DIGITAL ROCK DRAWING ON CZECH TOPOGRAPHIC MAPS: THE CURRENT STATE AND HISTORICAL CIRCUMSTANCES

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ABSTRACT

This article presents a method of digital cliff drawing that is used in the production of large-scale topographic maps by the Land Survey Office of the Czech Republic, with respect to the history of topographic mapping in the Czech Republic and former Czechoslovakia, which greatly influenced contemporary digital processing. The core of this article details the principles of this type of digital rock portrayal, illustrated with a variety of examples. The method described is based on filling a polygon with lines that resemble stylized hachures. The advantages, disadvantages and limitations of this approach are also discussed.

Keywords: digital cartography, digital cliff drawing, rock hachures, topographic map

1. Introduction

Rocks are often dominant features of the landscape, and therefore can expect to be present in large-scale topographic maps. However, the vivid portrayal of such a feature has always been a challenging task, even for a skilled cartographer. The term "rock drawing" (also often referred to as "cliff drawing") denotes the production of rock hachures: a way of providing the map reader a clear impression of the passability of rocky terrain, generally dictated by its relative height or structure. Various types of rock hachures have been developed, especially in alpine countries. While the style used in Swiss maps is generally considered to reach highest degree of perfection, this is not the case for the rock hachures commonly used in Czech maps. With very few high mountain rocky peaks, and only an insignificant part of its territory covered in other types of rocks, the demand for such precise depictions is lower in Czech maps. Moreover, in the era of contemporary GIS systems, some practitioners consider traditional rock hachures to be an anachronism or nothing more than a surviving curiosity.

Traditional work on rock drawing in analogue cartography comes from Imhof (1965), who argues for using hachures, and provides an in-depth description of the rules and best practices for Swiss-style rock depiction. Another approach was used by Austrian cartographers Brandstätter (1983) and Ebster (cf. also Čapek 1976). Works that are better suited to Czech cartographic traditions also exist, but are generally rare. These include Boguszak & Šlitr (1962), Kavan (1965), a complex thesis by Čapek (1973) and its later published parts (Čapek 1974; Čapek et al. 1992), and Lysák (2010). Over the years, the technology has changed from analogue drawing on plastic foils to digital drawing using a computer. However, the problem itself remains the same, or even worsens, as working without special hardware (e.g. a graphics tablet) and software is more time-consuming than using pen and paper, which is rare nowadays. Despite this, a more important issue seems to be the automation of rock drawing, and this has yet to be resolved. A key part of a solution to this is an in-depth analysis. For Swiss-style rock depiction it was done by Jenny et al. (2014), some notes about the Czech-style of rock drawing including digital processing were also published in Lysák & Traurig (2013).

This article aims to elaborate on the previously mentioned work to provide a more thorough description and analysis of the principles of digital rock drawing with respect to special cases of digital processing. The focus is on digital cartography and large-scale topographic maps produced by the Land Survey Office of the Czech Republic, whose experts have developed remarkable solutions to the problem.

Firstly, a short historical overview of rock drawing in modern, large-scale Czech topographic maps is given, as it has contributed concepts that are more or less used in contemporary digital processing. The principles and concepts of digital processing are described more thoroughly in the next section, as well as the advantages and drawbacks. Based on the description, a user can easily create suitable and visually acceptable representations of rock formations for large-scale maps. This paper may be useful not only for cartographers or GIS practitioners, but also researchers dealing with the large-scale mapping of rocky terrains, such as geomorphologists or

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geologists. Moreover, a detailed description of the digital portrayal can be used for the development of an algorithm that enables this type of representation to be created automatically.

2. Historical Overview

Contemporary digital rock processing is related to previous work on analogue maps, which warrants a brief discussion of the history of modern large-scale topographic mapping in the Czech Republic. Between 1957 and 1971, the entire territory was mapped in a large scale of 1 : 10,000 (Čapek 1985), resulting in the Topographic map (*Topografická mapa*) state military map series (TM 10). Cartographical symbols, including rocks, were drawn according to Soviet standards in order to unify maps for all countries of the former Communist Bloc.

