Adaptation of settlement strategies to environmental conditions in southern Slovakia in the Neolithic and Eneolithic

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ABSTRACT – *Environmental conditions such as climate, topography, and soil conditions had an impact on prehistoric settlement strategies. By studying changes in settlement structure in the Nitra, Hron and Ipel' valleys in southern Slovakia over the course of the Neolithic and Eneolithic, preferences for various climatic and topographic environments in different periods can be seen. Besides cultural and socio-economic factors, it can also be expected that changes in climate contributed to change in settlement patterns. Climatic changes in Neolithic and Eneolithic have been identified and correlated with major changes in socio-economic structure, as well as with known climate fluctuations in the North Atlantic area.*

IZVLEČEK – *Na strategije poselitev v prazgodovini so vplivali okoljski pogoji, kot so klima, topografija in vrste tal. Z raziskavo sprememb v strukturi poselitev v dolinah Nitre, Hrona in Ipela na južnem Slovaškem v obdobju neolitika in eneolitika lahko opazujemo preference za različna klimatska in topografska okolja v različnih obdobjih. Poleg kulturnih in družbeno-ekonomskih faktorjev lahko pričakujemo, da so tudi spremembe v klimi prispevale k spremembam v vzorcu poselitve. Prepoznali smo klimatske spremembe v neolitiku in eneolitiku ter jih povezali z glavnimi spremembami v družbeno-ekonomskih strukturah, pa tudi z znanimi klimatskimi nihanji na področju severnega Atlantika.*

KEY WORDS – *settlement strategies; climate fluctuations; Neolithic; Eneolithic; Central Europe; Slovakia*

Introduction

The increase in excavation activity over recent decades and the need to consolidate and make available in digital form the large body of archaeological data already collected has led to a renaissance in the study of settlement strategies and structure. Past micro-regional studies concerning the relationship between settlements and their natural environments indicated certain recurring patterns, which we attempt to verify using a larger dataset covering a broader geographical area. Our basic assumption is that the pattern of displacement of human settlements in the landscape is not random, but the result of a system of adaptation to different conditions – a settlement strategy. Diachronic change in this strategy is determined by resource usage and availability, cultural impulses and environmental influences such as climate change (*Škrdla 2006.34; Škrdla, Svoboda 1998.293*).

The source database for our analysis contains information on 1148 archaeological sites dating from the Neolithic and Eneolithic periods, and covers the area

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of the Nitra, Hron and Ipel' river valleys. The geographic localisation and dating[1] of 488 of these sites is sufficiently precise to be included in an analysis of the diachronic development of settlement structure with regard to environmental variables. All information was acquired from existing published or freely available sources. A recently compiled catalogue of sites was also used (*Tóth 2010a; 2010b*). The charting, analysis and synthesis of the data was performed using database software and geographical information systems.

The selection of analysed environmental variables is essentially unlimited and depends primarily on the focus of our study (*Kuna 1994.77; 1998.212*). In order to capture the environmental context of the settlements, we chose the following attributes: local elevation within a 200m radius (centred on the site location), walking distance to nearest potential water source, soil type (at the site location and in the site catchment area[2]), and the climatic zone of the site.

When calculating the distance to the nearest water source, the heavy regulation of mainly the lower reaches of the rivers in our area of focus was a major reason not to use recent data. A potential natural stream network was therefore modelled using an algorithm published by Tripcevich (online).

Recent data was used when determining soil types at and around the sites, based on the assumption that the soil cover did not fundamentally change in the late Holocene and was only subject to variations in its properties (*Wiedermann 2003.16*). The interpretation of the use of highly fertile chernozem and brown earth soils by Neolithic and Eneolithic farmers was based on the assumption that the basic difference between these soil types lies in moisture movement. Brown earths have a more favourable moisture regime and are less sensitive to fluctuations in precipitation than chernozem soils. On the other hand, brown earths are more difficult to work (they are stickier), and the tree roots and undergrowth connected with them pose an additional challenge to Neolithic and Eneolithic farming technology. In this respect, arid, more open chernozem areas with only insular, scattered forestation were better suited to agriculture (*Rulf 1981.127–128*).

Our study of relationships between settlement structure and climate conditions is also based on the present distribution of climatic zones (*Hrnčiarová* et al. *2002*). These are determined as a combination of average yearly temperatures and precipitation levels. While we have no data from climatic proxies in our focus area which would provide us with information on temperature and precipitation levels in the prehistoric period, we can assume that the relative differences in humidity and temperature between various climatic zones depend mainly on the geomorphological properties of the land, which have not significantly changed since the Neolithic (*Milo* et al. *2004.129; Modderman 1988.80*).

To reflect changes in demographics, which could also be subject to environmental influences, changes in settlement structure (represented by the mean distance between sites) were studied. Here, a simplified approach had to be taken, assuming that all sites dated to a particular culture (or its stage) were contemporaneous and of similar size. This simplification was necessary as the source base was insufficiently precise[3] to allow an assessment of contemporaneity between the settlements of a particular culture or cultural stage. It was also impossible to determine their exact lifespan or geographical extent (*cf. Milo* et al. *2004.132*).

The natural environment of the Nitra, Hron and Ipel' river valleys

The focus area of this study is delimited by the Nitra and Hron river valleys, the Slovak part of the River Ipel', and the adjoining left bank of the Danube, covering about 14 600 km^2 of western and central Slovakia (47,7–49° N, 17,8–20,3° E). Major climatic influences are the area of high pressure above the Azores and the area of low pressure over Iceland and Scandinavia. An oceanic climate prevails over a continental, the boundary passing approximately through central Slovakia. The northern boundary of our focus area is delimited by Carpathian mountain spurs, reaching altitudes of over 600m a.s.l. The southern part is flat and opens into the Pannonian Basin. The terrain does not exceed 300m a.s.l. over almost half of the area. The local climate is influenced by several highland and upland areas, which divide the

1 Also to avoid issues with synchronicity we did not involve finds from cultures which are not considered local to our area of focus and should be considered imports.

2 In a 1km radius around the site (*cf. Rulf 1983.61*).

3 The information about chronological assignment of the sites given in the respective literature was used. As the main body of our data comes from surface surveys, future re-evaluation of archaeological dating should be undertaken in order to obtain more reliable sources. This is especially true for the finds of stage Lengyel III where a major revision of the material has shown an incorrect assignment of many Lengyel IV finds to this stage (*Pavúk 2000.1–22; 2001.151*).

country into smaller regional units, cancelling the adverse effects of continental climatic influences (*Pavúk 1982.40; SHMÚ online*).

The subsoil on the upper reaches of the rivers is comprised mainly of pre-Quaternary rocks and undifferentiated rubble and slope deposits covered mainly by cambisols (41%). The quaternary deposits on the southern part of our focus area are mainly loess (15%), different soils (12%), and sandy loess terraces (8%). The soil cover in this part is mostly brown earth (20%), chernozem (12%), fluvisols (6%), and phaeozem (4%) (*Hrnčiarová* et al. *2002.Maps 17, 78*).

