SZENT ISTVÁN UNIVERSITY

PHYTOLITH PROFILE CADASTRE OF THE MOST SIGNIFICANT AND ABUNDANT SOIL TYPES OF HUNGARY

Theses of PhD dissertation

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Premises and Objectives

Premises

As an outcome of the researches in the field of landscape ecology, palaeoecology and palaeopedology - conducted at the Institute of Environmental and Landscape Management – we aimed to build a cadastre of various phytolith distribution patterns of the most significant and abundant soil types of Hungary. The objective was to create a database and to identify patterns typical for given soil forming process, which can be used as a proxy in palaeoecological studies. Focus was on to the sampling of soil profiles under potential (close to the natural) vegetation and under profile-typical land use forms. Based on these, the phytolith distribution curves of cultural layers and buried soil profiles could be explained and understood.

Actuality of the subject

Since the discovery of phytoliths in the first third of the 1800s, the method has grown to a sovereign discipline, and it has been proven that by the utilisation of phytolith analysis, novel information – in many cases not accessible by the means of other disciplines – can be obtained regarding the properties of natural environment and its relation to ancient societies.

As an evidence for that, we may refer to one of the most significant scientific journals, the *Science*, which – from the '60s onward – reports on prominent environmental archaeological results based on phytolith analysis. As representatives of the broad spectra of the method's utilisation and its potential, these spread from the field of absolute aging (WILDING, 1967) to the presentation of evidences on the time and manner of domestication of various plant taxa (PEARSALL, 1978; PIPERNO és STOTHERT, 2003).

Various methods are known amongst the scientific tools of archaeo- and palaeo-ethnobotany, which are applied routinely in palaeoecological analyses. However, in some cases – due to the limitation of environmental factors – the relationship between mankind and plants, and the reconstruction of past environments can not be analysed solely based on organic vestiges. The recognition of this has shad light on the relevance of phytolith analysis.

Due to the material properties of opal particles produced in the epidermis of plant taxa, they persist in geological media for a long time, therefore they can be used to understand given ecological aspects of ancient environments, even as old as the Mesozoic Era (PRASAD *et al.*, 2005). The discipline of geoarchaeology – that evolved as a result of British geologist, Charles Lyell's pioneering work in the XIXth century – and the discipline of bioarchaeology – that applies the scientific tools of biology – are both marginal scientific fields of phytolith analysis, because ecological information of the former vegetation is being transmitted through an inorganic by-product of plant metabolism. Besides all these, in most of the cases the phytolith record can only be interpreted together with the understanding of soil forming processes. One of the outcomes of this complexity is seen in the approaches of different, but previously evolved disciplines (e.g. geology, archaeology, botany) in the history of phytolith analysis. In the flourishing of inter- and multidisciplinary research the tendency of today is that phytolith analysis is integrated to the methodology of geoarchaeology and/or bioarchaeology, which improves the quality and effectiveness of complementary and multi-proxy approaches. This finally results in new results that are simultaneously serve the goals of archaeology and nature science, and shows their fruitful co-operation.

Plant opal assemblages that accumulate in the soil give an imprint of the inhabiting vegetation of the surface. Phytolith assemblages typical of a given vegetation is primarily affected by the type of plant association, however secondary, soil forming processes may significantly affect plant opal distribution, and therefore have an influence on the correctness of palaeovegetational and environmental reconstruction work.

Objectives

In the light of the above mentioned, by means of the examination of Hungary's most significant and abundant soil types, I intend to lay down the bases of a cadastre type database that stresses the importance of soil forming factors and processes in the use of phytolith analysis and in the interpretation of the phytolith record.

In order to fulfil the above mentioned aim, beside the proper pedological description of 20 soil profiles, I publish the phytolith record of the examined layers (descriptive part), and in the light of soil forming processes I explain the phytolith distribution profiles. I attempt to give a selection of diagnostic morphotypes of the vegetation type reflected by the analysed soil type (analytical part).

A further aim of the dissertation is to recommend on the introduction of the notion of morphotype-diversity, which could be used as an index in historical ecology and archaeological pedology.

