



Bohunician technology and thermoluminescence dating of the type locality of Brno-Bohunice (Czech Republic)

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ABSTRACT

Results of thermoluminescence (TL) dating of 11 heated flint artifacts from the 2002 excavation at Brno-Bohunice, Czech Republic, are presented. The samples are from the eponym locality for the Bohunician, an industrial type considered technologically transitional between Middle and Upper Paleolithic core reduction strategies. The Bohunician is the first early Upper Paleolithic technocomplex in the Middle Danube of Central Europe and, therefore, is implicated in several issues related to the origins of modern humans in Europe. The Bohunician provides an example of how one technological strategy combines crested blade initiation of a core with the surficial (almost Levalloisian) reduction of blanks as blades and points. As the Middle Danube lacks antecedents of the behavioral steps within this technology, several hypotheses of inter-regional cultural transmission, with and without hominin gene flow, could explain the appearance of the Bohunician. The elucidation of the temporal context of Bohunician assemblages is, therefore, a critical step in understanding the behavioral, and potentially biological, succession in this region. Radiocarbon age estimates from charcoal associated with Bohunician sites suggest a wide age range between 33 and 41 ka ¹⁴C BP, which is also observed for individual sites. TL dating of heated flint artifacts provides ages on the calendric time scale of an archeological event, the firing. The weighted mean of 48.2 ± 1.9 ka BP_{TL} for 11 heated flint samples from Brno-Bohunice provides the first non-radiocarbon data on archeological material from the Bohunician. The TL dating, in conjunction with the archeological and sedimentological analysis, allows the evaluation of the integrity of this new type-collection. The hypothetical possibility of the incorporation of Szeletian artifacts (i.e., leaf points) into the site formation processes can therefore be refuted.

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The Bohunician and the early Upper Paleolithic in the Middle Danube

The *Bohunician* was first described as an industrial type or technocomplex found in southern Moravia, Czech Republic, consisting of a Levallois-like core technology with a significant blade component and Upper Paleolithic tool types (Svoboda, 1980, 1987, 1990; Oliva, 1981, 1984). Initially, however, the type-collection from Brno-Bohunice or Bohunice Kejbaly (a local field name), located on the western margin of the city of Brno, Moravia, was defined by Valoch (1976) as a *Szeletien de facies levallois*, based on Valoch's emphasis of two artifactual characteristics in the type-collection: 1) Levallois-like core reduction apparent in elongated Levallois points; and 2) bifacial leaf points previously associated with the Szeletian as defined by Červinka (1927) and Prošek (1953). These two characteristics were also found in large surface collections from other

localities in southern Moravia (Svoboda, 1980, 1987). Subsequent excavation of stratified assemblages at Stránská skála on the east side of the Brno Basin, however, produced assemblages with the distinctive core reduction strategy but lacking the leaf points of the type-site or the surface collections (Svoboda, 1983, 1987, 1991). The reliability of the context of the Stránská skála assemblages, in the face of the surface associations at Líšeň and Ondratice as well as the lack of collection protocols for the Brno-Bohunice type-collection (see below), led to a redefinition of the Bohunician technology (Svoboda and Škrdla, 1995) and a clearer division of the early Upper Paleolithic in the region into two local technocomplexes, the Bohunician and the Szeletian (Svoboda, 1983, 1984, 1987).

The local early Upper Paleolithic technocomplexes are currently recognized as chronologically successive on the radiocarbon time scale but with significant overlap (see Svoboda et al., 1996: 99–130). The Szeletian, a technocomplex more widely known throughout Central Europe and argued to be the persistence of Micoquian tool types into an Upper Paleolithic context (Allsworth-Jones, 1986, 1989), appears only after 39 ka ¹⁴C BP (Valoch, 1984, 1993), but possibly

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lasting until at least 26 ka ¹⁴C BP (Adams and Ringer, 2004). The Bohunician in contrast is present in the region between 41 and at least 33 ka ¹⁴C BP (Svoboda and Bar-Yosef, 2003), or between 47 ka BP_{TL} (Zöller, 2000) and 180 ka BP_{TL} (Bluszcz et al., 1994) by TL dating of sediments (Table 1). At face value, the older range of these TL results, specifically from Dzierżysław I in southern Poland (Bluszcz et al., 1994), is unlikely to be correct. In addition, the method of TL-dating of sediments has been replaced by Optically stimulated luminescence (OSL) dating methods which do not suffer from some of the methodological problems of TL, such as an unbleachable component. As a result, the TL dating of sediments within the geological quarry (the Cihelna locality) near the 2002 Brno-Bohunice excavations to 47.3 ± 7.3 ka BP_{TL} (Zöller, 2000) should be considered with caution until new OSL data are obtained. The Bohunician is, thus, apparently contemporaneous with the Szeletian for at least 6,000 years on the radiocarbon time scale.

Stratigraphically, Bohunician artifacts are found in two soils of the Last Weichselian Interpleniglacial soil complex of Moravia (Damblon et al., 1996; Bar-Yosef and Svoboda, 2003). Bohunician assemblages associated with the lower soil of the Last Interpleniglacial (OIS 3) and correlated with the Hengelo interstadial, dated to approximately 41–37 ka ¹⁴C BP, whereas Bohunician assemblages located at the base of the upper soil of the Last Interpleniglacial paleosol sequence dated to between 38.5–34.5 ka ¹⁴C BP (Bar-Yosef and Svoboda, 2003:173–174). The occurrence of both Bohunician and Szeletian industries in the same lower soil of the Last Interpleniglacial complex, for instance the Bohunician at Stránská skála III (Svoboda, 1987, 2003b,c) and the Szeletian at Vedrovice V (Valoch, 1993) are an ever stronger claim for contemporaneity than the widely distributed radiocarbon data.

Elsewhere, the Bohunician is underlying, and thus older than, the Szeletian, as at Dzierżysław I in southern Poland (Bluszcz et al., 1994), which is also the most northerly example of the Bohunician and outside of the Middle Danube proper. The Bohunician has not yet been found in direct stratigraphic superposition over the Middle Paleolithic (MP) Micoquian in the region, as the Bohunician is not found in cave sites where the MP is preserved. The Bohunician, however, underlays the Aurignacian; at Stránská skála IIIa (Svoboda, 1991) the Aurignacian is found within the upper portion of the upper soil of the Interpleniglacial soil complex. In general, the Aurignacian, as representative of the first ‘classic’ Upper Paleolithic technocomplex, is late in the Middle Danube, with radiocarbon dates between 32 and 29 ka ¹⁴C BP (Svoboda et al., 1996). However, significantly older radiocarbon ages are available for the Aurignacian from Willendorf II in Lower Austria (Damblon et al., 1996; Haesaerts et al., 1996; Haesaerts and Teyssandier, 2003). In addition, AMS radiocarbon dates from sites in the Bükk Mountains of northern Hungary give late and overlapping ages for both the Aurignacian and the Szeletian in this portion of the Middle Danube basin, complicating the contemporaneity issue further. While the stratigraphic positions of these industries provide the backbone of the chronostratigraphy of the region, it is evident that other dating approaches are needed.

The Bohunician in the context of western Eurasia

While it is widely argued that the Szeletian is derived from the local Micoquian in Central Europe (Prošek, 1953; Valoch, 1990; Kozłowski, 2000; Neruda, 2000; see Adams and Ringer, 2004 for another view), it has been harder to explain the appearance of the

Table 1

Radiocarbon (¹⁴C BP) and luminescence dating (BP_{TL}) results for Bohunician assemblages, giving the location of samples, type of material, and method used

Age	Time scale	Locality	Archaeological layer	Geological layer	Sample type	Method	Sample number	Source
Dzierżysław I								
75,000	BP _{TL}		4		sediment	TL	GdTL-351	(Bluszcz et al., 1994)
≥100,000	BP _{TL}		5		sediment	TL	GdTL-350	(Bluszcz et al., 1994)
180,000 ± 35,000	BP _{TL}			below 4	sediment	TL	GdTL-348	(Bluszcz et al., 1994)
Stránská skála								
38,200 ± 1,100	¹⁴ C BP	III-1	5	Upper Paleosol	charcoal	¹⁴ C	GrN-12297	(Svoboda, 2003c)
38,500 + 1,400 -1,200	¹⁴ C BP	III-2	5	Upper Paleosol	charcoal	¹⁴ C	GrN-12298	(Svoboda, 2003c)
37,900 ± 1,100	¹⁴ C BP	IIIId	5	Upper Paleosol	charcoal	¹⁴ C	AA-32059	(Svoboda, 2003c)
37,270 ± 990	¹⁴ C BP	IIIId	5	Upper Paleosol	charcoal	¹⁴ C	AA-32060	(Svoboda, 2003c)
35,080 ± 830	¹⁴ C BP	IIIId	5	Upper Paleosol	charcoal	¹⁴ C	AA-32061	(Svoboda, 2003c)
34,530 + 830 -740	¹⁴ C BP	IIIId	5	Upper Paleosol	charcoal	¹⁴ C	GrN-11504	(Svoboda, 2003c)
35,320 ± 320 -300	¹⁴ C BP	IIIId	5	Upper Paleosol	charcoal	¹⁴ C	GrN-11808	(Svoboda, 2003c)
34,440 ± 720	¹⁴ C BP	IIIc	5	soil	charcoal	¹⁴ C	AA-41475	(Svoboda, 2003c)
36,570 ± 940	¹⁴ C BP	IIIc	5	soil	charcoal	¹⁴ C	AA-41476	(Svoboda, 2003c)
34,530 ± 770	¹⁴ C BP	IIIc	5	soil	charcoal	¹⁴ C	AA-41477	(Svoboda, 2003c)
36,350 ± 990	¹⁴ C BP	IIIc	5	soil	charcoal	¹⁴ C	AA-41478	(Svoboda, 2003c)
34,680 ± 820	¹⁴ C BP	IIIc	5	soil	charcoal	¹⁴ C	AA-41480	(Svoboda, 2003c)
38,300 ± 1,100	¹⁴ C BP	IIIc	5	from Lower Paleosol, cryoturbated into Upper Paleosol	charcoal	¹⁴ C	AA-32058	(Svoboda, 2003c)
41,300 + 3,100 -2,200	¹⁴ C BP	IIIa	4	from Lower Paleosol, cryoturbated into Upper Paleosol	charcoal	¹⁴ C	GrN-12606	(Svoboda, 2003c)
Bohunice-Cihelna (no associated artifacts)								
47,300 ± 7,300	BP _{TL}		4a	Lower Paleosol	sediment	TL		(Zöller, 2000)
42,900 + 1,700 -1,400	¹⁴ C BP		4a	Lower Paleosol	charcoal	¹⁴ C	GrN-6165	(Valoch, 1976)
36,000 ± 1,100	¹⁴ C BP		4a	Lower Paleosol	charcoal	¹⁴ C	GrN-16920	(Svoboda, 1993)
Bohunice-Kejčaly II								
41,400 + 1,400 -1,200	¹⁴ C BP		4a	Lower Paleosol	charcoal	¹⁴ C	GrN-6802	(Valoch, 1976)
Bohunice-Kejčaly I								
40,173 ± 1,200	¹⁴ C BP		4a	Lower Paleosol	charcoal	¹⁴ C	Q-1044	(Valoch, 1976)
Brno-Bohunice 2002								
32,740 ± 530	¹⁴ C BP		4a	Lower Paleosol	charcoal	¹⁴ C	ANU-12024	(Škrdla & Tostevin, 2005)
35,025 ± 730	¹⁴ C BP		4a	Lower Paleosol	charcoal	¹⁴ C	ANU-27214	(Škrdla & Tostevin, 2005)
>40,000	¹⁴ C BP		4a	Lower Paleosol	charcoal	¹⁴ C	WK-17757	(Nejman, pers. comm. 2005)

