NEW CHRONOLOGICAL EVIDENCE FOR THE MIDDLE TO UPPER PALAEOLITHIC TRANSITION IN THE CZECH REPUBLIC AND SLOVAKIA: NEW OPTICALLY STIMULATED LUMINESCENCE DATING RESULTS*

L. NEJMAN†
Department of Anthropology, Faculty of Science, Masaryk University, Kotlářská 2, 611 37 Brno, Czech Republic

E. RHODES
Department of Earth and Space Sciences, University of California, 595 Charles Young Drive East, Los Angeles, CA 90095-1567, USA

P. ŠKRDLA
Institute of Archaeology, Academy of Sciences of the Czech Republic, Královopolská 147, 612 00, Brno, Czech Republic

G. TOSTEVIN
Department of Anthropology, University of Minnesota, 395 H. H. Humphrey Center, 301 19th Ave. S., Minneapolis, MN 55455, USA

P. NERUDA, Z. NERUDOVÁ, K. VALOCH and M. OLIVA
Moravian Museum, Zelný trh 6, 659 37, Brno, Czech Republic

L. KAMINSKÁ
Institute of Archaeology, SAV, PVS, Hrnciarska 13, 040 01, Košice, Slovakia

J. A. SVOBODA
Department of Anthropology, Faculty of Science, Masaryk University, Kotlářská 2, 611 37 Brno, Czech Republic

and
Institute of Archaeology at Brno, Academy of Sciences of the Czech Republic CZ-69129 Dolní Věstonice 25, Czech Republic

and R. GRÜN
Research School of Earth Sciences, Building 61 (OHB-B), Mills Rd., Australian National University, Canberra, ACT, 0200, Australia

We report new optically stimulated luminescence (OSL) dates from the Central European sites of Kůlna, Stráňská skála, Bohunice, Vedrovice V, Vedrovice Ia, Moravský Krumlov IV and Dzeravá skála, which date to the Middle–Upper Palaeolithic transition period. There are important unresolved questions surrounding the timing of archaeological events during this

*Received 4 February 2010; accepted 15 November 2010
†Corresponding author: email lnejman81@gmail.com
© University of Oxford, 2011
crucial period in European prehistory. Archaeological layers from this time period are at the limits of the 14C method and most of these sites lack good chronology. The results of this dating project suggest that some parts of the current chronological framework may need to be revised. Although in many cases our OSL results are broadly consistent with previous dates obtained by 14C, in other cases they reveal unexpected surprises. One OSL result from Kůlna opens up the possibility that Neanderthals may have survived in this part of Europe past the 30 ka BP mark as has been argued for several Neanderthal sites in southern Europe. The large Szeletian assemblage recovered from Vedrovice V may be significantly older than previously thought, which undermines the idea that the Szeletian culture is exclusively an Early Upper Palaeolithic industry. More dating research is needed to confirm the more controversial results of this research.

**KEYWORDS:** MIDDLE–UPPER PALAEOLITHIC TRANSITION, CENTRAL EUROPE, NEANDERTHALS, ANATOMICALLY MODERN HUMANS, OPTICALLY STIMULATED LUMINESCENCE, CHRONOSTRATIGRAPHY

**INTRODUCTION AND BACKGROUND**

**Archaeological setting**

The European Middle–Upper Palaeolithic transition, which encompasses the time period between 50 and 30 ka BP, is considered by many authors to be one of the major revolutions in European prehistory (e.g., Binford 1985, 1989; Tattersall 1995; Mellars 1996; Klein 1999; Bar-Yosef 2002). One of the most important issues that is still subject to debate is the period of coexistence of anatomically modern humans and Neanderthals, and the degree of cultural mixing. Some authors maintain that this period of overlap was rather extended and lasted for several thousand years (e.g., Churchill and Smith 2000) and led to ‘acculturation’, explaining the common elements of Early Upper Palaeolithic (EUP) industries and the Middle Palaeolithic and Upper Palaeolithic industries (Mellars 2006; Tostevin 2007). Others argue against the acculturation model, maintaining that all transitional industries were manufactured by the Neanderthals before the arrival of modern humans (e.g., Zilhão and d’Errico 1999).

The Czech–Slovak region has a vital role in contributing to the Middle–Upper Palaeolithic transition debate. Historically, it has played an important role, with the discovery of late Middle Palaeolithic Neanderthal remains in the Moravian caves Kůlna, Šipka and Švédův Stůl (sometimes erroneously referred to as Ochoz Cave in the literature), the rich Aurignacian human fossil assemblages found in Mladěč caves, and middle Upper Palaeolithic (Gravettian) fossils found at Předmostí, Brno and Dolní Věstonice. In addition, several sites have yielded rich EUP lithic assemblages in stratified and datable contexts. These include Stránská skála, Bohunice and Vedrovicí V. The lithic assemblages at these three sites are widely seen to be chronologically, typologically and technologically transitional between the Middle Palaeolithic and the Upper Palaeolithic industries in this region. Unfortunately, the preservation of organic material is poor and no human remains are known from these sites. As a result, we do not yet know which hominin type manufactured these assemblages. In addition, several hundred surface sites with lithic scatters attributed to the EUP period have been documented in Moravia. The number of surface Szeletian sites is around 100 (Oliva 1991b), and the occurrence of Aurignacian surface sites has been described as ‘... the highest concentration of Aurignacian sites east of France’ (Oliva 1993a, 37). Oliva (1991a) also lists numerous Middle Palaeolithic surface sites. For the reasons discussed above, the archaeological record in Moravia is crucial to the questions pertaining to the Middle–Upper Palaeolithic transition and should be considered as an important staging point for debates about the Middle–Upper Palaeolithic transition.
Six of the sites (Stránská skála, Bohunice, Moravský Krumlov IV, Vedrovice V, Vedrovice Ia and Kúlna) that we dated are located in southern Moravia, within a relatively short distance from each other (see Fig. 1). Stránská skála and Bohunice are located within the city of Brno, on elevated hillsides on opposite sides of a river valley, 7 km from each other, with a direct line of sight between the two sites. Moravský Krumlov IV, Vedrovice V and Vedrovice Ia are located approximately 25 km to the south-west of Brno, in the Krumlovan Forest area, and Kúlna is located 30 km to the north of Brno. Dzeravá skala is located approximately 100 km to the south-east of Brno, in western Slovakia, in the foothills of the Lesser Carpathian mountains.

THE OSL DATING METHOD

Optically stimulated luminescence (OSL) dating (Aitken 1985, 1998) has had an increasingly greater role in dating sedimentary layers containing archaeological remains. The main characteristic of this method, which makes it very useful for dating applications, is that its ‘clock’ can be reset to zero by exposure to light. OSL measures the time a quartz or a feldspar sand grain was last exposed to daylight. Irradiation by naturally occurring uranium, thorium and radioactive potassium causes ionized electrons to become trapped in defects within the crystal lattice of minerals. The number of trapped electrons can be measured, and the rate at which they
accumulated can be estimated from the level of background radioactivity from measurements made in the field or by laboratory-based analyses. The longer the targeted sand grains are exposed to radiation, the greater is the number of trapped electrons, and thus the stronger is the OSL signal. By dividing the number of trapped electrons by the annual radiation dose, the elapsed time since the crystal traps were empty can be calculated.

Several laboratory techniques are used to separate different size ranges and to extract quartz mineral grains for dating. When the desired quartz grain size is obtained, the natural OSL signal is compared to regenerated signals from a calibrated radioisotope source. This allows evaluation of the laboratory dose of nuclear radiation needed to induce luminescence equal to that acquired since the most recent bleaching event (palaeodose). The age is obtained from the equation:

\[
\text{Age} = \frac{\text{Palaeodose}}{\text{Dose rate}},
\]

where the dose rate is the rate at which energy is absorbed from the flux of nuclear radiation, which is evaluated by assessment of the radioactivity of sediment in the field and by laboratory measurements. In reality, there are many complications and several dozen measured quantities are actually involved in evaluation of the age (Aitken 1998).

Optical dating using the OSL signal was developed from TL dating methods and was first applied to quartz by Huntley et al. (1985), and methodological details were further developed by Smith et al. (1986) and Rhodes (1988).