Logic of selecting the study sites

The dissertation presents the examination of 20 soil profiles of 7 main soil types. The selection of the study profiles is primarily based on geographical and pedological reasons (STEFANOVITS, 1963). As noted in the title, sampled profiles imply for abundant soil types with the most extended territory. Prior to profile openings, target territories were selected based on background literature and the analysis of map data. Based on this, different locations – under different land use types and vegetation – were selected for each soil type. Decision on profile opening was made according to field walking experience and the testing of soil types with Pürckhauer type soil mapping instrument (FINNERN, 1994). Finally the presented 20 soil profile – subjected to phytolith analysis – was selected based on on-site descriptions and basic pedological laboratory data.

On-site description of the study profile

On-site description of the study profiles was accomplished based on field methodology earlier elaborated by the Soil Information and Monitoring System (TIM MÓDSZERTAN, 1995), MSZ 1398:1998 Hungarian standard and SZABOLCS (1966). The digital versions of standardized data sheets used for on-site soil profile description were generated with the original codes recommended by the Soil Information and Monitoring System (TIM MÓDSZERTAN, 1995).

Soil sampling for pedological data

The opening and sampling of the study profiles were accomplished according to the criteria of Hungarian standard MSZ 1398:1998. An amount of 67 samples from 20 profiles were collected and processed.

Soil sampling for phytolith analysis

Phytolith samples – representative for the given profile – were collected using a continuous vertical column sampling of the examined layer (PEARSALL 2000, PIPERNO 1988). Sampling density (vertical intervals) was individually adjudged according to the depth and texture of each profile's horizons.

Methodology of basic pedological laboratory data

The following parameters of genetic soil horizons of the examined 20 study profiles are available: a) pH (MSZ-08-0206/2-78) (pH [H_2O, KCl]); b) carbonate content ($CaCO_3$%) (MSZ-08-0206/2-78); c) humus content (H%) (MSZ-08-0452-80); Total Organic Carbon (TOC) (MSZ-08-0210-77) (TOC%); d) Arany type texture coefficient (K_A) (MSZ-21470/51-83); e) mechanical composition (MSZ-08-0205-78). In case it was required, measuremts of total salt content (salt%) (MSZ-08-0206/2-78) (só%), and phosphorous content (MSZ-08-1933-12: 1986) (P_{total}) was measuered as well.

Methodology of phytolith recovery

Plant opal particles were recovered from the soil material in a multiple-step separation treatment, which included the separation of the clay, sand, silt and organic matter fraction of the bulk samples. Laboratory protocol used in the research was applied with a few modification, but according to GOLYEVA (1997) and PEARSALL (2000).

The utilised phytolith nomenclature and classification system

Plant opal particles were denominated with the help of the International Code for Phytolith Nomenclature (MADELLA *et al.*, 2005) by using the descriptor series for each morphotype as follows:

- *descriptor 1.:* precise shape in 2D or 3D;
- *descriptor 2.:* texture and ornamentation of the surface;
- *descriptor 3.:* anatomical origin of the plant opal (if applicable).

For the validation of the indicator role of plant opal particles, the ecological (typological) classification system, earlier developed by Golyeva (1997), was used as well.

Fitolit határozás, számolás, adatfelvétel és adatfeldolgozás módszertana

The phytolith record of the profiles were processed with C2 data visualisation and analysis software (JUGGINS, 2007), whilst the statistical analyses (PCA and CA) were carried out using PAST (HAMMER *et al.*, 2001).

Results

The present study gives an overview on the results and experience gained during the phytolith research of Hungary’s most significant and abundant soil types. A significant part of the accesible English, German, Russian and Spanish phytolith research literature has been reviewed in order to give an insight to the development of this discipline – sporadically utilised in Hungary – and to the approaches of classifications of the different schools (*see Chapter 2.*). Phytolith research data and conclusion drawn upon these have been analysed through the examination of 20 different soil types of 14 geographical microregions.

The 20 examined profiles imply 7 main types (rocky and mountain soils, brown forest soils, chernozems, solonetz soils, meadow and fluvisols) and 17 types. To establish the basis of a soil-phytolith cadastre, I have developed and applied a methodology on all 20 soil profiles that stretches from the utilisation of a descriptive pedological system to the stratigraphic phytolith analysis of the profiles (*see Chapter 3.*). To fulfill the main aim of the study, namely to establish a soil-phytolith database, the following research phases have been accomplished:

1) Soil profiles and their surrounding environment were described through physical and plant geographical data, on-site observations as well as 67 soil samples were measured for the most important soil physical and chemical data (Table 1).