Bohunician in the Middle Danube. Valoch (1986, 1990) first noticed the typological and technological similarity between the industry of Brno-Bohunice (Valoch, 1976, 1982) and the transitional industry of Boker Tachtit Level 1 (Marks, 1983; Marks and Kaufman, 1983) in the southern Levant. While Valoch did not attempt a systematic comparison, subsequent scholars presented more data-rich syntheses based on similarities in refitting sequences to argue that these industries represent one entity, a particular evolutionary stage in the development of the Middle to Upper Paleolithic transition across the regions (Demidenko and Usik, 1993; Ginter et al., 1996; Škrdlá, 1996; Kozłowski, 2000). Given the difficulty of comparing published refit sequences based on illustrations without a common representational system (despite the credible attempt by Volkman (1983, 1989) to present such a system), Škrdlá (2003a) re-examined the Boker Tachtit refitting sequences produced by Volkman in order to present cross-sectional representations compatible with his refitting sequences from the Bohunician assemblages of Stránská skála III, IIIa Layer 4, and IIIc (Svoboda and Škrdlá, 1995; Škrdlá, 2003b,c). The results of this core-by-core refit comparison suggest extremely similar approaches to the exploitation of core volumes and directionality of reduction between Level 2, even more so than Level 1, of Boker Tachtit with the Bohunician assemblages of Central Europe.

The dominant units of analysis in Paleolithic systematics (the industrial type and generalized *chaîne opératoire*) are unsuitable for systematically comparing assemblages through time and space because the industrial types are defined on the presence of a *fossile directeur* (such as “Aurignacian” or “Châtelperronian”) or are based on teleological models of a core reduction sequence (*sensu* Bleed, 2001: 120–121). Existing variation between typological definitions can therefore not be addressed properly. The epistemological approach of typing assemblages prevents the recognition of units of variability within each type (Tostevin, 2006). Additionally, these units do not structure the analysis of the archeological record in a way that is anthropologically-meaningful for testing questions of cultural evolution, including cultural transmission, through time and space. The current use of industrial types, a holdover from 19th and early 20th century periodizations (e.g., Mortillet, 1873; Breuil, 1906; Peyrony, 1933), is inappropriate for studying questions of theoretical, methodological, and quantitative complexity (Monnier, 2006).

In order to test the anthropological significance of the qualitative evaluations of the Bohunician mentioned above, the relevant assemblages were studied through the reconstruction of a technological signature for each lithic assemblage composed of quantifiable flintknapping behaviors for systematic comparison between assemblages (Tostevin, 2000a,b, 2003a,b). This research was an attempt to avoid the traditional and essentialist approach (*sensu* Clark, 1994; Tschauner, 1994) of industrial types. Taking a behavioral approach (Schiffer, 1975, 1976, 1996) to flintknapping, an artifact assemblage can be recognized as the central tendencies and dispersions in flake attributes reflecting the assemblage-wide performance of specific decisions a knapper must make during the reduction of a core for blanks for use on the landscape. On a flake by flake basis (or core by core basis for certain choices), a choice must be taken at each of these decision nodes regardless of the technology in a given assemblage, making them consistently comparable units of analysis across space and time. For instance, the knapper must decide with each strike of the percussor onto the core the platform depth, angle of the platform, and dorsal convexities opposite her/his point of percussion. While these are choices made consciously or unconsciously through the body technique of the prehistoric artisan, these choices are also preserved as physically observable and measurable attributes on flakes and tools in archaeological assemblages. This research, thus, focuses on etic (*sensu* Harris, 1976) archaeological evidence,

that is quantifiable evidence of attribute variation visible to the archaeologist, rather than on the interpretation of emic production rules (i.e., internal rules knowable only in the mind of the prehistoric artisan). By focusing on the etic evidence of attribute analysis at the assemblage level rather than at the level of an abstract estimation of the intuited production rules in a *chaîne opératoire* (which are often not comparable between assemblages), the method of studying Pleistocene assemblages can be brought into line with other bodies of anthropological and evolutionary theory.

Tostevin (2006, 2007, in press) combined this attribute analysis approach with a middle-range theory for predicting how cultural transmission processes are reflected in artifact assemblages. The kernel of this middle-range theory, built on ethnographic data (Lee and DeVore, 1976; Wiessner, 1982, 1983, 1984) and anthropological theory (Sackett, 1900; Wobst, 1977; Carr, 1995) on how, where, and when individual foragers learn and transmit their cultural behavior, was presented in Tostevin (2007) and predicts which aspects of a lithic operational sequence reflect behaviors learned and learnable in contexts of different levels of social intimacy among foragers. Tostevin (in press) develops these ideas in greater detail within the context of an evolutionary approach to Pleistocene culture history, building off of dual inheritance modeling within the cultural transmission theory of biological anthropologists such as Richerson and Boyd (1978, 2002); Boyd and Richerson (1985, 1996); Boesch and Tomasello (1998); Shennan and Steele (1999); Shennan (2000, 2003); Tehrani and Collard (2002), and Eerkens et al. (2006).

This approach to the analysis of the debitage, core, and tool attributes was performed on 18 assemblages from the Levant, Central Europe, and Eastern Europe dating between approximately 60 and 30 ka ¹⁴C BP (Tostevin, in press, 2003a,b). Each regional sequence of change in flintknapping behaviors was then contrasted with adjacent regions in order to evaluate model predictions derived from archeological, biological, and social anthropological theory designed to identify changes in flintknapping behaviors due to *in-situ* innovation versus cultural transmission between regions. Variation in lithic assemblages was systematically evaluated, behavior by behavior, to determine the likelihood that one assemblage contains enough statistically-similar behavioral choices to justify arguing that this assemblage is an antecedent for the cultural inheritance of the behavioral choices in a later assemblage (Tostevin, 2000a, 2003a,b, in press). As the lithic attributes used in these evaluations reflect directly observable, and thus, learnable knapping behaviors, their patterning through time and geography is anthropologically-meaningful, and thus, suitable for dual inheritance modeling (*sensu* Boyd and Richerson, 2005).

The systematic comparison of assemblages within and across these three regions isolated a suite of flintknapping behaviors, recognizable from crested initiation of the core, to platform treatment (preparation and platform thickness), dorsal surface convexity choices, bidirectional exploitation of core volumes, and preference for distal over lateral retouch (Tostevin, in press, 2000a: Table 5). This suite of behaviors was labeled the “Bohunician Behavioral Package”. The *Bohunician Behavioral Package* seems to appear first in the Levant at 47/46 ka ¹⁴C BP at Boker Tachtit Level 1, possibly next in the Balkans if the chronological and technological conclusions for Temnata Cave layer VI, sector TD-II (Ginter et al., 1996; Drobniewicz et al., 2000) are confirmed (a hypothesis solely based on the published literature), next in Moravia in Central Europe at about 40 ka ¹⁴C BP, and finally in Eastern Europe at Korolevo II Complex II by 38 ka ¹⁴C BP. The *Bohunician Behavioral Package* had no precedent in any of these three regions and represents a cultural transmission event in which technological ideas were introduced to the region.

Inter-regional connections: the “Bohunician Industrial Type” versus the “Bohunician Behavioral Package”

Tostevin's conclusions summarized above, and corroborated by Škrdla (2003a) through an independent method, have much in common with several recent syntheses of the appearance of the Initial Upper Paleolithic in Europe, which utilize the technological similarities between the Levantine Emiran and the Central European Bohunician (Bar-Yosef, 2000, 2002; Kozłowski, 2000, 2004; Bar-Yosef and Svoboda, 2003; Svoboda, 2003a; Mellars, 2006). The latter approaches rely on industrial types, however, and do not systematically evaluate behavioral units within the industrial types, making them less suitable for studying cultural evolution and transmission. In contrast to these industrial type syntheses, the term “behavioral package” (Tostevin, 2000a,b) describes the grouping or association of lithic attributes, acting as proxies for flintknapping behaviors learnable only in contexts of social intimacy, that constitute the evidence of a cultural transmission event. In other words, the behavioral package is the association of behaviors that link one assemblage to the next in the order of the package's chronological appearance (the geographical appearance must already be logical otherwise the pattern would not have been judged to be a cultural transmission event). Unlike an industrial type, a behavioral package may gain or lose constituents as it spreads through time and space. Industrial types are often depicted as evolving through time, say from an “Early Aurignacian” to an “Evolved Aurignacian,” but this is frequently presented (e.g., Otte and Kozłowski, 2003) as a transformative process akin to Whitean-Spencerian change (*sensu* Tschauer, 1994: 82) and, therefore, not suitable to evolutionary analysis. The behavioral package concept, however, does not have this problem as it is composed of different elements that can vary between assemblages; it is the consistency of the package from one assemblage to the next, chrono-geographically, that serves as an indicator of the transmission strength of the package, rather than an absolute similarity between end points. Thus, a behavioral package can connect, through a series of assemblages, two industrial types that are otherwise seen as distinctively different.

