Biśnik Cave. Final project results.

The idea of Open Archaeology in interdisciplinary projects

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Abstract: This year the process of preparation the system of documentation and data mining analyses for interdisciplinary cave sites process was finished. It consists of two independent modules: archaeological and paleozoological data storage entirely basing on the Open Source and elements of web applications, visualisation module partially open, based on Rash technology with additional Open Source 3D libraries. Thanks to the open solutions I was able to create independent from any platform, flexible, intra-site analysis tool for archaeology, paleozoology and geology. It allowed also to produce paper documentation as well. This publication shows the results of system implementation, samples of spatial analysis and future modifications of the project.

The basis of analysis of data and their visualization, in it reconstruction of stratigraphy, is based on natural layers structure. Layers can be combined in complexes among any part the site in any configuration. Thanks to them, all the data can be analyzed, at the same time, by any classifications: archaeological, zoological or geological. Moreover simultaneous analyses do not change the data core. All the characteristic stratigraphical complexes are stored in the separate, temporary filtering chart.

The adaptation to specific team needs, allows to presume that thanks to paleozoological archives, system can be used on the other collections. That give us hope for future among-sites analyses, which is especially important for interdisciplinary Palaeolithic cave sites' excavations.

Keywords: paleolithic, cave site, visualization, web based system

After over three years of project work and analysing data, the Biśnik Cave project has been recently concluded, yielding interesting results. The project’s aim was to facilitate the correlation of results obtained in various fields and disciplines, which required continuous cooperation and exchange of research data. The project involved the development of a comprehensive IT solution that would enable data documentation, integration and processing by a team representing all disciplines involved in the research. For this purpose, an innovative system had to be designed, implemented and evaluated for possible use in the effective handling of archaeological and environmental projects. The translation of these objectives into actual software was performed by a programmer specialising in the use of PHP, MySQL and Action Script.

Biśnik Cave, the object of the team’s research, is one of the oldest and most notable Palaeolithic cave sites in Poland, showing a very long settlement sequence. The site is located in the central part of the

Kraków-Częstochowa Upland, in the vale of the Wodąca river, near the village and castle of Smoleń (fig. 1, 2).

Fig. 1 – Biśnik Cave site.


Fig. 2 – Biśnik Rock, 2008 (photo: Ł. Czyżewski).

Research on the site has been conducted for sixteen years by an interdisciplinary team: prof. T. Madeyska, prof. T. Wiszniowska (1992–2005), prof. K. Cyrek, prof. A. Nadachowski, dr J. Mirosław-Grabowska, dr K. Stefaniak, mgr M. Sudoł, mgr Ł. Czyżewski, and mgr P. Socha. The cave system consists of several chambers and corridors in the rock of Biśnik, which probably connect Biśnik Cave (catalogue numbers: 383 and 384, KOWALSKI 1951) to the nearby Psia Cave (KOWALSKI 1951–1954). Over 20 geological layers of sediments accumulated in front of the cave entrance and inside the chambers have been documented, encompassing three main sedimentation series (MIROSŁAW–GRABOWSKA 1998, 2002; fig. 3), as well as petrologic and paleontological evidence of nine climate and fossil compelxes (WISZNIOWSKA, STEFANIAK, SOCHA 2002).

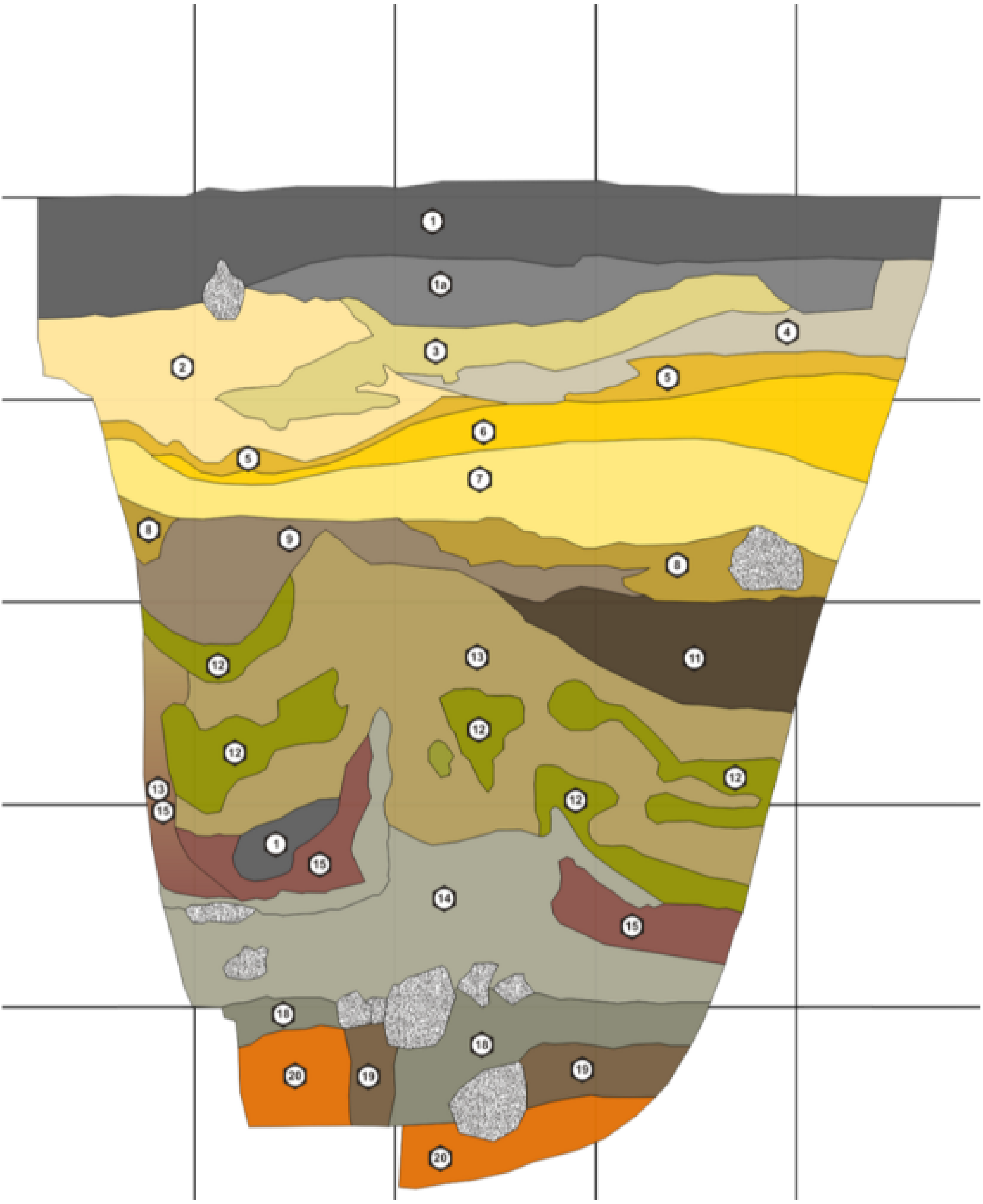

Fig. 3 – Biśnik Cave. Benchmark site profile – early stage of research, J profile under cave overhang (from: T. Madeyska, J. Mirosław-Grabowska).