Table 1. Soil classification and regional distribution of the examined profiles

Main Soil Type[1]	Soil Type[2]	TIM code[2]	Working code	Location[3]	WGS ’84 Co-ordinates
Shallow stony and sandy soils	stony soil	**010**	**PA03**	Vértes peremvidéke	47°22’12.04” 18°25’36.57”
	humous sandy soil	**051**	**PA18**	Kiskunsági-homokhát	47°05’26.46” 19°22’42.39”
			PA19		47°05’20.65” 19°22’48.00”
			PA20		47°06’00.57” 19°23’44.14”
Parent material effected shallow soils	ranker (granite)	**091**	**PA08**	Velencei-hegység	47°14’12.09” 18°31’52.32”
	ranker (gneiss)		**PA12**	Soproni-hegység	47°39’59.02” 16°34’03.74”
Brown forest soils	Ramann-type brown forest soil	**131**	**PA07**	Gödöllői-dombság	47°27’23.15” 19°20’54.20”
	Ramann-type brown forest soil	**132**	**PA09**	Fertőmelléki-dombság	47°42’14.24” 16°37’40.14”
	brown forest soils with clay illuviation	**112**	**PA01**	Bakonyi kismedencék	47°13’00.10” 17°47’26.30”
			PA11	Soproni-hegység	47°39’57.07” 16°34’37.61”
	acidic, non-podzolic brown forest soil	**090**	**PA13**		47°39’54.66” 16°34’20.10”

Chernozems	leached chernozem	**180**	**PA16**	Cserhátalja	47°41’25.59” 19°36’25.93”
	terrace chernozem, non-carbonate	**212**	**PA24**	Észak-magyarországi-medencék	47°41’45.31” 19°40’09.06”
	pseudomiceliar (calcareous) chernozem	**192**	**PA25**	Csanádi-hát	46°21’58.08” 20°58’08.74”
Solonetzes	meadow solonetz turning into steppe formation	**251**	**PA21**	Hortobágy	47°34’37.93” 21°14’09.63”
	meadow solonetz soil	**242**	**PA06**	Csongrádi-sík	46°24’07.15” 20°39’05.27”
Meadow soils	meadow soil with salt accumulation in the deeper layers	**303**	**PA22**	Hortobágy	47°34’01.43” 20°58’53.27”
	alluvial meadow soils	**311**	**PA14**	Kalocsai-sárköz	46°44’37.51” 19°01’47.03”
Alluvial soils	humous meadow alluvial soil	**395**	**PA15**		46°44’17.17” 19°02’43.60”
	humous alluvial soil, non-carbonate, multilayered	**394**	**PA23**	Tiszafüred-Kunhegyesi-sík	47°38’59.62” 20°44’17.57”

[1] based on the Hungarian soil classification system (STEFANOVITS *et al.*, 1999); [2] based on TIM MÓDSZERTAN (1995); [3] based on MAROSI and SOMOGYI (1999)

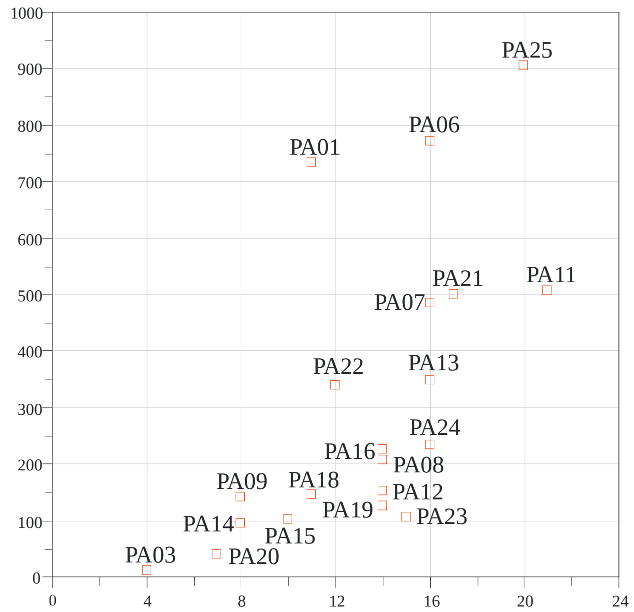
2) Baseline data for typical phytolith distribution patterns of the examined profiles were established through the identification of 6153 plant opal particles (phytolith) in 117 stratigraphical samples. I consider this database as a tool for future palaeoecological research. All 45 morphotypes were named and precisely described according to the international standard of the International Code for Phytolith Nomenclature.