The average temperature in January in the north highlands is in the range of –4 to –7°C, in July 12–18°C. In the southern lowlands, the temperature reaches –1 to –3°C in January and 18 to 21°C in July (*Lukniš 1972.maps 65–66*)[4]. The highest precipitation occurs in the summer. In winter, precipitation takes the form of snow at medium to high altitudes. The lowlands experience great variability in precipitation levels, which leads to frequent and sometimes prolonged periods of drought. This effect is intensified by the fact that this is the warmest and most windy area of Slovakia, with high evaporation potential (*SHMÚ online*).

Chronological framework

The chronological focus of this paper is on the following Neolithic and Eneolithic cultures (5700–2300 calBC): early and late Linear Pottery culture (LBK), the Želiezovce group, Lengyel culture (3 Neolithic and 1 Eneolitic stage), the Boleráz group, Baden culture, the Bošáca and Kostolac groups, and Kosihy-Čaka/Makó culture (Tab. 1).

The wide chronological and geographical extent of the archaeological sources studied in this paper was chosen to alleviate the relatively low precision of the available data. Only by sampling a large area with a wide chronological focus is it possible to follow long-term trends in changes in settlement strategies and study their relationship to environmental conditions (*cf. Demján 2009.14; Tóth 2010a.100*).

Previous studies

The first study concerning the relationship between settlement structure and the natural environment in our focus area was by Csalogovits. The author pointed out the necessity of a cartographic mapping of archaeological sites and listed the factors which influenced the displacement of sites in the landscape (*Csalogovits 1930.28*). No follow-up work to this progressive study appeared for the next 50 years. Large field excavations and theoretical groundwork (mainly concerning chronology) were the focus of archaeological study at that time.

A renaissance of research into the settlement strategies of prehistoric populations occurred in the 1980s and 1990s with the work of Pavúk, which now forms the groundwork for the study of relations between human settlement and the natural environment. These studies focused on the Neolithic and Eneolithic of southwest Slovakia, which was placed in a

Dating	Sites	Used for analysis
early LBK	31	25
late LBK	206	166
Eastern LBK	2	0
Szilmeg	2	0
Želiezovce	265	192
Bükk	22	0
LBK	110	0
Middle Neolithic	1	0
Protolengyel	9	7
Szakalhát	3	0
Lengyel I	29	25
Lengyel II	14	12
early Lengyel	27	0
Tisza	20	0
Stroked Pottery	2	0
Vinča	2	0
Lengyel III	33	32
Late Neolithic	5	0
Neolithic	303	0
Lengyel IV	104	82
late Lengyel	21	0
Lengyel	181	0
Bajč-Retz-Krepice	13	9
Early Eneolithic	20	0
Boleráz	85	49
class. Baden	72	67
unspec. Baden	228	0
Bošáca	11	11
Kostolac	3	3
Kosihy-Čaka/Makó	70	62
Late Eneolithic	18	0
Eneolithic	126	0

Tab. 1. Number of sites assigned to different cultures included in the database. Only finds considered local to our focus area with sufficiently precise localisation and dating were used for further analysis.

4 Based on meteorological data collected between 1931 and 1960.

broader Central European context. The displacement of settlements was studied according to their elevation, soil type, distance to water sources, and climatic fluctuations expected when they were occupied. The most important environmental variables were considered to be precipitation levels and their annual variation (*Pavúk 1976.331–342; 1981a.255–291; 1982.40–48; 1986.213–221; 1990.63–68; Pavúk* et al. *1995.116–124*). The major limitations of these studies lay in the level of information technology of the time and the relatively small archaeological data base.

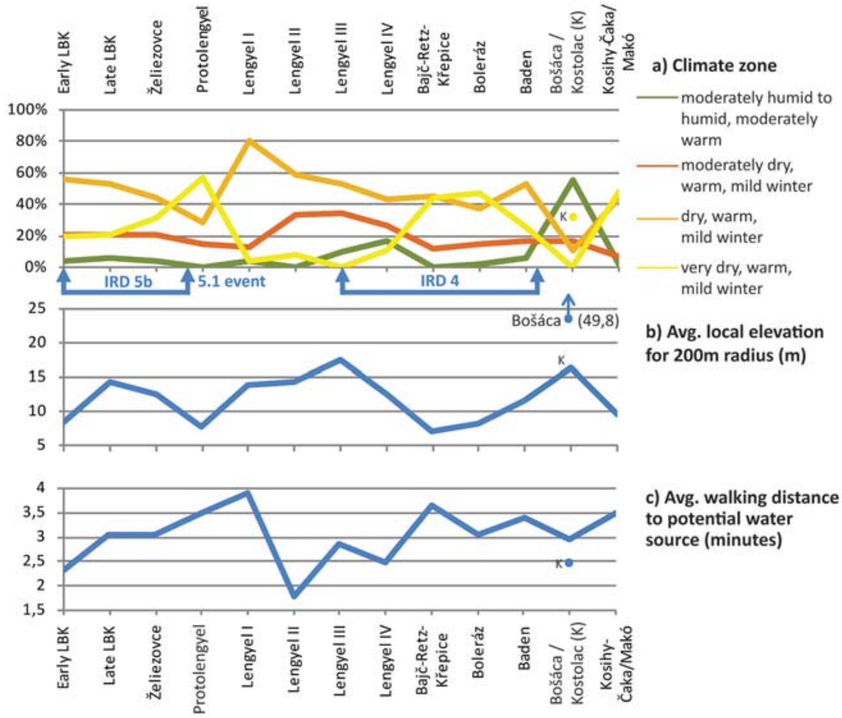

Fig. 1. Development of settlement structure in relation to climatic zones (with marked IRD phases according to* Gronenborn 2009.Fig. 2*), local elevation and distance to water source.

The turn of the millennium saw a surge in research in this field in Slovakia, mainly thanks to the increasing use of geographical information systems and the influx of new archaeological data from rescue excavations. It is now possible to include more environmental variables when studying settlement structure, and process large amounts of data relatively easily. The focus of the studies to date has been on smaller to medium-size regions (*Demján 2009.7–27; Kopčeková 2010; Milo* et al. *2004. 127–150; Tóth 2010a; 2010b. 63–148; in press a; in press b; Wiedermann 2003*).

Environmental factors and settlement distribution

Settlements of early Linear Pottery culture represent the beginning of productive agriculture in southwest Slovakia. The climatic conditions in the European Early Neolithic can be considered optimal (*Květina 2001.684; Pavúk 1990.66*), which is supported by the fact that settlements are situated in dry, warm climatic zones (Fig. 1.a) and dry chernozem soils predominate at these sites (less so in the site catchment areas; Fig. 2.a,b). Settlements are also found on sandy subsoil (*J. Pavúk, personal communication*). The most fertile sites for settlement were chosen (*Hajnalová 2007.297; Pavúk 1976.334*), and are situated at regular distances along larger rivers and less frequently on their tributaries (Fig. 3; *Sádlo* et al. *2008.58*), in lowlands (Fig. 1.b), and close to water sources (Fig. 1.c). In this period, we see the formation of seed areas for the later spread of settlements.

