Cartographic sources as a cultural heritage

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ABSTRACT
This contribution deals with new technologies for digitizing, processing and publicising of old cartographic products – maps, city plans, map atlases and also globes. Principles for precise digitizing of maps are mentioned and new equipment for globes digitizing is presented. On-line tools for map georeferencing are described briefly. Publishing old maps via Web Map Services (WMS) with respect to OGC standards (Open Geospatial Consortium) is recommended and some web applications and tools for further analytical works with maps are mentioned.

1. INTRODUCTION
Old maps, city plans and other cartographic products are important source of information. They complement and concretize what is mentioned in other archives (documents, publications, newspapers, books of cities, pictures,..) and they give us spatial information about the past. That is the reason why old cartographic products are valuable archive sources. On their basis it is possible to follow a development of displayed area, a historical development of towns or industrial areas or significant changes in a landscape and so on.

Today we are witnesses to massive digitizing of publications, manuscripts, documents and other archives which are stored in libraries, museums and archives. And we can also see a massive publication of digitized document on internet. This gives users - researchers a quick access to information. In the field of old maps we can see the same approach. But we have to take into account that maps have their own specific attributes like cartographic projection, scale, coordinate system etc. From maps we can measure distances, we can determine height difference between two objects, we are able to calculate areas. We can do that with digital copies of digitized map too and even more but to preserve these specific maps attributes it is necessary to choose different approach to old maps digitizing and publishing than digitizing and publishing of other paper documents.

2. WHY DIFFERENT APPROACH
When we are digitizing and publishing maps we have to realize that maps which were created with support of geodetic or astronomical measurements have their own accuracy. This accuracy is principally affected by a accuracy of measurement, applied cartographic projection, a map scale, used drawing method and so on. The map accuracy is important when we want to extract information about objects in maps and about their relationship. In most cases we want to know how precise the outputs are because it influences our next decisions. To preserve the accuracy of paper map when digitizing it is important to choose proper scanning devices and to follow specific processes. For map publishing on internet it is good to choose such technologies which are targeted for map publishing and which respect given standards. Keeping these simple rules we are able to offer users – researchers a great and powerful source of information which maps can provide. When we are speaking about standards in

maps publishing we have in mind OGC (Open Geospatial Consortium - *www.opengeospatial.org*) and their WMS (Web Map Service) standard for publishing maps in raster format. By respecting this standard users can use our maps with all their cartographic attributes. This means they can work with digital map as with paper map – measure distances, angles, azimuths and calculate areas. But the most important thing is that with maps published via WMS we are able to do things that ordinary paper maps are not able to offer. Then we can speak about added value of digitized map. The added value will be described in more details in chapter 6 but first we will look briefly at the digitizing of maps and globes.

3. DIGITIZING

Maps and map atlases digitization can be done in different ways and with various devices. But not all devices suitable for document digitizing are suitable for digitization of maps. The quality and accuracy of digitized map is influenced by two factors. The first factor is how the map is placed in scanning device and the second is how a picture of the map is taken. Both these factors influence on principle the final accuracy of transformation of paper (analogue) map into a digital one. A specific field is globe digitizing.

3.1 Map digitizing

In the course of map capturing in scanner it is necessary to ensure that the map is perfectly flat. Even small ripple can cause errors both in quality and in accuracy of digital copy of a map. Worse quality will be visible in an image as irregular presentation of colours and with blurred parts of the image due to unequal distance of map from the lens. Ripples cause deformations which have effect on map accuracy. These deformations have influence on our measurements on the map, they are irregular and unknown and they can't be easily eliminated. The flatness is very important when digitizing thick map atlases because sometimes it is impossible to make open atlas flat. Map is than deformed the most in the middle of atlas where the spine is. This problem can be solved by using a scanner with a cradle. More sophisticated solution is creation 3D model of each page when scanning (V. Tsioukas et al 2012).

The quality of capturing device – the lens– is the second factor. For map digitization should not be used one-camera systems which take pictures from long distance (>1m). Image is taken through lens of the camera by perspective projection when all rays go through single point of lens. This projection causes image deformation. For example, parallel lines are not reproduced as parallel in the image which is important for map reproduction. Perspective projection can be removed but it is complicated and it´s better to avoid using one-camera system for map digitization.

