ALTERNATIVE WAYS OF REPRESENTING ARCHAEOLOGICAL FINDS RECORDED USING MANUAL GPS DEVICES AND A METHODOLOGY FOR CREATING MAPS OF ARCHAEOLOGICAL SURFACE SITES

DALŠÍ MOŽNOSTI ZOBRAZOVÁNÍ ZAMĚŘENÝCH ARCHEOLOGICKÝCH NÁLEZŮ POMOCÍ RUČNÍHO GPS PŘIJÍMAČE A METODIKA TVORBY MAP ARCHEOLOGICKÝCH LOKALIT S POVRCHOVÝMI NÁLEZY

Martin Kuča, Petr Matějec, Lubomír Prokeš

Abstract

The article presents visualization options for archaeological sites employing a manual GPS receiver and a methodology for creating maps on the basis of surface finds using the MapSource program. Sophisticated analytical databases make it possible to examine the distribution and spatial relationships of different types of archaeological finds. Spatial data from the analytical database of MapSource were treated using open source statistical package R.

Keywords

Global Positioning System, Survey surface, Palaeolithic, Neolithic, Methodology

---

1. Introduction

Surface survey is an important part of archaeological research and remains a useful source of information about archaeological localities/sites, their material culture and the relations between people and the surrounding environment (e.g. Bintliff et al. 2000). Its methodology is also a subject of of research interest (Kuna et al. 2004). However, surface surveys have a negative impact on the state of preservation of a site, especially in terms of the exhaustion of its potential due to irreversible loss of information about artefact locations.

The employment of advanced technology, such as GPS (Global Positioning System) satellite navigation, adds another dimension to the research. Data concerning the location of finds gathered using a manual GPS device are transferred into a computer in digital form and subsequently recorded on maps. This approach yields information about the spatial distribution of the finds. This contribution presents another way of working with data acquired by surface prospecting, using simple software. It introduces a methodology for the creation of maps of archaeological sites on the basis of surface finds located by their position coordinates, using MapSource software and presents a possibility for their depiction in Google Earth satellite maps. GPS data from Stránská skála (Fig. 1) and "U kříže" Neolithic site near Rozdrojovice (Fig. 2) have been employed as case studies.

2. Systematic prospecting as a condition for the comprehensive mapping of the surface of a location

Systematic prospection is one of the prerequisites for the assembly of comprehensive information about a site through surface survey: random tracks extending across an area reduce the objectivity of the results. Attention should also be paid to the demarcation of the area to be searched, which determines the scope of the future map of the location with its archaeological finds. The area to be researched can be demarcated by a polygon; for smaller areas the sides of the polygon may be demarcated with a track or the edge of a field.

The ability of a GPS device to record tracks during movement over terrain (*Tracklog*) and the opportunity to visualize them on the GPS display enable precise continuity; the next phase of prospecting is able to start in the exact place where the previous one stopped. As the finds occurring at any given locality are vital for mapping, prospecting should be repeated.

3. Work with the manual GPS device, data recording and the MapSource program

All finds are located using a manual GPS device during the prospection, and each artefact located receives a waypoint number. These numbers are recorded on a form

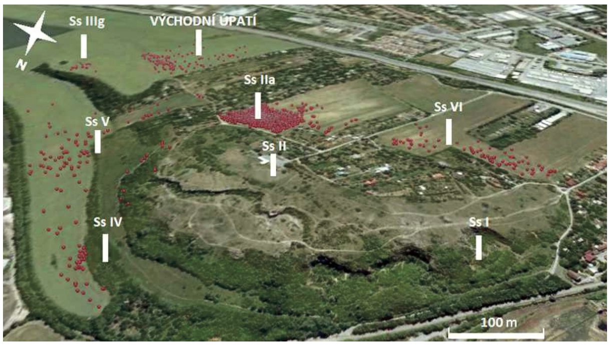

Fig. 1. Stránská skála (cad. Slatina, Brno-město district) on Google Earth satellite images with marked locations of Palaeolithic sites Stránská skála IIIg, V and VI.
Obr. 1. *Stránská skála (k. ú. Slatina, okr. Brno-město)na satelitních snímcích Google Earth s pracovně vyznačenými paleolitickými polohami Stránská skála IIIg, V a VI.*