The development of settlement structure during the late LBK and Želiezovce group seamlessly ties in to the trend set in the previous period. Settlements are situated along major rivers, and now more frequently on their tributaries (Fig. 3), occupying more elevated positions farther from water (Fig. 1.b,c). A substantial difference can be seen in the soil cover on and around the sites. The late LBK sites are found on more humid soil types (brown earth and fluvisol) than early LBK sites and the use of chernozem decreases (Fig. 2.a,b) indicating a shift to a dry climate. In the following Želiezovce group, we see again an increase in chernozem areas on sites and in site catchments, and an almost equal amount of brown earth and fluvisol (Fig. 2.a,b). The nearly equal ratio of arid and humid soil types on and around sites during the Želiezovce period coupled with the fact that more arid climatic zones were being settled (Fig. 1.a) could indicate an onset of climatic fluctuations, as well as changes in the economic sphere.

Fluctuations in climate during the late LBK and Želiezovce period can also be followed in the archaeological record. An example of a period of drought at this time is the settlement at Rybník, located in the Slovak Gate area where the river Hron enters the

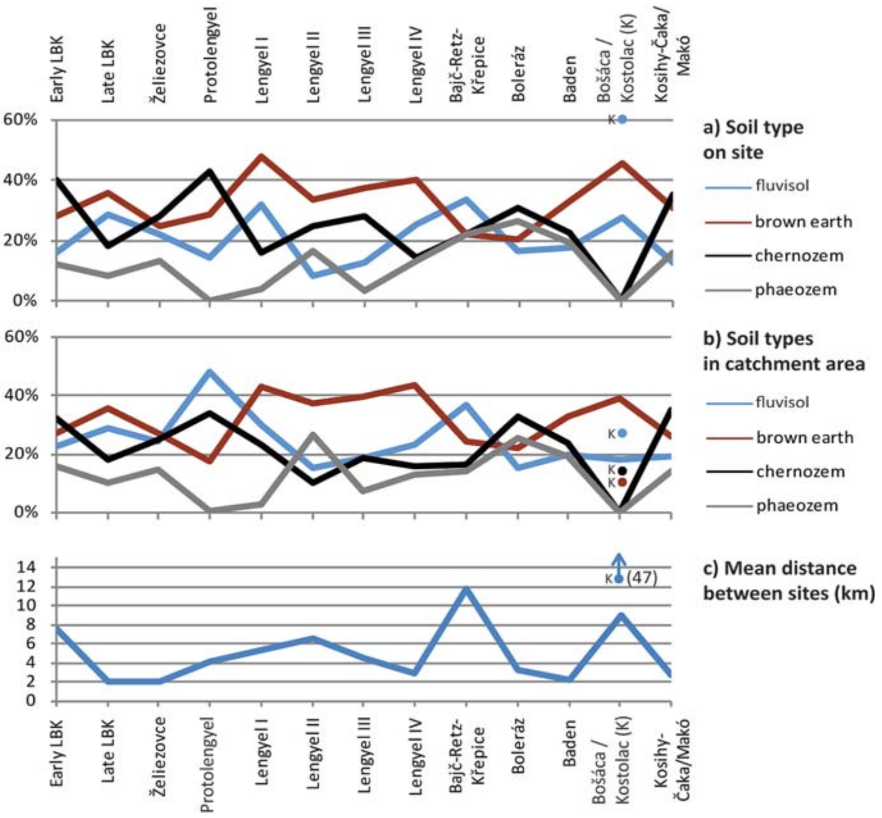

Fig. 2. Development of settlement structure in relation to soil conditions on site and in the catchment area, and mean distance between sites.

Bükk culture, there are indications of adverse climatic change in this period too. The intensively populated open settlements and caves were being abandoned towards the end of the Bükk culture, not to be repopulated in the following period (*Pavúk 2007b.268*). Several studies indicate that as a result of changes in climate conditions, the local soils could no longer sustain the population (*Pavúk 1982.42; Pavúk* et al. *1995.123; Šiška 1995.10*). A similar ecological-economic crisis can also be assumed in the east Tisza valley region in Hungary (*Šiška 1995.11–13*), eastern Slovakia and in Lesser Poland (*Pavúk 2007b.268*).

lowland – only under such climatic conditions could it have been founded in the inundation area of the River Hron. The discontinuation of the settlement in the Želiezovce period can be linked to a flood, as documented by two strong layers of sedimentation over a settlement feature (*Bátora Rassmann 2006. 32–33; Bátora 2009.140*). Furthermore, it can be observed that several settlements of the classic stage of the Želiezovce group, especially along the Danube, were abandoned, and in the subsequent Želiezovce III stage settlements appear at new, previously unsettled locations (*Pavúk 1976.334; 1990.66*). Apart from climatic influences[5], this development could have been connected with an economic and social crisis (*Pavúk 1986.216*). The evidence of a violent conflict at the late LBK and Želiezovce site in Asparn a.d. Zaya/Schletz (5070–4950 calBC) also points to a crisis at this time, which could indicate a scarcity of food resources resulting from an extended drought (*Gronenborn 2007.85; Windl 2009.192, 195*).

To the east of our focus area, in the regions of the Slovak Karst and northern Tisza valley, settled by the

In the following Protolengyel period, which represents a transition from the Middle to the Late Neolithic in Slovakia, a clear rupture can be seen in all observed trends. The number of settlements in very dry and warm climatic zones increases (Fig. 1.a), with a preference for lowlands (Fig. 1.b). Arid and humid soil types occur equally frequently at site locations, with a preference for chernozem (Fig. 2.a), while there was a strong preference for humid soils (especially fluvisol) in site catchment areas (Fig. 2.b). The sites are situated mostly along larger streams, mainly in the lower reaches of the Ipel' and Hron and in the surroundings of the city of Nitra (Fig. 4). Settlement density greatly decreased, as did settlement size (*Pavúk 1986.218*). Although some environmental indicators (more arid climatic zones, increasing distance from water) would suggest an abundance of precipitation in this period, the sudden shift in most environmental parameters, the disproportion in the presence of humid and arid soil types at sites and in site catchments, as well as the massive drop in population, lead us to the assumption of unstable climatic conditions, possibly influenced by a shift to a

5 The previously unsettled sites now newly occupied by the Želiezovce group (62% of all Želiezovce sites) are situated in higher elevated areas and in drier climatic zones. The ratio of chernozem soils on site and in site catchment areas also inceases which points to an adaptation to more humid climatic conditions.