The site represents about 300.000 years of well-preserved sequence, from OIS 8 to 1, since the Odranian glaciation until Holocene. The sediments contain archaeological material in 18 layers (CYREK 2002, 2004, 2006, 2007), described in 15 technological complexes (CYREK 2002, 2004, 2006, 2007; fig. 3). Apart from several thousand archaeological artifacts, the site has yielded over 150.000 bone fragments identified as belonging to rodents, birds and the great mammal fauna of the Pleistocene (fig. 4). Over 130 taxa have been identified altogether (WISZNIOWSKA, STEFANIAK, SOCHA 2002).

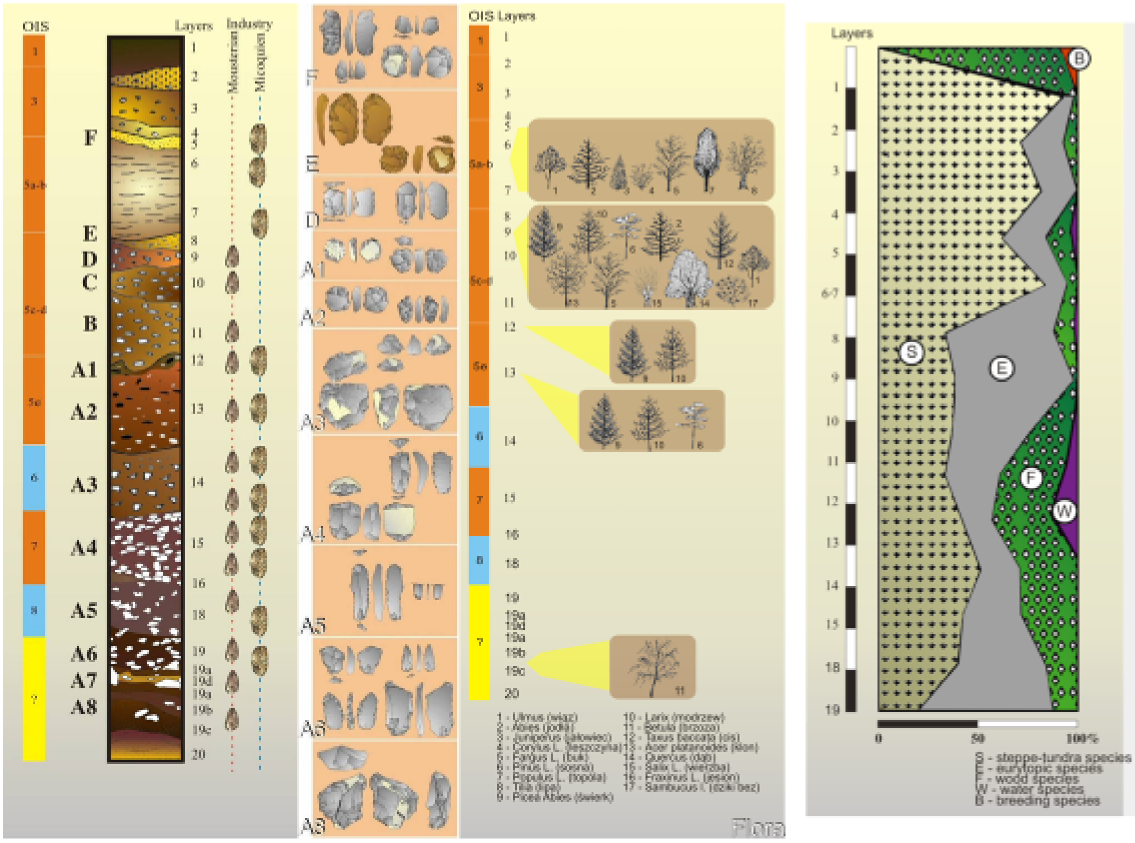

Fig. 4 – Diagram correlating archaeological, zoological and paleobotanical finds with stratigraphy (from: Cyrek, Stefaniak, CzyŜewski 2007 [poster]).

Archaeological and paleontological data had to be analysed according to the methodology of their individual disciplines, but a comprehensive spatial and stratigraphic analysis was also necessary, and thus the IT system had to provide for both documentation/archiving and at least basic visualisation/processing of the accumulated data.

Moreover, the project had to fulfil the following criteria: independence of the hardware platform and specialist software, easy copying and migration of data (open code, universal data exchange formats, such as CSV),

project scalability and easy expansion to new sites which could then conduct common research,

user-friendliness, intuitive interface for team members less familiar with information technology,

easy access to a variety of options: printing documentation, publication and source directories, a system for controlling object lending and data modification.

The documentation system, as well the system for data analysis and (partially) for data visualisation were based on Open Source solutions, which provided the cheapest option for data processing, presentation and exchange.

For one team, which comprised a dozen users, the system was based on a computer running under Ubuntu 8.04 LTS Linux, Apache web server with MySQL database and PHP, PgSQL, postGIS, and htmlDOC libraries.

The server is also a workstation, whose GNOME desktop environment enables the team to use such programs as QuantumGIS, QCAD, Open Office 3.0, Inkscape, Gimp and Google applications (Earth, Sketchup, Picasa). Mozilla Firefox 3.0 or higher, enabling Flash technology, is the preferred web browser, especially for printing.

The system is form-based, form complexity being defined for various user classes, and is entirely operated from the level of the web browser, which makes it user-friendly and facilitates access to the accumulated data. The database proper (fig. 5) consists of a dozen tables, which catalogue archaeological and zoological finds, sketches and photos, publications, objects lent, geological data and indirect data. Entries in the last category are defined by lists of properties which later enable the processing and visualisation of data. In order to facilitate the processing and entering of data, it is possible to define some dozen categories for selected artifacts, such as materials, sets, artifact types, or layer complexes. The categories also make it easier to introduce new forms.

Fig. 5 – Database structure (photo: Ł. CzyŜewski).

Layer complexes constitute one of the most important factors for further dynamic spatial correlation of the data entered into the system. They allow the system to link stratigraphic layers, which may be differently

defined in different parts of the site, into one, user-defined set, which then may be used in more advanced queries. All the tools for such analyses are available from the user interface, and do not require the use of SQL and other programming tools, although they, too, may be used to create queries (fig. 6).