The primary advantage of OSL dating for archaeological applications is its versatility: the targeted sand-sized grains of quartz are ubiquitous in the majority of archaeological layers containing archaeological deposits. However, unlike other dating techniques such as TL or $^{14}$C, there is less certainty that the OSL age is equal to the targeted archaeological event, because the OSL signal records the age of deposition of the sediment, which is not necessarily the age of the human occupation at the site.

All of our sediment samples were collected in opaque steel tubes at the respective sites in 2003 and 2005. The tubes were driven into the stratigraphic profile with a hammer. In several cases, it was not possible to drive the OSL containers into the profile due to large detrital pieces of rock in the sediment, so the sediment was instead collected in complete darkness at night and under a black tarpaulin, obscuring any residual light. The samples were subsequently analysed at the Luminescence Dating Laboratory at the Research School of Earth Sciences, Australian National University, Canberra, Australia. The samples were sieved in mechanical sieves to extract the required size fractions. Carbonate remains were eliminated using hydrochloric acid and mineral separation was achieved in several steps using hydrofluoric acid and a polytungstate solution. The technical details of the OSL results are published separately in Rhodes et al. (in prep.).

**THE BACKGROUND OF THE DATED SITES AND STRATIGRAPHIC SUMMARIES**

**Kůlna**

Kůlna is a tunnel-shaped limestone cave 469 m a.s.l., and about 92 m long, 25 m wide and 8 m high. It is located in the northern part of the Moravian Karst (N49°25′, E16°45′). Several hundred caves are known in this area, many with recorded Palaeolithic occupation (Svoboda 2002). Excavations began in 1880 and were continued by Karel Valoch in 1961–76. Existing stratigraphic profiles (remaining from Valoch’s 1961–76 excavation) were used to collect the sediment
samples. All of the samples were collected from near the cave entrance except for K0674 and K0675, which were collected from a stratigraphic profile previously recorded by Valoch (1988, 176, fig. 73) in the interior of the cave.

Sediments in the cave (see Fig. 2 (a)) are inhomogeneous, ranging from loess to fluvial sediments and breccias. The layers are generally composed of clastic detrital sediments ranging widely in grain size and homogeneity. Even single lithological units often differ in different parts of the cave. During the excavations, it was often not possible to ascertain the nature of the varied processes that formed the sedimentary deposits. As a result of the variety of sedimentary formation processes, which were often difficult to identify, the resulting plethora of sediments probably also affected the osteological material used for U/Th analysis (Michel et al. 2006a,b). It is likely that all these factors influenced the variability and incongruence of absolute dates obtained by various dating techniques (see Table 1).

The stratigraphic profile is up to 15 m deep with 26 stratigraphic units, and excavations have produced several tens of thousands of stone artefacts and faunal remains. In addition, layer 7a has also produced Neanderthal fossil remains of several individuals (Jelínek 1988). Previous datings (see Table 1) are confined to layer 7a, where several 14C dates (Mook 1988) and an ESR date (Rink et al. 1996) were obtained. An ESR age was also determined for layer 9b. Of special interest and significance is layer 6a, which is the last occurrence of Micoquian artefacts in the profile, and it probably represents the last known Neanderthal occupation in Central Europe.

Figure 2 (following page) Stratigraphic sequences.
(a) A schematized Kálma stratigraphy (from Valoch 1988) with sample locations. Layer descriptions: 6a, brownish-yellow loess with frequent detritus; 7a, brown to dark brown soil of loessic origin with infrequent detritus; 7b, brown to dark brown soil completely devoid of detritus, archaeological material and palaeontological material; 7c, dark brown argillaceous soil with detritus; 7d, dark brown soil (somewhat lighter than overlying layer) with infrequent detritus; 8a, reddish, grey–brown argillaceous soil with frequent limestone detritus; 8b, reddish brown soil with boulders; 9a, dark brown, argillaceous soil with infrequent detritus; 9b, dark brown soil (somewhat lighter than overlying layer) with rare detritus; 10, grey–black humic soil with small-sized detritus; 11a–d, a complex of grey–black sandy clay sediments with detritus and pebbles—individual layers can be differentiated by colour (light grey, yellow–grey, brown–grey and dark grey); 12a, fluvial, sandy-gravel sediment deposited by a stream flowing through the cave; 12b, compact, clay brown fluvial sediment; 13a, light grey, sandy clay sediment; 13b, yellow–brown sandy loess with coarse detritus; 14, dark brown soil (lighter-coloured and more unconsolidated than layer 12b) with abundant detritus and large boulders.
(b) Dzeravá skala stratigraphy (from Kaminská et al. 2005, 19, fig. 8) with sample locations. Layer descriptions: 1, grey–black, compact topsoil with a humic component; 2, loose travertine; 3, loess with small amount of stone debris; 4, black humus soil with a higher amount of angular clasts; 5, grey–green loess soil with angular clasts; 6, brown–red clayish soil with large and coarse angular stone; 7, dark brown clayish-sandy soil with angular clasts; 8, loess soil of grey–green colour with humus intrusions and a considerable amount of humus angular clasts; 9, dark brown loess soil with small angular clasts; 10, dark brown to black sediment with small stones, in place with larger angular detritus; 11, light brown–grey loamy to clayish-aleuritic layer with small angular and subangular detritus and larger stone pieces; 12, rusty-coloured, loamy-sandy sediment.
(c) Moravský Krumlov IV stratigraphy with sample locations (from Neruda and Nerudová 2009). Layer descriptions: 1, topsoil; 2, silt-dominated residuum; 3, Holocene B-horizon; 4, loess; 5, palaeosol; 6, soliflucted palaeosol; 7, loess; 8, weakly developed soil; 9, loess; 10–12, palaeosols; 13, Ca horizon; 14, complex of soil sediment blocks; 15, reworked loess.
(d) Stránská skála stratigraphy with sample locations. Layer descriptions: 1, topsoil; 2, loess; 3, upper palaeosol; 4, lower palaeosol; 5, soil sediment.
(e) Bohunice stratigraphy with sample locations. Layer descriptions: 1, topsoil; 2, loess; 3, upper palaeosol; 4, lower palaeosol; 5, soil sediment.
(f) Vedrovice V stratigraphy with sample locations. Layer descriptions: 1, topsoil; 2, loess; 3, palaeosol; 4, palaeosol with gravel; 5, palaeosol; 6, palaeosol; 7, Ca horizon; 8, loess.
(g) Vedrovice I stratigraphy (from Oliva 1993b) with sample locations. Layer descriptions: 1, topsoil; 2, Holocene B horizon; 3, loess; 4, reddish palaeosol; 5, loessic sediment affected by cryoturbation; 6, loess.

Dzeravá skala

Dzeravá skala cave is located in western Slovakia, in the Lesser Carpathian Mountains (N48°31′, E17°18′). It is a limestone cave, 22 m long, 18 m wide and up to 10 m in height, on a steep slope of a narrow valley, 450 m a.s.l. The Palaeolithic occupation of this cave was first discovered in 1913 by the Hungarian archaeologist Jenő Hillebrand, who also conducted the first systematic excavation in 1914 (Prošek 1951). The excavations were further continued by F. Prošek in 1950 and by a Slovakian–Czech–Polish team in 2002–3.

During the 1950 excavation, Prošek recovered several leafpoints identified as Szeletian, more than 20 Mladēč-type bone points (attributed to the Aurignacian) and various stone tools, in one of the basal layers. Prošek (1951) claims that the bone points are coeval with the leafpoints. The recent excavation does not confirm the theory that the Mladēč-type bone points belong to the Szeletian; the Aurignacian occupation was documented in layer 9 (see Fig. 2 (b)), which overlies the earlier (Micoquian) Palaeolithic occupation in layer 11 (Kaminská et al. 2005). Prošek’s claim is also at odds with current opinions that associate Mladēč-type bone points with the Aurignacian industry, and the leafpoint is considered a type artefact of the Szeletian industry. The Szeletian appears several thousand years before any Aurignacian assemblages (Svoboda and Simán 1989). The 14C results are presented in Table 2. As there are no known diagnostic human fossils associated with any Szeletian assemblages, this claim is made based on typological similarities of the Szeletian to earlier Middle Palaeolithic industries and on its antiquity; some Szeletian assemblages are thought to predate the arrival of modern humans in the region.

