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CERAMIS: INTERACTIVE INTERNET-BASED INFORMATION SYSTEM ON NEOLITHIC POTTERY

1. Introduction

The Middle Neolithic Bükk Culture ceramics is an important type of Neolithic pottery finds; the reconstruction and understanding of its transport and trade is of primary importance. Our activity is aimed at investigating the complex topic of prehistoric long distance trade through the archaeometric and petrologic-geochemical study of Middle Neolithic Bükk Culture ceramics from Hungary, among others in the framework of a bilateral DAAD-MÖB project, *Long distance trade in Neolithic pottery*[1].

According to our previous research (Szilágyi, Szakmány 2007; Leno 2009; Taubald 2009), Neolithic pottery manufacturing in the Carpathian Basin is usually a local activity, as the potters utilized raw materials (mainly clay paste) deriving from local or nearby sources. Concerning the tempering material of ceramics (if they were tempered), it is more common that components of more distant origin were used, mainly present as fragments of the stone utensils (grinders, etc.) found on the sites.

Long distance trade of pottery can be hypothesised only for some outstandingly high quality ceramics. Such fineware was investigated in minor

[1] http://www.ace.hu/daad/daad2/; http://www.ace.hu/daad/daad3.

Fig. 1 – Logo of the *CeraMis* software.

quantities during our previous Neolithic pottery archaeometry project from the Middle Neolithic Bükk Culture (Szilágyi *et al.* 2008; Szilágyi *et al.* in press). According to the assumptions of previous archaeological arguments (Kalicz, Makkay 1977), the long distance trade of this special ceramic type is very probable. Detailed archaeometrical (petro-minerological and geochemical) investigation can help us to decide whether these distant occurrences of Bükk fineware with the same quality, shapes and decorations derived from a certain location (their raw material was the same) or was the knowledge of the craftsman that was adapted in another cultural region using the local raw materials. In order to answer these questions, an extended and complex dataset of both "exports" of Bükk fineware, local pottery and comparative geological samples (local clay/soil) of selected archaeological sites has to be examined.

To get comparable analytical data, a logical, traditional methodological procedure has been applied, which combines petro-minerological and geochemical investigations, like petrographic microscopy (PM), X-ray diffraction (XRD), X-ray fluorescence spectroscopy (XRF), and prompt gamma activation analysis (PGAA). In this way, complex information on the pottery material (fabric, tempering, micro- and macro-scale mineralogical-chemical composition, etc.) can be provided. The measuring laboratories are located partly in Hungary (PM at Eötvös University, XRD at GKKI HAS, PGAA at IKI HAS) and partly in Germany (XRF at University of Tübingen).

Another aim of the bilateral project is to investigate not only the ceramic bodies (clay paste and non-plastic inclusions) but also the surface treatments (paintings, slips, other techniques). To analyze these thin, vulnerable constituents of pottery it is necessary to involve non-destructive, high-resolution methods (Raman, μ-Raman, μ-XRF, Fourier-transformation infrared spectroscopy-FTIR, single crystal X-ray diffractometry), which provide detailed information on the surface features.

The main subject of our research is the Middle Neolithic Bükk Culture fineware from sites both inside and outside of its "tribal" territory. For this purpose, in the framework of the project we are creating a representative data library for "genuine Bükk ware" involving 10 archaeological sites from the core area of the distribution of Bükk Culture and an average of 10 ceramic sherds per sites. In order to compare them to the potential local raw materials, sampling of soily-clayey sediments at each site was performed.

After selection and proper treatment (firing and analyses of preparata according to the methodology used for pottery pieces), the results are compared to that of pottery analyses and stored in the same information system, named CeraMIS (Ceramic Measurement and Information System, Fig. 1). In the next step of the project, archaeological samples will be collected from sites outside of the Bükk Culture territory, i.e. the so-called "exports" of the

Bükk Culture fineware will be investigated, based on analytical experiences obtained from the core areas.