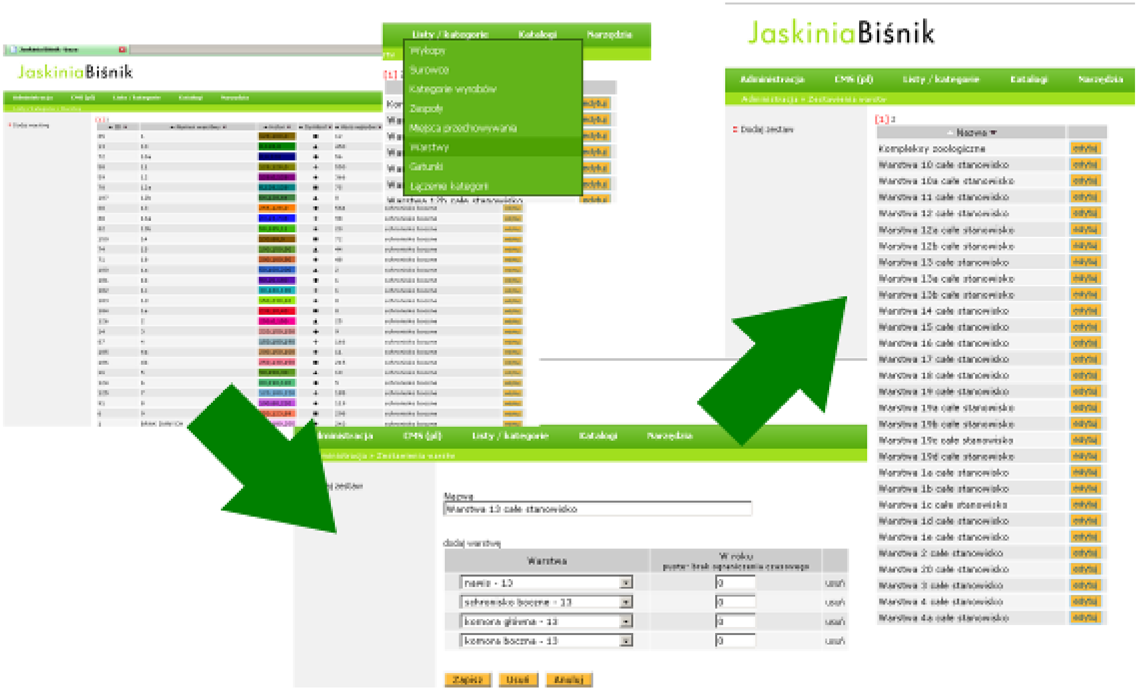

Fig. 6 – Layer complex correlation system (photo: Ł. CzyŜewski).

Designing the system meant the team had to take a stance on the much-discussed subject of collecting redundant data in situ (CHROUST 2003, LUND 2006, GENÇ 2007, DUCKE - not yet printed), and of defining standards of measurement accuracy that would ensure successful data analysis and interpretation. Discussions and field experience led the team to accept 1-centimeter accuracy in measuring and recording object locations. In the case of laboratory measurements for typological identification, measurement precision was to be limited to 1 mm, as only traceological research and paleozoological measurements of small rodent teeth might require greater accuracy - and these do not affect spatial analyses and constitute a separate area for documentation. Defining the accuracy of measurements in such a way made it possible to digitalize existing documentation archives, as well as to increase fieldwork efficiency, since digital measuring equipment proves difficult to use in the cave. Necessary as modern tools might be in some cases, traditional methods usually suffice when it comes to exploring niches, narrow, inaccessible crevices, etc. In the cave, with its high humidity and the risk of mechanical damage, even specialist electronic equipment tends to malfunction. Since a vast majority of finds are above 5 centimetres in size, one centimetre accuracy seemed sufficient for in situ documentation.

Methodologically, the system of detailed measurements and descriptions might be seen as a return to descriptive archaeology (artifactography? see ZALEWSKA 2005, p. 70, and LOCK 2003, pp. 1–13, ZUBROW 2005), imposed by the binary nature of computers, but the fact is not going to exert much influence on the present discussion. Of more methodological importance are going to be the descriptions and classifications of all possible measurable features, ranging from the definition of

sediment, to object categories and measurements. It is to be remembered that methodological solutions accepted for the team’s fieldwork are merely a means for archaeological insight proper.
The digitalization of documents involved some predictable, but important problems. The first of these were the often unclear or imprecise field descriptions of artifacts and sediments. In comparison, the systematics of zoological descriptions, despite the existence of many archaeological classifications and typologies, proves to be much more precise. Cultural facts, unlike zoological taxa, are often ambiguous and unrepeatable, which made it difficult to define a limited set of features to be implemented in the user interface for given types of sources (such as lists of layers, materials, sets, artifact categories, etc.). The problem is obviously one of reality/model relationships, usually illustrated with examples involving the field of stratigraphy and the Harris matrix (HERZOG 2001, 2003, 2005, not yet printed, DUCKE – not yet printed). Especially valid seems the juxtaposition of classical, formalist stratigraphic descriptions of the model and the discreet stratigraphy of the reality.
There were also discrepancies between documentation from various years, both in descriptions of geology (different numeral labels for layers) and in measurements themselves, e.g. ostensible shifts in the position of layers due to inaccuracies accumulated in the several years separating research projects on the site. It was thus necessary to verify original versions of the documentation again, and correct data manually. The meaning of those corrections was only visualised when it came to 3D rendering of the site (fig. 7). Naturally, it would be possible to manually verify such discrepancies while analysing archaeological sources, but the process would then be much more time-consuming. Tools designed for working with the archived data also include class or category lists not only for archaeological descriptions proper, but also for other elements - after all, the system also includes directories of documentary drawings or publications. Thus, it was necessary to include lists of their authors, layer complexes, and current locations of given archaeological objects. In forms dealing with analysing archaeological sources, the following sections are available:

- sections for preparing source documentation for further visualisation,
- a simple website Content Management System (CMS; fig. 8),
- basic analytical tools (queries).

Simple and crosstab queries have been implemented in way which reflects the team’s experience in the practice of data analysis. The system provides basic lists of artifacts with required properties, as well as standard statistics (numbers and percentages of objects). A form referring to previously defined object property and layer lists enables the user to save personalized queries, which may be used for analysis at any stage of research, as the source database is expanded (fig. 9). The option to search for particular strings in the longer text fields of object descriptions makes it possible to select objects with particular properties from among all entries, e.g. patinated ones. Thus, it is not necessary to define a special attribute for patina, nor assign it to all patinated objects – it suffices to include the word in any descriptive text field concerning a given object. The solution requires a certain degree of discipline to maintain consistency, but offers wide possibilities and flexibility of use.