Rocks were depicted by brown rock hachures in an attempt to express the jaggedness of the terrain. Drawings were based on an identification of the main ridges and gully lines of the rock formation. From ridges or cliff tops, lines following the fall direction were placed more or less mechanically and regularly. These were shaded based on the north-west illumination; i.e. tending to be thinner on the light sides, and thicker on the shaded sides. Generally, they also narrowed downwards. The fall lines were connected with short transverse horizontal strokes, which together formed a structure resembling a ladder (thus often referred to as "ladder manier"). The strokes were numerous on the side facing away from the direction of light, and placed only rarely on sunlit slopes. In both cases, they were thicker close to the ridges or cliff top. The closer to the bottom of a cliff, the thinner, shorter, and less frequently the lines were placed (Kavan 1965). An example is shown in Figure 1 (top). Based on these general principles, every mapmaker processed their map sheet significantly differently based on their own style, although such portrayals should be consistent across all map sheets. This presented a drawback, as the resulting image strongly depended on the experience and abilities of the author, varying from good artistic work to a schematic jumble of lines. More general disadvantages lie in the uniformly placed fall lines, which limit the possibility of expressing any specific feature of a certain rock, and which also evoke non-existing ridges. Although the main goal of this representation was to express the structure and passability of rocky terrain, this was hardly ever achieved, as noted by Čapek (1973).

In the TM 10 map key, a special symbol for sandstone rocks is present as such rocks tend to be smoother and more rounded. A typical cartographic portrayal of sandstone landscapes is based on a series of sack-like symbols (Figure 1, bottom). The symbol represents a stylised sandstone rock seen from an oblique view. These elements are ordered into adjacent rows one next to another to represent a rock face. The gaps between elements express

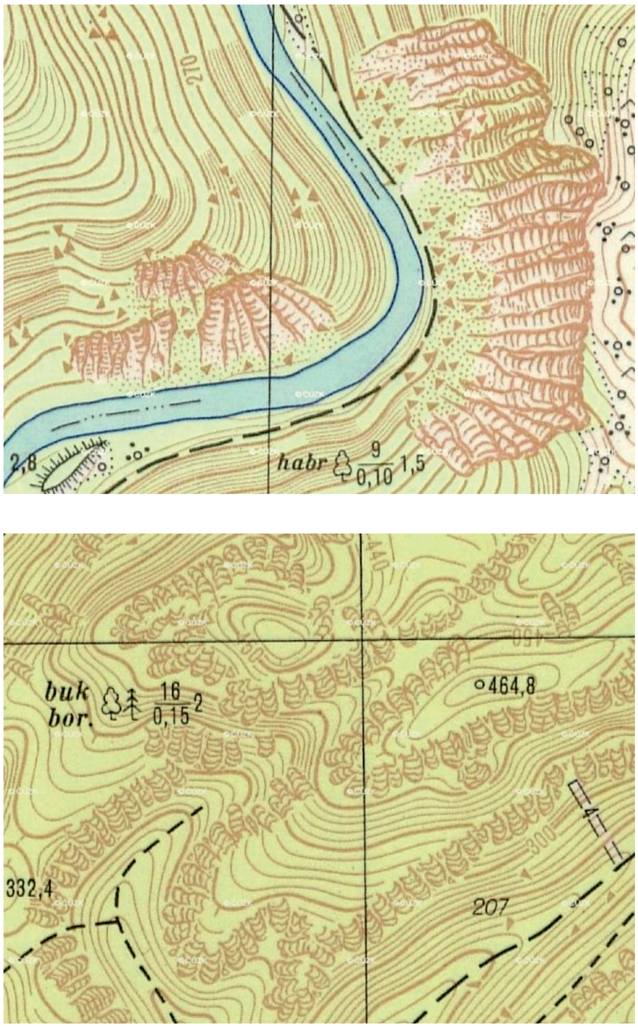

Fig. 1 A typical rock representation in TM 10 (top) and a sandstone landscape on the same map (bottom). Maps kindly provided by the Central Archives for Land Survey and Cadastre (*Ústřední archiv zeměměřictví a katastru*), © ČÚZK.