A human tooth (germ of a left M2) was found during the 1914 excavation in the same layer with the leaf points and bone points. It was described as Neanderthal by the excavator (see Churchill and Smith 2000), but Bailey et al. (2009) interpret this tooth as modern human, on the basis of diagnostic dental features.

Stránská skála

Stránská skála is a limestone cliff 310 m a.s.l., situated on the eastern outskirts of the city of Brno in southern Moravia (N49°11′, E16°41′). The limestone contains layers and nodules of chert, which was extensively used by prehistoric people and worked at the site. Human occupation is
documented here throughout the Palaeolithic and Aeneolithic periods, and all occupations have produced artefacts made on the local chert. Although surface collections have been conducted at the site since the 1930s, the first stratified Palaeolithic artefacts were found in 1945 when, during the final days of the Second World War, a grenade exposed a Palaeolithic layer with artefacts (Svoboda 1987). The various Upper Palaeolithic occupations were first systematically investigated by Karel Valoch and, beginning in 1982, by Jiří Svoboda. Numerous test pits have been excavated and many thousands of stone artefacts have been recovered since, most of them archaeological layers dating to the EUP period.

The stratigraphic profile most closely approximates that published for Stránská skála IIIa (Svoboda et al. 2002). Layer 5 (see Fig. 2 (d)) consists of soil sediments of lower to middle Pleistocene age, subsequently being removed by gelifluction. Layer 4 is formed from mildly humic soil sediment and contains the Bohunician artefacts. Layer 3 represents a phase of strong removal instability and sedimentation of loess. A short hiatus in loess sedimentation allowed the formation of black soil (pararendzines and chernozems). This layer contains the Aurignacian artefacts. The Pleistocene evolution of this profile is ended by layer 2, with an accumulation of Würm loess. The Bohunician occupation (layer 4) corresponds to the last phase of the lower Würm pleniglacial; some soil sediments were moved by the downslope movement of artefacts, and some of them were subsequently moved vertically into the overlying layer, by the alternate freezing and thawing of soil ice (Svoboda et al. 1996, 2002).

The \(^{14}\)C dates for each layer display quite a large range (see Table 3). This could be caused by different palaeosols, representing several small-scale oscillations, being incorporated into one
visible palaeosol layer (Svoboda 2003). Short-term climatic oscillations are documented for this period by the GRIP and GISP records. This is also likely to have affected at least some of the apparent discrepancies in the OSL results (see Table 7 below).

**Bohunice**

This site complex is situated in the city of Brno, in the area of Červený Kopec (Red Hill), 7 km east of Stránská skála. It is 280 m a.s.l., located at N49°10′, E16°35′. The site has the most complete sequence of Pleistocene fluvial sediments in Central Europe (Kukla 1975). The majority of artefacts were excavated in the early 1970s by Karel Valoch (Valoch 1976). A stratigraphic profile is provided in Figure 2 (e).

The lithic industry from this site is characterized by a mix of blade and Levallois reduction techniques (Allsworth-Jones 1986, 1990; Svoboda and Škrdla 1995; Škrdla 1999, 2000a,b), which is considered to be a unique combination of Middle Palaeolithic and Upper Palaeolithic reduction techniques. Likewise, the implement types are also considered to be a mix of the Middle Palaeolithic and Upper Palaeolithic; endscrapers and burins, as well as bifacially

**Table 3** *14C dates from Upper Palaeolithic layers at Stránská skála*

<table>
<thead>
<tr>
<th>Lab. code</th>
<th>Date</th>
<th>Calibrated age range (2σ)*</th>
<th>Site</th>
<th>Context</th>
<th>Industry</th>
<th>Year sampled</th>
</tr>
</thead>
<tbody>
<tr>
<td>GrN 16918</td>
<td>32 600 ± 1 700–1 400</td>
<td>33 930–41 198</td>
<td>IIIb</td>
<td>Upper palaeosol/top/Layer 3</td>
<td>Aurignacian</td>
<td>1989</td>
</tr>
<tr>
<td>GrN 14829</td>
<td>32 350 ± 900</td>
<td>35 004–38 899</td>
<td>IIa</td>
<td>Upper palaeosol/top/Layer 3</td>
<td>Aurignacian</td>
<td>1986</td>
</tr>
<tr>
<td>GrN 12605</td>
<td>30 980 ± 360</td>
<td>34 842–36 380</td>
<td>IIIa</td>
<td>Upper palaeosol/top/Layer 3</td>
<td>Aurignacian</td>
<td>1984</td>
</tr>
<tr>
<td>GrN 12606</td>
<td>41 300 ± 3 100</td>
<td>40 674–50 000†</td>
<td>IIIa</td>
<td>Lower palaeosol/Layer 4</td>
<td>Bohunician</td>
<td>1982</td>
</tr>
<tr>
<td>GrN 12298</td>
<td>38 500 ± 1 400–1 200</td>
<td>40 815–45 060</td>
<td>III-2</td>
<td>Upper palaeosol/base/Layer 5</td>
<td>Bohunician</td>
<td>1982</td>
</tr>
<tr>
<td>AA 32058</td>
<td>38 300 ± 1 100</td>
<td>41 220–44 440</td>
<td>IIIc</td>
<td>Lower palaeosol/Layer 5</td>
<td>Bohunician</td>
<td>1997</td>
</tr>
<tr>
<td>GrN 12297</td>
<td>38 200 ± 1 100</td>
<td>41 139–44 391</td>
<td>III-1</td>
<td>Upper palaeosol/base/Layer 5</td>
<td>Bohunician</td>
<td>1982</td>
</tr>
<tr>
<td>AA 32059</td>
<td>37 900 ± 1 100</td>
<td>40 854–44 269</td>
<td>IIIId</td>
<td>Upper palaeosol/middle/Layer 5</td>
<td>Bohunician</td>
<td>1998</td>
</tr>
<tr>
<td>AA 32060</td>
<td>37 270 ± 990</td>
<td>40 260–43 611</td>
<td>IIIId</td>
<td>Upper palaeosol/middle/Layer 5</td>
<td>Bohunician</td>
<td>1998</td>
</tr>
<tr>
<td>AA 41474</td>
<td>37 240 ± 890</td>
<td>40 496–43 355</td>
<td>IIIIf</td>
<td>Lower palaeosol/Layer 4</td>
<td>EUP</td>
<td>1999</td>
</tr>
<tr>
<td>AA 41476</td>
<td>36 570 ± 940</td>
<td>39 449–42 898</td>
<td>IIIc</td>
<td>Palaeosol complex/Layer 5</td>
<td>Bohunician</td>
<td>1999</td>
</tr>
<tr>
<td>AA 41478</td>
<td>36 350 ± 990</td>
<td>39 117–42 753</td>
<td>IIIc</td>
<td>Palaeosol complex/Layer 5</td>
<td>Bohunician</td>
<td>1999</td>
</tr>
<tr>
<td>GrA 11808</td>
<td>35 320 ± 320–300</td>
<td>39 460–41 257</td>
<td>IIIId</td>
<td>Upper palaeosol/middle/Layer 5</td>
<td>Bohunician</td>
<td>1998</td>
</tr>
<tr>
<td>AA 32061</td>
<td>35 080 ± 830</td>
<td>38 400–41 840</td>
<td>IIIId</td>
<td>Upper palaeosol/middle/Layer 5</td>
<td>Bohunician</td>
<td>1998</td>
</tr>
<tr>
<td>AA 41480</td>
<td>34 680 ± 820</td>
<td>37 612–41 421</td>
<td>IIIc</td>
<td>Palaeosol complex/Layer 5</td>
<td>Bohunician</td>
<td>1999</td>
</tr>
<tr>
<td>GrA 11504</td>
<td>34 530 ± 830–740</td>
<td>37 399–41 315</td>
<td>IIIId</td>
<td>Upper palaeosol/middle/Layer 5</td>
<td>Bohunician</td>
<td>1998</td>
</tr>
<tr>
<td>AA 41477</td>
<td>34 530 ± 770</td>
<td>37 536–41 245</td>
<td>IIIc</td>
<td>Palaeosol complex/Layer 5</td>
<td>Bohunician</td>
<td>1999</td>
</tr>
<tr>
<td>AA 41475</td>
<td>34 440 ± 720</td>
<td>37 537–41 118</td>
<td>IIIc</td>
<td>Palaeosol complex/Layer 5</td>
<td>Bohunician</td>
<td>1999</td>
</tr>
</tbody>
</table>

*Calibrated using Intcal09.*
†The range is suspect due to impingement on the end of the calibration data set.
Data from Svoboda (2003); all dates are on charcoal.

retouched leafpoints, are present. It has been argued that the Bohunician technology has antecedents at Boker Tachtit Level 1 and 2 in Israel, and that it spread to Moravia in 40–45 ka BP by cultural transmission, a diffusion process that could include migration of anatomically modern humans 40–45 ka BP (Tostevin 2000, 2003; Škrdla 2003).