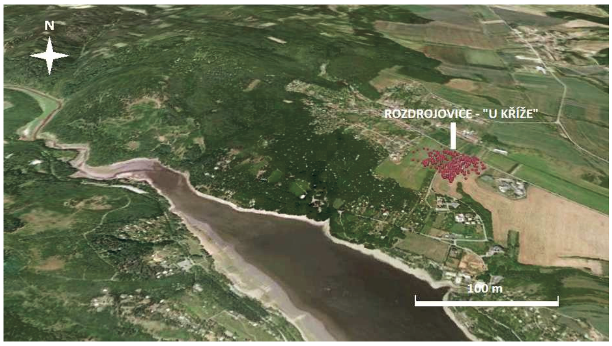

Fig. 2. Rozdrojovice (Brno-venkov district) – red dots from the GPS device depicted in Google Earth satellite photographs.
Obr. 2. *Rozdrojovice (okr. Brno-venkov) – červeně body z ručního GPS přijímače, vizualizované v satelitních snímcích Google Earth.*

that includes a checking box for noting what kind of a find it is.

Artefacts are located in the WGS 84 system of coordinates with a spatial accuracy of 2–3 m which, given the nature of surface finds, that have usually been interfered with and have had their locations changed by agricultural activities, does not devalue the positional information. Their presumed movement in the course of agricultural work is in the 2–3 m range, which roughly corresponds to the error of GPS localisation (Kuna et al. 2004, 315).

Archaeological finds at the studied sites were recorded using a handheld GPS (average GPS error 2–3 metres). The artefacts have been disturbed vertically and horizontally by agricultural activities. A number of authors have discussed this issue (e.g. Ammerman 1985, Odell, Cowan 1987, Schofield 1991, Reynolds 1982, summary by Kuna et al. 2004). Investigations of surface artefact movements and the relationships between their position on the surface in relation to their location in stratified contexts has led to a positive assessment of the spatial reliability of surface sites (Roper 1976, Redman, Waston 1970, Hayfield 1980, Schofield 1991). On the basis of computer simulations modelling dispersion of the original spatial position, M. Kuna (Yorston et. al. 1990) concedes that the original soil structure can disintegrate when subjected to long-term agricultural activities. However, the dispersion of the surface assemblage itself has not been demonstrated experimentally (Kuna et al. 2004). Horizontal and vertical movements of artefacts are not influenced only by agricultural activities, but also by other factors, especially erosion (cf. Škrdla, Matějec 2007), sheet wash and sloping terrain.

Points gathered during the prospection are transferred to the computer. The MapSource program features a graphical map in which transferred data can be represented by symbols, with tab lists in which individual bookmarks (maps/track points/tracks/traces/etc.) have thematically divided windows (e.g. TRACK POINTS bookmark title/symbol/comment/position/altitude/etc.). Position data with information contained in individual windows of the TRACK POINTS bookmark constitutes the material crucial to the creation of maps with displayed surface finds (Černý, Steinar 2006).

4. Creation of symbols attached to individual finds

The MapSource program uses set symbols for track points, but it also allows the use of individual map symbols. Several aspects should be kept in mind when creating individual symbols for archaeological and paleontological finds. Individual symbols should not only differ in colour but also in shape so they remain clear even in black-and-white printing. They can be produced in several graphical packages (Drawing, Corel Draw and others) or made up of other images in digital form. Their shape may represent the appearance of an artefact or at least indicate its chronological classification. The resulting map is then more comprehensible (it does not require continual reference to a key). The size of the inserted symbols is also important: with a dense concentration of finds the symbols may overlap, while in the opposite case they might appear less legible.

5. Making a data file and the methodology of working with points

The creation of a data file can be divided into two phases:

a) creation of a primary data file

After the transfer of data to the map file, each point on the map is given a specific symbol depending on the type of find that it represents. Information collected in the field and the laboratory is recorded.

b) creation of an analytical data file

By marking the Symbol window in the Track Points bookmark, map symbols can be arranged in sequence groups. These are created in terms of symbols that the individual types of finds have in common (e.g. ceramics, types of resources, etc.). These groups can then be easily portrayed on an analytical map, where their spatial rela-