passages between the walls (whereas when connected together they represent impassable terrain); stacked rows of symbolsrepresent "terraced" escarpments separated from each other by normal (i.e. non-rocky) ground. In some cases, the size of a symbol can be interpreted as the relative height of a cliff. This was not done consistently and the quality of the resulting image strongly depended upon the abilities of the mapmaker. These means of cartographic representation themselves pose another problem. As sandstone cliffs are usually almost vertical and thus very narrow in a plan view, the area of a map covered with symbols overestimates the actual size of the cliff. This leads to a very inaccurate depiction of reality, especially for a more rugged sandstone relief, as either the relief form is too generalized, or the result is a disorganized mixture of strokes and circles.

Eventually, the army stopped updating TM 10 and after 1968 these maps served as a basis for the civil national map series. The first edition of large-scale topographic maps with a scale of 1 : 10,000, Base Map (*Základní mapa*, ZM 10) was published between 1971 and 1988

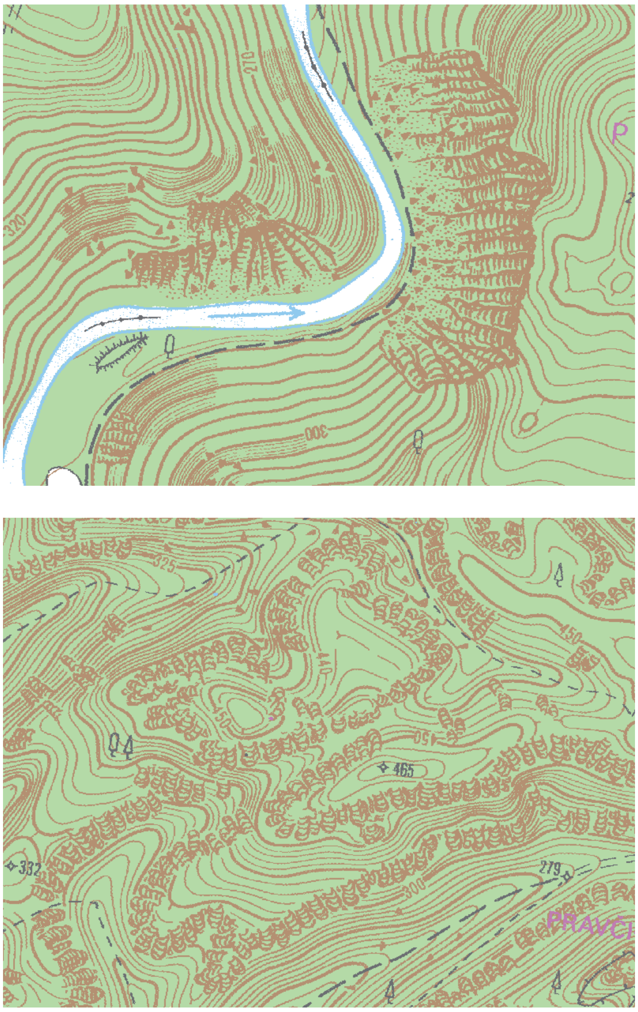

Fig. 2 The same areas as shown in Figure 1 in ZM 10. Maps kindly provided by the Central Archives for Land Survey and Cadastre (*Ústřední archiv zeměměřictví a katastru*), © ČÚZK.

and included a total of 4,533 sheets. Until the mid-1990s, these maps were regularly updated. Although the map content was reduced compared to TM 10, the cartographic portrayal of rocks remained almost the same (cf. Figure 2), exhibiting the disadvantages discussed earlier.

