

# Digital Rock Drawing on Czech Topographic Maps: Present and Future Development

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**Abstract.** Methods for digital cliff drawing, used in production of large-scale topographic maps by Land Survey Office of the Czech Republic, are discussed. This is done in the context of Czech natural conditions and history of mapping, which influenced contemporary digital processing to a great extent. A detailed description of digital rock portrayal is given. Experiments, regarding a possible future development of digital cliff drawing in sandstone landscapes, based on the use of airborne laser scanning data, are also introduced.

**Keywords:** digital cartography, digital cliff drawing, airborne laser scanning

## 1. Introduction

Production of well-made rock drawing has always been a challenge even for a skilled cartographer. Unlike alpine countries, the Czech Republic has hardly any high mountain peaks and other rock types cover only insignificant part of its territory. It may be the reason that cartographic portrayal of rocks has never been developed there to the high degree of precision seen for example in Swiss maps. Also many local practitioners consider traditional rock hachures to be a curiosity rather than a real problem. Despite these facts, we will introduce past, present and future of this phenomenon from the Czech point of view in this article briefly. Focus is put on large-scale topographic maps produced by the national authorities, especially by the Land Survey Office, which is the Czech national mapping agency.

Firstly, a short historical overview of rock drawing in modern large-scale Czech topographic maps will be mentioned. This is because its ideas were more or less used in contemporary digital processing, which will be de-

scribed more thoroughly in the next section. Finally, future development of digital rock portrayal will be discussed, particularly in the context of the new hypsographic mapping of the Czech Republic, performed by airborne laser scanning.

What should be mentioned is that the most common type of rock terrains in the Czech Republic are sandstone landscapes and outcrops on sides of valleys carved by bigger rivers. Especially the sandstone landscapes with rugged, high, steep, nearly vertical and sometimes overhanging rock escarpments, bizarre-shaped pillars and needles and narrow and hardly accessible gorges (see Fig. 1) represent an interesting task for cartographers and topographers. The situation is complicated by the fact, that these areas are covered with dense vegetation and the canopy allows photogrammetric processing only in limited cases. The main trouble for the cartographer is the predominant vertical dimension of sandstone objects. There is only little space left for drawing a feature in a map, as its size in the horizontal plane is insignificant. The northern part of the Czech Republic occupies the major part of the Bohemian Cretaceous Basin, probably the most extensive area of sandstones in Europe, which extends partly also to Poland and Germany (Härtel, 2007). Cartographic representation of this type of rock terrain is thus for the local map producers of the greatest importance.



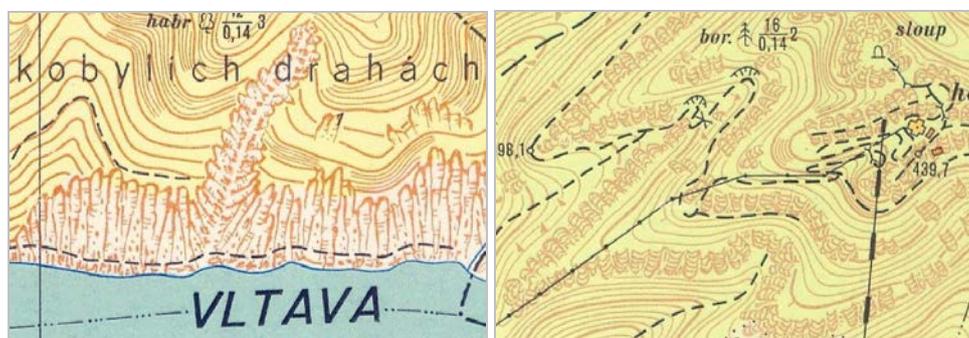
**Figure 1.** Photo and aerial image of Teplické skály (The Teplice Rocks), one of the most extensive and well-known sandstone formations in the Czech Republic. Photo taken by the author, aerial image © ČÚZK.