In total, 20 radiocarbon dates (see Table 4) and one thermoluminescence date (47.3 ± 7.3 ka calendrical) (Valoch et al. 2000) have been obtained for this site, in addition to 11 heated flint artefacts measured recently (weighted mean of 48.2 ± 1.9 ka) by Richter et al. (2008). A recent OSL date of 58.7 ± 5.8 ka published by Richter et al. (2009) is considered by the authors to be less accurate than the TL results. The TL age dates the firing (anthropogenic) event, whereas the OSL age is related to the formation of the sediment.

**Moravský Krumlov IV**

This site complex is situated at N49°01′, E16°21′, on the eastern slopes of the Krumlovian Forest. The height above sea level is in the vicinity of 320 m. It was excavated in the years 2000–4, with four archaeological layers being identified. A number of surface sites are known from the general area (Nerudová 2008). The site is expected to be much larger (Neruda et al. 2004). Stone artefacts

### Table 4  
**14C dates from Bohunice**

<table>
<thead>
<tr>
<th>Sample no.</th>
<th>Date</th>
<th>Calibrated age range (2σ)*</th>
<th>Site</th>
<th>Layer</th>
<th>Industry</th>
<th>Year of excavation</th>
</tr>
</thead>
<tbody>
<tr>
<td>OxA-18302</td>
<td>34 770 ± 240</td>
<td>38 974–40 596</td>
<td>B2002</td>
<td>4</td>
<td>Bohunician</td>
<td>2002</td>
</tr>
<tr>
<td>GrN 16920</td>
<td>36 000 ± 1000</td>
<td>38 689–42 695</td>
<td>Cihelna</td>
<td>4</td>
<td>Bohunician</td>
<td>1985</td>
</tr>
<tr>
<td>OxA-18298</td>
<td>36 050 ± 260</td>
<td>40 641–41 750</td>
<td>B2002</td>
<td>4</td>
<td>Bohunician</td>
<td>2002</td>
</tr>
<tr>
<td>OxA-18343</td>
<td>36 540 ± 310</td>
<td>41 068–42 074</td>
<td>B2002</td>
<td>4</td>
<td>Bohunician</td>
<td>2002</td>
</tr>
<tr>
<td>OxA-18303</td>
<td>38 200 ± 330</td>
<td>42 103–42 183</td>
<td>B2002</td>
<td>4</td>
<td>Bohunician</td>
<td>2002</td>
</tr>
<tr>
<td>OxA-18299</td>
<td>38 690 ± 320</td>
<td>42 408–43 575</td>
<td>B2002</td>
<td>4</td>
<td>Bohunician</td>
<td>2002</td>
</tr>
<tr>
<td>OxA-18300</td>
<td>38 770 ± 330</td>
<td>42 457–43 692</td>
<td>B2002</td>
<td>4</td>
<td>Bohunician</td>
<td>2002</td>
</tr>
<tr>
<td>OxA-18301</td>
<td>40 050 ± 360</td>
<td>43 305–44 647</td>
<td>B2002</td>
<td>4</td>
<td>Bohunician</td>
<td>2002</td>
</tr>
<tr>
<td>Q 1044</td>
<td>40 173 ± 1200</td>
<td>42 354–45 750</td>
<td>Kejbaly</td>
<td>4</td>
<td>Bohunician</td>
<td>1973</td>
</tr>
<tr>
<td>OxA-14845</td>
<td>41 250 ± 450</td>
<td>44 221–45 591</td>
<td>Cihelna</td>
<td>4</td>
<td>Bohunician</td>
<td>1973</td>
</tr>
<tr>
<td>OxA-14848</td>
<td>41 350 ± 450</td>
<td>44 277–45 649</td>
<td>Kejbaly</td>
<td>4</td>
<td>Bohunician</td>
<td>1973</td>
</tr>
<tr>
<td>GrN 6802</td>
<td>41 400 ± 1400</td>
<td>42 697–47 484</td>
<td>Kejbaly</td>
<td>4</td>
<td>Bohunician</td>
<td>1973</td>
</tr>
<tr>
<td>OxA-14843</td>
<td>42 100 ± 450</td>
<td>44 707–46 155</td>
<td>Cihelna</td>
<td>4</td>
<td>Bohunician</td>
<td>1973</td>
</tr>
<tr>
<td>OxA-14847</td>
<td>42 750 ± 550</td>
<td>44 961–46 894</td>
<td>Kejbaly</td>
<td>4</td>
<td>Bohunician</td>
<td>1973</td>
</tr>
<tr>
<td>GrN 6165</td>
<td>42 900 ± 1700</td>
<td>43 846–49 686</td>
<td>Cihelna</td>
<td>4</td>
<td>Bohunician</td>
<td>1973</td>
</tr>
<tr>
<td>OxA-14844</td>
<td>43 250 ± 550</td>
<td>45 264–47 649</td>
<td>Cihelna</td>
<td>4</td>
<td>Bohunician</td>
<td>1973</td>
</tr>
<tr>
<td>OxA-14846</td>
<td>43 600 ± 550</td>
<td>45 525–48 219</td>
<td>Kejbaly</td>
<td>4</td>
<td>Bohunician</td>
<td>1973</td>
</tr>
<tr>
<td>Wk-17757</td>
<td>&gt;40 000†</td>
<td>Uncalibrated</td>
<td>B2002</td>
<td>4</td>
<td>Bohunician</td>
<td>2002</td>
</tr>
</tbody>
</table>

*Calibrated using Intcal09.
†This is a minimum age; the Waikato Laboratory advises that the standard error overlaps with background within 2σ, so a finite age cannot be calculated.

Data compiled from Richter et al. (2009), Svoboda et al. (2002), Valoch (1976, 2008) and the present authors’ data; all dates are on charcoal.
recovered from Layer 5 (see Fig. 2 (c)) were classified as Szeletian on the basis of typological and technological elements (Nerudová and Neruda 2004; Neruda and Nerudová 2005). The 14C results from Layer 5 are presented in Table 5. Middle Palaeolithic assemblages were recovered from three of the underlying layers. The stratigraphy is described in detail in Neruda and Nerudová (2009) (for a brief description, see Fig. 2 (c)).

Vedrovice V

Vedrovice V is located on the gentle slopes of a ridge in the Krumlovský Les (Krumlovian Forest) area, at N49°01′, E16°21′, approximately 4 km from Moravský Krumlov IV. The site was discovered in 1981 during excavations of a Neolithic cemetery. Palaeolithic artefacts were found in the lower part of a palaeosol (see Fig. 2 (f)), approximately 90 cm from the surface (Valoch 1984). The site was subsequently excavated by Valoch in 1982–3 and 1989 (Nerudová 2000). A total of 17 064 artefacts were recovered during the excavations, and 727 were identified as retouched (Valoch 1993).

The 14C samples were collected in hearths or as concentrations of charcoal (for results, see Table 6). According to Valoch (1993), the dates obtained on samples collected in 1989 are considered to be unreliable (see explanations in Table 6).