3. Digital Processing

Digital processing of Czech topographic maps is based on ZABAGED, a large-scale digital topographic database (Fundamental Base of Geographic Data, *Základní báze geografických dat*). Work on ZABAGED started in 1995 with scanning and georeferencing of the printing masters from the most current edition of ZM 10, which were later vectorised. Populating the database was mostly finished in 2001, and finalized in 2004. Since 2001, this database has been regularly updated using orthophotos, field work, and external data. In ZABAGED, rocks are represented using points for small objects, and polygons for larger ones. The polygons originated from outlines of hachured areas in ZM 10 and their accuracy was improved by topographers where possible. Their total count exceeds 40,000.

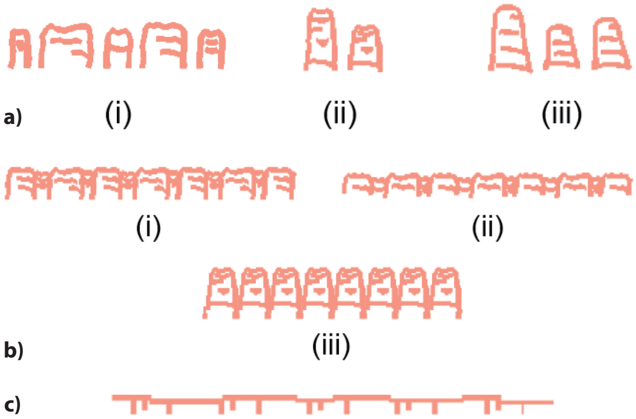

Fig. 3 The "anatomy" of digital rock drawing in the digital edition of ZM 10: a) upper symbols, b) lines derived from upper symbols, c) lower line. See below for a detailed explanation. Taken from the legend of topographic maps produced by the Land Survey Office, © ČÚZK.

Based on ZABAGED, base maps in the scale 1 : 10,000 have gradually been created using digital technology since 2001. The final sheet of the first digital edition was completed in 2006 and updates have been made continuously, since then. When processing the map sheet with rocks, the cartographer had to fill a polygon from ZABAGED with stylised hachures. Their style reflects hachures used in the analogue version of ZM 10, but the objective was to draw them more easily and not in a stroke-by-stroke fashion. For this purpose, several symbols are combined in order to achieve the desired results (Figure 3).

The first step was to create various symbols for a single stylised hachure (Figure 3a). We will refer to this as "upper symbols" in the following text (cf. Figure 4). Two general types of symbols were used; one for sandstone rocks (more rounded) and one for other rock types. Notes from topographers distinguished the type of rock. In practice, this was not done consistently. Figure 3a, group (i) depicts the most commonly used symbols. Group (ii) depicts the symbols used for sandstone rocks (not used in new production). Group (iii) depicts the symbols formerly used for sandstone rocks, which were probably not used in production at all, despite being present in the legend of earlier digital editions of ZM 10. In each group, there are more symbols due to the irregularity of the resulting representation.

From these upper symbols, several lines were derived (see Figure 3b), putting one or more types of symbols sequentially like pearls on a necklace (often colloquially referred to as "cartridge belts"), especially the sandstone variant, cf. Figure 3b (iii) and Figure 5b. This is done using Marker Line Symbol in ArcGIS for Desktop or using other cartographic software that also supports this feature. The main advantage of this approach is that a mapmaker does not need to place and rotate each symbol individually, but instead can simply draw the