From our long-time experience with map digitization we can recommend a large flat-bed scanner because the deformation in image is minimal. Map is placed on moving table which presses the map against a glass pane. The map is then perfectly flat in its entire area. On the other side of the glass runs scanning head with four cameras. tha captures step by step the whole area from thedistance of approximately 20 cm. The weakness of this system is to secure proper stitching between cameras.

Fig. 1 The large format flat-bed scanner ScannTech 800 with 800dpi optical resolution

To accuracy of digitization is best verified by tests. For testing we use a test plastic foil with insignificant expansivity. On the foil is a regular grid of crosses whose coordinates were measured with laser interferometer. After scanning the foil the crosses' coordinates in the image are compared with measured coordinates and the accuracy of digitization isevaluated on the basis of this comparison. Deformation of a scanner is displayed in a whole plane by vector of movement. By this method we can verify a real accuracy of any scanner. It is possible to detect place with more distortions and by repeated control measurement we are able to monitor trends and according to them determine ideal moments for scanner adjustment.

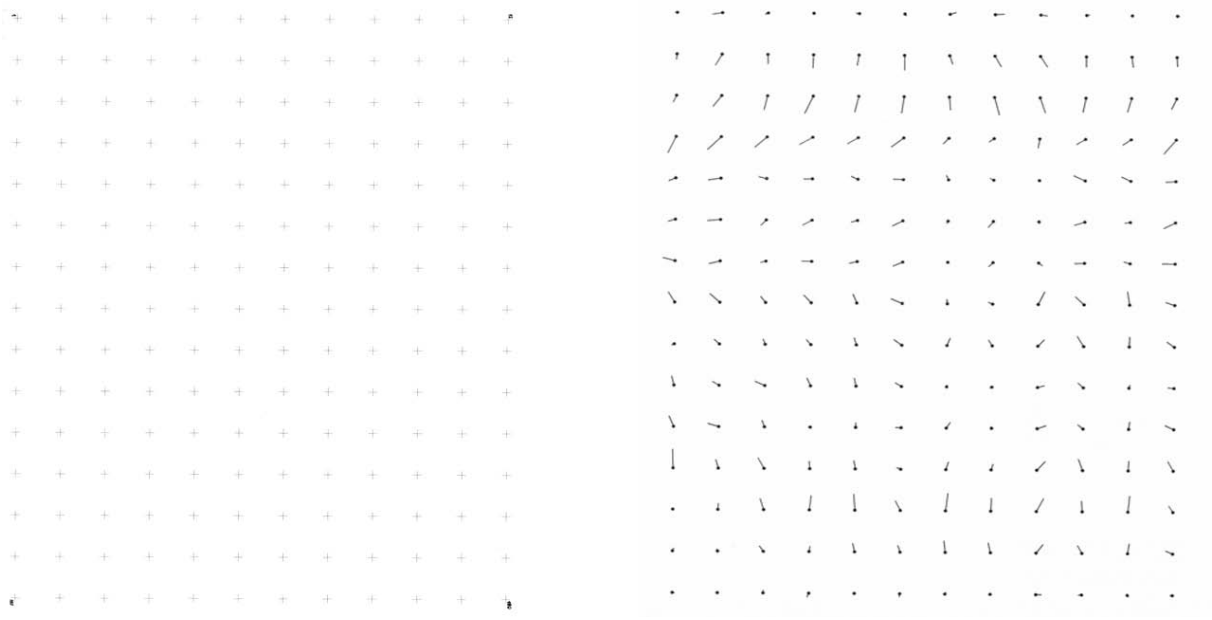

Fig. 2 Plastic used for scanner accuracy testing and the result of testing with vectors of movement

3.2 Globe digitizing

Digitization of globes can be basically done in three ways. In the case of availability of the globe in the form of a printed plane, the globe´s zones spherical cap can be digitized with flatbed scanner. If the printed plane is not available it is necessary to digitize the globe in his spherical form by a digital camera. If possible it is good to fit an image content to square grid on the globe. The third option is to obtain digital data by using non-contact 3D scanner.

In our research we focus on the second method – using digital camera. The camera's internal orientation elements should be known for it to be used for globe digitization. The internal orientation describes properties of the camera. They can be determined by method called geometric calibration. the result of the calibration is known course of lens deformation.