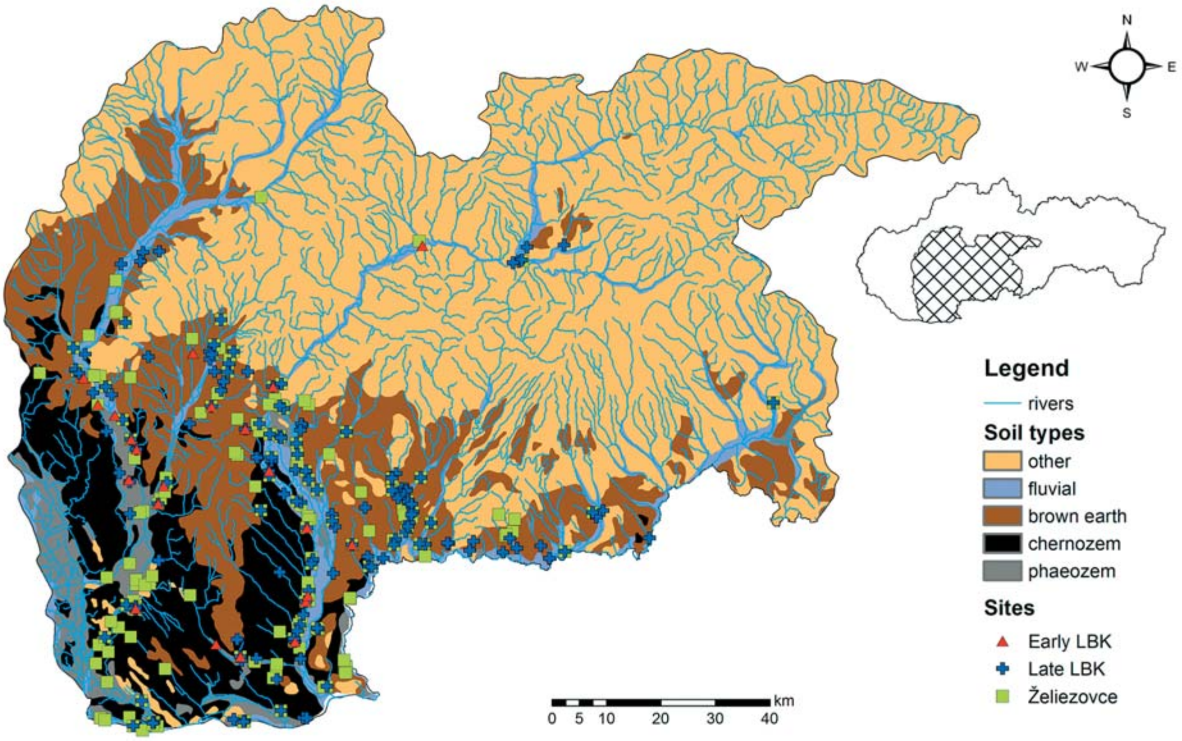

Fig. 3. Distribution of sites of the early and late LBK and the Želiezovce group on various soil types.

dry continental climate[6], which can be more readily observed in the ensuing periods.

The transition from the Želiezovce group to the Lengyel culture in this period is marked by significant cultural-historical changes in prehistoric Europe (*Pavúk 1990.41*). The newly constituted socio-economic structure can be considered a result of an adaptation to changed environmental conditions, as well as intensive contacts with Southeast Europe (*Pavúk* et al. *1995.119*).

A major shift in settlement strategies at this time can also be seen in the regions east of our focus area. The demise of Middle Neolithic cultures (the Szilmeg, Esztár and Szakalhát groups) in the Hungarian middle and upper Tisza valley and in the area west of Tisza marked the end of a relatively dense settlement network of many small sites. It was replaced by tell settlements of the Tisza culture and the Herpály and Csőszhalom groups, situated along major rivers, while the area to the west of Tisza remained depopulated (*Makkay 1982.122, 126; Pavúk 1986. 219; Pavúk* et al. *1995.120; Šiška 1995.11*).

Sites dating to Lengyel culture stages I and II are situated mostly on brown earths (Fig. 2.a), which predominate also in the site catchment area (Fig. 2.b) for the duration of Lengyel culture. This is a result of the shift of settlements to uplands and highlands (Fig. 1.b) with higher precipitation levels[7], covered at the time by forests (*Wiedermann 2003.64*). Connected with the shift to higher areas is the higher number of sites in dry, warm climatic zones, as opposed to very dry zones typical of the lowlands. This shift towards less arid climatic zones can be observed already in the Lengyel I stage, progressing gradually throughout the subsequent Lengyel stages and culminating in Lengyel III (Fig. 1.a). Settlements in uplands were concentrated along smaller streams, in lowlands along the major rivers. The area along the Danube and the sand dunes along the lower reach of the Nitra remained unsettled (Fig. 4; *Pavúk 1986.215*).

While Lengyel I settlements preferred a location farther removed from water sources (the farthest of all Neolithic and Eneolithic cultures in southwest Slovakia), this distance has halved in the Lengyel II stage

6 Other indices of a prevailing arid and unstable climate include the settlement discontinuity when compared to the late Želiezovce period (stage III; *Pavúk 1976.334; 1990.66*), an increased importance of hunting as a source of subsistence (*Ambros 1986. 12–13; Pavúk 1982.46*), and an analogous development in settlement structure in the Tisza valley (*Pavúk 1986.219; Pavúk et al. 1995.120; Šiška 1995.11*).

7 Brown earth areas receive only 100–150mm more precipitation than chernozem areas, but rainfall occurs more often and during the whole vegetative cycle (*Pavúk 1990.66*).

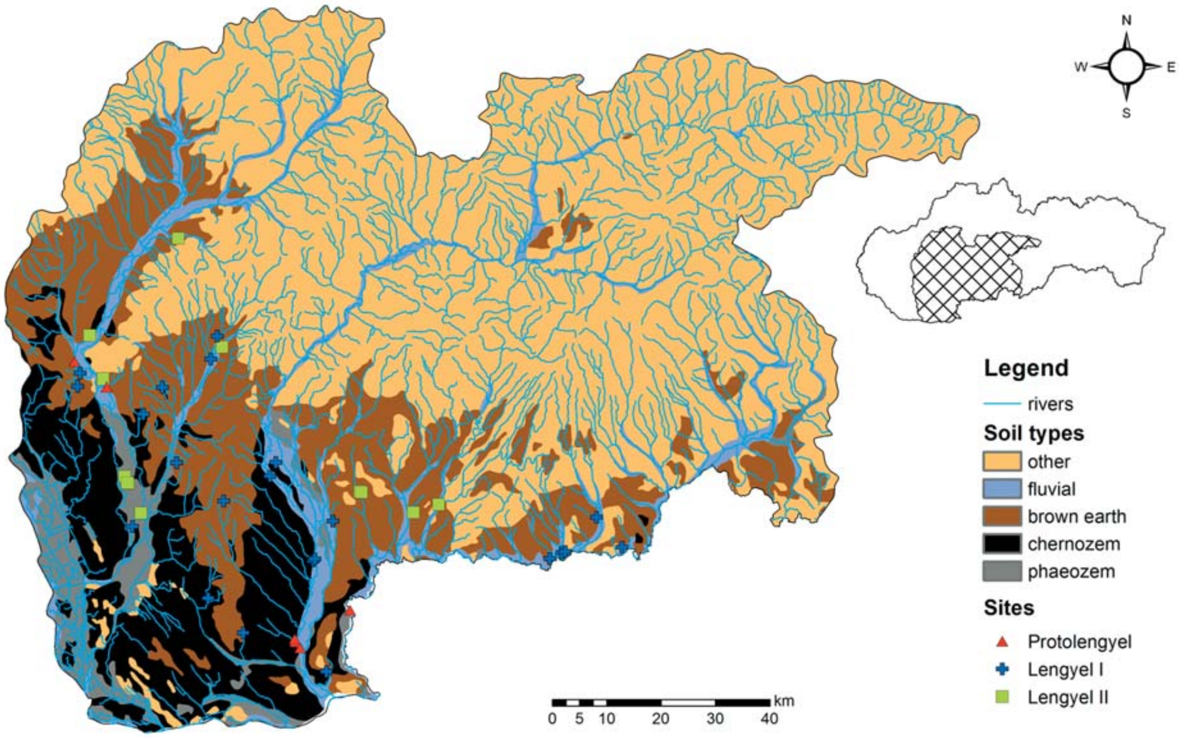

Fig. 4. Distribution of Protolengyel, Lengyel I and II sites on various soil types.