Vedrovice Ia

Vedrovice Ia is located in the Krumlovian Forest, approximately 800 m north-east of Vedrovice V (N49°01′, E16°23′) and at 285 m a.s.l. Lithic artefacts classified as Aurignacian were recovered from layers 1–4 (see Fig. 2 (g)). Fragmentary skeletal remains of horses, reindeer and bovids were also recovered, associated with the lithic artefacts (Oliva 1993b). A horse tooth was dated by ESR at the ANU laboratory yielding an age of 36.0 ± 2.0 ka, which is roughly in agreement with the expected age, given the typological classification of the lithic industry.

RESULTS AND DISCUSSION

Kůlna

The OSL results from Kůlna are generally in the correct temporal order (see Table 7 and Fig. 3). The results for layer 6a are crucial because this layer has not been previously dated by an absolute...
dating method, and it records the last occurrence of the Micoquian industry in Kúlna, and in this region of Europe. As Jíří Svoboda puts it, ‘The fact that we are not able to date the end of the Neanderthal occupation more precisely in this most promising case is a serious detriment to our understanding of the Middle to Upper Palaeolithic transition in our area’ (Svoboda et al. 1996, 215–17).

Layer 6a—cave entrance There is a discrepancy between the OSL result for a sample taken from layer 6a at the entrance of the cave (K0081) and the samples taken from a layer also designated as 6a from the interior of the cave (K0674 and K0675). While at the entrance of the cave the result for layer 6a indicates an age of around 30 ka, layer 6a in the interior of the cave is around 70 ka. Although this may indicate a problem with the dating method, it is more likely that the uncertainties associated with chronostratigraphic associations between the entrance of the cave and the interior of the cave (see Valoch 1988; Neruda 2005) may be to blame. The remaining sediment samples were also collected from the stratigraphic profiles at the cave entrance. The lithology of each stratigraphic unit varies considerably in different parts of the cave (Valoch 1988; Rink et al. 1996). Given the extremely complex nature of the stratigraphy at Kúlna and the uncertainties in associating the sediments in the interior of the cave with the sediments at the entrance, the most parsimonious conclusion is that the layer designated as 6a in the interior of the cave is not the same chronostratigraphic unit designated as 6a at the cave entrance. It is important to note that the stratigraphic sequence at the cave entrance where sample K0081 was collected is not sedimentologically consistent throughout the cave; the sediments overlying layer 7a inside the cave are mostly dark brown clays, whereas at the entrance they are composed of yellow–brown loess with varying amounts of detritus. There is no doubt that this loess represents accumulations from various periods, including stratigraphic hiatuses (which are not represented by sediments). There was no methodology available to distinguish the different loess accumulations at the time of the original excavation, but we do know that they represent sedimentation periods between 13 000 BP and 40 000 BP. Given such a large cave entrance, loess could have been accumulating in various periods. This notion is also corroborated by the presence of a layer of loess with Gravettian artefacts (dated by \(^{14}C\) to 27–28 cal ka) in this stratigraphic horizon.

Table 6 \(^{14}C\) dates from Vedrovice V

<table>
<thead>
<tr>
<th>Sample no.</th>
<th>Date</th>
<th>Calibrated age range (2(\sigma))*</th>
<th>Industry</th>
<th>Year(s) of excavation</th>
</tr>
</thead>
<tbody>
<tr>
<td>GrN 15513</td>
<td>35 150 ± 650</td>
<td>38 791–41 465</td>
<td>Szeletian</td>
<td>1982–3</td>
</tr>
<tr>
<td>GrN 15514</td>
<td>37 600 ± 800</td>
<td>41 084–43 450</td>
<td>Szeletian</td>
<td>1982–3</td>
</tr>
<tr>
<td>GrN 12374</td>
<td>37 650 ± 550</td>
<td>41 519–43 087</td>
<td>Szeletian</td>
<td>1982–3</td>
</tr>
<tr>
<td>GrN 12375</td>
<td>39 500 ± 1 100</td>
<td>42 064–45 174</td>
<td>Szeletian</td>
<td>1982–3</td>
</tr>
<tr>
<td>GrN 17261, sample contaminated with recent rootlets</td>
<td>30 170 ± 300</td>
<td>34 405–35 267</td>
<td>Szeletian</td>
<td>1989</td>
</tr>
<tr>
<td>GrN-19105, sample originated from a layer above the archaeological horizon</td>
<td>&gt;39 500</td>
<td>Uncalibrated</td>
<td>Szeletian</td>
<td>1989</td>
</tr>
<tr>
<td>GrN-19106, sample originated from a layer below the archaeological horizon</td>
<td>47 250 ± 3 700–2 500</td>
<td>Uncalibrated</td>
<td>Szeletian</td>
<td>1989</td>
</tr>
</tbody>
</table>

*Calibrated using Intcal.09.
Data compiled from Valoch (1993); all dates are on charcoal.