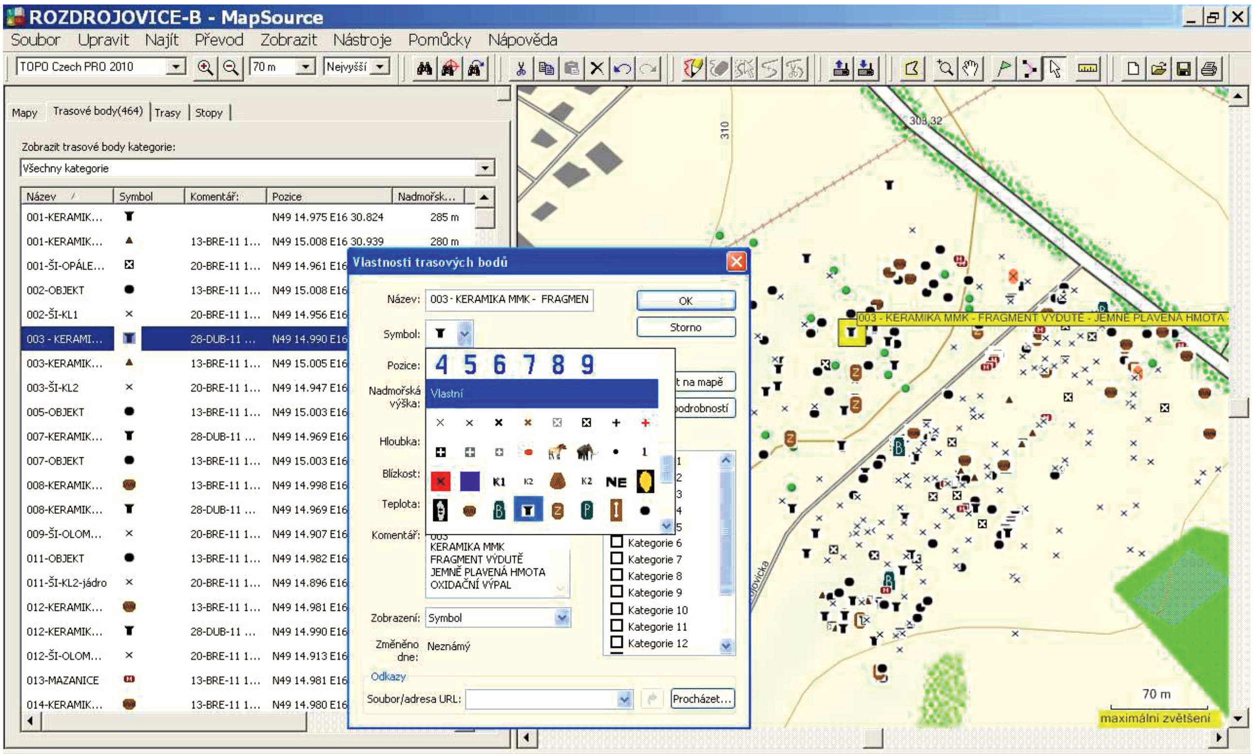

Fig. 3. Tab (left) and map lists (right) in MapSource program.
Obr. 3. *Databáze (vlevo), vlastní definované body a mapa (vpravo) v programu MapSource.*

tions (e.g. occurrence of ceramics of the early and late Neolithic in an area, relationship between lithic sources and ceramics of the early Neolithic and the late Neolithic and others) can be observed.

6. File of the located points as a database of archaeological finds and possibilities for their use in other software

Information about a find can be recorded with the map point number in the comment box (Fig. 3). With lithic material, the source can be recorded, as well as the manufacturing technology, morphology of the artefact and the type. Ceramic finds can be characterized by cultural chronology, as well as by data on the degree of firing, texture, morphology, etc. With Palaeolithic finds, it is also worthwhile recording the presence of calcareous sinter deposits on the artefact surfaces - this indicates the existence of intact sediments.

The file with artefact information thus becomes a database of archaeological finds and their characteristics. Data and records for finds from the MapSource file can then be processed in other, more advanced GIS and mathematical statistics programs.

Data from Rozdrojovice were processed using the freely available statistical package R (http://cran.rproject.org/), with MASS library (Venables, Ripley 2002). The probability of the occurrence of Neolithic pottery fragments (LBK, MPWC) at Rozdrojovice was shown using kernel density estimator (KDE; Baxter, Berdah, Wright 1997), derived from the distribution of the identified ceramic finds. GPS coordinates were transferred to the x and y axes of a diagram, with values on the "contours" corresponding to the density of probable occurrence of ceramic finds of a relevant Culture (detailed information about KDE and calculation methods; cf. e.g. Meloun, Militký 2004). Coordinates of the finds of the given type of resource were subsequently superposed into these diagrams.