For globe digitization with digital camera we have developed a special mobile device which enables taking pictures of globe without risk of its damage. The device is composed of a wooden tripod, a frame with wheels, an adjustable camera holder, an adjustable laser source holder and scales for moving the globe in direction of X and Y axis. The globe is placed to the frame with wheels where it can be horizontally and vertically rotated step by step and pictures are taken.

Fig. 3 New device for globe digitizing and an example of digital picture of globe

The device accompanied bye light lamps with stands for constant lighting of the globe and a large tent to shade the globe. The device is now in testing phase which is why there will be no close description in the contribution, just photos.

From these two chapters follows that the accuracy of digital copy of an old map can be significantly influenced just in the phase of digitization of the original paper map. In a sense of error accumulation the error made during digitization is carried into next phases of the digital map processing, for example georeferencing, and is gradually rising. There can be errors - shifts in position of objects in map in millimeters. When they are multiplied by a map scale they can significantly influence the outcome of our work with the map like measuring distances between objects or measuring areas.

4. PUBLISHING MAPS ON INTERNET

Just as with old manuscripts there is a trend to publish old maps on internet for scholarly and amateur community. The motivation is on one hand to enable continuous access to maps without necessity of visiting archive and on the other hand to protect paper archives from mechanical damage or even theft. Maps can be published in several ways. For maps and plans which were created without any measurement method but only by glance from a horse ridge is sufficient publishing in some simple software dedicated pro viewing large raster image. An example of this way of map publication is the Zoomify software.

But maps which were made on the basis of geodetic measurement and for maps created in some cartographic projection it is better to them publish in different way than in previous example. However preservation of basic cartometric characteristics of maps (where applicable of course) can also be considered a general demand on digitized maps. To preserve these cartographic attributes the digitized maps must be georeferenced, i.e. placed into a coordinate reference system with regard to their map projection. The georeference then must be taken into consideration when publishing the maps on-line, so users can measure distances etc. directly on the display. In this way the digitized map keeps its cartographic attributes. Georeferenced maps have some kind of added value compared to paper maps, that would give users better use of the map data then before and users can use them as effectively as possible.

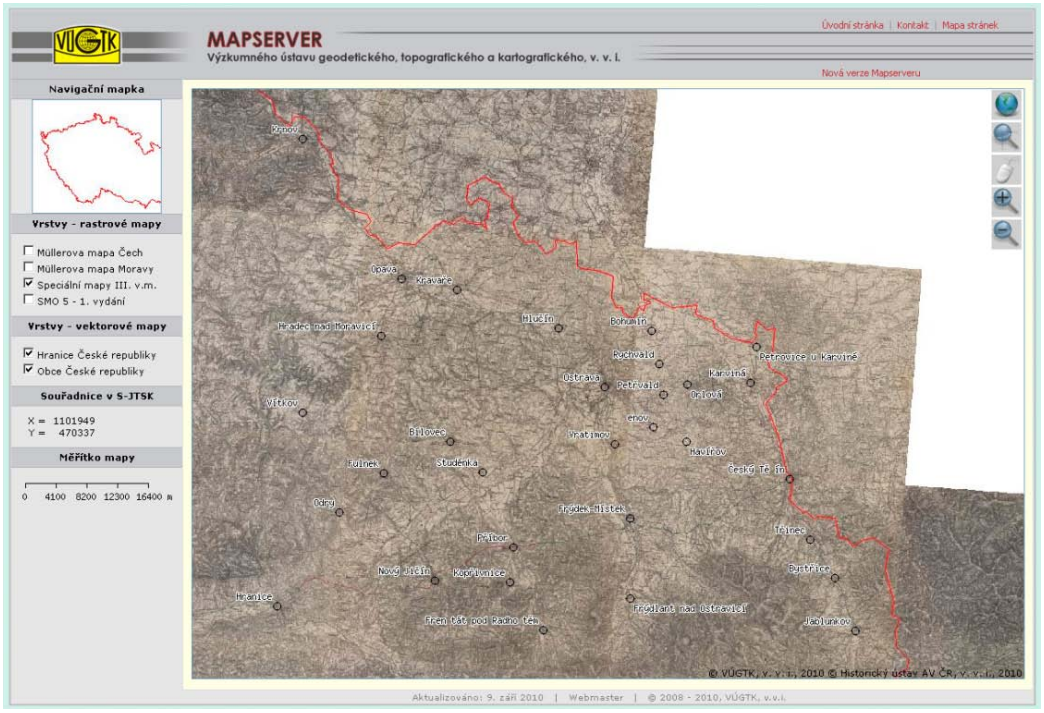

Fig. 4 Georeferenced map published via WMS and displayed in web application together with other data (town names, state border)