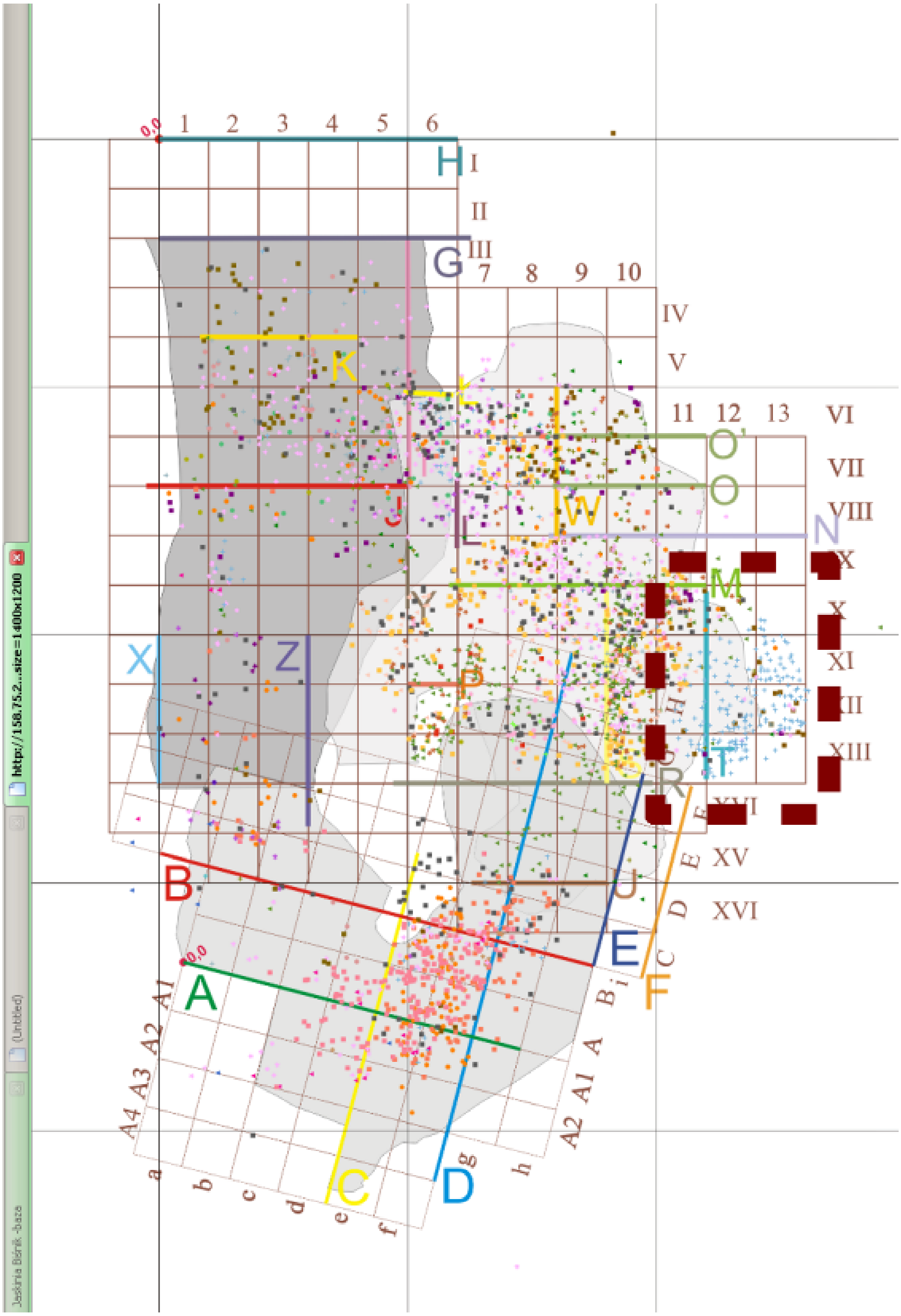

Fig. 7 – Ostensible shifts in object positions (including outside site area) due to measurement inaccuracies (photo: Ł. CzyŜewski).

Crosstab queries help to analyse the spatial distribution of archaeological finds on a 1x1 meter grid of the site, the order of rows and columns in the table being user-defined. As a result one histogram of

two variables may feature several excavations (reference grids). Crosstab queries also take into account those objects whose location has not been precisely measured while displaying object distribution on site grids. For example, if a given object's location is known with a 3 m ^{2} tolerance, the system "divides" the artfiact into fractions (3×0,33), adding them to the total number of moveable arifacts calculated for each of the square meters of the grid that might cover the object's true location. For the Biśnik Cave project, it may be assessed that some 80-90% of all artifacts had their location marked correctly on the grid. It is to be remembered that a vast majority of archaeological objects are located accurately, and doubts usually concern smaller bone yields.

Fig. 8 – Content management system and the webpage itself (photo: Ł. Czyżewski).

A two-dimensional histogram may be supplemented by an additional filter, providing the user with the distribution of artifacts belonging to certain sets (e.g. culture complexes, tools functions, etc.). The function automates spatial distribution analysis, which would be extremely time-consuming and prone to calculation mistakes if performed by traditional methods. These analyses are of particular importance in cave excavations.

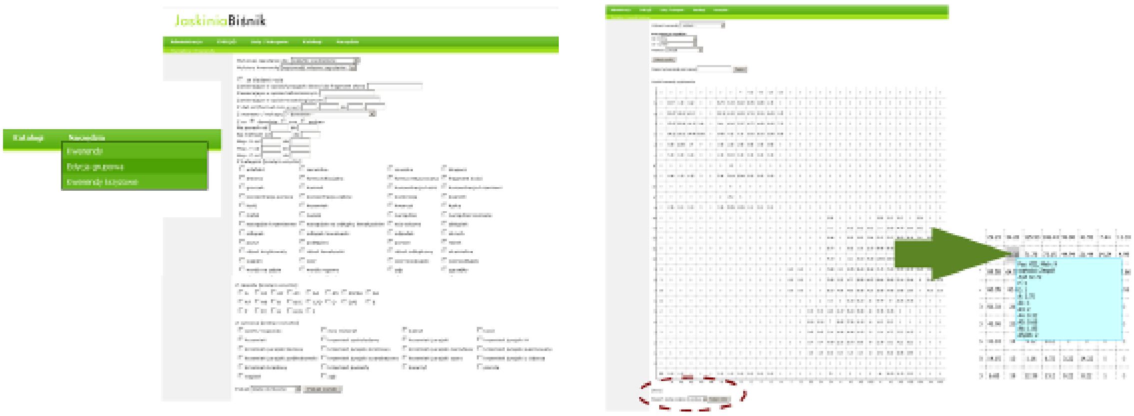

Fig. 9 – Simple query (left) and crosstab query results (right; photo: Ł. CzyŜewski).

In cave sites finds may often be separated only by floatation or extracted from compact material, as the sediments are often extremely heavy, sticky and agrillaceous. It is thus necessary to implement research methodology which will assume that some percentage of artifacts is only going to be found during further stages of examination. It is essential to stress that floatation applies almost exclusively to paleozological material, mostly small rodent bones and teeth, and 99% of archaeological yields are localised in situ. However, in assessing their distribution it is to be remembered that the location of some 20-30% is only known with an accuracy of several square meters – a percentage large enough to affect the overall distribution.

The methodology of in situ work had to take into account the need to close the excavations after each research season in such a state as to protect them from potential devastation by treasure hunters or speleologists. Unfortunately, the funds for the cave’s protection, and generally funds for the protection of cultural and environmental heritage, are not commensurate with the site’s erotological importance – unlike in Western Europe, where French or Belgian sites can be worked on throughout the year and archaeological teams are able to excavate 5-centimeter layers per year. Such excellent working conditions are only possible thanks to the decade-long existence of specially dedicated research centres, which both secure sites against looting and provide comprehensive facilities for fieldwork as well as the publication of results. Polish and Western research conditions are thus difficult to compare, and so are available IT systems, purchased or designed for Western and Polish projects. The present system, however, seems to match Western ones in efficiency. Moreover, its flexibility in terms of technological solutions makes it possible to expand it easily both by adding new sites and new analytical options or databases.

The function of exporting and importing CSV files allows for handling large quantities of data, as these files may then be processed by any other specialist application, such as CAD, statistical or office programmes, or Geographic Information Systems (this year the team used Quantum GIS with Grass plug-in).

Functions such as those offered by the Biśnik Cave IT system have been offered for over a decade by other applications designed for archaeologists (KOTSAKIS 1989, SCHLOEN 2001, KAMERMANS et al. 2002, LIEBERWITH 2006, 2007, LUND 2006, GENÇ 2007, ECKKRAMMER et al. 2007, etc.), which are usually based on relational databases and statistical tools.

The project’s originality, however, is to use this analytical system already during excavation work. One of the most innovative solutions, an answer to questions of interpreting stratigraphy (HERZOG 2001, 2003, 2005, not yet printed, DUCKE - not yet printed), is the model for dynamic layer correlation implemented in the system’s analytical tools. Using the smallest stratigraphic units marked on the site, the system is able to construct any layer complex present in a given excavation, which then can be used for spatial analysis. These complexes may be horizontal (e.g. all types of one layer present in all excavations on a given site) as well as vertical (e.g. along sedimentation series or environmental phases). It is also possible to use both vertical and horizontal imaging at the same time, and it is the visualisation module that makes the IT system designed for the Biśnik Cave (and, generally, for interdisciplinary research on Palaeolithic archaeological and environmental sites) a unique solution. The distributed nature of the project, which assumes telework and Internet access to data, made it necessary to include a graphic application that would only require a “middle-end” laptop with a web browser to use.