3) Vertical phytolith distribution profiles were drawn in cases of soil profiles fulfilling the established criteria. Based on the distribution patterns determined by the morphotype spectra of the stratigraphic samples, assessment of historical information related to soil development was feasible.

4) Comparative statistical analyses based on the cumulative data of the stratigraphic samples were conducted on each profile. The phytolith production potential of the vegetation cover indicated by the soil profiles has been assessed through the morphotype diversity of the soils. Morphotype diversity was calculated according to the methodological aspects of the Shannon-Weiner and Simpson diversity indices. Based on the analyses of the morphotype diversity I have attempted to demostrate the effect of anthropogenic impact manifested in the morphotype spectra of the soils. On the basis of the research data of 20 soil profiles and as a result of the comparative analysis I have established a reference system, which enables to detect the habitat and soil type through the quantitative and qualitative characteristics of the diagnostic morphotypes.

Figure 1 shows the correlation betwen the total phytolith content of a profile (n) (on the *y* axis) and the number of morphotypes identified (p) (on the *x* axis). Profiles located in the left lower corner of the graph are characterised by low phytolith content and poor phytolith morphotype spectra. These profiles can be characterised by interfered biological soil activity (shallow stony and sandy soils, alluvial soils), and developed under circumstances lacking stable vegetation development phases. In this sense the absence of plant opals are not only a result of the vegetation quality, but can be traced back to external, soil degradation processes as well. Moving right and up-wards on the graph, profiles that yielded higher phytolith content and more diverse phytolith morphotype spectra are located. These are mainly soils opened under climax plant assciations. Brown forest soil profiles, and soils of high biomass productivity habitats (solonetzes and chernozems) are found here. In the examination series the most morphotype were found in the samples of the brown forest soil with clay illuviation located in the Soproni-hegység (p_{PA11} = 21), whilst the highest phytolith content was found in the pseudomiceliar chernozem of Battonya (n_{PA25} = 906). Mean values for the examined profiles vary between 200 and 500 plant opal particles and 12-18 morphotypes per profile.

Figure 1. Characterisation of the examined soil profiles according to total phytolith content (y) and the number of morphotypes (x)

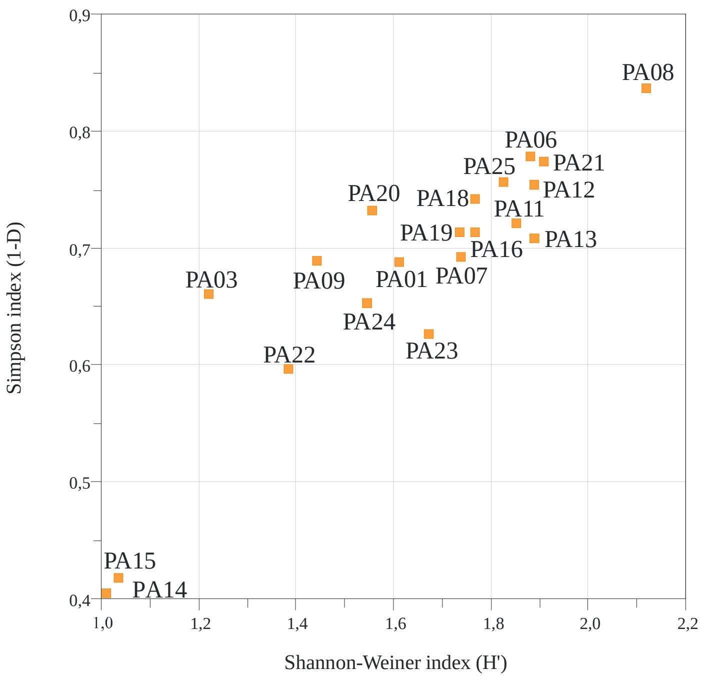


Notes: PA03-stony soil; PA18, PA19, PA20-humous sandy soils; PA08, PA12-ranker; PA07, PA09-Ramann type brown forest soils; PA01, PA11-brown forest soils with clay illuviation; PA13-acidic, non-podzolic brown forest soil; PA16-leached chernozem; PA24-terrace chernozem; PA25-pseudomiceliar (calcareous) chernozem; PA21-meadow solonetz; PA06-meadow solonetz soil; PA22-meadow soil, PA14-alluvial meadow soil; PA15, PA23-humous alluvial soil.