<table>
<thead>
<tr>
<th>Site</th>
<th>Layer</th>
<th>Burial depth (cm)</th>
<th>Radiocarbon date (1σ) cal BC</th>
<th>Radiocarbon date (2σ) cal BC</th>
<th>Optical age (cal BC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kozlovka</td>
<td>K0031</td>
<td>6</td>
<td>2.48 ± 0.30</td>
<td>1.98 ± 0.12</td>
<td>5.40 ± 0.36</td>
</tr>
<tr>
<td>Kozlovka</td>
<td>K0032</td>
<td>6</td>
<td>2.41 ± 0.29</td>
<td>2.11 ± 0.12</td>
<td>5.30 ± 0.22</td>
</tr>
<tr>
<td>Kozlovka</td>
<td>K0033</td>
<td>6</td>
<td>2.39 ± 0.30</td>
<td>2.09 ± 0.12</td>
<td>5.20 ± 0.23</td>
</tr>
<tr>
<td>Kozlovka</td>
<td>K0034</td>
<td>6</td>
<td>2.37 ± 0.30</td>
<td>2.07 ± 0.12</td>
<td>5.10 ± 0.23</td>
</tr>
<tr>
<td>Kozlovka</td>
<td>K0035</td>
<td>6</td>
<td>2.35 ± 0.30</td>
<td>2.05 ± 0.12</td>
<td>5.00 ± 0.23</td>
</tr>
<tr>
<td>Kozlovka</td>
<td>K0036</td>
<td>6</td>
<td>2.33 ± 0.30</td>
<td>2.03 ± 0.12</td>
<td>4.90 ± 0.23</td>
</tr>
<tr>
<td>Kozlovka</td>
<td>K0037</td>
<td>6</td>
<td>2.31 ± 0.30</td>
<td>2.01 ± 0.12</td>
<td>4.80 ± 0.23</td>
</tr>
<tr>
<td>Kozlovka</td>
<td>K0038</td>
<td>6</td>
<td>2.29 ± 0.30</td>
<td>1.99 ± 0.12</td>
<td>4.70 ± 0.23</td>
</tr>
<tr>
<td>Kozlovka</td>
<td>K0039</td>
<td>6</td>
<td>2.27 ± 0.30</td>
<td>1.97 ± 0.12</td>
<td>4.60 ± 0.23</td>
</tr>
<tr>
<td>Kozlovka</td>
<td>K0040</td>
<td>6</td>
<td>2.25 ± 0.30</td>
<td>1.95 ± 0.12</td>
<td>4.50 ± 0.23</td>
</tr>
<tr>
<td>Kozlovka</td>
<td>K0041</td>
<td>6</td>
<td>2.23 ± 0.30</td>
<td>1.93 ± 0.12</td>
<td>4.40 ± 0.23</td>
</tr>
<tr>
<td>Kozlovka</td>
<td>K0042</td>
<td>6</td>
<td>2.21 ± 0.30</td>
<td>1.91 ± 0.12</td>
<td>4.30 ± 0.23</td>
</tr>
<tr>
<td>Kozlovka</td>
<td>K0043</td>
<td>6</td>
<td>2.19 ± 0.30</td>
<td>1.89 ± 0.12</td>
<td>4.20 ± 0.23</td>
</tr>
<tr>
<td>Kozlovka</td>
<td>K0044</td>
<td>6</td>
<td>2.17 ± 0.30</td>
<td>1.87 ± 0.12</td>
<td>4.10 ± 0.23</td>
</tr>
<tr>
<td>Kozlovka</td>
<td>K0045</td>
<td>6</td>
<td>2.15 ± 0.30</td>
<td>1.85 ± 0.12</td>
<td>4.00 ± 0.23</td>
</tr>
<tr>
<td>Kozlovka</td>
<td>K0046</td>
<td>6</td>
<td>2.13 ± 0.30</td>
<td>1.83 ± 0.12</td>
<td>3.90 ± 0.23</td>
</tr>
<tr>
<td>Kozlovka</td>
<td>K0047</td>
<td>6</td>
<td>2.11 ± 0.30</td>
<td>1.81 ± 0.12</td>
<td>3.80 ± 0.23</td>
</tr>
<tr>
<td>Kozlovka</td>
<td>K0048</td>
<td>6</td>
<td>2.09 ± 0.30</td>
<td>1.79 ± 0.12</td>
<td>3.70 ± 0.23</td>
</tr>
<tr>
<td>Kozlovka</td>
<td>K0049</td>
<td>6</td>
<td>2.07 ± 0.30</td>
<td>1.77 ± 0.12</td>
<td>3.60 ± 0.23</td>
</tr>
<tr>
<td>Kozlovka</td>
<td>K0050</td>
<td>6</td>
<td>2.05 ± 0.30</td>
<td>1.75 ± 0.12</td>
<td>3.50 ± 0.23</td>
</tr>
<tr>
<td>Kozlovka</td>
<td>K0051</td>
<td>6</td>
<td>2.03 ± 0.30</td>
<td>1.73 ± 0.12</td>
<td>3.40 ± 0.23</td>
</tr>
<tr>
<td>Kozlovka</td>
<td>K0052</td>
<td>6</td>
<td>2.01 ± 0.30</td>
<td>1.71 ± 0.12</td>
<td>3.30 ± 0.23</td>
</tr>
<tr>
<td>Kozlovka</td>
<td>K0053</td>
<td>6</td>
<td>1.99 ± 0.30</td>
<td>1.69 ± 0.12</td>
<td>3.20 ± 0.23</td>
</tr>
<tr>
<td>Kozlovka</td>
<td>K0054</td>
<td>6</td>
<td>1.97 ± 0.30</td>
<td>1.67 ± 0.12</td>
<td>3.10 ± 0.23</td>
</tr>
<tr>
<td>Kozlovka</td>
<td>K0055</td>
<td>6</td>
<td>1.95 ± 0.30</td>
<td>1.65 ± 0.12</td>
<td>3.00 ± 0.23</td>
</tr>
<tr>
<td>Kozlovka</td>
<td>K0056</td>
<td>6</td>
<td>1.93 ± 0.30</td>
<td>1.63 ± 0.12</td>
<td>2.90 ± 0.23</td>
</tr>
<tr>
<td>Kozlovka</td>
<td>K0057</td>
<td>6</td>
<td>1.91 ± 0.30</td>
<td>1.61 ± 0.12</td>
<td>2.80 ± 0.23</td>
</tr>
<tr>
<td>Kozlovka</td>
<td>K0058</td>
<td>6</td>
<td>1.89 ± 0.30</td>
<td>1.59 ± 0.12</td>
<td>2.70 ± 0.23</td>
</tr>
<tr>
<td>Kozlovka</td>
<td>K0059</td>
<td>6</td>
<td>1.87 ± 0.30</td>
<td>1.57 ± 0.12</td>
<td>2.60 ± 0.23</td>
</tr>
<tr>
<td>Kozlovka</td>
<td>K0060</td>
<td>6</td>
<td>1.85 ± 0.30</td>
<td>1.55 ± 0.12</td>
<td>2.50 ± 0.23</td>
</tr>
<tr>
<td>Kozlovka</td>
<td>K0061</td>
<td>6</td>
<td>1.83 ± 0.30</td>
<td>1.53 ± 0.12</td>
<td>2.40 ± 0.23</td>
</tr>
</tbody>
</table>

*Test pit 1 as shown in figure 2 in Škrdla and Tostevin (2005, 37).
†Test pit 3 as shown in figure 2 in Škrdla and Tostevin (2005, 37).
‡An ESR date obtained for a horse tooth from this layer yielded an age of 36.0 ± 2.0 ka (Nejman et al. in prep.).
example of the complex nature of sedimentation in the cave entrance is the discovery of artefacts indisputably identified as Magdalenian, whereas 1 m away (still in the same level) artefacts that were indisputably identified as Micoquian were discovered. When the area was being excavated and vertical control over stratigraphy was maintained, it was possible to distinguish various industries, but in the residual sections remaining today, this is not possible. Sample K0081 was collected where the detritus in the loess was relatively large-sized, which was a general diagnostic feature of layer 6a, so it was postulated that the OSL result would confirm our expectations. The actual result, however, strongly suggests that the loess was a younger age than would be expected for a Micoquian layer, so interpreting this OSL age as an indication of a late Neanderthal occupation is problematic and inconclusive.

Layer 6a—cave interior  The samples collected from layer 6a inside the cave (K0674 and K0675) present a different situation to the cave entrance. Overlying the clearly distinguishable
Layer 7a was a thick layer consisting of loess with detritus containing only Micoquian artefacts. Younger loess containing Gravettian and Magdalenian artefacts was not continuous and was present sporadically (it was partially destroyed by surface modifications during the Second World War, when the cave was converted into a factory by the German military) and was clearly distinguishable from the older loess. Samples K0674 and K0675 produced results with large variation in the same age bracket as samples K0676 (layer 7a), K0080 (layer 7c) and K0079 (layer 9b). We expected a result of around 40,000 BP, which would have been supported by the presence of faunal remains of cold-adapted (pleni-glacial) fauna recovered from this layer. Cryogenic structures were present in the contact zone between layers 6a and 7a.

Layer 7a  Samples K0676 and K0677 produced results that are almost equivalent to samples K0674 and K0675 (layer 6a) and are markedly older than the ESR results (see Table 1) before the chronostratigraphic estimate was made based on fauna (interval Moershoofd, Valoch 1989, ~50 ka BP; van Andel 2003, fig. 2.6).

Layer 7b  Layer 7b is composed of various sediments. The lower part contains clearly layered clays redeposited by solifluction, which means that they represent a mixture of older sediments. The upper part consists of primary sediments deposited during a very cold period in a wet/moist environment. This means that sample K0678 indicates the real age of the sediment, but it is younger than the result for the overlying sediment in layer 7a.

Layer 7c  The result for sample K0080 is very similar to the results for samples K0676 and K0677, so from this perspective they are acceptable, because it can be expected that the formation period of layer 7b was very brief (OIS 4?: Musil 2003, table 10.1A) and so the age can be within the statistical variation of OSL dates for layers 7a and 7c (the statistical error is around 5 ka). Given that a similar date was also obtained for sample K0079 (layer 9b), it would appear that ~70 ka is too high. Faunal remains from layer 7c suggest a warmer temperate climate (Valoch 1988).

Layer 9b  The result for sample K0079 and the results of ESR analysis (Rink et al. 1996) are almost identical and indicate that the sedimentary units relate to the Odderade interval (van Andel 2003, fig. 2.6, OIS 5b?).

Layer 11  This sediment complex was formed by four relatively thick horizons (11a–d), similar in colour and grain size and with a sandy component. The faunal assemblage from the entire complex suggests a warm, temperate climate. A lens in the lower part of this complex (probably layer 11c) produced several artefacts and molluscs belonging to a warm climate (interglacial) assemblage. Sample K0078 was collected from the uppermost layer (11a) and probably dates the final phase of the formation of this sedimentary complex.

Layer 12a  This layer represents the upper part of sandy, fluvial deposits with a clay component that was deposited by a river flowing into the cave. The OSL result for sample K0077 may be related to the above-mentioned lens containing the warm climate molluscs, and may have been deposited during the final phase of river activity in the cave, possibly during the final phase of the interglacial.
Layer 14 This layer contained a small assemblage of steppe fauna, so it was thought that it might date to the final phase of OIS 6 or the beginning of OIS 5e. The result for sample K0075 does not support this hypothesis because it is too young, but when we consider the statistical error of almost 9 ka, the OSL result is broadly consistent with the period of the last interglacial.