5. GEOREFERENCING

To locate old maps in selected coordinate system can a dicey issue. In the course of the georeferencing process we should try to keep accuracy of original paper map as much as possible. However some old maps or map series were created by wrong or imprecise procedure and the map situation is therefore deformed. By our opinion there is no sense in trying to rectify them by any complicated transformation method. Doing this we actually create a new map work and we should know we want to do that. Maybe it can help us to solve some specific task but we don´t recommend doing that. A good example of such a deformed map series is I. Military Survey of Habsburg Empire (1763 - 1787).

Each map can be georeferenced in a different way. It depends on what we know about the map. Do we know original map dimensions, used cartographic projection and system of coordinates, is it one sheet map or is the map part of any map series? How to proceed in these cases is described in article "Methods of Georeferencing Old Maps on the Example of Czech Early Maps" (Cajthaml 2011).
A person who deals with map georeferencing should have knowledge and skills in history of cartography, mathematic cartography and he should also have some knowledge and experience with using various transformations. He should have appropriate software to do the transformation. Quite a lot of conditions to georeference map in a correct way for expert let alone for a layman.

The solution of this problem is to give the user a tool in a form of a web application for online map georeferencing which will be intended for experts as well as for laymen. There are several applications in existence, but they are either designed for specific map sets or they do not respect cartographic projections (*www.georeferencer.org*). The application should offer such tools which will enable mainly to laymen without any cartographic skills to georeference maps as precisely as possible. Therefore the application must be composed as an expert system. This means that the system asks the user questions about the map effectively guiding him through the georeferencing process and in the end offers him the best solution. It can be a suggestion of projection which was probably used when the map was created, it can be a recommendation of transformation type which should be used for georeferencing, it can be control points arrangement and so on. Such system is based on a knowledge database and on statistical computation. Filling the knowledge database is not easy because it should contain complex information about map formation, cartographic signs in maps and on a map frame, projections, local customs of cartographers etc. But outputs of such system will be precisely georeferenced images together with metadata about method used for georeferencing and with information about resulting accuracy of georeferencing. This metadata is important for other users to inform them how an information extracted from the map is accurate and if it's sufficient for his purposes.

Situation with globe georeferencing is a little bit different from plain map georeferencing. From digital photos we can build two types of models. The first can be model of the globe as a single large plane image. This means we have to manage to somehow compose a huge set of photos. But photos must be transformed before into equidistant cylindrical projection with help of latitude and longitude intersection as identical points. The cylindrical projection in normal position is not sufficient for displaying polar areas but digital globe can be easy published on internet by this type of model. The second type of model is a real 3D model. The idea is taking pictures of globe by camera is the same as taking pictures of Earth from Space. In this case if a picture taking distance is well defined and camera´s optical axis goes through a globe center we can speak about Vertical Near-Side Perspective Projection. This projection is azimuthal projection which is defined by lines converging in arbitrary

point which is placed on line going through a globe center and perpendicular to projection plane. Digital globe can be published in GoogleEarth software as a layer on the globe.

6. ADDING VALUE TO DIGITIZED MAPS

Georeferenced maps published via Web Map Service can be used for further work and now we come back to the so called added map value. The following paragraphs present some thoughts as to what this added value might be. Digitized maps offer great possibilities for comparing the drawing of two or even more maps. In contrast with paper maps the digital ones can be placed side by side on the monitor independent of where the paper originals are stored. Also the possibility of changing the scale of individual maps makes the comparison easier.

6.1 Comparing of changes in maps

Even more useful is comparing the maps by stacking them onto each other as several layers and adjusting the opacity of these layers. This method allows to better discern differences in the various map elements (courses of communication, forested areas etc.). As useful as this method may be it is more demanding on the provided data.