Based on the measurements the habitat (*Inulo-Festucetum pseudodalmaticae*) represented by profile PA08 produces the highest morphotype diversity (*Figure 2* and *3*). However, it must be considered that external effects in the phytolith spectra of this soil could be indentified, which manifested in the presence of phytoliths typical of arboreal species located in the wider environment.

As both grassy and closed forest environments are located in almost the same position on the graphs it can be stated that both of the habitat types may produces similarly diverse morphotype spectra in the underlying soils. Based on this we may conclude that solely based on morphotype diversity (as a quantitative indicator), it is difficult to separate arboreal from non-arboreal habitats, therefore it must be complemented with qualitative parameters. (All above the mentioned, it must be underlined that habitats represented by solonetz and chernozem profiles (e.g. *Artemisio-Festucetum pseudovinae*, *Achilleo-Festucetum pseudovinaem or Salvio-Festucetum rupicolae*) bear slightly higher values.)

Figure 2. Characterisation of the examined soil profiles according to the applied diversity indices

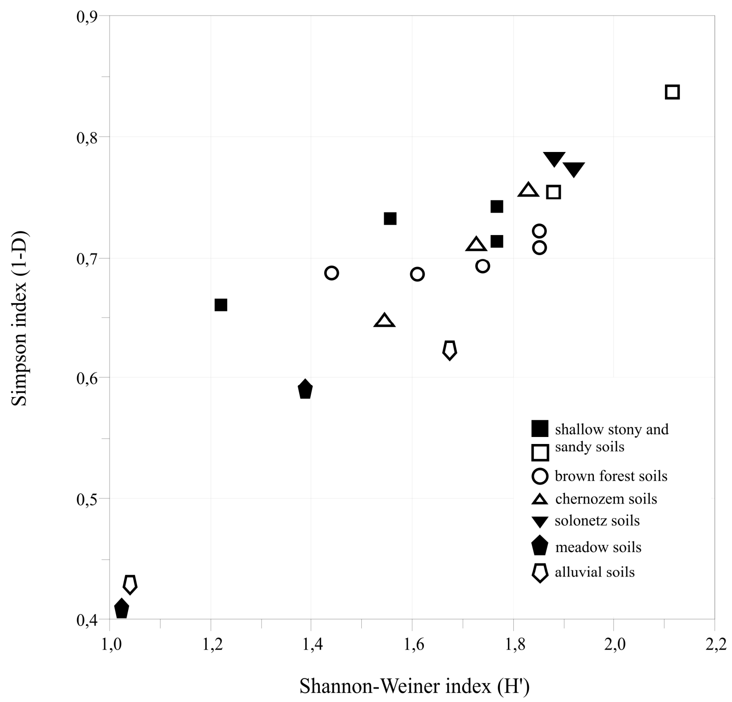


Based on the analysis of the profile's morphotype diversity, three dissimilar soil types can be outlined. The first type can be charaterised by the increase of phytolith morphotypes due to external natural and artificial effects (e.g. colluvial effect in case of sample PA08, or multiple land use changes in the case of PA01), therefore a qualitative phytolith surplus appears in comparison with the natural conditions. According to my opinion this phenomenon can be indetified as a microregional sedimentary effect. Anthropogenic impact positively effects the morphotype diversity of a soil profiles, because each new species on the given territory increases the potential of the appearence of a new phytolith morphotype in the soil. In this sense, territories and soils with diversified land use history and those in an accumulative geomorphological position are likely to conserve more phtyolith morphotypes and yield higher morphotype diversity.

In case of the second type, phytolith and organic matter deficit appears, which negatively affects the morphotype diversity of the soil profile (e.g. constant or cyclical presence of erosion – PA03, fluvial effects – PA14).

The third type is characterised by the a phytolith distribution pattern solely influenced and generated by the inhabiting vegetation. No stronger external effect can be identified.