The application would need to allow the user to freely manipulate and model data without the need to run such specialist programs as GIS or CAD. However necessary these programs might be for some purposes, a vast majority of in situ tasks and documentary descriptions on sites such as the Biśnik Cave may be performed without their use. Visualisation is mostly used to analyse the spatial distribution of excavated objects on the site, which is presented as plans and profiles (fig. 10).

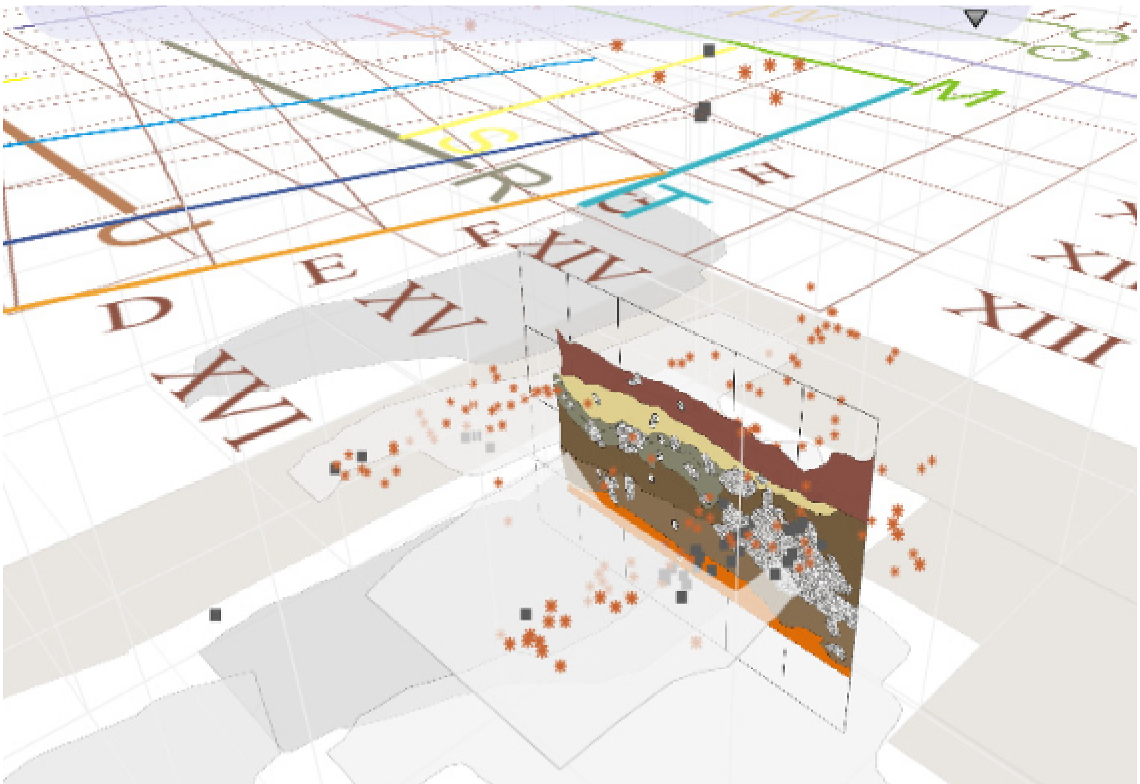

Fig. 10 – Biśnik Cave. Sample visualisation (site area, profile and layer; photo: Ł. CzyŜewski)..

Previous solutions for the visualisation of grid data (GRÖNING 2005) involved the designing of separate applications or the use of external tools, while programming and documentary languages for archaeology used tagging to mark database information in the natural text (HOLMEN 2003). This far, despite numerous postulates, no single, consistent, documentary AML (Archaeological Markup Language) has been introduced that would make it possible to create a networking environment for archaeological applications – which the present project also had to accommodate.

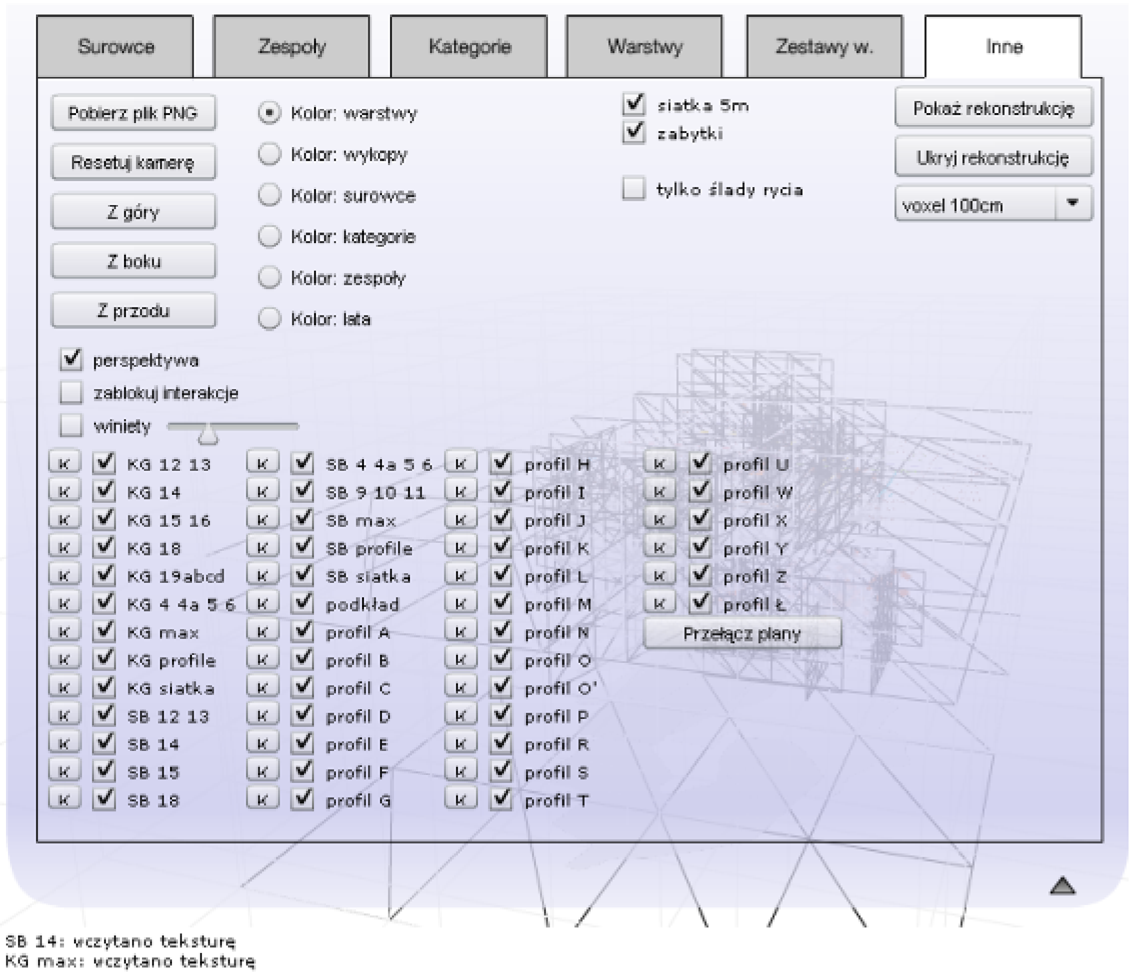

Fig. 11 – Visualisation: administrative panel (photo: Ł. CzyŜewski).