(Fig. 1.c). This coincides with a higher ratio of phaeozem soils in the site catchments (Fig. 2.b). The Lengyel I sites were situated at regular distances from each other, forming a fairly regular network. A certain concentration of sites can be observed on the middle reaches of the Ipel'. The Lengyel II stage saw a further reduction in the number of settlements. Sites from this stage can be found only on the lower reaches of the Ipel' and the middle reach of the Nitra (Fig. 4). It seems that a continuing dry period prevailed in Slovakia at this time.

An important aspect of the settlement patterns of Lengyel culture is the discontinuity of settlements in the lowlands and uplands of southwest Slovakia. There were settlements founded on previously uninhabited locations, never lasting longer than one ceramic stage (*Pavúk 1976.336; 1982.47; 1986. 213–214; Pavúk* et al. *1995.122; Tóth 2010a.tab. 9; Wiedermann 2003.69*). This phenomenon of 'single-stage' settlements begins with stage III of the Želiezovce group and is best observed in the early stages of Lengyel culture (*Pavúk 2009.258*). There are several reasons for this trend of discontinuity. The Lengyel settlements are typically large in extent, with dense populations, more houses and planned development. The construction of monumental rondel enclosures in earlier Lengyel settlements indicates a certain social hierarchy (*Pavúk 1982.48; 1986.216*). Such a density of population places higher demands on natural resources (wood, game animals), which could lead to the gradual devastation of the surrounding natural environment. Deforestation and a reduction in the number of game animals could have led to the abandonment of large settlements at relatively regular intervals, coinciding with the chronological stages determined by ceramic material and possibly related to a worsening of climatic conditions (*Pavúk 1986.220*). The regular abandonment of sites and founding of new, larger ones could also have been connected with a spiritual aspect, reflected in the building of rondels with a calendric function, providing the inhabitants with a relatively precise means of temporal orientation for the whole year (*Karlovský, Pavúk 2002.124*). The building of these structures could also be understood as a response to the need to predict regular flooding, observe weather cycles and estimate the correct time for sowing cereals – all abilities necessary to maintain subsistence from agriculture in adverse climatic conditions (*Karlovský, Pavúk 2002.120; Pavúk, Karlovský 2004. 265–266; 2008.497*).

The more frequently settled upland areas provided sufficient moisture during the growing season, and were better suited for crop cultivation than chernozem areas, which were more prone to desiccation. This also coincides with the structure of faunal assemblages found at settlements. When compared to the previous LBK and Želiezovce periods, where the bones of domestic animals predominate (up to 95%) we see an increase in game animals (15,6% to 68,9%; *Ambros 1986.12–13; Pavúk* et al. *1995.121*) at Lengyel settlements. A similar change in faunal assemblages in the Late Neolithic can be observed at settlements in Hungary, Moravia and southwest Germany (*Ambros 1986.14; Dreslerová 2006.8, 22*). Animal proteins compensated for the shortage of plant proteins (*Dreslerová 2006.22; Pavúk 1982.46*).

The assumed onset of climate change in the Lengyel I stage is closely related to the phenomenon of migration from the Pannonian Basin to the west into Lower Austria and Moravia. An unbroken sequence of cultural development from Želiezovce III through Protolengyel I, Protolengyel II to Lengyel I can only be observed in southwest Slovakia and Transdanubia. This kind of continuity is absent in Lower Austria and Moravia, where settlements of stage III of the Stroked Pottery culture can be found at this time. We register a sudden cultural shift in this area during the Lengyel I period. In the first phase (IA), the Austrian Weinviertel region was settled by a Lengyel population, and the settlements spread to Moravia in phase IB (MBK Ia and MOG Ia; *Pavúk 1983. 41–42; 2007a.16–17*). The Lengyel settlements occupied mostly other sites than the contemporary Stroked Pottery settlements and settlement density was larger than that in southwest Slovakia (*Kalábková 2009.69–70, graf 11; Kazdová* et al. *1994.149–150, Abb. 1*). This cultural change happened without any signs of continuity in the material or cultural sphere. During the Lengyel II stage, the number of sites in Moravia (MBK II) further increased and settlement density grew (*Kazdová* et al. *1994.Abb. 8*). Lengyel settlement at this stage spread to middle Moravia and Upper Silesia (*Pavúk 2007a.23*).

The settlements of the Lengyel III stage continued to shift into upland and highland regions with higher precipitation levels and a less arid climate (Fig. 1.a,b; *Wiedermann 2003.64*). The average distance to water sources slightly increased (Fig. 1.c). The sites are situated mainly on the southern precipices of the volcanic mountains in the north of the Danubian Lowland. There was an increase in the number of sites compared to the previous period, but the area approximately 25km from the Danube remains unsettled (Fig. 5). Settlements were founded mainly on brown earth soils (Fig. 2.a) which predominate also in the site catchment areas (Fig. 2.b). This suggests the continuation of a period of dry climate. The findings on the Budmerice (*Pavúk 1981b.220–221*) and Sl'ažany sites, which are situated in the Carpathian foothills, provide evidence for this interpretation of ecological parameters. Both of these Lengyel III stage sites were covered with several metres of alluvial sediment from nearby small streams (*Pavúk* et al. *1995.122*). This indicates uneven rainfall distribution over the year during a dry period, which leads to flash floods from small streams.

The onset of the Eneolithic period, represented in southwest Slovakia by stage IV of Lengyel culture, marks a shift in cultural, social and economic development. The appearance of copper ore mining and copper manufacturing, together with other technological innovations over the whole Pannonian Basin is closely connected with changes in social structure and an increased stratification of the population of prehistoric Europe.

In regard to the studied environmental parameters, Lengyel IV settlements are situated on less elevated sites, still relatively close to water sources (Fig. 1. b,c). Sites are mostly on brown earth soils, which also predominate in site catchments (Fig. 2.a,b), while the ratio of chernozem sites decreases. The number of settlements grew and their size decreased, resulting in higher settlement density (*Balážová 2007.98*). Multicultural sites from the Early and Middle Neolithic as well as the previously desolate Danube bank were resettled, and the finds from several caves are also dated to the Lengyel IV stage (Fig. 5; *Pavúk 2009.260; Wiedermann 2003.54, 72*). Compared to the previous period, there was a further increase in the settling of humid climatic zones (Fig. 1.a) which suggests a continuation of the dry climate, although the resettling of previously depopulated areas and a slight increase in the number of sites in very dry climatic zones could indicate an improvement in climatic conditions during this period (*Pavúk* et al. *1995.122; Wiedermann 2003.64*).

Another major shift in all the observed parameters occured towards the end of the Early Eneolithic in the Bajč-Retz-Křepice group. There was a significant reduction in settlement density compared to the previous period. Sites were situated on flatland and at greater distances from water sources (Fig. 1.b,c) only on the lower reaches of the rivers (Fig. 5). Most settlements were on fluvisols (Fig. 2.a), and humid soil types also predominated in the site catchment areas (Fig. 2.b). There was a high ratio of sites in very dry and warm climatic zones (Fig. 1.a), which could suggest the return of more humid climatic conditions (*Pavúk* et al. *1995.122*).