Figure 3. Distribution of the main soil type categories of the examined profiles in the light of the deiversity indices



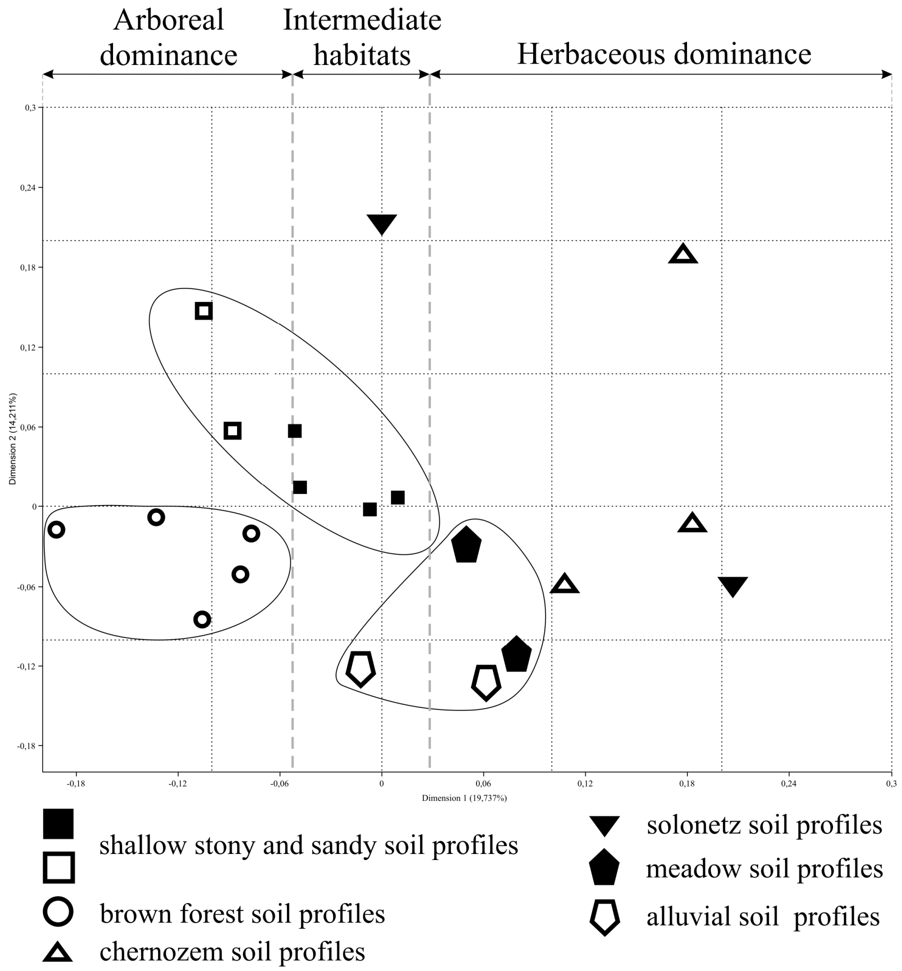
Based upon this theory it can be explained why the PA08 ranker profile bears the highest morphotype diversity (Type I.). For the similar reasons profile PA01, PA18 and PA19 can be typified the same way.

In my opinion Type III. is represented by the solonetz profiles, the shallow stony soil profiles located on plain territories, brown forest soil profiles and the chernozems. In the case of these it can hypothesised that no significant external effect influenced the phytolith distribution within the soil profile, therefore they represent the original and indigenous phytoliths of the habitat. Type II. is represented by profiles located the closest to the lower left corner of the graph (*Figure 3*). In the case of these soil profiles the in-put of plant opal particles to the soil is detained, and the phytolith loss is facilitated by postgenetical processes.

5) The comparative statistical analysis was performed based on the cumulative results of each profile. Data of the different layers and horizons within a soil were contracted. As a result of the comparative analysis, I have established an identification key system, which enables the detection of the habitats reflected by the examined profiles, based on the quantitative and qualitative diagnostic features of their phytolith content. Phytolith morphotypes were grouped in five different diagnostic indicator groups (zones from A-F). Beside the general indicators, morphotypes diagnostic for steppe, closed forest environments and plough lands were separated.