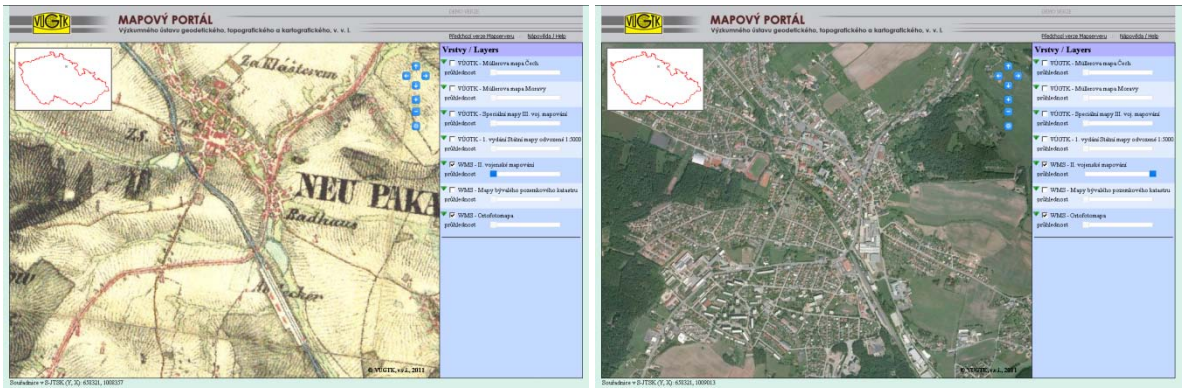

Fig. 5 Nová Paka city on II. Military Survey map and on contemporary orthophoto

The area around city Nová Paka can serve as an example of map drawing comparison. When someone is interested in the changes in city development in the last 150 years, he can use the web application on the map portal of VÚGTK (http://mapy.vugtk.cz). The application offers several map series – old and contemporary maps. Among others it is map series II. Military Survey (also known as Survey of Franz Joseph I.) created between 1836 and 1852 with scale of 1:28 800. These maps can be displayed together with current orthophotomap. Each map series is displayed in its own layer and the layers' opacity can be adjusted, which allows for fairly comfortable comparison of both maps as demonstrated in Fig. 6. By inspecting the combined image we can easily see how and in which direction Nová Paka city has been developing from 19th century over the years.