Our aims are:

– to determine and gather those (chemical, physical, petro-mineralogical) characteristics which specifically describe the Bükk Culture fineware using mainly non-destructive methods;
– to reconsider the distribution map of the Bükk Culture fineware by scientific investigations and to better understand the civilization that produced these archaeological objects through the information acquired;
– to investigate the surface treatments and materials of the Bükk Culture fineware;
– to deposit all the information obtained in an Internet-based database providing access for all experts interested in the topic.

2. Problems of data management

As is clear from the statements above, though many data are gathered from field surveys, analytical measurements and literature study during the research project, the standards for raw data publication are quite different from the requirements for research publications. Most of the editorial boards discourage the publication of voluminous raw data; however, some journals provide data repository functions. Even if a repository is provided, the storage must be organised in such a way that the structure and format are comprehensible for researchers worldwide. Furthermore, the data must be filed in reliable data centres where they are maintained and are stored in archives for a long time, migrated on need and remain available even if the IT solutions change.

To avoid the common situation that, after the termination of the project, the vast majority of the data remains unpublished, an interactive Internet-based information system on Neolithic pottery, CeraMIS, has been established. The basis of the data management system is adapted from the MissMarble database, which was developed for the processing of an archaeometric dataset of marbles (Zöldföldi, Hegedüs, Székely 2008a, 2008b, 2009a, 2009b).

There is a general agreement in the scientific community that the co-ordinated and free availability of research data serves all scientists, fosters interdisciplinary studies and helps international efforts. Via the availability of the raw data, the original research results also gain importance and become more valuable.

3. Data types

It is advantageous to integrate the data of the two main fields of ceramic archaeometric studies, the provenance and technological investigations. Research aiming at the identification of the potential raw materials of archaeological pottery is based on the petro-mineralogical and geochemical characterization of both the archaeological and comparative geological samples. It is clear that the researchers create and process huge amounts of descriptive petrographic (optical-mineralogical, fabric) information, mineralogical and chemical composition data by various methods (XRD, XRF, INAA, ICP-MS) and local analytical records provided by variable devices (SEM-EDS/WDS, EMPA, LA-ICP-MS, PIXE-PIGE, FTIR, Raman spectroscopy). In addition, the analytical results on essentially differing archaeological and geological samples have to be handled together.

Since it is a primary condition for the success of a provenance study to have as wide a knowledge of the feasible raw materials as possible, the accessibility to results of other research is more than helpful. Investigations concentrating on the manufacturing technology deal with the fabric and mineralogical changes occurring during the firing, determination of the composition and production process of surface treatments (like glazes, etc.). To achieve these goals, local analytical techniques are currently utilized (SEM-EDS/WDS, EMPA, LA-ICP-MS, PIXE-PIGE, FTIR, Raman spectroscopy). The resulting data have mineralogical-chemical and textural content as well.

Both fields of ceramic archaeometric studies take into consideration that, basically, ceramics are composite materials, which means that more than one component was mixed and/or modified to create the appropriate substance for the pottery manufacturing. The consequence of this feature is that, in addition to the investigation of the whole pot (bulk sample), physically or at least virtually separated constituents (paste, temper, surface layers) of the object also have to be analysed. It is necessary to handle the information obtained separately; the combination of the different data can only be possible during the interpretation.

4. The data managing system: general properties and conceptual elements

The rapid rate of information technology development in the last years makes it possible to create a general information system including already existing results of archaeological objects and potential raw materials. Conceptually, we intend to manage the results of analyses of both types of material together to handle the data in the same manner. In this way, it is easier to connect data, which can be parallelized. In addition, it helps to overcome the overlaps and gaps in the analytical results by defining the further analyses to be done.

4.1 *General properties of CeraMIS*

Like all software (or IT) solutions of this kind, the system should fulfil the following criteria:

– User friendliness: the typical (trained) user should be able to use the system effectively, including, among others, data input, retrieval and update.
– Scalability: the system should provide means for the extension in scope, number of users, increasing access, and amount of data.
– Data security: the system should be tailored to prevent unwanted, incidental data loss as well as intruder attacks or malicious access.