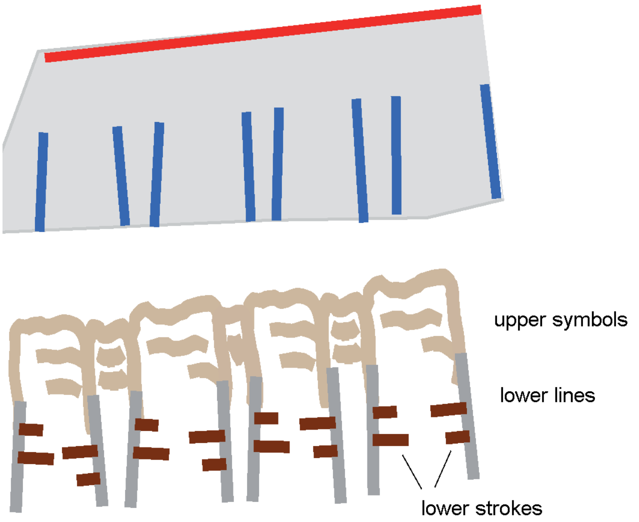

Fig. 4 From lines to hachures. The upper figure portrays the polygon geometry from ZABAGED with lines that needed to be drawn by a cartographer. The lower figure illustrates the resulting representation. For better illustration, single components of the result are distinguished by colour. ZABAGED data from Geoportal ČÚZK, © ČÚZK.

line and the cartographic software places the symbols next to each other automatically, perpendicular to the line. The smaller symbols serve as transitional strokes between the larger ones, which to some extent helps to avoid undesired regularity. There are also variants for wide (using a larger symbol, cf. Figure 3b (i)) and narrow (using a smaller symbol cf. Figure 3b (ii)) rocks. For sandstone rocks, no transitional strokes were used and the result tends to be of poorer visual quality (cf. Figure 3b (iii) and Figure 5b). This may be the reason that the "sandstone variant" is not used any more for the production of new hachures, and can rarely be found in map sheets that were produced earlier. When filling a polygon, the described lines were drawn along the upper edges. To increase output irregularity, not only was a single line along the upper edge used, but shorter sections with slight displacements or spaces between line parts are also often present.

Finally, the line for depicting the lower part of a rock was utilised, cf. Figure 3c. These lines (referred to below as "lower lines"), which generally follow the fall direction, were drawn to fill the section of the polygon not covered by the upper symbols. The lower lines meet the lower part of each upper symbol. They were used for larger (and especially wider) polygons and can be omitted for polygons that are narrow enough. For extensive polygons, these lines were placed more unevenly to avoid an excessively regular pattern. This was also sometimes achieved by bending the lower lines slightly (cf. Figure 5c). The impression of irregularity was supported by short, transverse strokes, perpendicular to a lower line (referred to as "lower strokes" in the following text). Although they seem to be distributed randomly, this effect was achieved by a simple symbolization using uniform placement with

