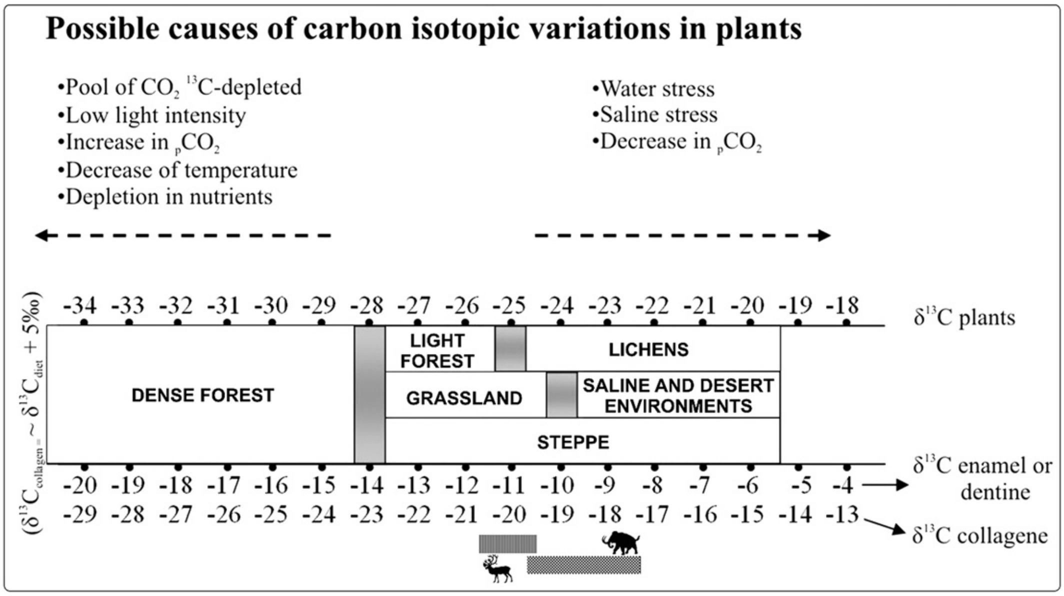

Fig. 13. The range of $\delta\ ^{13}C$ values of collagen and dental enamel/dentine measured in the current arctic, moderate and steppe environments, with possible causes of carbon isotopic variations in plants and herbivores. Modified after Bocherens (2003). Values are compiled from Nelson et al. (1986); Bocherens et al. (1994a, b; 1996); Rodiére et al. (1996); Bocherens (2000). Range of $\delta\ ^{13}C$ values of studied reindeers teeth (dashed) and mammoth tusk (hatched) from the Trenčianske Bohuslavice-Pod Tureckom site are marked on the bottom of the figure.

9–10‰ (Nelson et al., 1986; Bocherens et al., 1994a, 1994b, 1996; 2000; Rodiére et al., 1996; Bocherens, 2003).

Observed $\delta^{13}C$ values from mammoth dentine tusk from the Trenčianske Bohuslavice-Pod Tureckom site are similar to mammoth enamel values from Dolní Věstonice – Czech Republic (−10.6‰ to −8.1‰; Pryor, 2006) and Switzerland (from −11.8‰ to −8.3‰; Tütken et al., 2007). The values recorded from North European mammoths are a little bit lower for this time span (−13.2‰ to −10.3‰; Bocherens et al., 1995; Jones et al., 2001; Arppe and Karhu, 2005). The $\delta^{13}C$ values of the food consumed by studied mammoth are similar to food consumed by mammoths from Dolní Věstonice, Czech Republic (−24.7‰ to −22.2‰, calculated on the base of $\delta^{13}C$ from Pryor, 2006) and Switzerland (−25.9‰ to −22.4‰, calculated on the base of $\delta^{13}C$ from Tütken et al., 2007).

Considering that C_4 plants did not grow in the area of Central Europe during the Last Glacial, calculated values indicate that the mammoth fed on C_3 plants. In natural environments where all plants use C_3 photosynthesis, $\delta^{13}C$ values represent differences caused by natural parameters (Heaton, 1999). Plants growing in closed environments show more negative $\delta^{13}C$ values in comparison with those growing in open environments (Drucker et al., 2003). Geographic variation in $\delta^{13}C$ values of plant food inferred from mammoth remains from Europe, Russia and Siberia are caused by environmental factors affecting the plants and animals and/or the differential availability of different plant species (Iacumin et al., 2000). Variability in $\delta^{13}C$ values of studied mammoth tusk reflects differences in the natural environment. On the whole, this environment had a steppe and meadow character, in some cases with presence of scattered trees (Fig. 13). These conclusions are confirmed by the sympatry of typical large grazing animals such as *R. tarandus*, *E. germanicus* or *C. antiquitatis* (e.g., Holec and Kernátsová, 1997; Vlačiky, 2008a, 2008b, 2009). These animals dominated in tundra or steppe environments. On the basis of stomach contents from frozen mammoths, they consumed mainly grass (Vereshchagin and Baryshnikov, 1982; Mead et al., 1986; Guthrie, 1990). tree bark and twigs were also found in stomach contents, representing part of their winter food (Olivier, 1982; Vereshchagin and Baryshnikov, 1982).