The results show that the Krumlovský les I-type chert is predominantly associated with LBK finds, apart from two finds associated with Lengyel culture ceramics (Fig. 4). The Krumlovský les II-type chert and the Olomučany-type chert do not show any marked differences in occurrence between the LBK and the MPWC (Fig. 5). The Krakow-Czestochowa Jurassic Flint is positively associated with Lengyel ceramics (Fig. 6). Chocolate silicite also showed connections to the Lengyel ceramics. The remaining raw materials (chalk, chert, etc.) produced ambiguous results due to the small number of finds.

7. Digital map base for a hiking map in the MapSource program and possibilities for displaying located finds in Google Earth satellite photographs

The MapSource program features a set of digital maps, the latest version (in the hiking maps category) is the TOPO Czech PRO 2010. It is a digital hiking map with 10 m contours.

One of the advanced functions of the MapSource program is the depiction of GPS points in Google Earth satellite photographs, which also enables the introduction of dedicated symbols for individual located points. The basic advantage of this map base is the depiction of finds with regard to the relief of the landscape. The visuali-

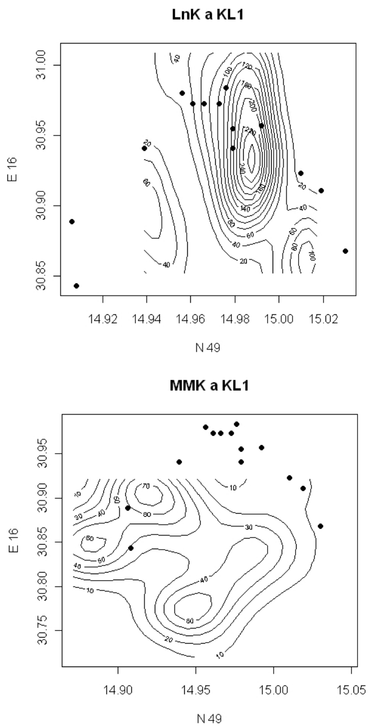

Fig. 4. Diagram showing the relation between LBK pottery and Moravian Painted Ware Culture pottery and KL1-type chert.
Obr. 4. *Grafy se znázorněnou vazbou I variety rohovce typu Krumlovský les na hustotu výskytu keramiky LnK a MMK.*

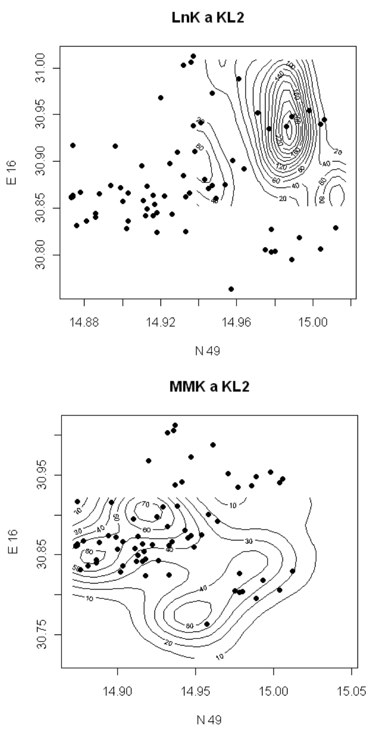

Fig. 5. Diagram showing the relation between LBK pottery and Moravian Painted Ware Culture pottery and KL2-type chert.
Obr. 5. *Grafy se znázorněnou vazbou II variety rohovce typu Krumlovský les na hustotu výskytu keramiky LnK a MMK.*