The data behind a behavioral package is the variability of quantified flake and core attributes. But it is not the archaeological data (lithic attributes) which are transmitted between culturally-receptive individuals; it is the behavior which produced the attributes, just as DNA is transmitted and not simple skeletal morphology. This definition of the units of cultural evolution structures the analysis according to what actually drives cultural transmission. Thus, while the industrial type concept uses an incongruous mix of processes to define its units, from raw material conservation to tool function to unique tool types, the behavioral package concept does not pigeon-hole assemblages into larger, more abstract units. Instead, the behavioral package concept utilizes the behavioral choices that produced an assemblage, which could only have been performed, and thus, learned in socially intimate contexts. In comparing a series of assemblages, this approach thus highlights the similar and dissimilar behavioral choices which produced each individual assemblage. The evaluation of the chrono-geographic pattern of these behaviors is what gives meaning to the assortment of similar behaviors as a behavioral package or the chance independent innovation of similar behaviors in different regions.

Traditional syntheses using industrial types (e.g., Bar-Yosef, 2000, 2002; Kozłowski, 2000, 2004; Bar-Yosef and Svoboda, 2003; Svoboda, 2003a, 2004; Mellars, 2006) do, however, provide the basis for communication and are particularly suited for proposing hypotheses. However, they require further testing using intra-assemblage units of variation. Syntheses such as Mellars' (2006) also have a significant advantage of being able to incorporate a far

larger sample of the archeological record into their cultural evolutionary arguments than analytically-specific studies that rely upon attribute measures not yet commonly published in archeological literature.

The publication of the Piekary IIa assemblages (Sitlivy et al., 1999; Valladas et al., 2003) in southern Poland provides a good example for how differences in technological description limit the analytical study of cultural transmission hypotheses. Zilhão (2006) argues for a southern Polish antecedent for the Bohunician on basis of a *chaîne opératoire* approach by Sitlivy et al. (1999) and Valladas et al. (2003) at Piekary IIa, where they found “in-situ development of volumetric Upper Paleolithic methods of blade debitage out of Levallois flake-based technologies.... Parsimony dictates that there is no need to look into the Middle East for the source of the Bohunician if a better local alternative is available” (Zilhão, 2006: 187, 189). The data published is based on a qualitative and categorical approach, without the necessary systematic analysis of variables appropriate for the modeling of cultural transmission. Given this it is premature to give these assemblages such explanatory power, particularly when the assemblages contain only a few hundred pieces. There were many inventions of blade technologies and Levallois-like approaches to reduction in the past 200 ka (e.g. Zilhão, 2006), but it will remain unclear whether Piekary IIa evidences of the evolution of the same specific behavioral tendencies as seen in the Bohunician assemblages to the south until the assemblages are tested using a quantitative and behavioral approach. The TL dating of the Brno-Bohunice 2002 assemblage presented in this paper draws into question Zilhão's (2006: 189) observation of an apparent hiatus of 10 ka in the chronometric data for the hominin occupation of Moravia between 53–43 ka calBP (Zilhão, 2006: 189). With the Neanderthal occupation of Kůlna Cave layer 7a dated by ESR (Rink et al., 1996) to 50 ± 5 ka BP_{ESR} for a linear uptake model (53 ± 6 ka BP_{ESR} recent uptake model) and the Bohunician at Brno-Bohunice 2002 dated to 48.2 ± 1.9 ka BP_{TL}, there is overlap already at the 1- σ probability level. There is thus no longer any period of time unrepresented by archaeological data on lithic technology during which the Micoquian could evolve in situ into the Bohunician in Moravia.

Hominin associations

The traditional syntheses of the origins of modern humans frequently assume a simple correlation between industrial type and hominin type responsible for the diffusion of the lithic industry. Cultural transmission from one generation to the next, however, can be either symmetric with biological inheritance (i.e., the individual learns cultural traits from kin) or asymmetric, with non-kin contributing to the cultural learning sets of the individual (Boyd and Richerson, 1985, 2005). In all of the recent discussions of modern human dispersals, the dual nature of inheritance is too frequently forgotten; Zilhão (2006) is a notable exception. Instead of assuming all aspects of the archeological record should be transmitted by one or the other mode, it is necessary to use the archeological record itself to test the likelihood of one mode versus the other. The behavioral approach to attribute analysis (Tostevin, 2000a, 2003b) and middle-range theory (Tostevin, 2007, in press) are only the first steps in differentiating the patterns resulting from more symmetrical versus more asymmetrical cultural transmission in Pleistocene lithic assemblages. The strict association of hominin species with industrial type can always be questioned, until the wide application of a method differentiating such patterns makes such associations more likely. Mellars' (2005, 2006) arguments that the industrial types leading to the Bohunician and Aurignacian must all be made by modern humans because of the modern human remains ('Egbert') found in the early Ahmarian at Ksar 'Akil, Lebanon (Bergman and Stringer, 1989; Mellars and Tixier, 1989),

suffer from the above assumption. Even if the Ahmarian is culturally descended through specific behavioral traits from the Levantine Emiran, and therefore related to the Bohunician Behavioral Package, by the postulated time (based on radiocarbon data) of the Ksar 'Akil modern human, the *Bohunician Behavioral Package* had already reached Central Europe, and thus, his modern human status does not help us eliminate any biological populations that may have been involved in the cultural transmission event elsewhere.

It is not yet clear which hominin(s) are responsible for the Bohunician industrial type, as no fossil has been found in any Bohunician assemblage, or indeed in the larger pool of assemblages possessing the *Bohunician Behavioral Package*. However, the geographical and chronological trajectory of the *Bohunician Behavioral Package* data is consistent with the hypothesis of anatomically modern humans being involved at the southern end of the transmission event.

Despite these differences in methodology and assumptions between the industrial type syntheses and the arguments for the *Bohunician Behavioral Package*, these different approaches have one major issue in common: the heavy reliance on the knowledge of the age of assemblages provided by stratigraphy and chronometric dating methods. The validity of any culture historical scenario rests upon the establishment of high resolution calendric time frames for each assemblage involved.

The type-site of Brno-Bohunice and the homogeneity of the Bohunician technocomplex

The initial type-collection from Brno-Bohunice, published by Valoch (1976, 1982), was acquired by a rock collector and amateur archeologist during building activities between 1962–1981 on the top of Red Hill, an elevation on the western margin of the Brno Basin, in the Bohunice quarter of the city of Brno. Artifacts were extracted from bulldozer trenches according to stratigraphic location, but no systematic collection protocols for the positions of artifacts were used and no sieving was done. Four localities on the Red Hill produced amateur collections of artifacts during this

period (Kejbaly I through IV; see Škrdla and Tostevin, 2003, their Fig. 8). Three dating projects (Valoch, 1976; Svoboda, 1993; Zöllner, 2000) produced numerical ages for the lower soil of the Last Interpleniglacial paleosol sequence, but without artifactual associations, as the samples were taken from the geological quarry, the Cihelna locality, to the east of the Kejbaly sites. In 2002, the Institute of Archeology, Brno, and the University of Minnesota, USA, excavated adjacent to Kejbaly IV a 3 m wide strip of intact sediments (Fig. 1) between the quarry wall and the adjacent road which had survived the intensive building activities in late 1970s (Škrdla and Tostevin, 2003, 2005). The 2002 team recovered all of the artifacts and information possible before the destruction of this sediment block for a new road. A portion of the block is preserved between the new road and the quarry wall for future research.

The type-site collection has always appeared to have a greater variety of raw materials and retouched tool typologies as compared to other Bohunician assemblages. Specifically, the original Brno-Bohunice collection contains bifacial leaf points but lacks manufacturing debris (biface thinning flakes). The collection procedures could have biased the assemblage against small items. However, as no other Bohunician stratified assemblage produced leaf points, until the publication of Dzierżysław I in southern Poland (Bluszcz et al., 1994; Foltyn and Kozłowski, 2003), Oliva (1981, 1984) and later Valoch (1982, 1990) hypothesized that Bohunician artisans did not make the leaf points found at the type-site, but traded for them or scavenged them from contemporaneous Szeletian tool makers or sites.