6.8.2. Faunal migration

The $^{87}Sr/^{86}Sr$ ratio in herbivores reflects their diet as well as soil and water composition. This correlates with the geological sub-soil, and this finding can be used to reconstruct human and animal migration patterns. Results from analyses of four reindeers (Fig. 10) indicate that these animals were born and lived elsewhere, and had probably come to the locality by seasonal migration (Hoppe et al., 1999; Pellegrini et al., 2008; Britton et al., 2009). This is very different from the situation in Moravia, where the reindeer population did not migrate and was a forest species of reindeer (Nývltová Fišáková, 2008). The arctic fox was a migrant as well. Arctic foxes are capable of traveling hundreds of kilometres (Wrigley and Hatch, 1976).

6.9. Evaluation of malacofauna

There were found very well developed communities typical for the upper stage of the Last Glacial period, common for cultural layers with the Gravettian (in Slovakia e.g., Ambrož et al., 1951; Alexandrowicz, 1998, 2005). In the coldest loess accumulation period, the profile shows the presence of fixed taxa (*V. parcedentata*, *P. loessica*, *Columella columella*, and *V. tenuilabris*) concentrated in the upper part of the profile (samples from depth 25 cm and 45 cm), whereas the community from the depth 125 cm is from a much more favourable stage of the glacial period. Calculated quantitative palaeoclimatic values (Table 7) show the same result: communities from the richest cultural layer III (samples from 85 cm, 105 cm and 125 cm) indicates relatively high mean July palaeotemperature (17.1–17.4 °C), sample from cultural layer II (65 cm) 15.8 °C and the samples from upper part of the profile (45 cm and 25 cm) with layer I suggest paleotemperatures of only 14.7–14.5 °C. The decreasing trend of mean July paleotemperatures from 17.1 to 14.5 °C took place during the time interval 29.5 to 27 ka BP.

According to radiocarbon dates and malacological studies made by Sümegi and Krolopp (2002), a thermophilous malacofauna can be found in the fossil soil layer at the beginning of the Upper Weichselian (32,500–28,000 cal. BP) in the Carpathian Basin. Based on the malacothermometer method, mean July temperature values of 16–17 °C were calculated for the northern part of the Great Hungarian Plain for this period. By the end of the period when this fossil soil formed, about 27,000–28,000 cal. BP, the xerophilous snail *P. triplicata* had become absolutely dominant, indicating extremely dry climatic conditions. The reconstructed warm phases must have occurred simultaneously with GI 3 and 4 (Johnsen et al., 1992; Andersen et al., 2006). Between 27,000 and 25,000 cal. BP, a significant change in environmental conditions for the Carpathian Basin can be traced, initiating the process of loess deposition. This change refers to a significant cooling and development of a cold continental steppe-forest steppe environment with tundra-like spots in Hungary. The July palaeotemperature decreased to 11–12 °C in the northern part of the basin. Meanwhile, July palaeotemperature values around 14 °C prevailed in the southern parts of the basin (Sümegi and Krolopp, 2002). Therefore, the calculated quantitative palaeoclimatic values from Trenčianske Bohuslavice-Pod Tureckom are consistent with results of Sümegi and Krolopp (2002) for the time interval 29.5–27 ka BP.

6.10. Pollen analysis and palaeovegetation overview in the Gravettian period in Central Europe

Interpretation is not possible due to the lack of palynomorphs. Only 10 pollen grains were found in the whole studied profile, all in the upper part, in loess and the upper part of geliflucted colluvial deposits. Loess is not very suitable for preserving palynomorphs, they could be dispersed in a large amount of this aeolian sediment. Palynomorphs are also sensitive to oxidizing agents, so the probability of preserving them in the environment of geliflucted colluvial sediments, where they could be repeatedly exposed to oxidation, bacteria or fungi, is even smaller than in loess.