Late Neanderthals in Külna? The sediment sample K0081 was collected from layer 6a at the cave entrance, where this layer is up to 1 m thick. This layer contained numerous Micoquian artefacts but, as discussed above, it is not possible to unequivocally attribute this date to the Micoquian industry. But if it could be shown that it is dating the Neanderthal occupation, it would strongly suggest that Neanderthals and H. sapiens overlapped in this region of Moravia by up to five or six thousand years. This would be an important discovery, as Neanderthal/H. sapiens coexistence has not been previously demonstrated for this region. Although at this stage we do not have firm evidence of late Neanderthals in Külna, the following discussion will outline the implications should such a finding be confirmed by future research. The straight-line distance between the Mladěč caves (fossil remains of early modern humans) and Külna cave is approximately 38 km. There are two 14C dates on carbonates from sinter overlying the Mladěč skeletons; they are 34 160 ± 520–490 14C-years (37 578–40 566 cal yrs BP) for the upper sample and 34 930 ± 520–490 14C-years (38 812–41 125 cal yrs BP) for the lower sample—these would be minimum ages for the fossils (Svoboda et al. 2002). Tooth samples of the Mladěč hominids were recently dated by AMS, yielding dates of approximately 31 ka 14C-years (34.6–36.7 cal ka BP) (Wild et al. 2005). If these results are correct, the Mladěč remains would then be five or six thousand years older than the Neanderthal-manufactured Micoquian industry in Külna layer 6a. Mellars (2006) has recently argued that due to contamination by percolating groundwater, 14C ages underestimate true ages by up to 5000–12 000 years. If this estimate was correct for Mladěč, then the overlap period would be even longer.

The Mladěč human bone assemblage is the largest, most important and best studied assemblage of early modern humans associated with the Aurignacian (Churchill and Smith 2000; Teschler-Nicola 2006). It is now also the oldest since the Vogelherd remains were recently re-dated to the Neolithic (Conard et al. 2004). H. sapiens bones (dated by AMS to 34 950 ± 990 14C-years, which corresponds to 37 553–41 816 cal yrs BP) were recently discovered in Peștera cu Oase cave in Romania, but no archaeological artefacts were reported with these finds (Trinkaus et al. 2003). The Mladěč human bones were also associated with Mladěč points (bone projectiles considered culturally diagnostic for EUP and especially the Aurignacian period), various other bone tools, 22 perforated animal teeth, a few stone artefacts and fauna (Svoboda 2001; Oliva 2006).

The chronological overlap of modern humans and Neanderthals has already been demonstrated in parts of southern Europe (see, e.g., Churchill and Smith 2000: for evidence of late Neanderthals, see Smith et al. 1999; Carbonell et al. 2000; Ovchinnikov et al. 2000). The Neanderthal occupation of Gorham’s Cave, Gibraltar, has recently been reported to have lasted until at least 28 000 14C-years (31–34 cal ka BP) and possibly until as late as 24 000 ka 14C-years (28–29 cal ka BP) (Finlayson et al. 2006). The Lagar Velho skeleton found in Portugal has been dated by AMS to 24 520 ± 240 ka (28 554–29 937 cal BP) and has been taxonomically assessed as a Neanderthal/H. sapiens hybrid (Zilhão and Trinkaus 2002), although Bailey et al. (2009) suggest that this specimen is a modern human, on the basis of diagnostic dental features. Many authors have used an extrapolation argument for Neanderthal/H. sapiens coexistence, as H. sapiens are known to have arrived in Europe by 37–41 cal ka BP (at the latest), as is evident from sites such as Mladěč (Svoboda et al. 2002) and Peștera cu Oase, Romania (Trinkaus et al. 2003), but may
have arrived as early as 47 ka (van Andel and Davies 2003). In the case of Moravia, the idea of the two species overlapping is even more intriguing, because Mladeč and Kůlna are separated by a mere 38 km.

**Dzeravá skala**

The sediment samples were collected from the northern profile of test pit PP1, excavated during the 2002–3 excavation (Kaminská et al. 2005, 19; fig. 8). Layer 9 is described as a dark brown loess soil with infrequently occurring small angular clasts and weakly sorted sand particles (Kaminská et al. 2005, 22). The OSL age (K0085) for layer 9 agrees well with the AMS $^{14}$C dates and the artefacts that appear Aurignacian. Layer 11 is described as a light brown–grey, loamy to clayish aleuritic layer, with small, angular and sub-angular detritus, including some pieces up to 10–20 cm in diameter and some weakly sorted sand (Kaminská et al. 2005, 23). The most recent analysis by Kaminská et al. (2005) did not find evidence for the proposition that the bone points and leafpoints occur in association in this layer. The artefacts previously identified as Szeletian have now been reinterpreted as Micoquian (Kaminská et al. 2005).

**Stránská skála**

The samples were collected from two test pits directly adjacent to the western/southwestern edge of pit IIIc, which were excavated in order to collect sediment samples for OSL analysis. The results for this site are also in the correct temporal order (within the error ranges). The ages of 40.5 ± 3 and 42.6 ± 2.6 ka for layer 2 roughly agree with the three $^{14}$C dates available for this layer (when error ranges are taken into account). We have three results for layer 3. The first two, 40.6 ± 3.8 and 45.7 ± 3.6 ka, agree well with the $^{14}$C dates. The date 64 ± 5.9 ka for layer 4 appears far too old; the 15 $^{14}$C dates (see Table 3) available for this layer at this site range between 37.5 and 45.0 calibrated years (disregarding GrN 12606, which has an uncertain range). The $^{14}$C dates for the Bohunician layer at Bohunice suggest a similar antiquity to Stránská skála. Thus it would appear that our OSL date of 64 ka does not fit with the $^{14}$C dates. However, given that it was collected in the lower part of this layer, it may have been contaminated by sediment from the underlying layer—although as Svoboda et al. (1996) point out, it is important to be mindful of the fact that the use of $^{14}$C dating puts serious limitations on dating sites of this antiquity, and these assemblages with a number of Middle Palaeolithic elements (i.e., Szeletian, Bohunician) may have started significantly earlier than has been believed up to now. Also, at 64 ka it would place it into the Lower Pleniglacial, when soils could not form. Likewise, the OSL age of the underlying layer 5 (141.9 ± 11.0 ka) also appears too old. The unexpectedly older age of layers 4 (K0088) and 5 could possibly be explained by contamination by older sand grains from the underlying sediments. Cryoturbations (which are well documented at this site—but not in the test pit where the OSL samples were collected) could have caused this contamination.

**Bohunice**

The sediment samples collected in 2003 were from the northern profile of test pit 3, while the sediment samples collected in 2005 were collected from the northern profile of test pit 1: these two test pits were opened at the same time as the main trench of the 2002 Bohunice excavation, by the Institute of Archaeology, Brno and the University of Minnesota, USA (see fig. 2 in Škrádla and Tostevin 2005, 37). The results for Bohunice samples are also generally in the correct
temporal order. The apparent anomaly for the result from layer 2 (41.0 ± 3.3 ka) may not actually be an anomaly, given the standard deviation. Theoretically, this age could still be younger than the obtained age for the underlying layer (which is 37.1 ± 3.0 ka). The results for layers 4 and 5 are in the correct ballpark. Layer 4 contains the Bohunician artefacts where 14C dates are available (see Table 4). The 14C dates are in the same ballpark as the OSL date for this layer (38.3 ± 3.0 ka).

Despite the major recent attempts at dating the human occupation at this important EUP locality, including new 14C dates (Valoch 2008; Richter et al. 2009) and TL dates (Richter et al. 2008), a consensus on the age of the archaeological layer has still not been reached and further verification is required (Richter et al. 2009). Bohunice is currently the most extensively dated EUP site in Central Europe.