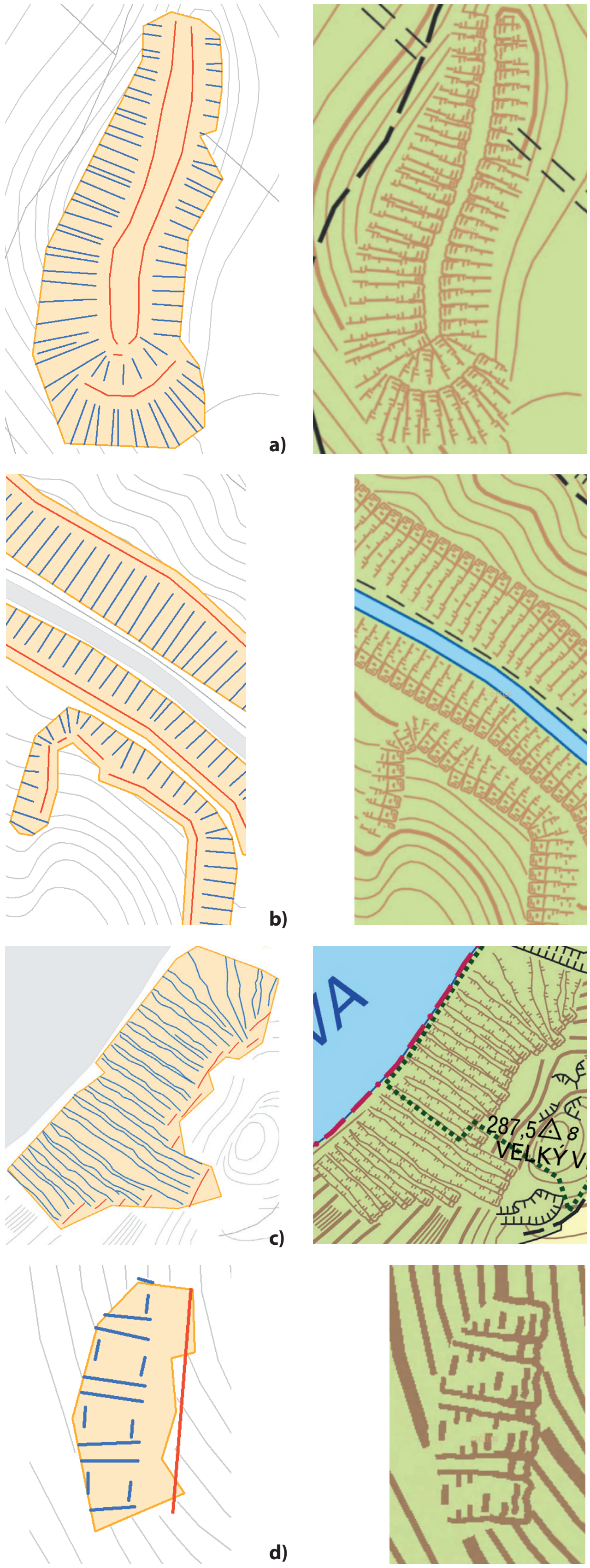

Fig. 5 Practical examples of the use of a combination of lines. Each pair shows in the left figure geometry from ZABAGED, and the lines were drawn by a cartographer. In the right figure, the result of the digital edition of ZM 10 is shown. See above for a detailed explanation of cases a–d. ZABAGED data and maps taken from Geoportal ČÚZK, © ČÚZK.

a long period for repeating and especially by changing the direction of the drawing (if one lower line was drawn from top to bottom, the next was sketched from bottom to top, and vice versa). These individual strokes do not have to be drawn by a cartographer as they can be easily done using Hash Line Symbols in ArcGIS. However, in rare cases when the lower lines were too far from each other and even decoration with lower strokes did not help to fill a polygon enough, additional lines were drawn freely between them (Figure 5d).

While processing data from ZABAGED for the first digital edition, no automation was used and all lines mentioned above were drawn by operators. During the vectorization of rock polygons for ZABAGED, details inside the rocky areas (e.g. ridges or upper edges) were not captured and the orientation of hachures had to be inferred from the original analogue ZM 10 or other relevant sources. In the case of more complicated shapes, the cartographer had to use these lines for creating a ridge or a valley (as in Figure 5a). For the next edition of the map sheet, the data was adapted from the previous edition and only minor changes were made (based on the update of polygons in ZABAGED).

A very similar approach for rock portrayal is used for the base map in scale 1 : 25,000. For scales of 1 : 50,000 and 1 : 100,000, lines alone are used to depict the upper edges in various widths using upper symbols, i.e. lower lines are not used. Very short lines with just a single upper symbol are used more often in these maps. At a scale of 1 : 200,000, only one type of line is used for upper edges.

In terms of technology, between 2001 and 2010, the digital processing was carried out using MicroStation and MGE. Since 2010, maps have been produced in a new technological line called IS SMD (Information System of National Map Series, *Informační systém státního*