CeraMIS provides a user-friendly interface for those who are familiar with the principles of the sampling and various types of pottery analyses. The menu structure follows the logic of the sample identification, processing and measurements, therefore it is easy to understand and use.

The system is designed to be scalable, especially extendable to include new methods that are developed. The database from the server side can be extended to include new fields for each record; the client-side application can be easily updated by the user if the system administration sends a message to do so. The access is password protected; however, there is no need for more protection since major attacks are not expected.

Finally, yet most importantly, the system is designed to perform user defined filtering operations practically on any combination of logical "AND" criteria, i.e., restricting the selection set by multiple selection.

4.2 *Conceptual issues*

The data entries are organized in a scheme in which all records contain the following entries: sample identification; basic description; methods applied on the sample; macroscopic description; physical properties; microscopic petrological description; mineralogical composition; chemical composition; isotope geochemical data.

The system manages both archaeological and geological types of data using the same concept, and most of the data entries are the same for both object types. Because of the nature of the stored data, however, in some aspects the two data structures differ. On the one hand, dependencies on the type of sample are the following: (a) in the case of geological sample: geological classification (age, *facies*); mode of sampling (depth of drilling, etc.); (b) while in the case of archaeological samples: archaeological description of the objects (like shape, decoration, surface treatment); conservational and restoration experience, probable provenance if determined, etc. On the other hand, (a) archaeological ceramics have structural components (whole ceramic body, paste, non-plastics and temper, surface treatments/layers) which can be investigated separately; and (b) potential raw materials can be prepared similarly to the pottery (firing experiments) and investigate their "artificial" or "prepared" characteristics. The data managing system gives scope for choosing the sample type which the analytical data refer to.

The system is designed so that further adjustments and extensions are possible without data loss. It will be updated and modified according to the experience acquired during its use. It is planned to revise the system functionalities, data structure and data content regularly, according to the requirements of the users and data providers. However, adjustments should be made so that the changes do not hamper the comparisons with the previous data and applied methods.

5. The data managing system: the design

5.1 *Implementation*

From the point of view of implementation, our software solution is based on a client/server architecture. The server-side engine is based on the freeware PostgresSQL technique that can be installed both on Windows and on Linux systems, while the client software is Windows-based. The client software connects to the server via a standard Internet connection layer in such a way that the user does not need to install any additional software. The client-side software can be easily updated: the user receives a message to automatically update the software and the update is done by a single mouse click. This solution ascertains that the whole community has the same interface and no outdated access tools exist.

5.2 *The data content*

In the following, the database structure is outlined. The structure is determined by all possible features of pottery and its potential raw materials that may be useful in the distinction of their different types. The data entries are organized in the following scheme:

1. Sample identification.
2. Basic description. Depending on the type of the sample:
    2.a In the case of archaeological samples: archaeological description of the objects; probable provenance if determined;
    2.b In the case of geological sample: geological classification (age, *facies*).
3. Methods applied on the sample:
    3.a Macroscopic description;
    3.b Physical properties;
    3.c Microscopic petrological description;
    3.d Mineralogical composition;
    3.e Chemical composition;
    3.f Isotope geochemical data;
4. Conservational and restoration experience.