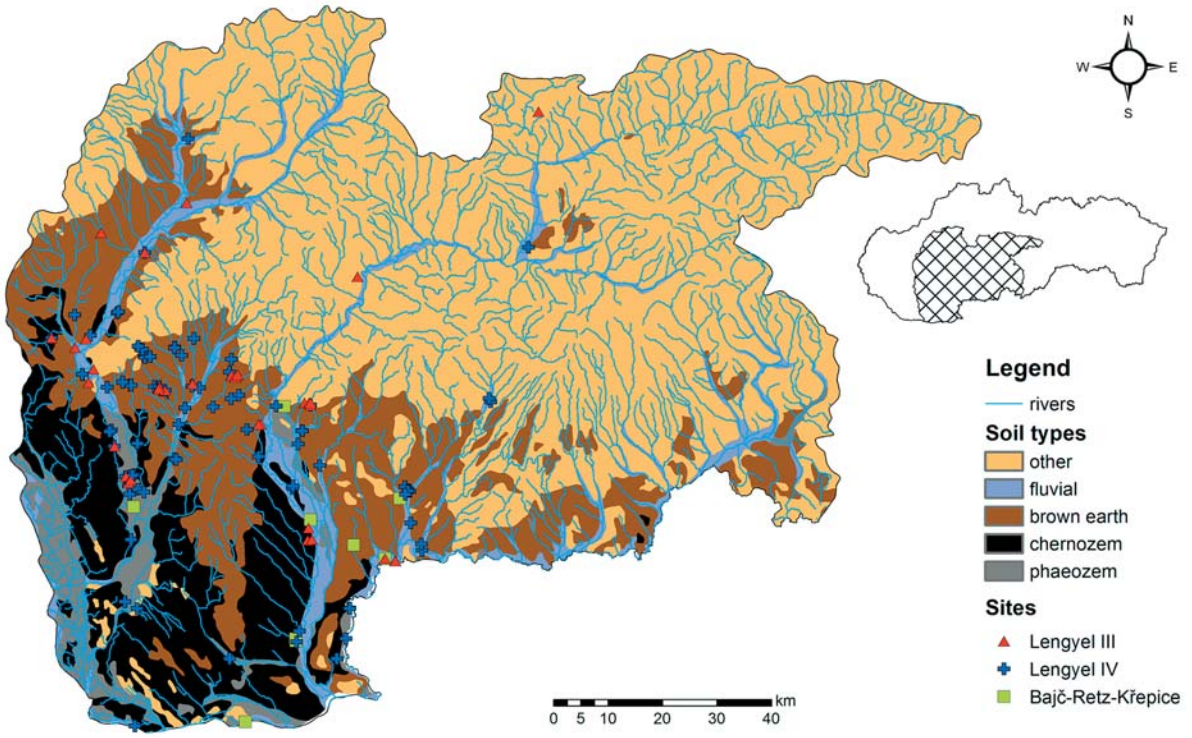

Fig. 5. Distribution of Lengyel III, IV and Bajč-Retz-Křepice group sites on various soil types.

A real contrast to the preceding development is observable with the onset of the Middle Eneolithic Boleráz group and the subsequent Baden culture, which were based on a new socio-economic foundation (*Pavúk 1986.220*). During the Boleráz group, the climate stabilised – as indicated by the large number of sites located in very dry and dry climatic zones (similar to the previous period; Fig. 1.a) and the return to more arid chernozem areas (Fig. 2.a,b). The density of settlements increased and settlement clusters started to form, mainly on the lower reaches of the Nitra and Hron and along the Danube (Fig. 6). The settlements were relatively small (*Pavúk* et al. *1995.122*). Lowlands were preferred (Fig. 1.b) and the distance to water sources slightly decreased (Fig. 1.c). The sites were situated along major rivers, as well as their tributaries (Fig. 6). The role of game animals as a source of subsistence also diminished and remained constant throughout the Middle and Late Eneolithic (*Ambros 1986.13*).

The settlement patterns of Baden culture fully tie with Boleráz development, whilst increasing in density. Previously unsettled sites were occupied, especially in mountain valleys (Fig. 6) (*Pavúk 1982.47*). Similarly to the preceding period, lowlands were preferred (Fig. 1.b) and the distance to water sources increased only slightly (Fig. 1.c). The number of sites on brown earth soils increased and the ratio of soil types in catchment areas also suggests a slight preference for more humid soils (Fig. 2.a,b). This development suggests the return of a drier climate, which is more evident in the following period.

With the onset of the Late Eneolithic post-Baden cultural groups, there was another major shift in settlements. The geographical and demographic changes were accompanied by a significant change in material culture (*Pavúk* et al. *1995.123*).

Settlements of the Bošáca group concentrated in the mountainous regions on the upper reaches of large rivers (Fig. 7), occupying more humid climatic zones (Fig. 1.a). The sites were situated in elevated positions (Fig. 1.b) along smaller streams, while the distance to water sources slightly decreased (Fig. 1.c). Humid soil types, predominantly brown earth, were found in site locations and in catchment areas (Fig. 2.a,b).

A different situation can be seen at the three sites belonging to the Kostolac group which fall into our focus area (Fig. 7). One site is in a very dry climatic zone on the bank of Danube, the other two are in mountainous area with a humid climate (Fig. 1.a). The distance to water is comparably low (Fig. 1.c) and fluvisols are the predominant soil type at the sites and in their catchment areas (Fig. 2.a,b). A major decrease in settlement density (Fig. 2.c) at this time can be observed also in neighbouring regions