The new excavation by Škrdla and Tostevin in 2002 provided a detailed study of the artifact distribution within the paleosols and the application of modern proveniencing and collection protocols to artifact recovery (McPherron and Dibble, 2002), specifically designed to resolve the questions concerning the type-collection. These new data confirm the presence of a single archeological layer within the Lower Paleosol and the association of characteristic products of Bohunician bladey-levallousian technology with the on-site production of leaf points (Škrdla and Tostevin, 2005; Fig. 2). The

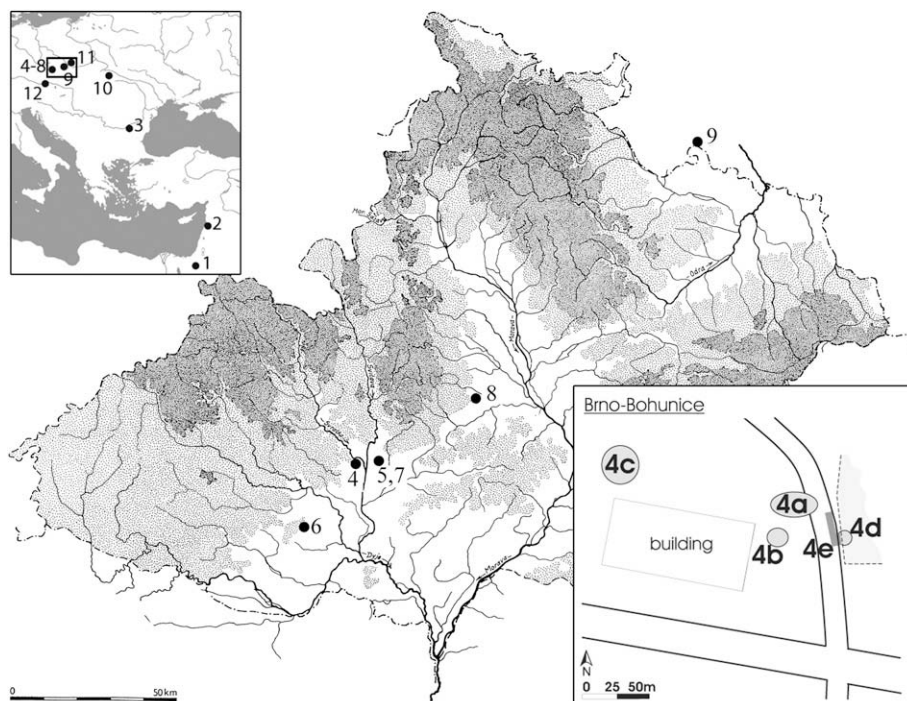


Fig. 1. Locations of sites mentioned in the text: 1) Boker Tachtit, 2) Ksar 'Akil, 3) Temnata, 4) Brno-Bohunice (4a–4d) Kejbaly I–IV, 4e) Brno-Bohunice 2002; Cihelna (dashed line and shaded area to the E), 5) Stránská skála, 6) Vedrovice V, 7) Líšeň, 8) Ondratice, 9) Dzierżysław, 10) Korolevo, 11) Piekary, and 12) Willendorf.

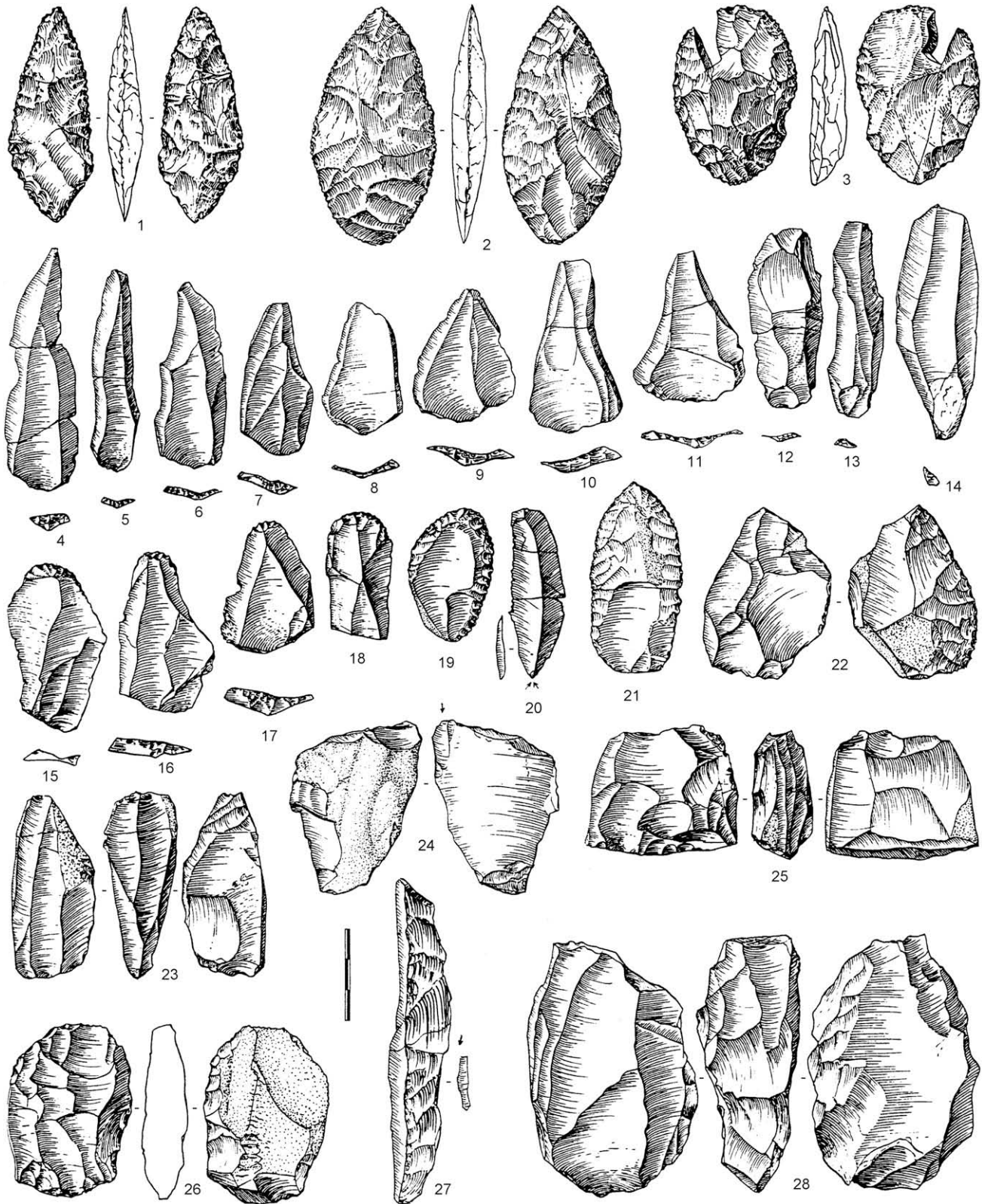


Fig. 2. Selected lithic artifacts from the Lower Paleosol assemblage from the Brno-Bohunice 2002 excavation: 1–3) leaf points; 4–14) Levallois products; 15–19) endscrapers; 20, 24) burins; 21) convergent sidescraper; 22) bifacially-retouched scraper with refitted flake; 23, 25, 26, 28) cores; and 27) crested blade.

stratigraphic section of the 2002 excavation also corroborates the stratigraphic picture seen at the Stránská skála localities. In general, the geology of the site is well-studied as it is directly adjacent to a classic Pleistocene geological profile (Dambon et al., 1996); the modern soil overlies a later Upper Paleolithic loess stratum, which

overlies two paleosols, the Upper and Lower Last Interpleniglacial soils (indicated by lines in Fig. 3), about 30 cm and 30–50 cm thick, respectively, above a thick loess deposit.

Five hypotheses of site formation processes are systematically evaluated and might explain the apparent differences between the

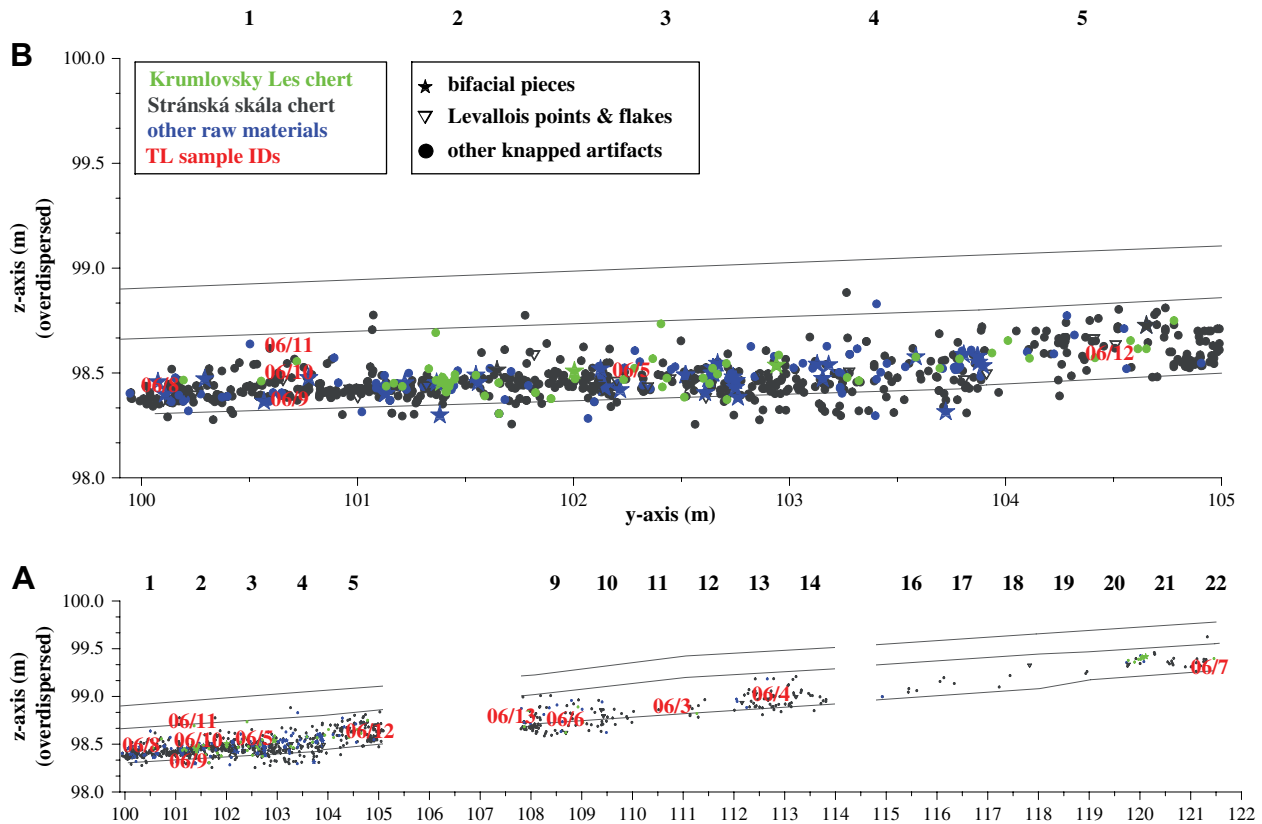


Fig. 3. Projection of the vertical distribution A) for the entire excavation, and B) for area A, of lithic material (> 1.5 cm) according to raw material types: Krumlovský Les chert in green, Stránská skála chert in grey, and others in blue. Leaf points, biface thinning flakes, and bifacial pieces are symbolized by stars; Levallois points and flakes by triangles; and all other knapped artifacts by dots. The approximate boundaries of the two paleosols are indicated by grey lines, and the locations of TL-samples are plotted (06/11 and 06/9 above and below their vertical position, respectively). Z-axis refers to an arbitrary level.