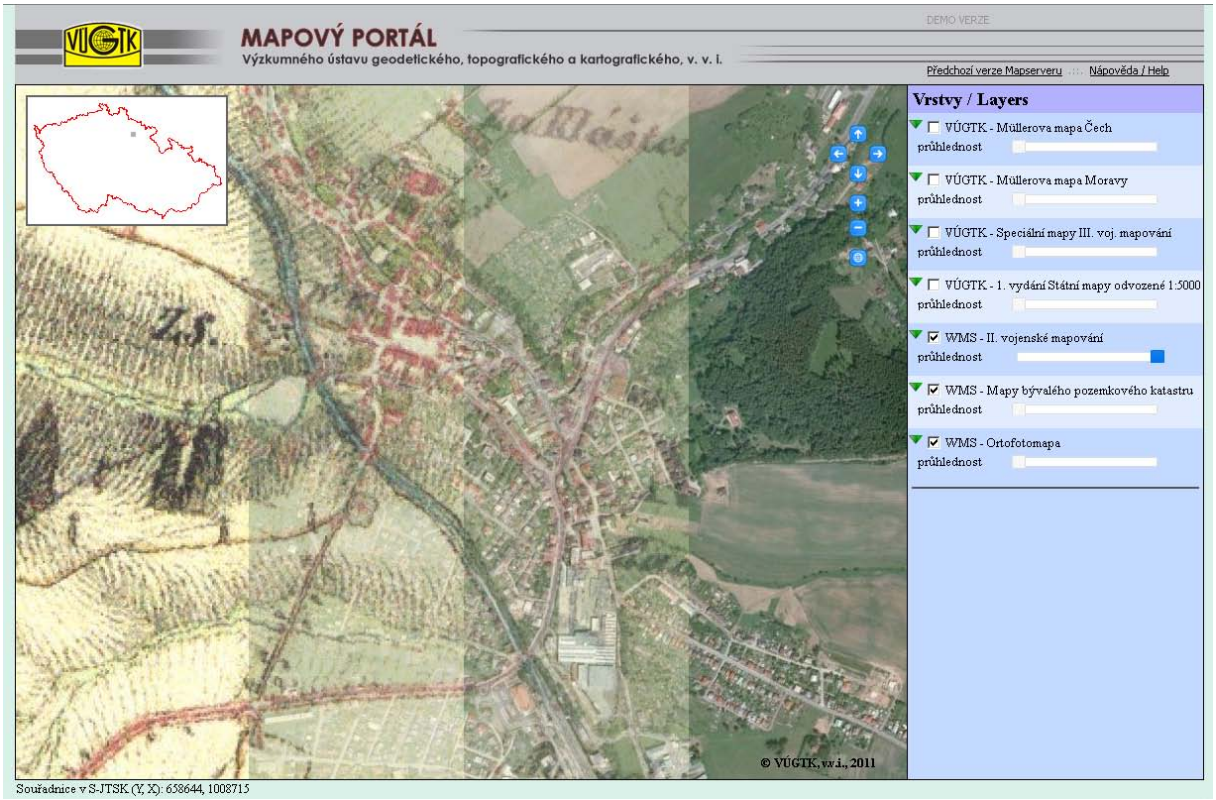

Fig. 6 Map of II. Military Survey compared with contemporary orthophoto by adjusting the opacity of map layers

6.2 Automatic detection of map elements and classification of raster images

Another important enhancement of digital maps can be automatic detection and recognition of map objects. This tool would detect with certain level of reliability for example map symbols. It would be useful especially when dealing with large map series with many map sheets. Because these maps series share common map projection, method of representing earth surface, map key and colours, such a tool would make work with these maps much easier for researchers.

Another useful tool is automatic classification of digital maps. This process allows to automatically detect areas with common characteristic, i.e. forests, water surfaces, buildings etc. Technically it is a problem of assigning the image's pixels to one of several classes defined in advance. If the map is georeferenced the classified image can be used to determine the surface areas of the classified regions, or otherwise evaluate their position.

Unfortunately quite substantial difficulties can be expected when attempting to apply these tools. The main cause of these difficulties is varied quality of digitized maps resulting from damage caused to the original maps by time or storage conditions and from varying scanning procedures. Even individual maps from a single map series can differ quite a lot. The basic prerequisite for processing old maps in this way is to have them scanned and published on-line in standardized way, because only then the maps will be available easily enough to research, develop and try sufficiently robust and efficient solutions to presented problems.