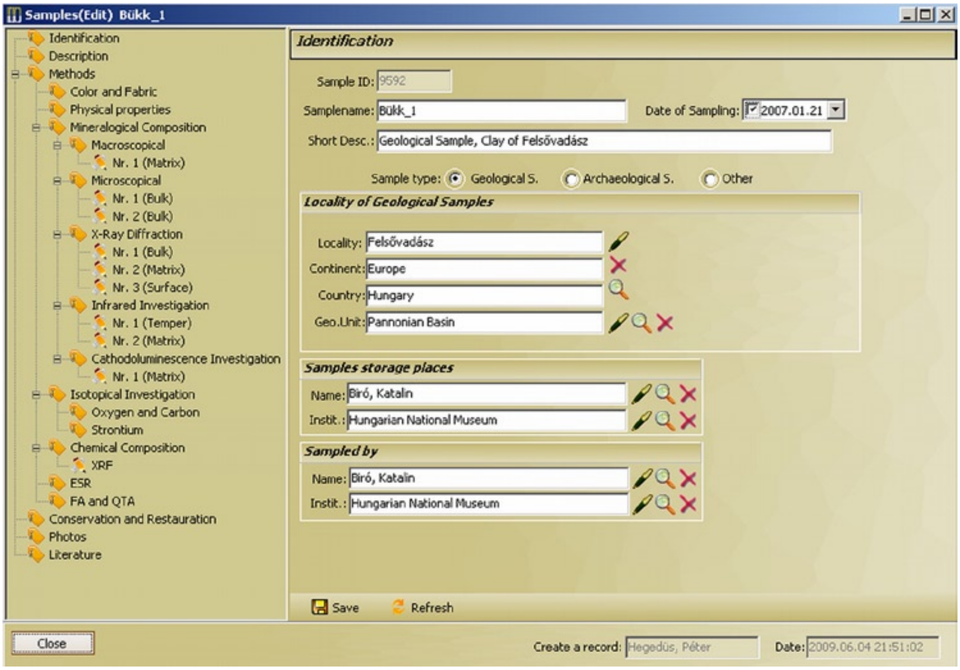

Fig. 2 – Identification sheet including the basic information of the samples: ID, name, sample type, sample storage place, etc.

5. Photos.
6. Literature.

5.2.1 Sample identification

In order to handle the archaeological and geological samples in the same manner, the data of the geological sample and the artefact properties are stored in separate relational databases. However, they are connected via unique key field entries. Each sample is assigned to one of the categories; consequently, the samples inherit properties from the ancestor category. Some of the identifying properties are compulsory, to avoid any indetermination in the database. These properties basically belong to the identification data block, so that the analytical result can be added later (Fig. 2).

5.2.2 Geographic identification of the artefact and sampling locations

It is important to emphasize that the data of the localities and the artefacts are entered and managed separately to allow any number of samples in the database for a given locality/artefact (Fig. 3). The system allows even the localization of borehole data: since the geographic coordinates are only a