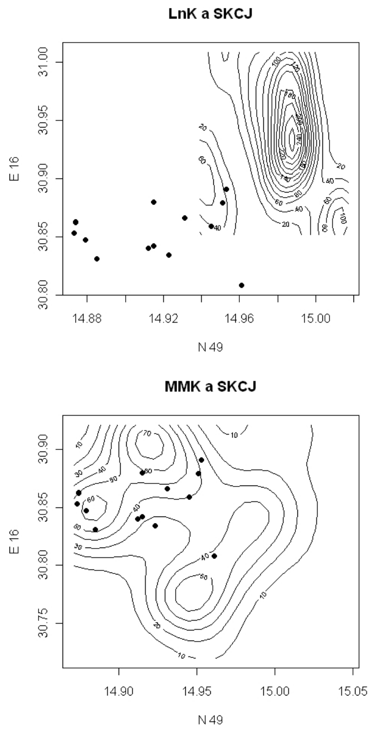

Fig. 6. Diagram showing the relation between LBK pottery and Moravian Painted Ware Culture pottery and the Krakow-Czestochowa Jurassic flint.
Obr. 6. *Grafy se znázorněnou vazbou silicitu krakovsko-čenstochovské jury na hustotu výskytu keramiky LnK a MMK.*

sation of the surrounding terrain in 3D is important for the interpretation of settlement strategies in the given microregion.

8. The use of aerial photographs from the early 1960s as a map base and their importance for the terrain data and its interpretation

The original appearance of an area can be reconstructed with the aid of aerial maps from the mid-20th century (www.cenia.kontaminace.cz). In the past ca. 50 years, intensive anthropogenic activity has radically altered the appearance of many locations, and a number of archaeological locations can no longer be identified.

An example is the newly-discovered concentration of artefacts at the eastern foot of the Stránská skála hill (Fig. 7). Older aerial photographs of the site surroundings show a limestone quarry of which no visible trace remains today. The quarry was obviously filled in and the terrain levelled.

The transfer of points acquired during surface collecting onto the map base of aerial photographs from 1953 has shown that finds are concentrated near the quarry wall and the area behind it. No artefacts could be found at the site of the former quarry. It appears to be a remnant of a previously uknown site where the main concentration of finds occurred on a former, indistinct terrain elevation.

9. Examples

9.1 Brno, Stránská skála

Extensive systematic prospection was carried out at Stránská skála, Brno during 2009-2011, aiming to demarcate the spatial extent of local Palaeolithic sites. Lithic artefacts were acquired, as well as other evidence of the activities of Palaeolithic hunters: osteo-dental material of Pleistocene fauna and concretions of limonite pigments. The shell of a Tertiary snail perforated by human hand comes from the south slope of the massif, Stránská skála IIa (Matějec, in preparation).

One of the authors (P.M.) discovered lithic artefacts accompanied by the remains of Pleistocene fauna and ochre pigments by the eastern foot of the massif. The site was designated as Stránská skála IIIg (Ss IIIg), and was employed as the first case study.

The location file comprises 18 located points. Nine points represent lithic artefacts, five points are concretions of limonite pigments and four points designate the remains of fossilised teeth of Pleistocene horses (*Equus* sp.). Lithic artefacts exhibited properties that are a source of information about the state of preservation (calcareous sinter deposits), as well as site activities (traces of fire). A burnt artefact is frequently the only evidence of the presence of a Palaeolithic fireplace so it is an important piece of information for reconstructing site activities during Palaeolithic occupation.

Fig. 7. Map points from the Stránská skála IIIg location transferred onto a map base of aerial photographs from 1953.
Obr. 7. *Zaměřené body z polohy Stránská skála IIIg na mapovém podkladě leteckých snímků z r. 1953.*

Artefacts with a sinter crust were marked by a red cross on a white background, artefacts showing traces of fire by a white ×on a dark background. If an artefact with traces of burning featured a sinter crust, it was marked by a white cross on a black background. Artefacts without the sinter were marked by a dark ×on a white background.

The remains of fossilised horse teeth were marked by the symbol of a horse, limonite pigment by an ochre oval on a white background. Google Earth satellite photography was used as a map base.

9.2 Rozdrojovice, "U kříže"

This large Neolithic settlement is situated on the north-western edge of the Brno Basin above the town reservoir, almost in the central section of the village cadaster, on a distinct elevation sloping south-east, with a loess surface. The prehistoric settlement extends partially into the adjacent cadaster of Brno-Kníničky. The location is encircled by the Rozdrojovický potok stream. The settlement lies 270–318 m above sea level. The site was interfered with in the 1990s when the Atlantis hotel was built there and the location was divided into two parts. Part of the settlement is scheduled for further housing development.

The settlement of phases II and III of the LBK and phase Ib of the Moravian Painted Ware Culture is documented according to the relative chronology (cf. Kazdová et al. 1994; Čižmář et al. 2004).

A total of 450 points were located on the site during prospection in spring 2011 (Fig. 8).