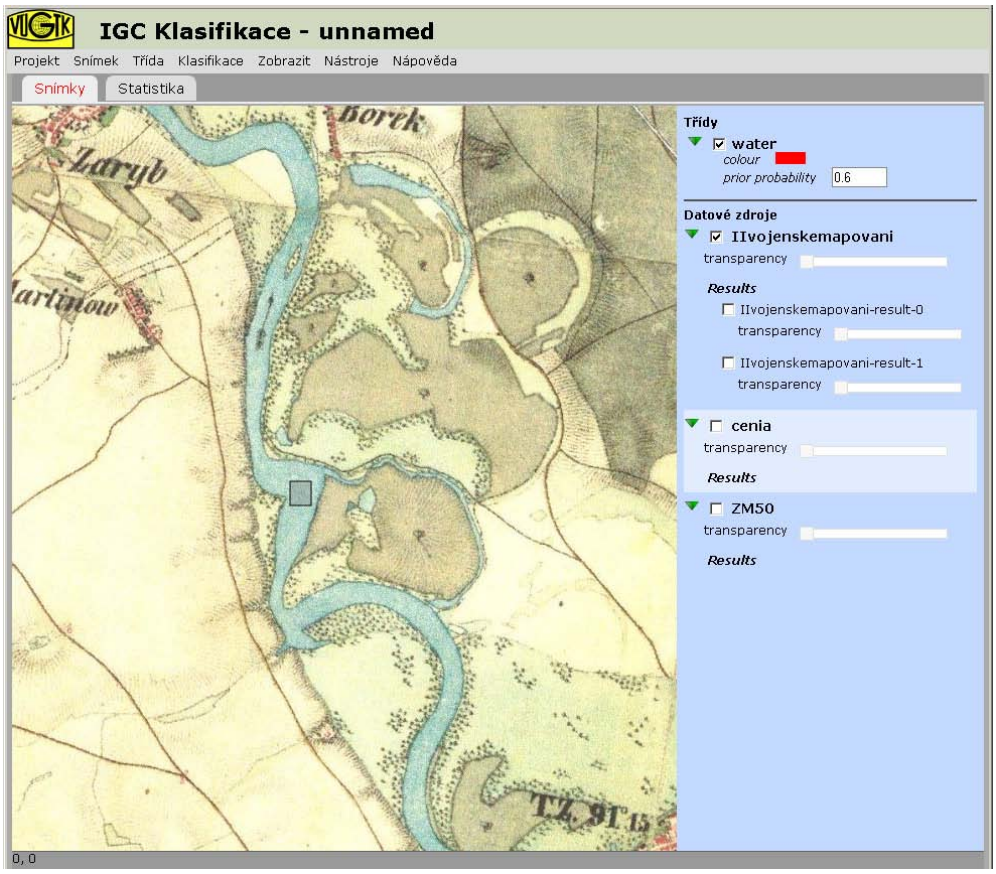

Fig. 7 Example of Labe river with its meanders on II. Military Survey map

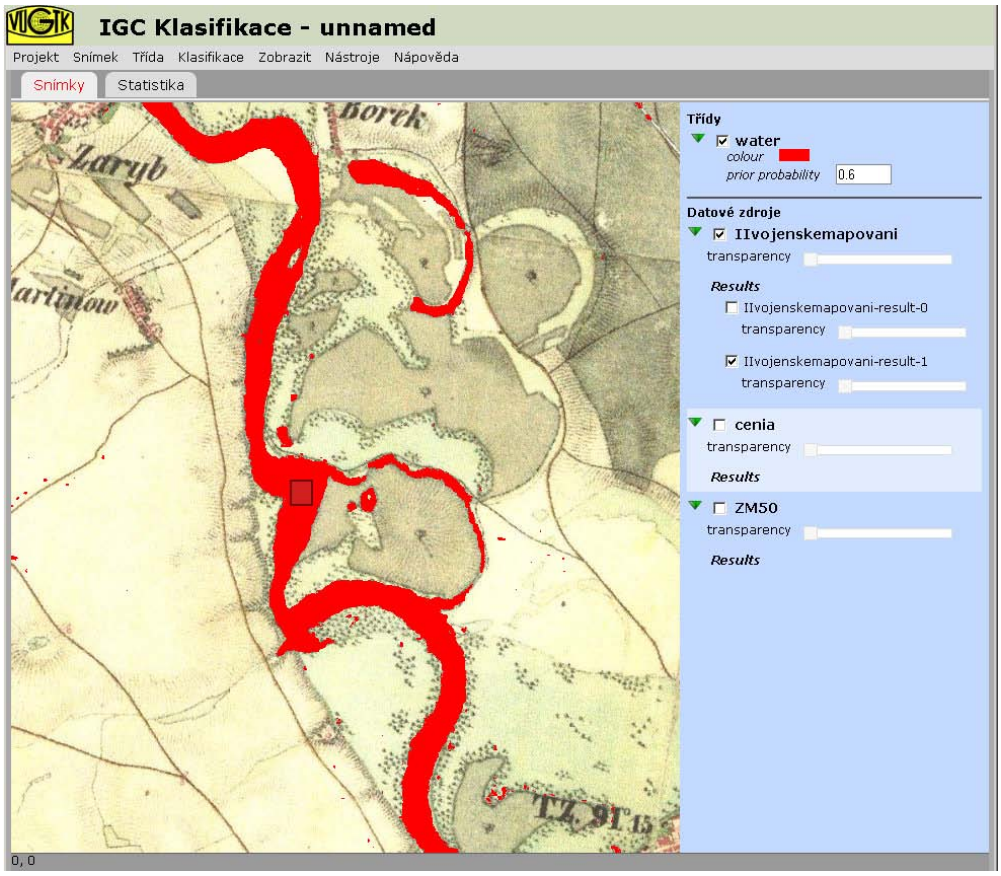

Fig. 8 Classification of Labe river. Water surface is classified and enhanced by red color