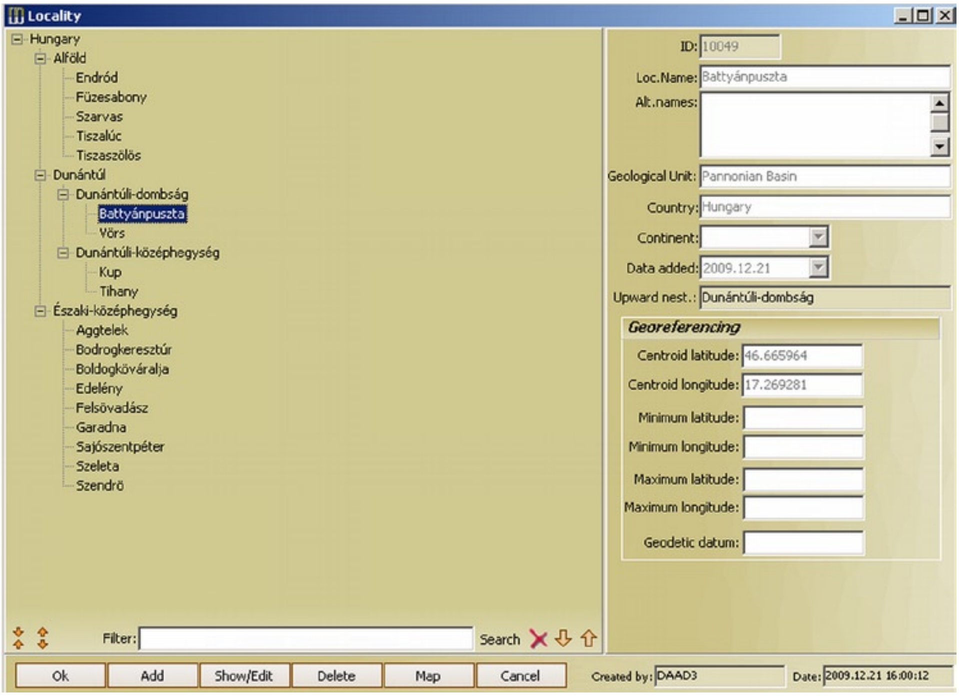

Fig. 3 – Data sheet to enter localities using nesting concept, building a geographic structure pyramid.

property of the localization, there can be many localization items at the same coordinates. The localization system uses a nesting concept (hereafter referred to, somewhat generically, as georeference). It is assumed that the sample has an approximate localization (e.g., continent). This is then the top level of georeference; consequently, all samples must have this property.

Having defined the region of origin, the user may define a deeper level of georeference. It is possible to give any level of geographic identification (region, country, locality, mountains, island, quarry, drilling, etc.) without any restrictions. The logical structure is maintained by the property of encompassing, that is, the geographic entity that completely contains the entity has to be defined (in the most general case it can be the continent). Since all samples have the encompassing continent property defined, all sampling localities can be assigned to at least a higher (larger) geographic entity. As was mentioned above, the geographic entities are managed separately from the samples, since the geographic context does not depend on the actual sample.

In this way a geographic structure pyramid can be built. This structure is collected dynamically as the database grows, and the users do not have to make an extra effort for its maintenance, since all new entries are defined by their first occurrence. Even if the geographical assignment has an error, later it can be corrected, and the samples themselves should not be modified.

The structure allows to store unlimited nested features, e.g., within a quarry several raw material types can be present, and the system allows this separation, e.g., western wall, NE pit, etc. If the user later decides to split up a locality, it can be done by the introduction of a new geographic level, and the samples belonging to the new geographic units can be reordered accordingly.

Similarly, the artefacts can be handled in this manner. The larger unit (e.g., a sculpture) can be later divided into sampling units. In this sense, the artefact is the geographical entity, which can be split into theoretical parts according to the needs.

5.2.3 Basic description

The sampling history of the specimens analysed is summarized here. In the case of archaeological samples, the archaeological description of the object and its probable provenance (if determined) can be added. In this sheet, there is the possibility to indicate the circumstances of the excavation, the stratigraphic context or the description of the archaeological site. In the case of the geological samples, the position of the sampling location in the geological unit (geological classification: age, *facies*), the theoretical lithological column, the circumstances of the sampling (collecting from outcrop or drilling) and the position of the sample in the sampling point (e.g. depth in the drilling) can be determined.

5.2.4 Method summary sheet

In this part of the database, the measurement history of the sample is summarized. Besides the date and type of the measurements and related information (e.g. laboratory, instrument type), the external references (sample identification) of the measuring laboratories are stored. Ample space is provided for further investigation types and other bookkeeping information.

The different measurements can be summarized on the very same sheet only if the measurement was made on the very same specimen. If not, the measurements will be separated to different samples with their own sample ID. This approach assures that artefacts made of various materials can be separately stored in the scheme.

5.2.5 Macroscopic properties

This sheet summarizes all the observations, which can be taken without instrumentation, made during field work or in the lab (Fig. 4). The description can refer to the macroscopic textural outlook, colour and external features relevant from an archaeological or geological point of view (average grain size, grain properties).