Based on the appearance and disappearance of phytolith morphotypes, I have examined wether the pedogenetically similar soil profiles give the same environmental signal or not. The grouping of the soil types – shown by *Figure 4* – is in good correspondence with the habitats ferlected by them. Brown forest soils and rankers are characterised with similar morphotype spectra and form one group, representing forest habitats. The zone of so called transition environments consists of profiles, which represents habitats that developed under vegetation with more or less arboreal spceies (PA06 is the only exception to that). It is worth noting how the points of chernozems and solonetzes diverge in the right side of the graph (*Figure 4*) in the zone of the herbaceous habitats. However, the correspondence analysis soundly grouped the diagnostic forms of the steppe habitats, in this case the higher deviation of the morphotype diversity causes this graphical outcome. All above the previously mentioned, the mutual vegetation influence in the soil development is visible.

Figure 4. Grouping of the profiles based on the correspondence analysis (CA) of the morphotypes present in each profile



New scientific results

1. I consider the descriptive soil-phytolith database, containing the data of 117 soil samples from 20 Hungarian profiles new to Hungarian soil scientific research.

2. The sound description of 45 different phytolith morphotypes based on the International Code for Phytolith Nomenclature and the analysis of phytolith distribution patterns is a new result to the systematic soil-phytolith research in Hungary.

3. The ecological classification system earlier developed of Golyeva has been complemented with further qualitative and quantitative observations and adopted to Hungarian circumstances, which enables higher precision in the Quaternary environmental reconstructions of the Carpathian Basin.

4. Based on over 6000 phytolith identification an indicator grouping was perfomed with the help of multivariate statistics, which can be used in the assessment of palaeosoil studies focusing on environmental reconstruction.

5. Based on the statistical analysis of the cumulative database I consider that the vegetation, as an important factor of soil forming processes, can be – to a certain extent – reconstructed by the means of phytolith analysis of the main soil types.

6. In the case of target areas with multiple land use history the phytolith analysis of soil profiles pointed out natural and anthropogenic impacts, which significantly influenced landscape evolution.

7. On the basis of the research results the following indicative phenomenon have been identified for the main soil types:

   7.a. A quantitative indicator of habitats linked to chernozem soils is the appearance of rondel SC morphotype in higher than 50% in the phytolith record, whilst qualitative indications are the appearance of infundibulate (rondel) SC, trapeziform elongate trilobate LC and lanceolate digitate T morphotypes.

   7.b. A quantitative indicator of habitats linked to brown forest soils is the higher amount of lanceolate psilate T morphotype than of rondel SC, whilst qualitative indications are the appearance of globular echinate, globular psilate, facetted psilate bulliform, elongated reflexed psilate LC and bilobate SC (PA13) morphotypes.

   7.c. Characteristic relationship was found between the physico-chemical parameters and the vertical phytolith distribution of phytoliths in solonetz profiles. Texture differentiation detected on the boundary of elluvial (E) and B_1 horizons in solonetzes serves as a physical boundary for phytolith distribution. The increase of pH means a chemical boundary for phytoliths, as hydrated silicon-dioxide is dissolved in a soil environment with a pH above 9.

8. A recommendation was made on the introduction of the morphotype diversity of a soil, which would serve as a numeric indicator for assessing the land use history and vegetation changes of a territory through the phytolith analysis of soil profiles.

Recommendations

The environmental reconstruction of a landscape should be based on a refernce database built of modern analogues. This helps to understand phytolith distribution record gained from palaeoenvironmental context. From the view of environmental reconstructions, this aim is served by two different types of database. One is the collection of phytolith recovered from the recent flora, whilst the other consists of phytolith distribution pattern of soils.

Present study focuses on the explanation and mapping of phytolith distribution in Hungarian soils. In this sense further studies can be imagined in the following directions:

- By the analysis of same soil types, further qualitative phytolith distribution patterns can probably be indentified, which would improve the precision of environmental reconstructions.

- By the analysis of profiles from under the same vegetation type (plant association) the effectivness of direct palaeobotanical reconstruction can be improved. This requires the permament extension of modern plant reference collections.

- The precision of reconstructing anthropogenic effects shown by soils can also be improved by the phytolith distribution analysis of soils profiles managed and influenced by given human impacts (e.g. ploughing, grazing).

Related publications

Research articles

Peer-reviewed research articles in English

BARCZI, A. – JOÓ, K. – **PETŐ, Á.** – BUCSI, T. (2006): Survey of the buried paleosol under Lyukas-mound. *Eurasian Soil Science*. Vol. 39., Supplement 1., Publisher: MAIK Nauka/Interperiodica, p. 133-140. IF(2006): 0,036**,** doi: 10.1134/S1064229306130217

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Proceedings

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