Some 126 points represent ceramic finds (pottery) (25 items LBK; 89 items Moravian Painted Ware Culture, 12 items general Neolithic); 188 points represent lithic artefacts, five points represent polished stones and 21 points represent material used in stone processing (porphyric microdiorite and amphibolic diorite). Twenty-two pieces are daub and two are stone hammers; 91 Sunken Features have been identified. The authors of this contribution have tested the relationship between the distribution of various types of stone material and datable fragments of ceramics in an analytical map file in the MapSource program and with the use of R software. The results of the data analysed in the R correspond with images in analytical maps in which the relationship between the distribution of lithic raw materials and Neolithic ceramics was represented.

The Krumlovský les I-type chert is, associated with finds of the LBK (Fig. 9), with the exception of two finds. The Krumlovský les II type and the Olomučany-type cherts do not show marked differences in occurrence between the LBK and the MPWC (Fig. 10). The Krakow-Czestochowa Jurassic and chocolate silicites are positively associated with the finds of Moravian Painted Ware Culture pottery (Fig. 11). The remaining raw materials (chalk, chert and others) show ambiguous associations, since the number of finds is small.

The results presented can be compared with existing knowledge of the distribution and occurrence of individual materials in the LBK and the MPWC. The connection between the Krumlovský les I and Olomučany-type chert and the later phase of the LBK is in accord with the situation at other locations observed in the area (e. g. Veverská Bítýška, Kuřim; Kuča et al. 2002; Mateiciucová 2008). The Krakow-Czestochowa Jurassic Flint is also often found around Brno in Moravian Painted Ware Culture locations (e. g. Mokrá, Brno-Žebětín; Kuča 2008; Šebela, Kuča 2004). Ideally, the surface prospection results should be verified by the use of stratified collections.

10. Conclusion

This study demonstrates the use of methods for the depiction of surface archaeological finds recorded using a manual GPS device and the creation of maps of archaeo-

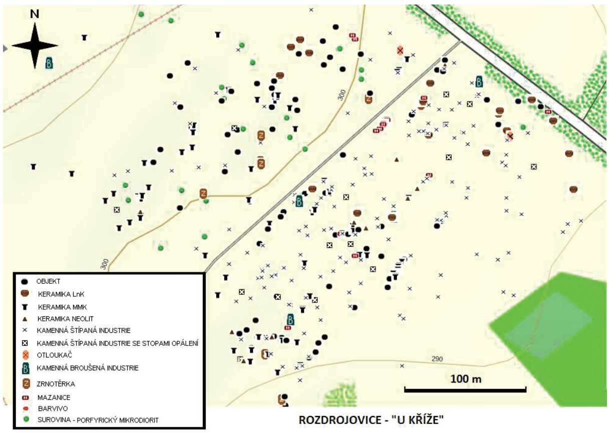

Fig. 8. Map of Rozdrojovice – "U Kříže" archaeological location made on the basis of surface finds and drawn on the digital-map base of a hiking map.
Obr. 8. *Mapa archeologické lokality Rozdrojovice – „U Kříže" vytvořená na základě povrchových nálezů na digitálním mapovém podkladu turistické mapy.*

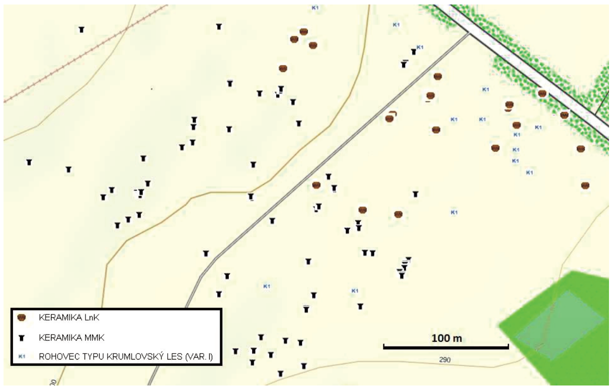

Fig. 9. Rozdrojovice – analytical map of the spatial distribution of Krumlovský les I-type chert in relation to the pottery of the early and late Neolithic.
Obr. 9. *Rozdrojovice – analytická mapa prostorové distribuce I variety rohovce typu Krumlovský les ke keramice staršího a mladšího neolitu.*