original Brno-Bohunice collections from Kejbaly I and II and the Stránská skála assemblages (Tostevin and Škrdlá, 2006). Particular attention was paid to the possibility of mixing between Bohunician artifacts and a hypothetical superimposed Szeletian occupation. The first, or “Excavation Bias” hypothesis, argues that the original collection resulted in the mixing of otherwise geologically and vertically-discrete Szeletian and Bohunician occupations at the locality, resulting in the addition of Szeletian leaf points into an otherwise Bohunician context. This hypothesis was quickly disproved through the study of the vertical distribution of piece plotted artifacts (Fig. 3). While a small assemblage of non-diagnostic artifacts is present in the Upper Paleosol (only 43 pieces), the Lower Paleosol contains a single vertical distribution of a large number of artifacts (3,360 pieces) of about 30–50 cm spread, which is a common phenomenon for sites in pedogenically-altered loessic sediments. This also provides a relative age estimate for the assemblage as either pre-dating the formation of the paleosol, or as contemporaneous if the soil developed while sediment slowly accumulated. The second, or “Traded Point” hypothesis (Oliva, 1981, 1984), was also disproved by the recovery of 4 leaf points, 5 bifacially-retouched tools, and 52 diagnostic biface thinning flakes, one of which refits to a bifacial tool (Tostevin and Škrdlá, 2006: Fig. 2, 17). This bifacial reduction debitage is situated within the artifact horizon bearing Bohunician blades, Levalloisian points, and bidirectional cores of a classic Bohunician strategy, as defined by Škrdlá (1996, 2003b), (Tostevin and Škrdlá, 2006: Fig. 3), thus pointing towards *in situ* production rather than trade. The “Pedogenic” hypothesis suggests pedogenic mixing of otherwise temporally-discrete Szeletian and Bohunician occupations producing assemblages which, when excavated, looked to be a single occupation. Alternatively, the fourth or ‘Sequential Occupation’

hypothesis suggests that the stable land surface represented by the lower soil of the Last Interpleniglacial paleosol complex allowed the sequential occupation of the locality by different flintknappers of both Szeletian and Bohunician traditions. Their respective tool kits could have been mixed spatially into the same sedimentary matrix that eventually buried the artifacts. While the third and fourth hypotheses are impossible to disprove, since soil formation moves artifacts within sediments (Goldberg, 1992; Holliday, 1992) and no Bohunician assemblage has ever been found outside of a paleosol, no patterns in the vertical or horizontal distributions of the finds appear to indicate different occupations as might be distinguished through the pattern of raw material types, dorsal scar patterns, retouched tools, or combinations of the above (Škrdlá and Tostevin, 2005). While it is evident from the distribution of finds (Fig. 3A) that the main concentration is located in Area A, no differences are evident in these variables between the three areas of the 2002 excavation.

The analytical treatment in Tostevin and Škrdlá (2006) was designed to test the fifth or “Landscape” hypothesis that hominins who produced the typically Bohunician core reduction strategies also engaged in the production, utilization, and discard of leaf points but at other points on the landscape than the Stránská skála hillside (i.e., at Brno-Bohunice). The “Landscape” hypothesis was judged more successful at explaining the differences in technological behaviors at the type-site for two reasons. First, Brno-Bohunice is more distant to raw material sources than is Stránská skála. Second, the lengths of knapping events were shorter during visits to the Brno-Bohunice locality than at other Bohunician localities, as evidenced by fewer production sequence refits despite the same ability to refit breaks (Škrdlá and Tostevin, 2005: 59–60; Tostevin and Škrdlá, 2006: 44). Under this hypothesis, therefore, no geological process is required to

explain the artifact associations seen in the original collection. The 2002 assemblage excavated from the lower soil is considered to have derived from one occupation series, which created the observed palimpsest. If this hypothesis is correct, one would predict that the dating of the assemblage would show only one normally-distributed series of dates, by both converted (calibrated) radiocarbon and TL methods, provided that time is the only factor influencing the age distribution.

¹⁴C age estimation of Brno-Bohunice

Previous collections and surveys at the site were undertaken under very limited rescue conditions and it was not possible to provide good documentation, especially for the samples taken for dating purposes. However, the paleosol horizons across the Red Hill provide a good guide for the relative position for a wider area that probably incorporates all the sites. Radiocarbon dating by beta counting of charcoal estimates the age of two previous Bohunice artifact palimpsests (Kejbaly I + II) between 40 and 41 ka ¹⁴C BP, while a third and fourth date not associated with artifacts produced ages of the Lower Paleosol between 36 and 43 ka ¹⁴C BP (Table 1). Given the high yield of carbon usually obtained from charcoal, the physical age estimates should be correct on the radiocarbon time scale, and only questions about the potential origin of the samples from animal burrows, as well as the association with the human occupation, remain. Charcoal is mobile in fine grained sediments, especially through bioturbation, thus the association of the charcoal with the human occupation can be questioned unless a sample comes from the distinct feature of a hearth, which is not the case for previous samples taken at Bohunice. Given the large spread in radiocarbon ages, it is rather likely that at least some of the samples were not originally associated with the Bohunician assemblage in the Lower Paleosol. New AMS data from well-provenanced samples from charcoal concentrations that are interpreted as pedogenically-altered hearths (2002 excavation at Brno-Bohunice) does not improve the picture because according to these data the site could be 32–35 ka ¹⁴C BP, or perhaps even older than 40 ka ¹⁴C BP (Table 1). Given the slope of the find distribution (Fig. 3), it is likely that at least some of the charcoal was concentrated by slope wash. However, this does not reject the hearth interpretation, especially given the presence of a large number of heated lithics. Aside from the potential problem of association of single samples with the archaeology, the young ages also raise the possibility of a problem with contamination by rootlets. Furthermore, the age of the Bohunician is at the limits of the method of radiocarbon dating, and because radiocarbon data are given in ¹⁴C-years, it is thus not possible to directly compare these dimensionless ¹⁴C age results with other dating methods.

Archaeological research focuses on the understanding of processes and the relation of sites, technocomplexes, and evolution of artifact production, among other things. To answer such questions, a linear time scale, which is not provided by radiocarbon dating, is required. Even using radiocarbon data as a relative basis for evaluating hypotheses, such as the chronology of modern human dispersals into Europe (e.g. Bocquet-Appel and Demars, 2000), has to be viewed with caution because of potential shifts (wiggles) in the radiocarbon curve during this time period and in the light of the fine chronological resolution required. With the notable exception of U-series and Ar/Ar-dating, no dating methods are in fact available to provide a resolution for distinguishing processes as fast as the dispersal of humans or cultural knowledge into a region, which may have taken a few thousand or even only a few hundred years. Nevertheless, other dating methods are required to establish and check the chronostratigraphical framework of regions and sites.

Thermoluminescence dating

Thermoluminescence dating of a heated flint determines the time elapsed since the last incidence of firing. In contrast to many other chronometric dating methods, it is thus possible to directly date a past human activity. The resulting ages are given in calendar years and do not need to be calibrated. The principles of luminescence dating methods have been described in great detail elsewhere (Aitken, 1985; Aitken, 1998; Wagner, 1998; Bøtter-Jensen et al., 2003), and with a special emphasis on TL dating of heated flint (Valladas, 1992; Richter et al., 2000; Richter, 2007). Therefore only a brief summary is given below.

Luminescence dating is based on the accumulation of a radiation dose (paleodose: P) in the crystal lattice of the flint from omnipresent ionizing radiation (dose rate: \dot{D}) from the sample itself ($\dot{D}_{\text{internal}}$), the sediment ($\dot{D}_{\text{external}}$), and cosmic radiation (\dot{D}_{cosmic}). The radiation dose (P) gets zeroed when a flint is heated above 400 °C and accumulates again as soon as the flint is cooled and buried in sediment. The age formula, therefore, is straightforward and simple:

$$\begin{aligned} \text{age (a)} &= \frac{P(\text{Gy})}{\dot{D}(\text{Gy}\cdot\text{a}^{-1})} = \frac{P}{\dot{D}_{\text{internal}} + \dot{D}_{\text{external}}} \\ &= \frac{P}{(\dot{D}_{\alpha} + \dot{D}_{\beta}) + (\dot{D}_{\gamma\text{-external}} + \dot{D}_{\text{cosmic}})}, \end{aligned}$$

where the paleodose (P) is expressed in Gy and the dose rate (\dot{D}) in Gy a⁻¹.