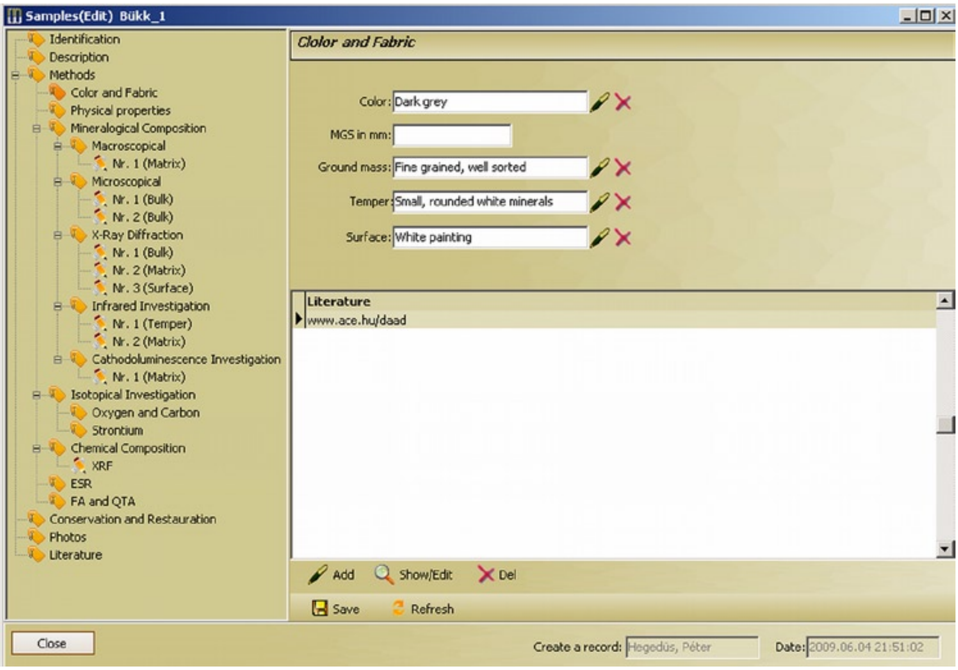

Fig. 4 – Data sheet of the properties color and texture of the sample with the possibility to give detailed information of ground mass, temper and surface treatment.

5.2.6 Physical properties

Macroscopically observable physical properties – which are correlated to the conservation conditions – of the archaeological artefact (toughness, resistance to water, hardness) are described here. In the case of geological samples, features of both their *in situ* and prepared state can be detailed (e.g. hardness; plasticity and workability by adding water, shrinkage during the drying, etc.).

5.2.7 Microscopic properties

This group sums up the results of different observation methods (Fig. 5):

1. Petrographic microscopy (fabric – granulometry, optical behaviour of the fine-grained paste, mineralogical composition of non-plastics, surface treatment);
2. Scanning electron microscopy and microprobe investigation (fabric; chemical composition of paste and non-plastic constituents and surface layers);
3. Cathodoluminescence imaging (origin of mineral grains in the ceramic).