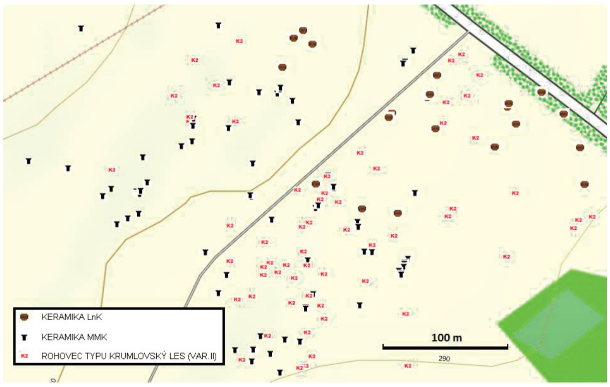

Fig. 10. Rozdrojovice – analytical map of the spatial distribution of Krumlovský les II-type chert in relation to the pottery of the early and late Neolithic.
Obr. 10. *Rozdrojovice – analytická mapa prostorové distribuce II variety rohovce typu Krumlovský les ke keramice staršího a mladšího neolitu.*

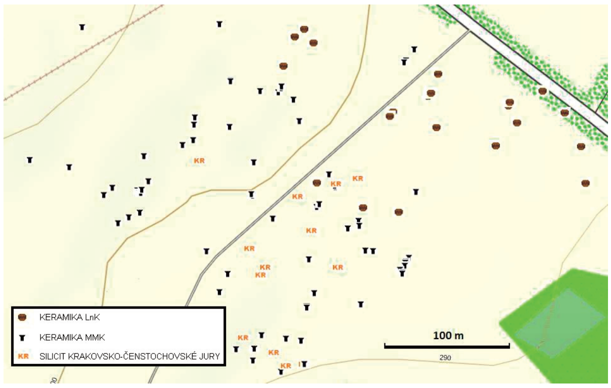

Fig. 11. Rozdrojovice – analytical map of the spatial distribution of silicite of the Krakow-Czestochowa Jurassic in relation to the pottery of the early and late Neolithic.
Obr. 11. *Rozdrojovice – analytická mapa prostorové distribuce silicitu krakovsko-čenstochovské jury ke keramice staršího a mladšího neolitu.*

logical sites using the geo-referenced surface finds in the MapSource program.

With the help of this software, user-friendly maps of archaeological sites with clearly marked surface finds are produced. Easy accessibility and minimum costs make this method ideal, for example, for the training of archaeology students. Mastering this program may prove a springboard for work with more complex software in the field of GIS and mathematical statistics.

The article was financed from the GA ČR grant no. 404/09/H020.

References

Ammerman, A. J. 1985: Plow-zone experiments in Calabria, Italy. *Journal of Field Archaeology* 12, 33–40.

Baxter, M. J., Berdah, C. C., Wright, R. V. S. 1997: Some archaeological applications of kernel density estimates. *Journal of Archaeological Science* 24, 347–354.

Bintliff, J., Kuna, M., Venclová, N. (eds.) 2000: *The Future of Surface Artifact Survey in Europe*. Sheffield University Press, Sheffield.

Černý, J., Steinar, I. 2006: *GPS od A do Z.* PICODAS, Praha.

Čižmář, Z., Pavúk, J., Procházková, P., Šmíd, M. 2004: K problému definování finálního stadia lengyelské kultury. In: Hänsel, B., Studeníková, E. (Hrsg.), *Zwischen Karpaten und Ägäis. Neolithikum und ältere Bronzezeit. Gedenkschrift fűr Viera Němejcová-Pavúková.* Internationale Archäologie, Studia honoraria Bd. 21. Verlag Maria Leidorf Rahden/Westf. 2004, 207–232.

Hayfield, C. 1980: *Fieldwalking as a Method of Archaeological Research*. Department of Enviroment, Occasional paper 2, London.

Kazdová, E., Koštuřík, P., Rakovský, I. 1994: Der gegenwärtige Forschungsstand der Kultur mit mährischer bemalter Keramik. In: *Internationales*

Symposium űber die Lengyel-Kultur 1888–1988, Znojmo-Kravsko-Těšetice 3.–7. 10. 1988, Brno-Łódź, 131–155.

Kuča, M. 2008: Exploitation of raw materials suitable for chipped stone industry manufacture in the Moravan Painted Ware Culture in the Brno region. *Přehled výzkumů* 49, 93–107.