TL method used

The TL-dating technique used in this study follows Aitken (1985), Valladas (1992), and Richter et al. (2000). Two mm of the surface of each sample were stripped with a water-cooled diamond saw. The obtained 'cores' were carefully crushed in a hydraulic press, sieved, and crushed until <160 μm. A sample of about 200 mg for neutron activation analysis (NAA) was taken before further sieving through a 90 μm mesh. Some of the 90–160 μm (coarse grain) material was heated to 360 °C for 90 minutes in order to remove the natural TL signal without causing severe sensitivity changes, before all crushed material was subjected to a 10 % HCl treatment to remove the carbonates. Measurement of the glow curves (Fig. 4) was performed with a Risøe-DA15 system under a constant flow of N₂. Luminescence detection by an 'EMI 9236QA' photomultiplier was restricted to the UV-blue spectral region by optical filters (BG25 + HA30). A heating rate of 5° C s⁻¹ up to 450 °C was used, and the background was subtracted immediately by a second measurement. The heating plateau (Fig. 4) derived from the ratio of the luminescence signal of the first additive to the natural dose point indicates the sufficiency of the heating for TL-dating purposes. Paleodoses were determined by irradiating multiple coarse grain aliquots with increasing doses from a calibrated ⁹⁰Sr/⁹⁰Y-source (delivering 0.106 Gy s⁻¹ at the time of irradiation). The increasing doses for the 3 to 4 additive dose points (additive growth curve to obtain the equivalent dose [D_E] with natural sample material) were set according to a first approximation of the natural dose, in order to step increase the TL-signal by an amount roughly equivalent to the natural dose. The dose points for the 4 to 5 regeneration dose points (regeneration growth curve to obtain the supralinearity correction [D_J] with the laboratory heated material) were set to match the TL obtained for the additive growth curve (Fig. 5). Linear regressions of the integrals defined by the overlapping temperature range of the heating plateau (Fig. 4) with the D_E-plateau (not shown) were employed to obtain the paleodose as the sum of the x-intercepts of both growth curves. The overestimation of D_E by regression of the additive growth curve due to the non-supralinear

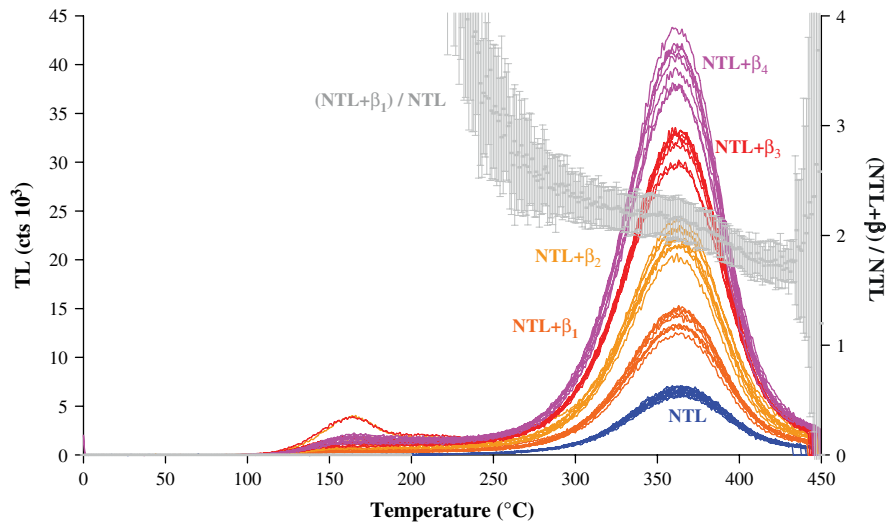


Fig. 4. Glow curves (natural and additive) and heating plateau ($NTL + \beta/NTL$) for sample EVA-LUM-06/7.

response to alpha radiation is estimated as proportional to the natural alpha dose rate contribution to the total dose rate, and accordingly subtracted from D_1 (Valladas, pers. comm., 2001). The slope of both growth curves was similar for all samples, indicating that the supra-linearity correction (extrapolation of the regeneration growth curve - D_1) can be considered to be valid (Fig. 5).

The alpha sensitivity was determined by the additive method, where sets of six fine grain (4–11 μm) aliquots were irradiated with calibrated alpha (^{241}Am) and beta ($^{90}\text{Sr}/^{90}\text{Y}$) sources, with two and three dose points, respectively. Linear extrapolation provided dose equivalent values for these two kinds of radiation, and the b-value system (Bowman and Huntley, 1984) was used to express the alpha sensitivity of the samples in terms of beta.

TL samples

Few sufficiently sized heated flint samples, evaluated according to the criteria described in Richter (2007) for TL-dating, were present in the main areas of the 2002 excavation (Fig. 1). Therefore, more samples were sought from the collection of artifacts recovered in the last-minute excavation of the profiles of the areas A and C before their destruction due to road work. These artifact samples lack the piece plotting data of artifacts from the main excavations of areas A, C, and D (Table 2), but they are associated with a specific paleosol horizon and their provenance is known to

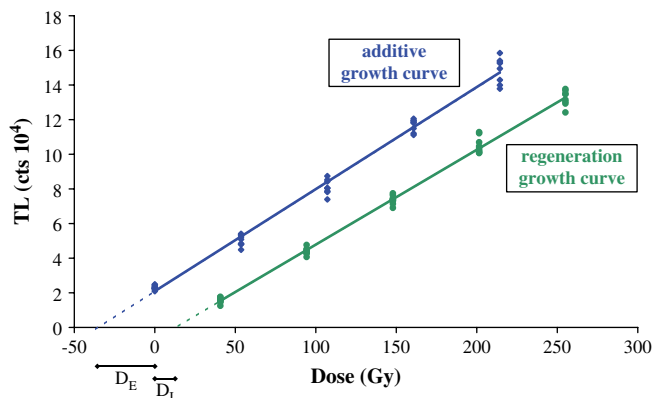


Fig. 5. Additive and regeneration growth curves for sample EVA-LUM-06/7, derived from the integrated luminescence signal between 315 and 365 °C.

an average precision of better than 25 cm horizontally and, more importantly, 10 cm vertically (Fig. 3). The maximum horizontal distance of these dating samples to the excavated areas is 50 cm, but for most samples much less. Given the overall vertical distribution of all artifacts, which is interpreted as one palimpsest of rather short duration, there is no doubt that these samples belong to the assemblage and their resulting ages can be regarded as equally valid, especially as none is coming from an especially high or low vertical position. Also, five production sequence refits exist between artifacts collected from the profiles and the main point plotted artifacts of areas A, C, and D, further corroborating the integrity of their temporal connection (Škrdla and Tostevin, 2005).

Dosimetry

The determination of the various dose rate parameters is crucial in luminescence dating because the resulting ages are highly dependant on these calculations (see e.g., Richter, 2007). One important parameter is the external gamma dose rate ($\dot{D}_{\gamma\text{-external}}$) which has to be corrected for some energy absorption within the sample, that is dependant on its shape and size. This parameter was estimated by Monte-Carlo calculations (Valladas, 1985a). The gamma dose rate from the sediment was measured on dry sediment samples from area A (1242 $\mu\text{Gy a}^{-1}$) and D (1206 $\mu\text{Gy a}^{-1}$) supported by on-site scintillation measurements with HPGe-spectrometry in the laboratory. No evidence of radioactive disequilibria was found. The observed difference of about five percent between the samples is likely due to the high concentration of charcoal in Area A. Therefore, the result for Area D is considered as representative for the samples from Area C as well, because the density of finds and low charcoal content were very similar. This is supported by scintillation measurements of the samples with a portable NaI-detector (Aitken, 1985), with a difference of 4% between areas A and D, but only 1% between areas C and D. However, an error estimate of 10% for the external gamma dose rate was used for the age calculations in order to incorporate unknown variables. This value is much higher than the associated error of $\sim 3\%$ of the gamma spectrometry results.

The correct estimation of the moisture content is one of the most influential parameters of the external gamma dose rate estimate since water attenuates gamma rays considerably (Aitken, 1985), thus decreasing the dose rate (see Richter, 2007). The 'as is' moisture of the sediment was measured (14%) but is probably an underestimation since the excavated section had been exposed for

Table 2

Laboratory and excavation IDs, coordinates, raw material, macroscopic indications of heating (after Richter, 2007), and technological classification.

EVA-LUM-	Square	Inv.-No.	x	y	z	Raw material	Heating attribute	Blank
06/3	C11	13	100.057	110.516	98.861	Stránská skála chert	reddish; grey/black	medial flake fragment
06/4	C13	19	100.942	112.509	98.981	Stránská skála chert	grey/black	shatter
06/5	D3	19	101.476	102.282	98.522	Krumlovsky-Les chert	grey/black	shatter
06/6	D9	12	101.105	108.362	98.723	Stránská skála chert or Krumlovsky-Les chert	grey/black	medial flake fragment
06/7	D22	7	101.718	121.108	99.264	Stránská skála chert	pinkish; grey/black; potlids; crazing; cracked faces	shatter
06/8	B1 profile		99.500–100.000	100.000–101.000	98.300–98.600	Stránská skála chert	grey/black potlids;	flake
06/9	B1 profile		99.500–100.000	100.000–101.000	98.300–98.600	Stránská skála chert	reddish; grey/black; potlids; crazing; cracked faces	shatter
06/10	B1 profile		as above	as above	as above	as above	as above	as above
06/11	B1 profile		as above	as above	as above	as above	as above	as above
06/12	B5 profile		99.500–100.000	104.000–105.000	98.500–98.700	unknown	reddish; grey/black	shatter
06/13	C8 profile		100.000–101.000	107.300–107.800	98.600–98.900	unknown	reddish; cracked faces	flake

a number of years. Additionally, the present day moisture probably has little relevance to the moisture over the entire burial period. The saturation water content measured in the laboratory of three sediment samples from Brno-Bohunice was determined to be 40%. While in luminescence dating, often a value half that of the laboratory-determined moisture saturation (i.e. 20%) is used for late Pleistocene sites (Singhvi and Wagner, 1986), we prefer to use a higher value of 25% (using the formulae of Aitken and Xie, 1990). This assumption is based on the strong indications of long and wet periods in the late Pleistocene in this area of Europe (Smolíková, 1984), which is also evidenced as gley-like features in the sediment of Brno-Bohunice (Smolíková, 1976; Frechen et al., 1999). However, during glacial periods, large quantities of water were bound in cavities and ice lenses in the sediment (Haesaerts, pers. comm., 2007). We therefore base our age calculation on a moisture content of 25 %, assuming that on average the sediment was slightly more moist than present day.