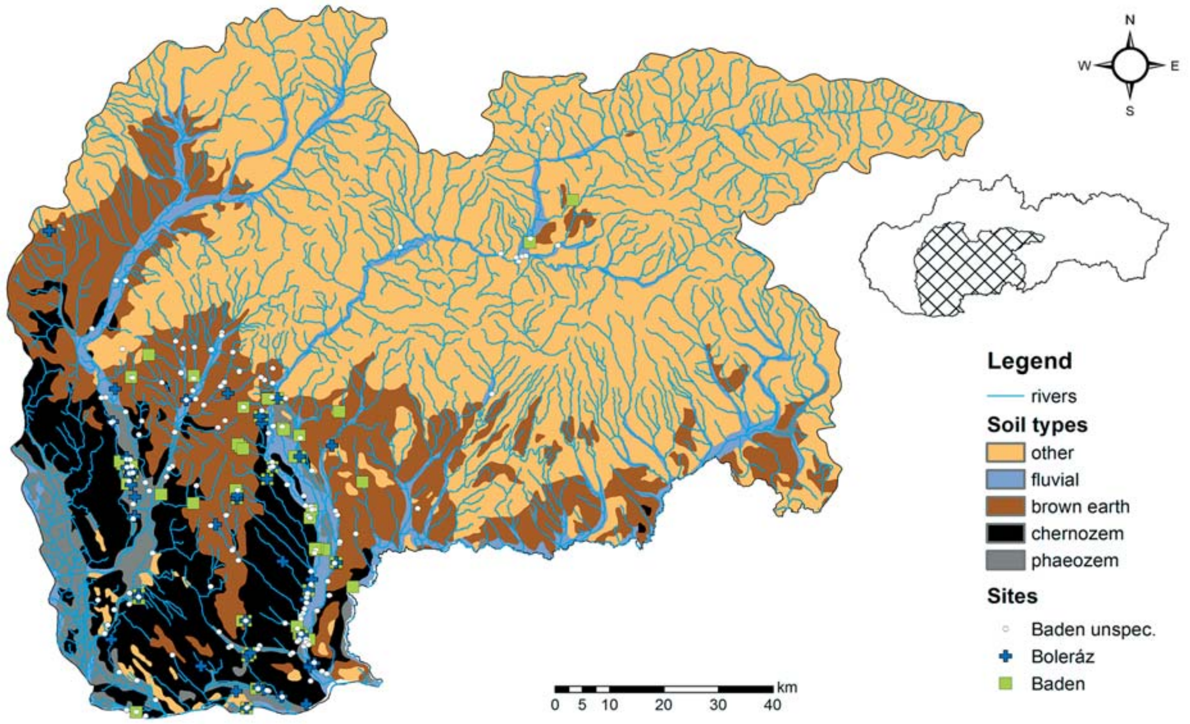

Fig. 6. Distribution of Boleráz group, Baden culture and unspecified Middle Eneolithic sites on various soil types.

and further south as far as Macedonia. It is possible that the climate fluctuation observable already in the preceding period culminated in an extremely dry continental climate at this time, leading to the depopulation of the central part of the Danubian Lowland (*Němejcová-Pavúková 1995.29; Pavúk* et al. *1995.123*).

The final Eneolithic in southwest Slovakia is represented by the Kosihy-Čaka/Makó culture. A high percentage of sites in the dry to very dry climatic zones (Fig. 1.a) often on chernozem soils (which also appear in the site catchments; Fig. 2.a,b) suggests the return of a more favourable, humid climate (*cf. Němejcová-Pavúková 1995.29*). The improvement in natural conditions was followed by an increase in settlement density. Again, we see the formation of settlement clusters, concentrating mainly in the lower reaches of the Hron and Nitra (Fig. 7) along the major streams and their tributaries. Lowland locations were characteristic of the sites (Fig. 1.b), and the distance to water sources does not exceed those observed for the Baden culture (Fig. 1.c). The settlements at this time were usually large, with widely scattered settlement features (*Kulcsár 2009.66*). The preferred environmental parameters in this period indicate trends in settlement strategies observed in the subsequent Early Bronze Age in southwest Slovakia (*Demján 2009.12; Pavúk* et al. *1995.124*; although with a difference in the structure and hierarchy of the settlements; *J Batora, personal communication*).

Discussion: climate vs. culture

Climate fluctuations in the Middle Danubian Neolithic in light of North Atlantic drift ice proxies

In the last decade, several studies have attempted to correlate archaeological data with information from various climate proxies. For our study, the data on ice drift in the sub-polar North Atlantic region (*Bond* et al. *2001*) seem most appropriate, as previous studies by Gronenborn (*2009*) have shown promising results in correlating the socio-economic development of the European Neolithic with fluctuations captured in this climate proxy.

Analyses of settlement structure in relation to environmental parameters indicate a climatic optimum in the Early and Middle Neolithic. A humid Atlantic climate predominated during the early and late Linear Pottery culture and the Želiezovce group, but environmental parameters indicate climatic oscillations during the Middle Neolithic, which would correlate with a sudden drop in ice-rafted debris (IRD) in the North Atlantic at this time (Fig. 8.1–3). This period falls into the IRD 5b phase, which terminated with the IRD 5.1 climatic event identified by Gronenborn (*2009.100*). Following this fluctuation, we observe a cultural transformation of the Želiezovce group into Protolengyel culture (Fig. 8.4) marking the transition to the Late Neolithic.

Following the Protolengyel, in the Neolithic stages of Lengyel culture, a shift towards a dry continental climate which culminated in the Lengyel III period is indicated by the observed environmental variables. Fluctuations in the IRD proxy during this period correlate with constant shifts in the settlement strategies ('one-stage settlements') of Lengyel culture (Fig. 8.5–8). The stabilisation of a more humid Atlantic climate during the Lengyel IV phase is also reflected in the change in settlement patterns and corresponds with the onset of phase 4 in the IRD record, which spans the period 4400–3200 calBC (*Gronenborn 2009.100*). This climatic optimum continues throughout the Early and Middle Eneolithic.

A period of dry continental climate can be suspected in the Late Eneolithic, triggered by a strong climatic fluctuation during the Bošáca and Kostolac groups (Fig. 8.12, 13). The Kosihy-Čaka/Makó culture saw a shift back towards the more hospitable climatic conditions corresponding with the IRD 3 phase (Fig. 8. 14; *Gronenborn 2009.Fig. 2*).

Cultural and economic adaptation to a changing environment

Major changes in climate conditions result not only in a shift in preferred environmental factors, but are often also visible in changes in settlement structure. There is a remarkable correlation between climate conditions and the distance between sites; distance increases following a deterioration in the climate (Fig. 2.c) which results in a lower settlement density. We also see a decline in the overall number of settlements (Tab. 1, Figs. 3–7), and the size of individual sites also changes. This process is reversed when conditions improve.

Periods with a very low number of settlements, namely the Protolengyel and the Bajč-Retz-Křepice, Bošáca and Kostolac groups are especially interesting. We assume that this situation is not a result of the current state of field research, and that adverse natural conditions during the lifetimes of these cultures played an important role in the observed depopulation. Radical changes in several observed environmental parameters compared to previous periods suggest that natural conditions had changed so much that the existing subsistence strategies became obsolete and could not sustain the population. Changes in the economy must have also affected the social order. Shifts in social hierarchies and political destabilisation can be expected. After the stabilisation of the environment, the society could reorganise and adapt to the new conditions (*Gronenborn 2007.85; 2009.101–102*).

Each of the aforementioned shifts resulted in a consolidation of the settlement structure and in impor-