The present visualisation module was designed with the use of Flash technology, which is popular on the computers of the system’s end users. It employs Action Script 3 programming language and 3DSandy libraries (www.flashsandy.org). Data are entered into visualisation software with the use of XML.Action Script 3 provides object programming tools, which make application code more lucid and efficient, and also facilitate software management and maintenance. Sandy3D libraries were, at the time the project was designed, the best established and documented 3D environment for the Adobe Flash platform, and efficient enough to launch the project.

On launching the visualisation module, the application feeds it query result data, and the module itself loads the object list and permanent visualisation elements: plans, colours and keys for particular layers and categories, which have been set in the administrative panel. Then, the module launches its PHP-based interface, which generates an XML file containing data necessary for the visualisation, based on the object list.

Apart from Sandy3D libraries that were selected for the project, before the work began on the visualisation module (but after the project had already been designed), the market also offered Papervision3D and Away3D libraries. Papervision3D did not then allow for 2D sprites, which are the most efficient method for presenting objects. The library required that even single points representing finds be saved as 3D objects, which of course would make it necessary to include coordinates for at least 6 vertices to create the smallest body visible from all angles (hedra). For several hundreds of objects this would amount to thousands of vertices, and become a serious strain or barrier for the projected end computers. Additionally, to manage symbol categorisation for marking objects would probably add another order of magnitude to the number of required data, if, for example, objects were to be marked with asterisks or circles. Away 3D, on the other hand, proved an unreliable tool for triangulation, which could for example cause incorrect texturing of plans, and offered hardly any documentation when the project was launched, which disqualified the environment even without a detailed analysis of its potential.

As the project was being launched, a new library, Alternativa3D, entered the market, offering a more efficient rendering of complex scenes. However, since this is a commercial solution, available as SWC archive, the use of the library would exclude any adjustments of its main functions, so that the team kept to its platform of choice – Sandy3D, which proved to best fulfil the project’s requirements. Sandy3D combined the most comprehensive documentation with open code, allowed for combining 3D (for site planes and plans, meter grids, and object location) with 2D techniques (for object symbols), and also facilitated the inclusion of Flash-native elements (filters, MovieClip, graphics, bitmap, stage objects, etc.), which were useful for the user interface and for exporting visualisation results to graphic files. (fig.12)

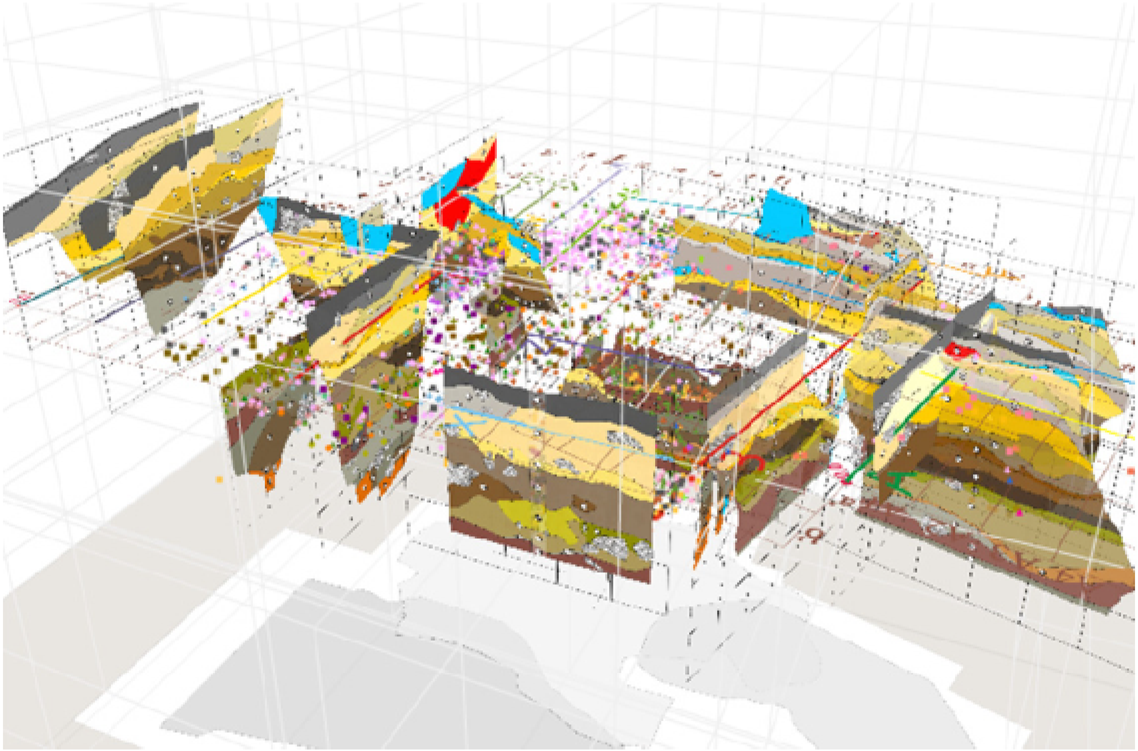

Fig. 12 – Biśnik Cave. Full site visualisation: all profiles, grids, maximum excavation area, all artifacts (photo: Ł. CzyŜewski).

One of the most interesting options offered by the visualisation module is surely pseudovoxel modelling of site space, especially useful for visualising settlement stages by using cubes ranging from five centimeters to one meter in size. 5×5×5 cm to 1×1×1 m user-defined cubes are generated if an object fulfilling user-defined criteria is found inside this particular space (e.g. one that belongs to a given layer). The grid is addend to the meter grid of the site. The distribution of such cubes reconstructs the area in which there have been found objects of a particular kind, layer, or layer complex. As for the accuracy of such a model, tests prove that with sites relatively sparse in objects, 25-50 centimetre pseudovoxels are advisable to give the visualisation sufficient consistency and sufficiently realistic layer shape. Smaller size means that the cubes become smaller than sprites representing object symbols used in the visualisation, while larger sizes do not provide the reconstruction with necessary details (fig.13abc).

Initial assumptions of the project required stratigraphic unit reconstruction to be based on vector profiles and layer plans as well. However, efficiency limitations of the Flash platform did not allow such extensive calculations, and besides the great number of factors proved to make such attempted reconstructions less than lucid, which excluded this type of visualisation from among basic analytical tools.