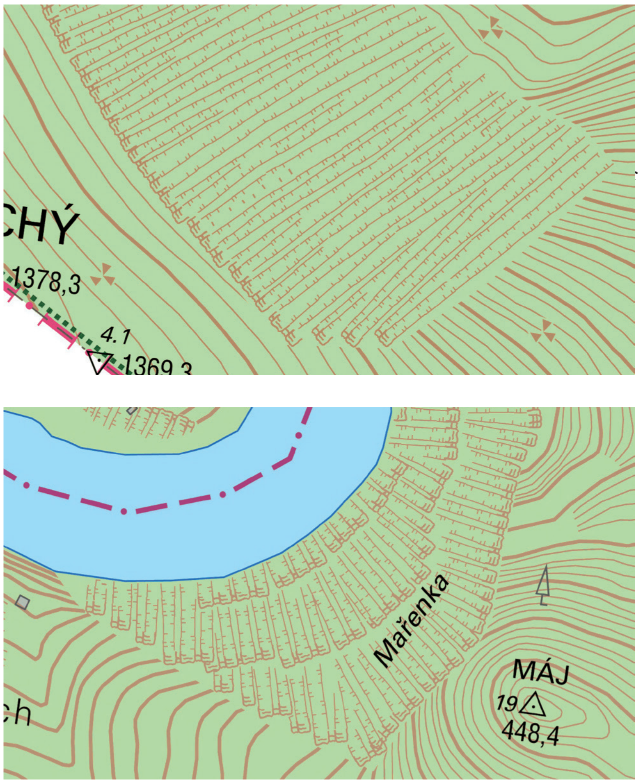

Fig. 6 Digital rock drawing for large polygons. The upper figure illustrates long lower lines. The lower figure includes more lines consisting of upper symbols. Maps taken from Geoportal ČÚZK, © ČÚZK.

er level of stylisation, it is visually better than a simple filling with a regular (or irregular) pattern, that can often be found in contemporary geoportals and poor digital maps. It also helps the map reader identify the upper and lower part of cliffs, but can be unsatisfactory for bigger polygons with extra elongated lower lines (cf. Figure 6, top) and more complicated shapes inside of a polygon. The

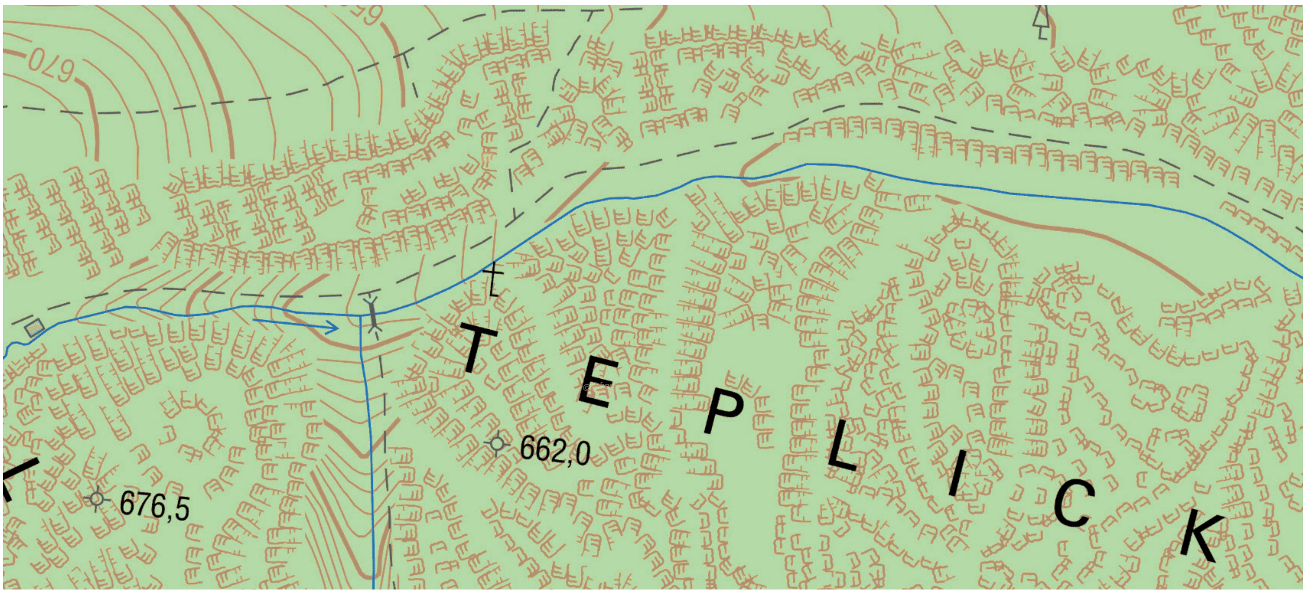

Fig. 7 Digital rock drawing for a complicated sandstone relief. Map taken from Geoportal ČÚZK, © ČÚZK.