The internal dose rates ($\dot{D}_{internal}$) for the samples were determined by the analysis of U, Th, and K concentrations using NAA on about 200 mg of crushed material from each of the extracted

cores or sub samples (Table 3). Unfortunately, the internal dose rates ($\dot{D}_{internal}$) are rather low, never contributing more than 18 % to the total dose rate (Table 3). The dependency of the resulting ages on the external gamma dose rate ($\dot{D}_{external}$), which is the main contributor to the total dose, is therefore high (see e.g. Richter, 2007).

The small cosmic contribution to the external dose rate was calculated with the formulae provided by Prescott and Stephan (1982), Prescott and Hutton (1994) and Barbouti and Rastin (1983) and using the specified error estimate of 5%. The calculation of $120 \mu\text{Gy a}^{-1}$ is based on the latitudinal (49.105°N) and longitudinal (16.35°E) position of the site, as well as its elevation above sea level (283 m) and an assumed 4.5 m of overburden of sediment for the entire burial period of the samples.

TL results

One of the artifact samples was large enough to be split in to three parts, which were treated as independent samples EVA-LUM-06/9, 06/10 and 06/11 (Table 3). The obtained ages are statistically

Table 3Table 3 Data used for age calculations^a

EVA-LUM-	U (ppm)	Th (ppm)	K (ppm)	Paleodose (Gy)	b-value (Gy cm ²)	$\dot{D}_{internal}$ ($\mu\text{Gy a}^{-1}$)	$\dot{D}_{external}$ ($\mu\text{Gy a}^{-1}$)	\dot{D} ($\mu\text{Gy a}^{-1}$)	$\dot{D}_{internal}$ (% \dot{D})	$\dot{D}_{external}$ (% \dot{D})	Age (ka BP _{TL})
06/3	0.50 ± 0.04	0.12 ± 0.02	338 ± 98	52.54 ± 1.24	0.55	117 ± 10	1015 ± 90	1133 ± 90	10	90	46.4 ± 5.1
06/4	0.64 ± 0.05	0.07 ± 0.02	356 ± 135	56.83 ± 1.70	1.54	151 ± 13	1030 ± 91	1181 ± 92	13	87	48.1 ± 5.4
06/5	0.66 ± 0.05	0.21 ± 0.02	554 ± 222	62.18 ± 0.77	1.48	175 ± 19	1042 ± 92	1217 ± 94	14	86	51.1 ± 5.0
06/6	0.58 ± 0.07	0.20 ± 0.03	1110 ± 289	53.58 ± 0.72	0.99	200 ± 25	1034 ± 92	1234 ± 95	16	84	43.4 ± 4.3
06/7	0.39 ± 0.04	0.08 ± 0.02	354 ± 252	50.40 ± 1.50	1.19	102 ± 21	1037 ± 92	1139 ± 94	9	91	44.2 ± 4.9
06/8	0.68 ± 0.05	0.10 ± 0.02	283 ± 127	56.93 ± 1.47	1.17	149 ± 12	1071 ± 95	1220 ± 96	12	88	46.7 ± 4.9
06/9	0.65 ± 0.05	0.12 ± 0.02	368 ± 132	59.50 ± 0.66	1.11	152 ± 13	1052 ± 93	1204 ± 94	13	87	49.4 ± 4.9
06/10	0.52 ± 0.05	0.10 ± 0.02	383 ± 207	57.98 ± 1.27	1.42	132 ± 18	1032 ± 91	1164 ± 93	11	89	49.8 ± 5.5
06/11	0.53 ± 0.04	0.13 ± 0.04	393 ± 212	59.82 ± 0.87	0.80	130 ± 18	1062 ± 94	1192 ± 96	11	89	50.2 ± 5.1
06/12	0.77 ± 0.06	0.10 ± 0.02	197 ± 144	55.86 ± 1.59	0.95	157 ± 14	1047 ± 93	1204 ± 94	13	87	46.4 ± 5.3
06/13	0.93 ± 0.06	0.12 ± 0.03	584 ± 140	60.89 ± 0.73	1.34	222 ± 14	1025 ± 91	1246 ± 92	18	82	48.9 ± 4.7

^a Thermoluminescence data giving the paleodose, alpha sensitivity (b-value), effective internal ($\dot{D}_{internal}$), and effective external dose rates ($\dot{D}_{external}$), as well as the effective total dose rate (\dot{D}); element concentrations by Neutron Activation Analysis (NAA) of U, Th and K; fractional internal and external (including cosmic) dose rates as percentages of the total dose rate and resulting TL ages for the heated flints from Brno-Bohunice 2002. (all data 1- σ).

identical at the 1σ level of confidence, which indicates that the procedures to determine the individual parameters seem to be correct. The small differences observed for these three samples in paleodose and alpha sensitivity, as well as in the radionuclide contents are not significant. However, they point towards a serious potential problem in TL dating of heated flint, the inhomogeneous distribution of radionuclides in the solid sample (Valladas, 1985b). In spite of this, the tightly-clustered age results in this case indicate that each sample was sufficiently homogenized after crushing, which is reassuring for the methods used.

Alpha sensitivities are extremely low (Table 3), and together with low concentrations of radionuclides ($U < 1$ ppm, $Th < 0.21$ ppm, and $K < 1.11\%$), result in very small internal dose rates, making up between 9 and 18% of the total dose rate only (Table 3).

The low spread in ages of less than 8,000 years obtained for the last heating of the artifacts is less than 2σ for each age. Such a spread can be mainly attributed to small unquantifiable differences in the specific external gamma fields for each individual sample. Within this data set, and the uncertainties associated with the method, there is no indication that more than one heating event is present. Statistical analysis (Chi-squared and Shapiro-Wilk) shows that the data are normally distributed. Additionally, the sedimentology as well as the archeology indicate that the assemblage was accumulated over a very short period of time. Thus, samples can be considered of the same age (heating event), and a weighted mean (individual ages with their statistical errors) with an error estimate (weighted mean of total individual errors plus the systematic errors, after Walcher [1985]) may be calculated. On this basis, an age estimate for the artifact assemblage from the Lower Paleosol at Brno-Bohunice of 48.2 ± 1.8 ka BP_{TL} is obtained, which does not differ from the weighted mean if the split samples are treated as one only.

However, the above age estimate is dependent on the chosen value for the moisture content of the sediment. An absolute maximum age of the last heating of these flint artifacts can be calculated under the assumption of complete water saturation for the entire burial time, which would result in a weighted average age of 54.7 ± 2.0 ka BP_{TL} . But this scenario is certainly false, because water saturation would result in severe changes in the sediments that are not observed at Brno-Bohunice. At the other end of the theoretical limits is an equally invalid 0% scenario for an absolute minimum age of 41.6 ± 1.7 ka BP_{TL} . More likely moisture contents of 10% result in a weighted average age of 45.1 ± 1.8 ka BP_{TL} , whereas 30% moisture would give 51.6 ± 2.0 ka BP_{TL} , both statistically indistinguishable from one other. The error of 10% used for the external gamma dose rate incorporates a variation of 50% in the moisture value of 20% (as indicated in the latter two examples above). Thus, the weighted average of 48.2 ± 1.9 ka BP_{TL} is considered as the best estimate of the age of the last heating of the flint artifacts from Brno-Bohunice.

Discussion

No differences can be observed in ages obtained for samples having a precise provenance from the excavated areas and those collected from the adjacent profiles (Table 2; Table 3). Neither the vertical nor the horizontal positions of the dating samples within the artifact distribution of Brno-Bohunice 2002 give rise to an interpretation of more than one occupation, although that occupation is probably a palimpsest of several hominin visitations to the site, given both the high density of finds and the number of shorter production refit sequences reconstructed from this assemblage compared to other Bohunician assemblages (Tostevin and Škrdla, 2006: 44; Škrdla and Tostevin, 2005: 59–60; Tostevin and Škrdla, 2006: 44). This is also true for any vertical or horizontal distribution of artifact types, technological features, raw materials, or any

combination of the above (Škrdla and Tostevin, 2005). For example, a later Szeletian occupation at the site would be expected to result in the almost exclusively-high vertical position of biface thinning flakes as well as for the generally-preferred Szeletian raw material (Krumlovsky Les chert) for leaf points. Neither is the case at Brno-Bohunice, and the presence of these leaf points including an unfinished example and the biface thinning flakes, indicate that the hominins responsible for the assemblage engaged in both bifacial reduction as well as typical 'Bohunician' core reductions (Oliva, 1981, 1984).

In order to compare the TL results with the radiocarbon data, the latter must be calibrated, or converted to the calendric time scale. While this approach is certainly not commonly agreed upon, and the methods and data used certainly are not perfect (unlike the accepted tree-ring based calibration curve, which has been recently revised again; see Friedrich et al., 2004), the radiocarbon ages are the only data available for comparison. We therefore prefer to convert the radiocarbon data in order to obtain an approximation on a calendric time scale, instead of not being able to use dimensionless radiocarbon data in a meaningful sense in archeological and evolutionary interpretation. In Figure 6, the radiocarbon data associated with all the Bohunician assemblages have been converted using CalPal-2007-HULU (Weninger and Jöris, 2004, 2008) and are shown together with the Eifel Lake grayscale record (ELSA; tuned to the ice core N-GRIP; Sirocko et al., 2005). The converted data show a similar spread in ages, as without conversion, but in general give older ages. The Bohunician occupation at Stránská skála appears to start during Greenland-Intestadial (GI) event 12 with Stránská skála IIIa, based on the sample for GrN-12606, which was pushed up by cryoturbation from the Lower to the Upper Paleosol. The assemblage was found in the Lower Paleosol rather than at the base of the Upper Paleosol of the Interpleniglacial soil sequence, where Stránská skála III and IIIc are located. Bohunician occupation appears to have ceased before GI 8.