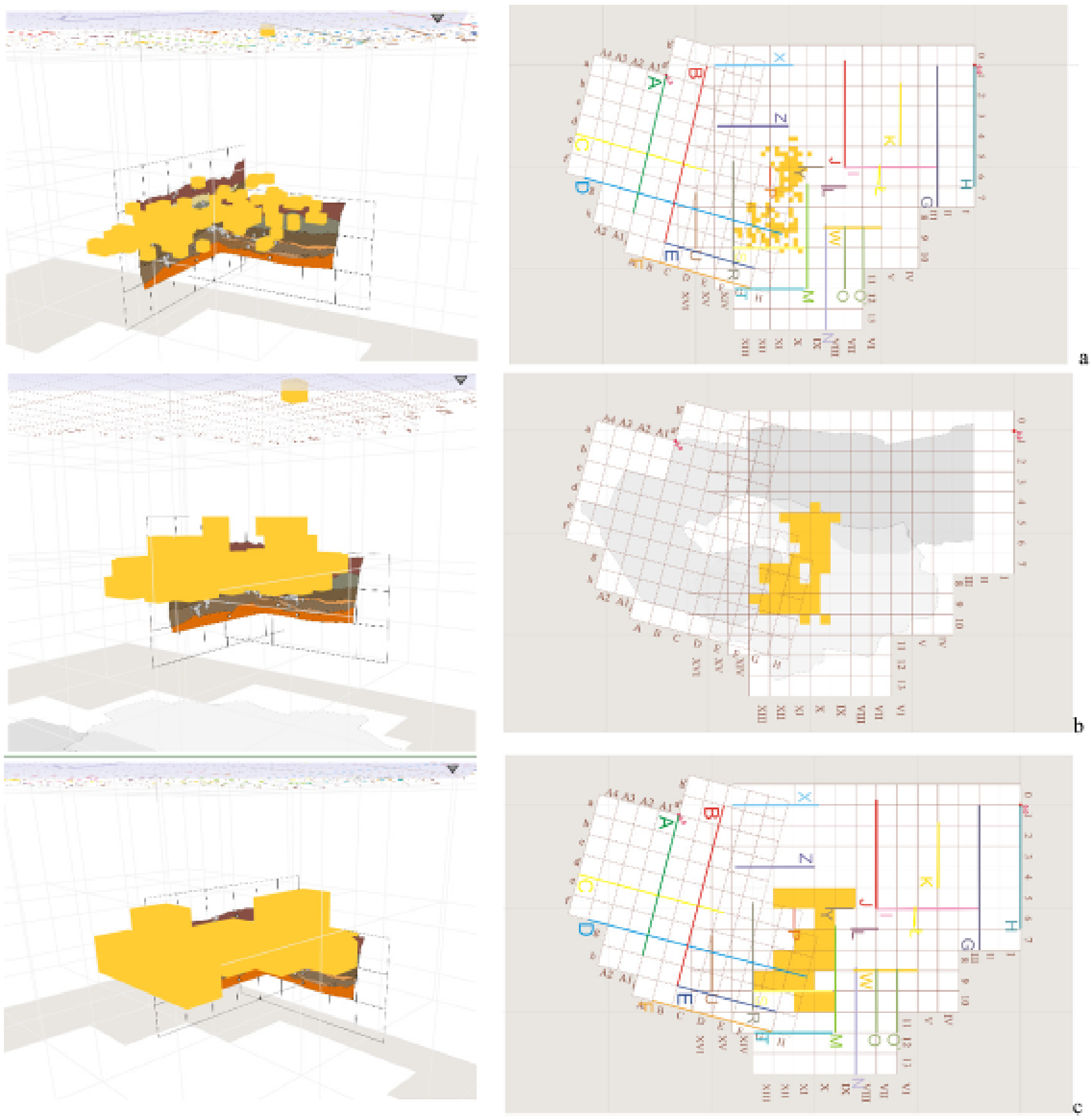

Fig. 13 – Biśnik Cave. Visualisation of layer 15, three pseudovoxel sizes (a – 25cm; b – 50 cm; c– 1m; photo: Ł. CzyŜewski).

The platform not only allows users to prepare 3D visualisations, but also 2D planigraphy (fig. 14) and projections of sets of objects on selected profiles (fig. 15). All the available projections of 3D space are based on transformations and vector rotations of the camera angle that eliminate perspective and space distortions. This is especially important with grid shifts and rotations in the visualisation of various excavations on the site.

Visualisation is also an analytical tool, as it helps to reconstruct the ranges, structure and exploitation forms in particular settlement phases, basing on the spatial distribution of sources, traceological analysis and typological categories. It is also possible to compare settlement changes on the site in the context of paleozoological material (usually taphonomic data), to mark areas of human activities on the site, etc. Many such observations would be difficult to perform without digitalised data, or would prove extremely time-consuming and prone to mistakes. The integration of all the archaeological and environmental data in files available to all researchers not only greatly facilitates research, but also helps identify potentially important locations on the site and plan for further excavations.

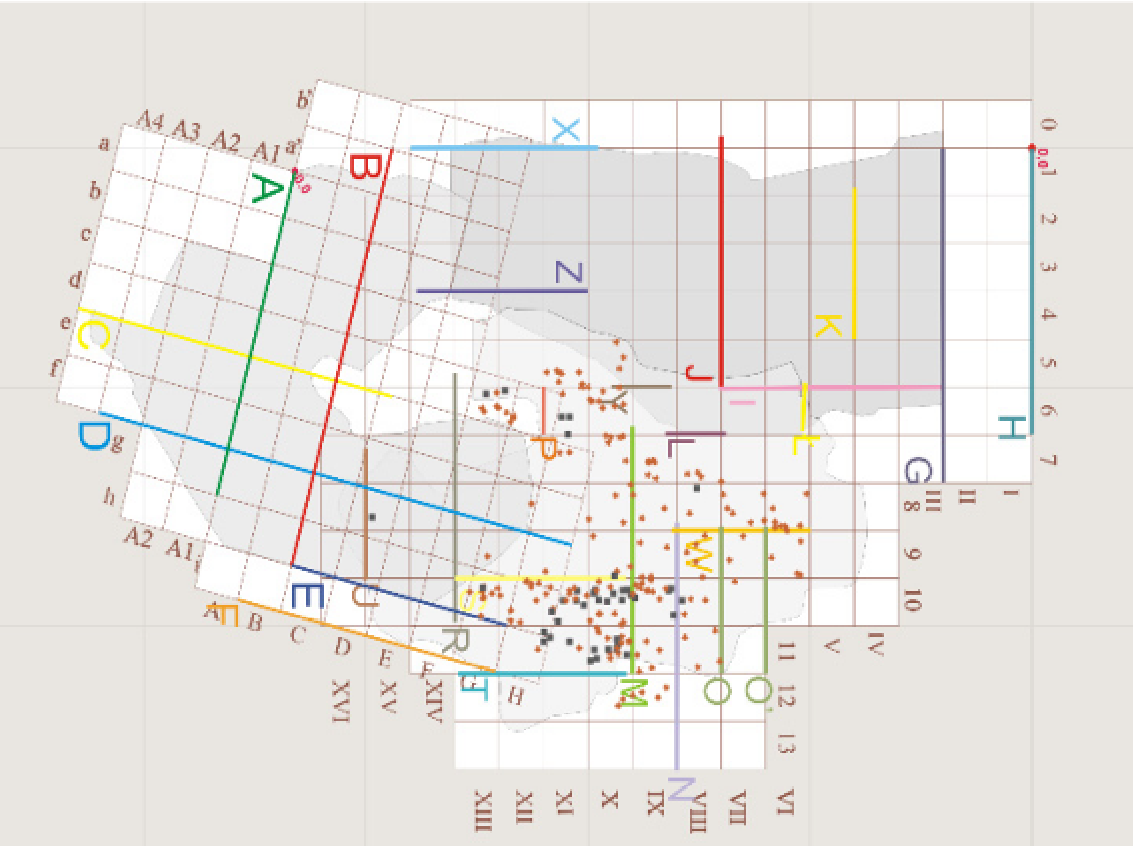

Fig. 14 – Biśnik Cave. Typical program-generated planigraphy. Layer 18, main chamber (photo: Ł. CzyŜewski).