Bárta (1988) mentioned the analysis of charcoals from his research in Trenčianske Bohuslavice made by his colleague E. Hajnalová. From the hearth on the boundaries of trenches 26/84–85 and 27/85 (cultural layer II), Hajnalová identified the charcoals of *Picea abies* and another Pinopsida, from the main layer (cultural layer III) Hajnalová determined charcoals of *P. abies*, *Pinus* sp. and Pinopsida. At seven other Gravettian sites in Slovakia, yielding also some radiocarbon dates, mostly the wood of *Pinus* sp. and/or *Pinus mugo* was burned. Fragments of *Taxus baccata*, *Abies alba* and *Quercus* sp. show that the vegetation was probably more diverse, as documented in pollen records (Hajnalová and Hajnalová, 2005). The vegetation of the Gravettian layers 4 and 5 in the Dzeravá skala Cave, about 50 km SW from Trenčianske Bohuslavice, is dated to 29,633 ± 210 cal. BP (GrA-22758) and 29,583 ± 249 cal. BP (OxA-13861). These ages lie in the same age range as the radiocarbon date of cultural layer III (Table 1). The vegetation was formed by mixed deciduous and coniferous forests with trees of *Fagus sylvatica*, *P. abies*, *Ulmus* sp., cf. *Acer* sp. (identified from charcoals). Also found were seeds of *Rubus* sp., *Carex* sp., *Chenopodium album*, *Ch. hybridum*, Lamiaceae and Poaceae (Hajnalová and Hajnalová, 2005). The pollen spectra from Trenčianske Bohuslavice-Pod Tureckom contain species, which are also known from the Gravettian localities in Czech Republic (e.g. Petřkovice – Roszková, 2008). An overview of the vegetation in the Gravettian period in Central Europe was introduced by Pokorný (2009). The results of palaeobotanic research in the Moravian Gravettian were summarized by Svobodová (2002), characterizing the Gravettian landscape as extremely variable, with cold steppe on exposed slopes, gallery forests along watercourses, and thick plant vegetation in moist sites. Svobodová (2002) assumes a reconstructed park forest steppe in typical sites. A buried peat profile in Bulhary, a southern Moravian site near the Pavlovské vrchy Hills (Rybníčková and Rybníček, 1991), with rather imprecise radiocarbon dating of 30,149 ± 3109 cal. BP is consistent with the current numerical chronology obtained for the Gravettian sites in nearby Pavlov and Dolní Věstonice (Svoboda, 1999) and also with cultural layer III from the Trenčianske Bohuslavice-Pod Tureckom site. The pollen diagram from Bulhary (Rybníčková and Rybníček, 1991) indicates an open coniferous forest of the continental taiga type with *Pinus sylvestris*, *Pinus cembra*, *Picea*, *Larix*, *Juniperus* and an additional mixture of deciduous trees, such as *Ulmus*, *Corylus*, *Quercus*, *Tilia* and *Acer*. Due to the lack of palynological results, it can only be assumed that the character of vegetation in Trenčianske Bohuslavice-Pod Tureckom was similar to that of other sites in Central Europe in the given time period.

7. Conclusions

Trenčianske Bohuslavice is the most important representative shouldered points horizon locality in the Trenčín Basin, with surprisingly strong Gravettian settlement. Its importance lies mainly in the extent of Bárta's research in 1980s, with a minimum of 3 radiocarbon dated cultural layers, evidence of drilling of the silicious pebbles and presence of several tens of leaf points in a clear Gravettian context. The interdisciplinary research in 2008 completed the mosaic of Bárta's results successfully with the new ones, obtained with modern methods and provided a solid basis for future research.

The results of detailed archaeological, sedimentological, malacozoological, palynological, faunal spectrum, seasonality, lithic raw materials and fired clay pellets analyses were similar to those obtained from other Gravettian sites in the Middle Danube region. Quantitative palaeoclimatic values calculated from gastropod communities showed a decreasing trend of mean July paleotemperatures. Analyses of the tooth cement microstructure of reindeer indicates that the site was seasonal and probably related to spring and autumn migrations. Migration of reindeer and arctic fox was also confirmed by the results of $^{87}Sr/^{86}Sr$ ratio analyses. The stable isotope analyses were used for the first time in Palaeolithic research in Slovakia. Carbon isotope analyses of five tusk layers of *M. primigenius* from Trenčianske Bohuslavice indicated variability of $\delta^{13}C$ values. This indicates changes in dietary intake during the life of the animal. This could be related to annual climatic periodicity and vegetation cover, reaction to changes in climatic conditions, or to the migration of this animal. This finding demonstrates that the mammoth steppe was a complex mosaic of environments during the Gravettian period (e.g. Barnosky et al., 1987; Guthrie, 1990). The results of $^{13}C/^{12}C$ and $^{15}N/^{14}N$ isotope ratios analyses of reindeer support this mosaic character of the Gravettian palaeoenvironment. This corroborates phytopaleontological and palynological studies reporting that mosaic areas existed in Gravettian time: gallery woodland along streams and rivers with open environments around them (e.g. Jankovská, 2003; Musil, 2003). Jankovská (2008) and Pokorný (2009) mentioned that an analogy of vegetation conditions in the Last Glacial period can be observed in continental Siberia today. All these floral and faunal analyses agreed well with the dates of all three cultural layers, which represent rather colder stadial than warmer interstadial conditions. However, the two GI (Andersen et al., 2006) lie just between the three cultural layers and climatic and environmental changes surely occurred during this changeable period of the late MIS 3. The higher magnetic susceptibility and frequency-dependent magnetic susceptibility values in the lowermost cultural layer are induced by admixture of soil sediments, whereas no clear magnetic signal could be found for the middle cultural layer, which appeared during the short cold Greenland Stadial between GI 4 and 3. The upper cultural layer was found in the loess unit directly below the topsoil. Radiocarbon dating of the upper cultural layer also suggests the early beginning of aeolian deposition in this area shortly after GI 3, i.e. ~27.5 ka BP.

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