monotonous structure of long lower lines can be mitigated by adding more horizontal rows of upper symbols (cf. Figure 6, bottom). This breaks the undesired uniformity of the representation, but also evokes unrealistic terracing of the cliff, which can lead to a misinterpretation of the relief form.

For the cases mentioned above, in particular, the described solution does not reach the clarity and beauty of classic, hand-drawn rock portrayal for obvious reasons; drawing is too stylised and fades out the detailed information about the structure of a rock, as sometimes expressed in ZM 10.

Another disadvantage is in regards to the portrayal of rugged sandstone landscapes with high, steep, almost vertical and sometimes overhanging rock escarpments, bizarre-shaped pillars and needles, narrow and hardly accessible gorges, as well as wildly-jagged plateaus. The main challenge for the cartographer is the predominant vertical dimension of sandstone objects, which leaves little space for drawing even a dominant feature in a map, as its size in the horizontal plane is insignificant. The described method requires at least the placement of upper symbols, which often results in disorganised placement and orientation (cf. Figure 7). The overall impression of such work is a formless drawing that lacks any information. From a local point of view, this problem becomes more serious if we consider the fact that sandstones are a predominant type of rocky relief in the Czech Republic. The northern portion of the country occupies a major part of the Bohemian Cretaceous Basin which also extends partly into Poland and Germany, and is probably the most extensive sandstone area in Europe (Härtel 2007).

4. Conclusion

This article presented a local method of digital cliff drawing, developed and used by the Czech Land Survey Office, including its historical roots and the general principles and guidelines for its application. Although the result is very schematic, this method can bring to a map reader extra information about the morphology of a rock formation. A cartographer may not require any special artistic skills to create the described type of a digital cliff drawing; however, the process of filling a polygon with hachures based on the rules described above is quite time-consuming. On the other hand, the individual steps seem to be clear and simple enough to be algorithmized. Thus, the automation of this process will be the subject of the author's further research. The author hopes that this article contributes somewhat to improvements in the depiction of rocky terrains, often expressed poorly in contemporary digital maps.

Acknowledgements

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Author's Note

Significant parts of this article were presented at the 26th International Cartographic Conference in Dresden, Germany, and published in the conference proceedings. This article is an extension of the conference publications, and is more analytically-oriented, serving as a necessary precursor to the automation of the entire process. Style files for ArcGIS for Desktop can be downloaded from: http://goo.gl/VkjuHz.

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RESUMÉ

Znázorňování skal na českých digitálních topografických mapách: současný stav a historické souvislosti

Článek podrobně představuje metodu pro znázorňování skal s využitím prostředků digitální kartografie, vyvinutou Zeměměřickým úřadem a používanou na topografických mapách jím vydávaných. Podstatou této metody je vyplňování půdorysu skalního útvaru liniemi, které mají připomínat stylizované skalní šrafy. Samotný popis metody byl vytvořen na základě analýzy práce kartografů a výsledné reprezentace na mapách. Představuje podrobný návod, ilustrovaný na řadě příkladů a lze podle něj uvedený způsob kresby bez problémů reprodukovat ve většině kartografického software. Souhrn používaných pravidel může také posloužit jako vhodný podklad pro automatizaci popisovaného způsobu znázornění skal, kterou kartografové dosud vytváří ručně, což je poměrně časově náročně. Součástí textu je i hodnocení této metody, kde jsou shrnuty její hlavní výhody a nevýhody. V úvodních částech článku je rovněž stručně popsána historie znázorňování skal v československých topografických mapách vydávaných po druhé světové válce, protože popisovaná metoda na ni v určitém smyslu navazuje.

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