The data from the recent Bohunice 2002 excavation and the sites of Bohunice-Kejbaly I + II show a contrasting picture. There is little overlap in the probability plot between those two datasets (Fig. 6), thus suggesting different occupational events and/or different associations of dating samples with the archeological event, despite their apparent identical stratigraphical position. The infinite age estimate from the recent Bohunice 2002 excavation is not included in the data set because it can not be converted or calibrated. This infinite age points to the possibility that the age of the archaeological occupation might be beyond the range of radiocarbon, and/or point to problems in radiocarbon dating and/or age conversion/calibration. However, identical ages cannot be expected from a hillside that might have witnessed multiple occupations over a longer time span where all charcoal might have ended up, at approximately the same stratigraphical position. But it appears that radiocarbon dating of charcoal cannot establish a single age for the archeological site(s) at Brno-Bohunice, whereas the data from Stránská skála appears to provide a more meaningful age estimate for the Bohunician. However, the wide range of radiocarbon data from Stránská skála sites of similar stratigraphical positions points towards problems either in association of dating material, or the soil formations were of much longer duration. The application of Bayesian statistics as a technique for constraining the age of the Bohunician is not possible because of the small number of radiocarbon dates available. And in any event, the radiocarbon data from Brno-Bohunice is problematic as the ages approach the limits of the method, and the association between ^{14}C -dating samples and the occupation is frequently questioned. Charcoal is mobile and occurs naturally in loess sediments, in contrast to heated lithics, so it is difficult to determine a secure association for the former, while there appears

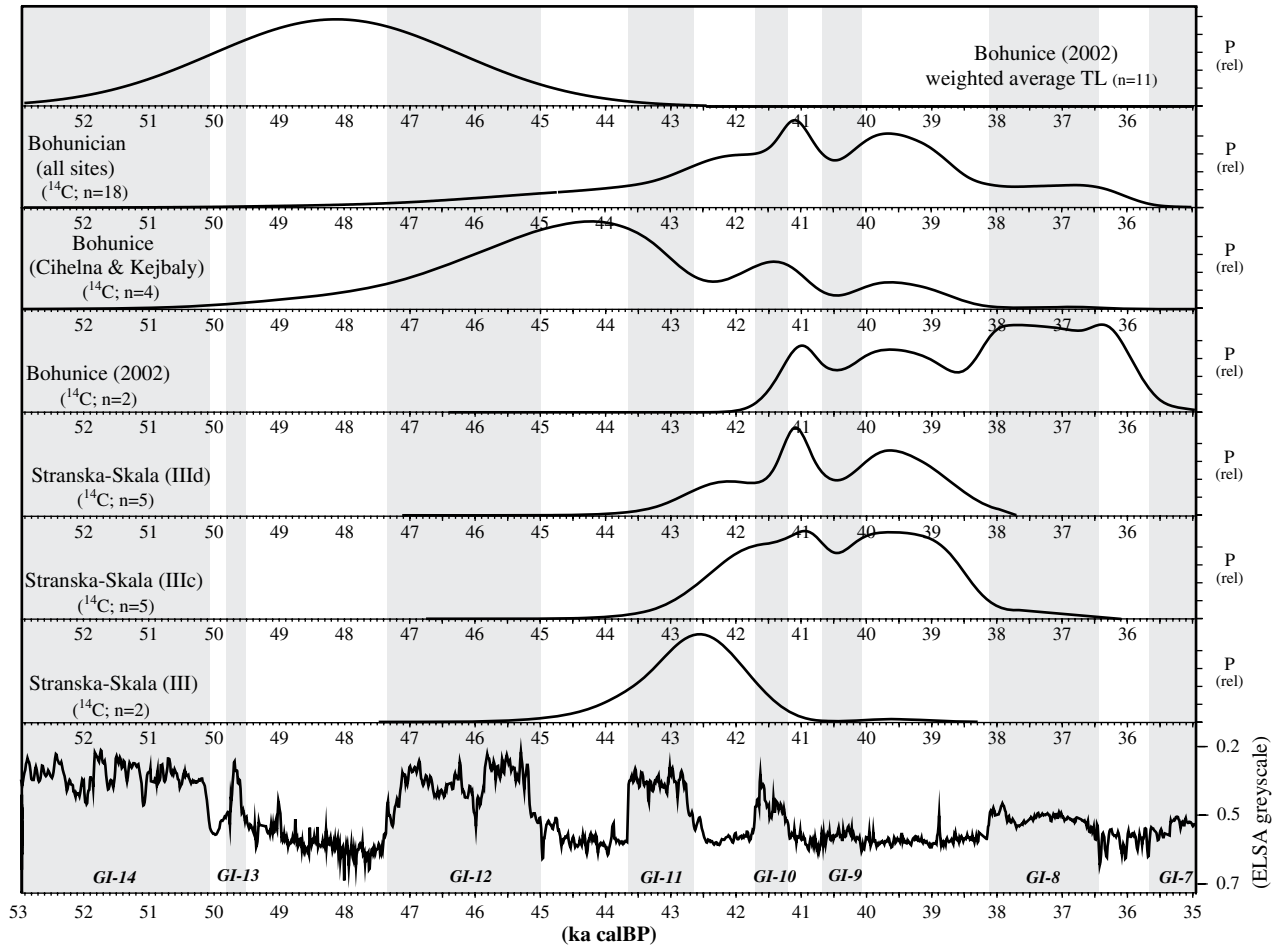


Fig. 6. Age conversion of the radiocarbon ages from Table 1 using the CalPal-2007_HULU data set with the software package CalPal (Weninger and Jöris, 2004, 2008). The larger error estimate was used in case of asymmetrical errors. The Greenland Interstadials (GI) are shown in grey. The bottom box shows the Eifel Lake grayscale record (ELSA, tuned to N-GRIP; Sirocko et al., 2005), and the weighted average heated flint TL data is plotted onto the ^{14}C calBP time scale for convenience.

to be little doubt of the position of the latter. The upper 2σ limit of the weighted mean age of 48.2 ± 1.9 ka BP_{TL} on 11 heated flints excavated from Brno-Bohunice in 2002 is just before the very first part of the apparent Bohunician occupation at Stránská skála based on converted ^{14}C data (Fig. 6). A higher age than the Stránská skála III sites has to be expected for the Brno-Bohunice 2002 assemblage because of its lower stratigraphical position in relation to the two soils, which are generally assumed to be contemporaneous between the sites. At the 95.5% probability level (2σ), the TL data is fully compatible with converted radiocarbon results from Cihelna and Kejbaly, but not from Brno-Bohunice 2002 (Fig. 6). However, the infinite age from Brno-Bohunice 2002 points towards the possibility of the site being of older age (Table 1). The TL result of 47.3 ± 7.3 ka BP_{TL} on sediment from the Lower Paleosol at Cihelna (Zöller, 2000), which certainly represents a mixed sedimentation age because of bioturbation, is compatible with the TL ages on heated flint from the archaeological site.

It is interesting to note, that all peaks of the radiocarbon probability distributions for the individual sites, as well as for the combined data set, occur between GI's (Fig. 6). This is in contrast to the expectation of having either an increased (or more likely) human occupation, and/or larger plant species available for charcoal in warmer periods. Presuming soil formation is related to warm climate, the locations of the probability peaks also point towards the notion that the soils formed after and not during artifact deposition, which would explain the older TL ages in relation to radiocarbon charcoal cal BP ages.

Conclusions

The thermoluminescence dating of heated flint artifacts from Brno-Bohunice provides a confirmation of the early chronological position of the type-locality for this early Upper Paleolithic technocomplex in the Middle Danube. In addition to giving more credibility to radiocarbon dates from other Bohunician assemblages, the sequence of 11 heated flint samples produced dates with a normal distribution, providing a weighted mean age of 48.2 ± 1.9 ka BP_{TL} and adding further, independent support for the behavioral integrity of the palimpsest from the 2002 assemblage from Brno-Bohunice. This confirmation of the contemporaneity of the artifacts within the assemblage supports the interpretation of Brno-Bohunice's technological differences when compared to other Bohunician assemblages as an effect of different landscape use of the Brno-Bohunice locality. Results of the 2002 excavation and dating projects thus demonstrate the integrity of the new assemblage at the Bohunician type-locality as a palimpsest of a series of hominin visits of rather short duration captured within the Lower Paleosol. No evidence of vertical or horizontal intrusions from a hypothetical Szeletian occupation was found. The documentation of bifacial reduction within the 2002 Brno-Bohunice assemblage indicates that leaf points are an integral part of the Bohunician at this locality.

The method of TL dating of heated flint was internally checked by the independent treatment of three samples from a single heated flint. The resulting ages are identical and overlap at 1σ ,

which gives confidence in the method used. The weighted TL age of 48.2 ± 1.9 ka BP_{TL} provides a much better age estimate than does the radiocarbon data, because of the secure association with the archeological event. It places the human occupation in a time range between the ends of GI 14 and GI 12, roughly at the time of Heinrich event 5. However, these dating results should be corroborated by optically stimulated luminescence dating of sediments from the Upper and Lower Paleosol, as well as the underlying loess. The latter would probably provide a better sedimentation age for the accumulation of the lithic assemblages, compared to the pedogenically-altered sediments, although it will be a maximum age estimate for the archeological site (Richter et al., in press).

Brno-Bohunice is the first Bohunician assemblage for which an age estimate is provided on a calendric time scale. The chronological position of the Bohunician industry is thus confirmed, with the result that this end-point to the proposed Bohunician Behavioral Package cultural transmission event remains chronologically, as well as geographically, consistent with previous research. Had the TL results placed Brno-Bohunice earlier (i.e., outside the 2σ range) than the 47/46 ka ¹⁴C BP age (~51/50 ka cal BP) for Boker Tachtit Level 1, the Bohunician Behavioral Package hypothesis would have been disproved.

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