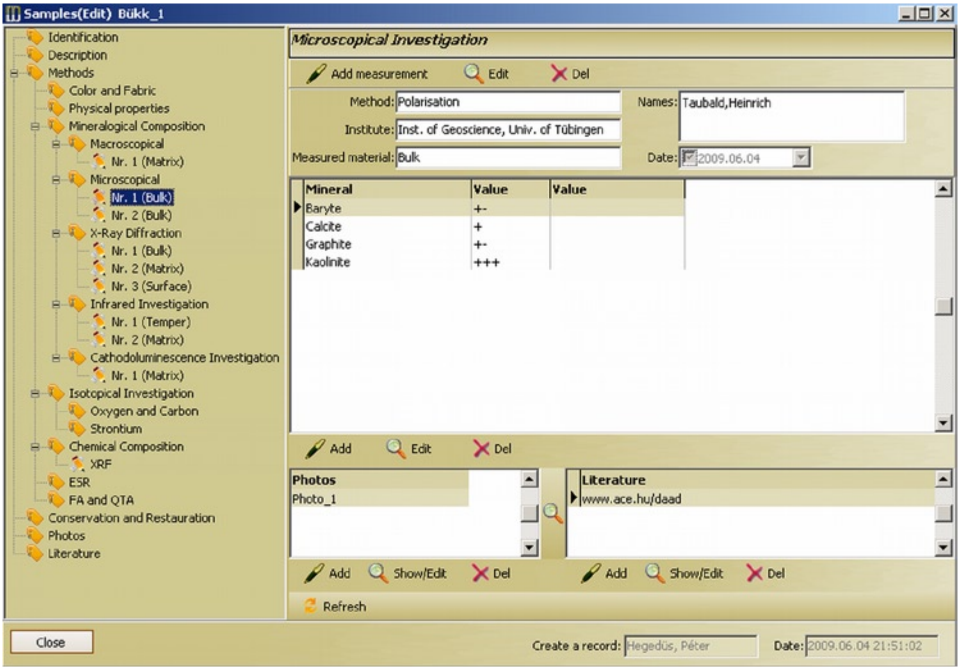

Fig. 5 – Data sheet with results of microscopic investigation, with the option to enter numerous measurements with specification of the laboratory and methods that were used, different photos and possibly literature.

5.2.8 Instrumental data

Detailed description of samples is given on the base of instrumental studies, which include:

1. X-ray diffraction (XRD);
2. X-ray fluorescence (XRF), inductively coupled plasma mass spectrometry (ICP-MS), instrumental neutron activation analyses (INAA), and prompt gamma activation analyses (PGAA);
3. Raman, μ-Raman, Fourier transform infrared spectroscopy (FTIR), single crystal XRD microanalytical techniques (mineralogical composition of surface treatments), μ-XRF, laser ablation ICP-MS (LA-ICP-MS);
4. Isotope geochemistry.

6. Availability and access technology

The system is currently implemented as a client-server connection interface using the Internet and can be accessed via special client software.

We plan to implement some restricted functionality via a web-access, but these are rather query options. The majority of the data input, data revision and update are done using the client software. Database housekeeping and maintenance (like data integrity tests, archiving, and server update) are done at the server side.

An internal communication channel for the users is also implemented and can be used to inform the users about the system development as well.

7. Summary

CeraMIS is intended and developed as a tool for archaeometric research of prehistoric pottery. Basically, it is addressing problems strictly concentrated in space and time, relevant to the Neolithic period of Central Europe and, more specifically, the Carpathian Basin. The solutions applied in the management of the data and the philosophy of open access to basic information, however, have a much wider appeal. The research group involved in this specialistic study firmly believes that technical information should circulate and be accessible to the wide community of experts on each field in the spirit of "fair use".

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ABSTRACT

Most Neolithic pottery, except for some high quality fineware, is thought to be made of local material. However, in order to be able to conclude whether certain types of fineware were contemporaneously imported or not, considerable archaeometric analysis is required as well as the systemization of the acquired data.

The development of CeraMIS, an interdisciplinary database management system for analytical results of raw materials for pottery (geological samples of clay and temper) and pottery artefacts (archaeological samples) is modelled on earlier ceramic provenance studies. It is an innovation established as part of a German-Hungarian bilateral project on "Long distance trade in Neolithic pottery". The database management system contains two main

components: the SQL database and the software CeraMIS that organizes the storage of data. Applying a logical, already traditional methodological procedure of provenance analysis on archaeological pottery, in this paper results of petro-mineralogical and geochemical investigations of the samples are presented. The collection of results on surface treatment (painting, slip, and other techniques), investigations by non-destructive, high-resolution methods is also an important part of this procedure. Moreover, one of the important features of the database is that of clarifying the differences between analyses made on complete vessels, shards, the clay paste, temper and surface treatments.

To present the results of these complex investigations and make the information available to specialists involved in this field of research, we have developed a software solution based on client/server architecture. The client software CeraMIS connects the server via Internet, so that the user does not need to install any additional software. The database can be queried using traditional search methods. The system is designed in a way that makes further amendments and extensions possible without loss of data. It is updated and tailored according to the experience acquired during its use. The system functionalities, data structure and data content are regularly revised according to the requirements of the users and data providers.