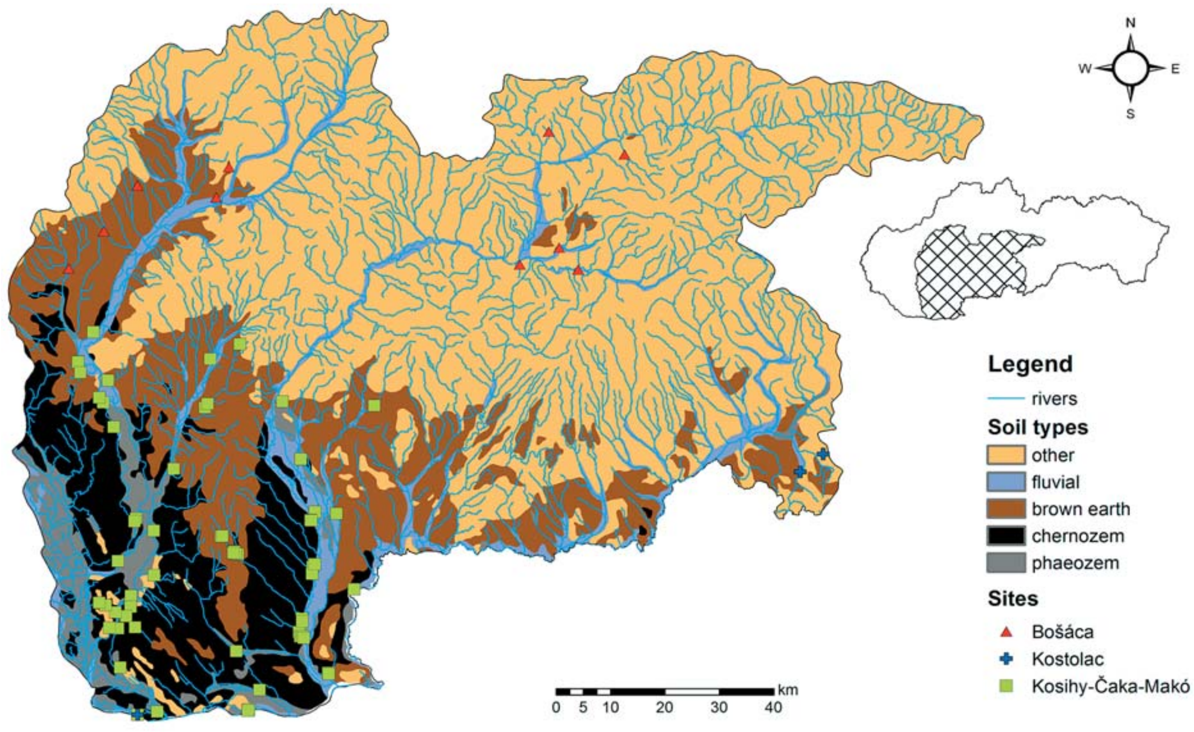

Fig. 7. Distribution of Bošáca and Kostolac group, and Kosihy-Čaka/Makó culture sites on various soil types.

tant changes in the social and economic sphere. After the Protolengyel, the first stage of Lengyel culture followed, with extensive settlements on which planned development and the building of monumental rondel structures can be observed (*Pavúk 1986.216*). Following the Bajč-Retz-Křepice group, our focus area experienced a period of dense settlement by the Boleráz group and the subsequent Baden culture. Strong influences from the Balkans and Anatolia can be observed, and the non-ferrous metallurgy characteristic of the previous Early Eneolithic period declined and was replaced by the manufacture of different prestigious artefacts. After the decline in settlement density in the post-Baden period (Bošáca and Kostolac groups) our focus area was resettled by the Kosihy-Čaka/Makó culture, which cannot be genetically traced to the previous cultural development (*Kulcsár 2009.355–357*). New impulses from the southeast also led to an intensification of non-ferrous metallurgy in southwest Slovakia in this period (*Bátora 2006.37*).

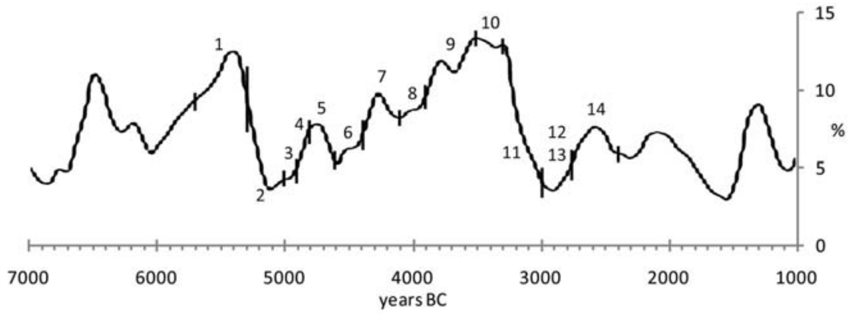

Fig. 8. The stacked record of Holocene ice drift in the North Atlantic (modified after* Bond *et al.* 2001.Fig. 2*) with the chronological extent of archaeological cultures marked on the chart. Higher values can be linked to increased annual rainfall (*Bond *et al.* 2001.2133*). 1 early LBK. 2 late LBK. 3 Želiezovce. 4 Protolengyel. 5 Lengyel I. 6 Lengyel II. 7 Lengyel III. 8 Lengyel IV. 9 Bajč-Retz-Křepice. 10 Boleráz. 11 Baden. 12 Bošáca. 13 Kostolac. 14 Kosihy-Čaka/Makó.

The social and environmental crises in the Protolengyel, Bajč-Retz-Křepice, and post-Baden periods together with the onset of a new Eneolithic economy in the Lengyel IV stage divide early prehistoric development into several distinct cultural-historical periods:

❶ the Early and Middle Neolithic, with early and late Linear Pottery cultures and the Želiezovce group;
❷ the Late Neolithic represented by the Protolengyel and three Neolithic Lengyel stages;
❸ the Early Eneolithic with Lengyel stage IV and the Bajč-Retz-Křepice group;
❹ the Middle Eneolithic with the Boleráz group and Baden culture;
❺ the Late Eneolithic with the Bošáca and Kostolac groups;
❻ the final Eneolithic with the Kosihy-Čaka/Makó culture.

At the beginning of each of these periods, we observe an influx of new cultural impulses from the southeast which, together with local elements, built a new cultural entity. Interestingly, all of these transitions were connected to some degree of climate change, often a strong fluctuation followed by a period of changed climatic conditions which compelled the population to respond with a new social, cultural, and economic order. These observations coincide with the socio-political trajectory laid out for the area of Southeast Europe by Gronenborn (*2009.Fig. 4*). We can assume that development in Southeast Europe at the time was reflected in our focus area. It remains a question as to what degree the impact of climate changes, besides influences from Southeast Europe, and social and economic impulses, played a part in the formation of new, more complex societies which are reflected today in their cultural artefacts.

Conclusion

By studying changes in settlement patterns in relation to environmental variables over a large area and with a broad chronological focus, it was shown that such observations can yield evidence about the adaptation of settlement strategies in reaction to changes in climate. In the Early and Middle Neolithic, a humid Atlantic climate predominated in our focus area. At the end of this period, climatic fluctuations occurred which were later fully manifested in the subsequent Late Neolithic, followed by a prolonged period of dry continental climate. These conditions prevailed until the Early Eneolithic, followed by a shift back to a humid Atlantic climate, which lasted throughout the Middle Eneolithic. Towards the end of this era and more prominently in the Late Eneolithic, a period of extreme drought occurred, as indicated by the depopulation of the central Danubian Lowland. A more humid climate returned in the final Eneolithic. These findings largely agree with previous research in this area (*Pavúk 1982.46–47; 1986. 214–220; 1990.66; Pavúk* et al. *1995.116–123; Wiedermann 2003.72*).

The aforementioned climate fluctuations correlate with data collected from climatic proxies in the North Atlantic (Fig. 8) and seem to reflect a similar development in Southeast Europe (*Bond* et al. *2001*). Changes in environmental conditions resulted in a different preference of ecological parameters, changes in settlement density, area and average distance. Periods of crisis brought on by a rapid decline in climatic conditions could also have acted as catalysts for major cultural-historical changes in the Neolithic and Eneolithic in southwest Slovakia, which appears in the chronological division of this era into six major periods.

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