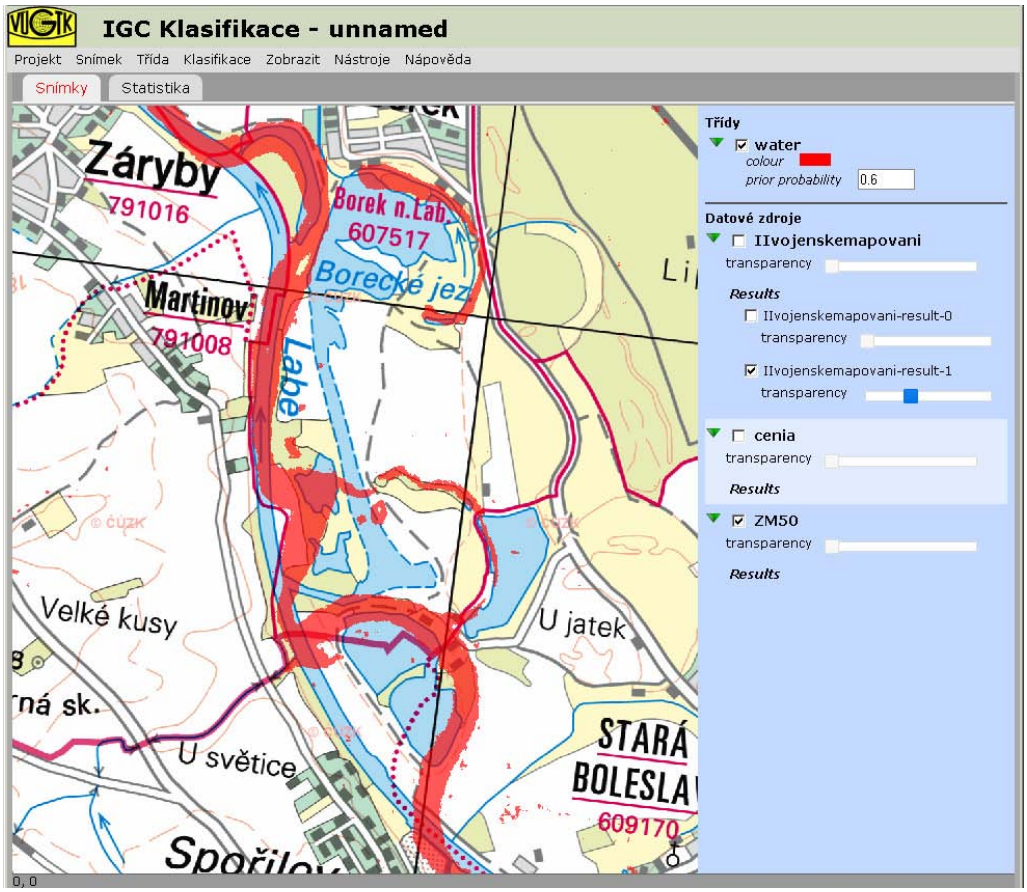

Fig. 9 Classification of Labe river. Water surface classified on II. Military Survey (red color) displayed on contemporary Base map of Czech Republic 1 : 50 000. The river regulation is thanks to classification visible very well.

7. USING DIGITIZED MAPS IN CUSTOM APPLICATIONS

The possibility of using digitized maps in custom applications is probably the most useful added value. If the digitized old maps are accessible free of charge and in accordance with agreed upon standards then individual users are able to use them in their own application catering to their specific needs. The point is that the set of potential users of old maps is very large and maps can be utilised in almost every field of human activity. It is therefore impossible to anticipate every possible use case and create appropriate application.

8. CONCLUSION

The goal of this contribution was to highlight an importance of different approach to digitizing and publishing of old cartographic products with comparison to other archive documents. If technologies and standards recommended in the contribution will be followed users will be able to work with digital maps more efficiently than with original paper maps.

When we are publishing old maps we should take into account what kind of users will use our maps and what are their needs. Most users don´t want just to explore maps but they want to work with them, they want to extract information from maps, they want to do analyses and they want to do some statistics. If we give them free access to georeferenced maps and if we also give them web applications which were described in the contribution they can do all these things using ordinary web browser. And skilled users can build their own applications we do not think about now. It is much more efficient to

provide the old maps as a data service and allow users to create applications and tools suited for their needs.

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