Moravský Krumlov IV

All of the sediment samples were collected from sector IV-3, which was available during the 2003 excavation season (see Neruda and Nerudová 2009). The archaeological and geological evaluation of OSL results for this site is somewhat complex. The OSL result for sample K0069 (43.6 ± 3.3 ka) from the upper part of this horizon correlates with the 14C dates (see Table 5) and with the cluster of 14C dates from the nearby site of Vedrovice V (see Table 6) and it dates this layer to the EUP period. Our OSL date for the lower part of layer 5 (64.6 ± 7.0 ka), underlying the archaeological horizon described above, is unexpectedly high, and it is relevant to note that during the collection of the sample an admixture with detritic material was noticed. This indicates that, as has been hypothesized at Stránská skála, there is possible contamination by older sediment from lower layers. On the other hand, it is also possible that the sediment contamination hypothesis is incorrect and the OSL dates for the Szeletian are in the correct ballpark (this alternative explanation is also supported by the OSL age estimate for the Vedrovice V assemblage). The OSL dates for the remaining sediments are in the correct temporal order and concur with the techno-typological analysis of the lithic industry. It is difficult to achieve an accurate cultural classification of these assemblages due to a lack of implements, but some artefacts even in layer 10 suggest an affinity with the Micoquian, even though the actual OSL result (97.2 ± 7.3 ka) would mean that this is the oldest example of the Micoquian industry in Central Europe. Nevertheless, we have Micoquian assemblages in Western Europe dating to the later stages of OIS 6. Layer 15 has been dated to 151.4 ± 13.8 ka (sample K0074), which places it into the earlier stages of OIS 6. The small artefact assemblage is similar to the local Krumlovian, which, based on the type site, is associated with the Eemian interglacial, but it is possible that such industries can be even older; we do not have extensive collections from stratified contexts from this period in this region (see Neruda and Nerudová 2009).

Vedrovice V

The sediment samples were collected from a test pit excavated in order to collect these samples. This test pit was located approximately 10 m to the south-west from the western edge of Valoch’s excavation. A stone artefact was found in layer 5, approximately 150 cm from the surface. The OSL dates for this site are in the correct temporal order, but they are surprisingly older than expected. The 14C dates (see Table 6) are significantly younger than our OSL dates, so the real age of the Vedrovice V assemblage is still in question. Based on the OSL results, the youngest possible age of the Vedrovice V assemblage is 45.1 ± 2.5 ka, because this is the OSL age of the overlying layer 4. The OSL age for the top of the artefact-bearing layer is 60.3 ± 3.4 ka and for the bottom of the layer 102.1 ± 7.0 ka.

When we compare these results to Moravský Krumlov IV, Bohunice layer 4 and Stránská skála layer 4, a similar phenomenon is apparent, according to which the OSL results push the age of the sediment deeper into the Middle Palaeolithic than previously suggested by the \(^{14}\)C dates. It is possible that this phenomenon could be related to post-depositional processes. One example could be the difference between the results for the Vedrovice V samples, where a 30 cm interval represents over 55 000 years. It is also possible that the soil that formed during the last interglacial is not represented in this profile, while the date for sample K0670 corresponds to this period. It is possible that this site was inhabited by the Szeletians during the time while the interglacial soil was being formed and acted as a substrate for the soil that developed during the Würmian interpleniaglacial. This hypothesis is supported by the fact that sample K0670 was collected just above noticeable solifluction, which indicates movement of the above-mentioned sediments.

It is difficult to identify the causes of the noted differences between the OSL and \(^{14}\)C results with the current state of knowledge. The OSL results are very useful and will be a basis for further dating projects in EUP studies, but it is important to realize that \(^{14}\)C dates have the potential to provide dates for actual anthropogenic events (when the dated sample can be associated with human activity), so they are able date the actual human activities more precisely than OSL dates. However, \(^{14}\)C dates can also have a large statistical error, and it has been shown that \(^{14}\)C results from the same horizon can produce large differences depending on whether it is bone or charcoal that is being dated (Sinitsyn 2003, table 1). There also tend to be significant differences between \(^{14}\)C samples measured recently and those measured in the past; this is related to methodological improvements in sample preparation (Bronk Ramsey 2008).

If, however, the Vedrovice V Szeletian assemblage does date to between 60 and 100 ka as the OSL results suggest, then this antiquity would place it well into the Middle Palaeolithic. It would also mean that the Vedrovice V assemblage classified as Szeletian would have been manufactured by the Neanderthals, because they were the only known hominids occupying this region at the time. This may not be as surprising when we consider the numerous similarities of the Vedrovice V assemblage to the Ku˚lna Micoquian assemblage. The typological and technological similarities between these two assemblages have led previous researchers to postulate an ‘evolutionary’ link between the local Micoquian represented at K˚lina, the Szeletian represented by Vedrovice V and numerous surface assemblages (Valoch 1990a,b; Neruda 2000). As well as this technological continuity argument, the parallelism of Mousterian and Chatelperronian industries being manufactured by Neanderthals in Western Europe, has been used to argue for the Micoquian and Szeletian connection in Central Europe (cf., Svoboda 2001). It has also been argued in a recent study that the similarities in numerous lithic patterns between the Vedrovice V assemblage and the K˚lina assemblages (layers 6a and 7a) indicate a similar low level of residential mobility, a relatively small home range and a predominant technological strategy of provisioning individuals rather than provisioning of places (Nejman 2006). Our OSL results bolster the argument for a Middle Palaeolithic antiquity of the Vedrovice V occupation, but further research is needed to confirm this finding.

**Vedrovice Ia**

The sediment samples were collected from a test pit excavated in order to collect these samples. This test pit was adjacent to the original test pit excavated by Oliva (see Oliva 1993b). The OSL age of 37.3 ± 2.5 ka is the minimum (calibrated) age for the Aurignacian industry at Vedrovice Ia, because it was taken from the lower part of the overlying layer. The OSL age of 44.6 ± 2.2 ka
seems a little bit older than expected, especially given that the ESR age of a horse tooth recovered from this layer gave an age of $36.0 \pm 2.0 \text{ ka}$ (Nejman et al. in prep.)

CONCLUSIONS

Important new dating results have been obtained for seven key sites in Central Europe that date to the Middle–Upper Palaeolithic transition. Although there have previously been numerous attempts to date these sites using several different dating methods, the OSL results presented here offer new evidence and will add new information for arguments regarding the timing of events during the Middle–Upper Palaeolithic transition. In many cases, our OSL results are consistent with previous age estimates derived from other dating methods, or with expectations based on stratigraphic observations. Although at this stage it appears unlikely that our OSL age estimate of ~30 ka for previously undated layer 6a in Kůlna (K0081) dates the Neanderthal occupation, this issue warrants further investigation. The existence for such late-surviving Neanderthals has been argued for several sites in southern Europe, so it is not out of the question in Kůlna. If confirmed by future research, Kůlna would be the most northerly site representing such late Neanderthal occupation. Another key finding of this research is that the Vedrovice V assemblage may date to the Middle Palaeolithic. As hinted by the results of this dating project, further dating research in this part of Europe has the potential to make important new contributions to the study of the European Middle–Upper Palaeolithic transition. A project is currently under way where the dating results are being analysed together with the results of sedimentological and soil micro-morphological studies.

ACKNOWLEDGEMENTS

This research was made possible, in part, by a small New Initiatives grant from the Centre of Archaeological Research, Australian National University, institutional research project of the Ministry of Culture (MK00009486202) and an AVČR grant (# IAA800010801).

REFERENCES

Carbonell, E., Vaquero, M., Maroto, J., Rando, J. M., and Mallol, C., 2000, A geographic perspective on the Middle to Upper Palaeolithic transition in the Iberian Peninsula, in The geography of Neandertals and modern humans in
Michel, V., Bocherens, H., Théry-Pariset, I., Valoch, K., and Valensi, P., 2006b, Coloring and preservation state of faunal remains from the Neanderthal levels at Külna Cave, Czech Republic, Geoarchaeology, 21(5), 479–501.
Nejman, L., 2006, Lithic patterning and land-use during the Middle–Upper Palaeolithic transition in Moravia (Czech Republic), unpublished Ph.D. dissertation, Australian National University.
Neruda, P., 2000, The cultural significance of bifacial retouch. The transition from the Middle to Upper Palaeolithic Age in Moravia, in Neandertals and modern humans: discussing the transition. Central and Eastern Europe from 50,000–30,000 BP (eds. G. C. Weniger and J. Orschiedt), 151–8, Neanderthal Museum, Düsseldorf.