The main advantage of the analytical and documentary IT system prepared for the Bi śnik Cave project is its wide applicability. The project was designed so that it could be easily extended to other sites of interdisciplinary Palaeolithic research and provide for a wider use of the present digital methods for analyses of archaeological and environmental data. The flexible method for creating layer complexes, added to a network environment and an intuitive user interface make the system accessible and functional for all team members. The system also provides a platform for data exchange between users – and thus proves an innovative comprehensive tool for data collecting, exchange, analysis and management for various disciplines, and an illustration of a new approach to source processing. It is worth stressing that the system is also wholly independent of commercial software providers, which additionally makes the platform cheap and expandable. Open source tools (except Action Script 3 language and Flash platform) allow for the further development of their code. CVS files enable data exportation and importation, regardless of the current platform, and for their use with other visualisation and processing tools, should those provided by the present system prove insufficient.

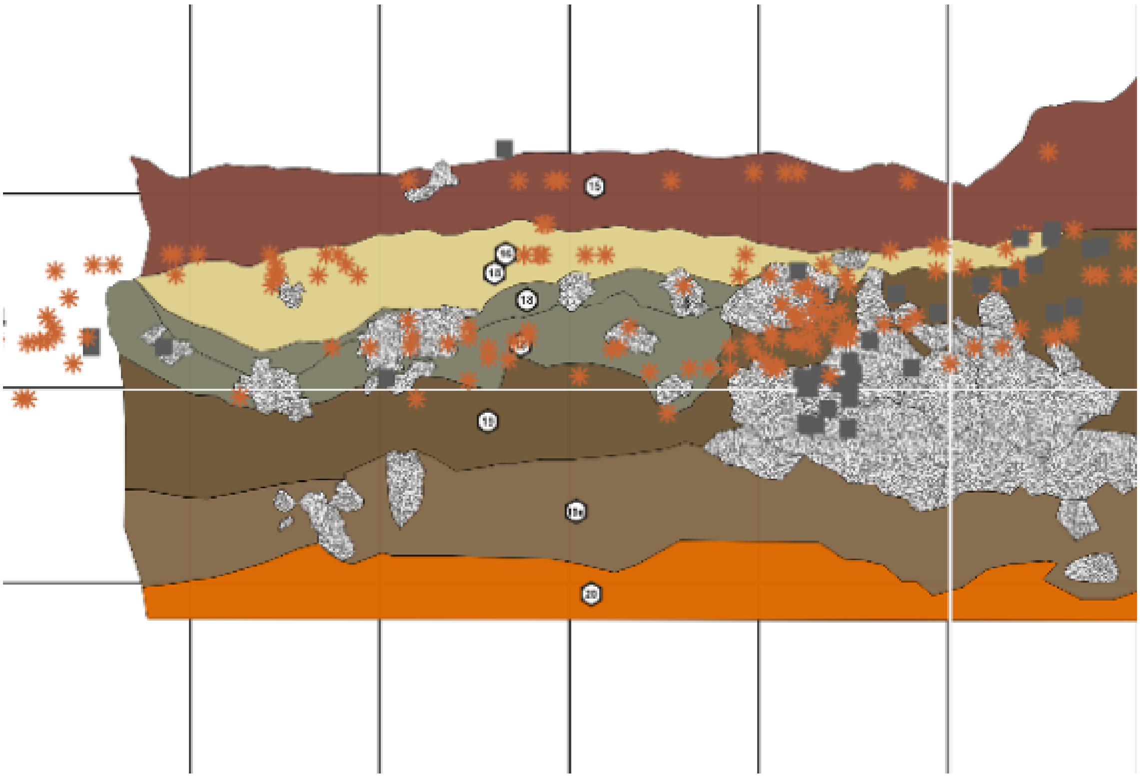

Fig. 15 – Biśnik Cave. Objects from layers 15–18 projected onto profile M (photo: Ł. CzyŜewski).

It is also noteworthy that the system is as beneficial to researches working on a single site. Firstly, the entire documentation is available to all users simultaneously, while being gathered in one place, i.e. on the server. Any user may employ and adjust the system’s internal tools independently from other team members. Secondly, the use of these tools does not require the user to master several specialist applications, such as GIS or CAD. Finally, the paper versions of documentation are produced on the basis of the single, central source, which eliminates the problems of correcting archive materials. As such, the system may also be considered innovative in the field of digitalizing various data sources.

For the Biśnik Cave project, implementing the IT system yielded the following results:

There is now a single and consistent system for all data sources and publications, which has positive effects on the standardization of data processing.

The system is used in documenting and archiving as a tool for cataloguing, as well as for the management of zoological and archaeological object collections.

Extended simple and crosstab queries are saved in the system, so that they may be conveniently used again as new data are introduced, or during later comprehensive analyses.

Objects may be analysed and visualised by spatial sequences of layers, which means an unlimited number of profiles may be created (in this case: archaeological, geological and zoological). All the disciplines may access their layers created on the basis of the smallest stratigraphic units defined in situ, so that, for instance, the ranges of various categories of objects may be easily compared.

The integration of various data made it possible to create a model reconstructing the range of cultural layers, based on scalable pseudovoxels that define the accuracy of visualised renderings. The tool’s accuracy proves satisfactory for standard archaeological tasks, without the need to resort to specialist geographical or engineering techniques.

Tools designed with the use of a single network platform enable users to visualise the vertical distribution of artifacts according to current standards (TORRE, MORA, MARTÍNEZ-MORENO 2008) without resorting to external applications. They also facilitate spatial analysis and tentative classification of objects not only on the basis of their morphological or typological characteristics, but also their spatial distribution in specific areas and settlement layers of the site. This, in turn, makes it possible to formulate additional functional and taphonomic hypotheses.

The inclusion of gird, profile and geological plans in visualisations made it possible to check data consistency in and between various research seasons. It was also possible to note differences between various researchers in their perceptions and descriptions of some stratigraphic units of the site. The system also allows researchers to confirm startigraphic markings on the site in different seasons.

3D positioning of moveable objects and of geological documentation (profiles and plans) helped to pinpoint mistakes in in situ measurements in some research seasons, and to correct the existing documentation as a whole, without the need to correct every single element. This also meant further standardization of documentation and printouts.

As for the discussion that has been going on the field of archaeological informatics about the relationship between hyper-precise measurement equipment (CHROUST 2003, DUCKE – not yet printed, LUND 2006, GENÇ 2007) and the level of accuracy actually helpful in archaeological reflection and methodology (LOCK 2003 p. 8 et al., ZUBORW 2005, p. 10 et al.), the experience with the IT system has lead the team to side with humanist reflection. This does not mean an exclusion of digital measuring methods, since reflection and methodology of in situ work with the use of digital equipment should be complementary. The present IT solution also supports the still developing family of specialised, interdisciplinary, non-commercial applications. It is able to support everyday documentation work and help fulfil certain standard, repeatable tasks common for many disciplines. It also helps to process source data into user-friendly form, ready for comprehensive, humanist analysis, but not divorced from their material, tangible, environmental basis.

Further development of the project is going to increase the number of sites under analysis, and thus enable comparisons between these sites. An IT superstructure – a comprehensive system for inter-site analysis – is going to be added, probably allowing for the importation of data from any universal carrier, as a development of the current CSV file management system. Another important new feature would be to use some of the new options available with Nvidia CUDA library and employ multi-threading to increase the efficiency of visualisation – this would substitute the rendering engine with one that would be much more efficient.

As a consequence, the system would be developed, and layer analysis tools expanded by adding vector profiles and plans, which could not be included in the present version. It would also be possible to add some analytical tools. If the system were to be used for additional sites, advanced data-mining options would also be worth considering.

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