Kuča, M., Žákovský, P., Smíšek, K. 2002: Nové neolitické sídliště šáreckého stupně u Veverské Bítýšky, okr. Brno-venkov. *SPFFBU M 7*, 155–160.

Kuna, M., Beneš, J., Dreslerová, D., Gojda, M., Hrubý, P., Křivánek, R., Majer, A., Prach, K., Tomášek, M. 2004: *Nedestruktivní archeologie. Teorie, metody a cíle*. Academia, Praha.

Mateiciucová, I. 2008: *Talking stones: The Chipped Stone Industry in Lower Austria and Moravia and the Beginnings of the Neolithic in Central Europe (LBK), 5700–4900 BC*. Brno.

Meloun, M., Militký, J. 2004: *Statistické zpracování experimentálních dat*. Academia, Praha.

Odell, G.H., Cowan, F. 1987: Estimating tillage effects on artifact distribution. *American Antiquity* 52, No. 3, 456–484.

Redman, C.L., Watson P.J. 1970: Systematic, intensive surface collection. *American Antiquity* 35, 279–291.

Reynolds, P.J. 1982: The ploughzone. In: *Festschrift zum 100-jahriges Bestehen der Naturhistorischen Gesselschaft*. Nürnberg, 315–341.

Roper, D.C. 1976: Lateral displacement of artifacts due to plowing. *American Antiquity* 41, 372–375.

Schofield, A.J. 1991: Artefact distributions as activity areas. Examples from South-East Hampshire. In: Schofield, A.J. (ed.), *Interpreting artefact scatters. Contributions to ploughzone archaeology*. Oxford, 117–128.

Šebela, L., Kuča, M. 2004: Objekt 3/1996 z Mokré (okr. Brno-venkov) a jeho přínos k datování závěru I. stupně kultury s MMK. In: Lutovský, M. (ed.), *Otázky neolitu a eneolitu našich zemí 2003*, 271–285, Praha.

Škrdla, P., Matějec, P. 2009: Brno (k. ú. Líšeň, okr. Brno-město). *Přehled výzkumů* 50, 217–219.

Venables, W. N., Ripley, B. D. 2002: *Modern Applied Statistics with S*. Springer, New York.

Yorston, R.M., Gaffney, V., Reynolds, P.J. 1990: Simulation of artefact movement due to cultivation. *Journal of Archaeological Science* 17, 67–83.

Resumé

Výzkumy archeologických nalezišť metodou povrchových sběrů přináší stále významné informace o poloze a kulturnímu zařazení archeologických lokalit a poznávání struktury dávného osídlení. Samotnými povrchovými sběry ovšem také dochází k destrukci nálezového fondu lokalit a k nezvratné ztrátě informací o nálezových polohách artefaktů. Rozvoj GPS technologií a jejich aplikace do výzkumných metod archeologie však dává této metodě již poněkud jiný rozměr: nálezová poloha artefaktu zůstává zaznamenána a shromážděná GPS data je možné použít pro jiné analýzy a řešení výzkumných otázek.

V příspěvku jsou aplikovány další metody vizualizace povrchových archeologických nálezů zaměřených ručním GPS přijímačem a tvorby map archeologických lokalit na základě georeferencovaných povrchových nálezů. Jako případové studie zde byly předloženy nálezy a sebraná data z lokalit Brno-Stránská skála a Rozdrojovice u Brna. Za použití jednoduchého mapového softwaru MapSource byly vytvořeny lehce srozumitelné mapy těchto lokalit s vyobrazenými povrchovými nálezy. U druhé případové lokality (Rozdrojovice) bylo přistoupeno k tvorbě analytické databáze v programu MapSource, v níž byla zkoumána relace prostorového vztahu mezi keramikou staršího a mladšího neolitu a zároveň distribuce surovin kamenné štípané industrie vůči těmto keramickým okruhům. Výsledky těchto analytických mapových projektů naznačily vazbu některých surovin kamenné štípané industrie k různě chronologicky odlišným okruhům keramických nálezů.

Snadná dostupnost použité GPS technologie i digitálního mapového softwaru a společně s nízkými pořizovacími náklady předurčují tuto metodu pro výuku studentů a studentské práce v oboru archeologie. Zvládnutí práce s tímto programem může být předstupněm k práci se složitějšími softwarovými produkty z oblasti GIS a matematické statistiky.