## 2. Short Historical Overview

To understand the reasons and background of contemporary digital rock processing, we have to describe the history of modern large-scale topographic mapping in the Czech Republic in short. The whole territory was mapped in large scale 1:10 000 between 1957 and 1971 (Čapek 1985). This

process resulted in military state map series (TM 10; abbreviation for *Topografická mapa*, Topographic map). Cartographical symbols in these maps were drawn according to Soviet instruction, in order to get unified maps for all the countries of the former Communist Bloc.

Drawing an image of a rock started with identification of main ridges and gully lines. From the ridges or from the top of a cliff, lines following the fall direction were mechanically and more or less regularly placed. These were shaded based on north-west illumination; on the light sides thinner, on the shadow sides thicker. Generally, they were also narrowing downwards. Fall lines were connected with horizontal strokes, forming together a structure resembling a ladder. These were numerous on the side facing away from the direction of light, on sunlit slopes only rare. In both cases, they were thicker close to the ridges / top of a cliff; the closer to the bottom of a cliff, the thinner and shorter and less frequently placed they should be (Kavan, 1965). An example is shown in Figure 2 (left side). Although the main goal of described representation was to express the structure and passability of rocky terrains, this assumption was hardly ever met. The main disadvantage lies in uniformly placed fall lines, which suppress possibility to express any specific feature of a certain rock and also evoke non-existing ridges. A significant difference between processed maps sheets, strongly depending on abilities of authors, should be also mentioned as another drawback (Čapek, 1973).

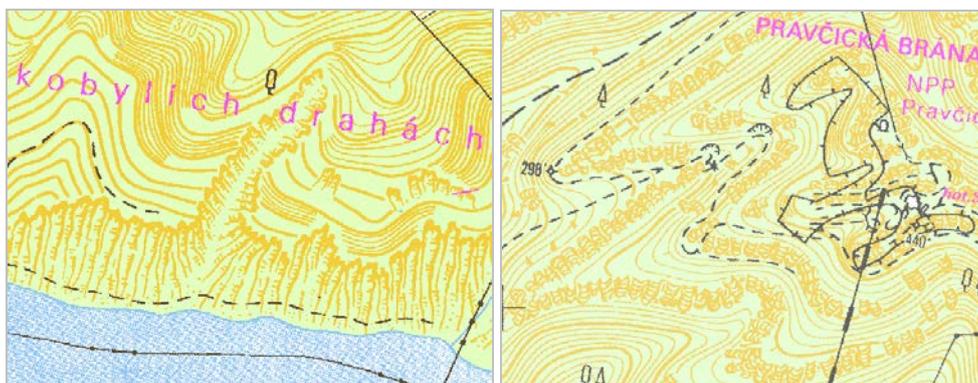


**Figure 2.** A typical rock representation in TM 10 (left side) and sandstone landscape on the same map (right side). Maps taken from Central Archives for Land Survey and Cadastre (*Ústřední archiv zeměměřictví a katastru*), © ČÚZK.

A typical cartographic portrayal of sandstone landscapes is based on sack-like symbols (see Fig. 2, right side). The symbol should represent a stylised sandstone rock seen from oblique view. These elements are ordered into rows, which represent a rock face. As it is usually nearly vertical and thus very narrow in a plan view, the area covered with symbols in a map overestimates the real size of a cliff. The gaps between elements express passages

between the walls (whereas their connection together means impassable terrain); more symbols above each other mean “terraced” escarpments separated from each other by a normal (i.e. non-rocky) ground. The size of symbol can be in some cases interpreted as a relative height of a cliff. However, representing more rugged sandstone relief accurately using *only* these symbols is a pipe dream, resulting in a jumble of strokes and circles.

The army stopped updating TM 10 later and after 1968, these maps served as basis for the civil national map series. The first edition of large-scale topographic maps in scale 1:10,000 (ZM 10; abbreviation for *Základní mapa*, Base map) was published between 1971 and 1988 (4,533 sheets in total). These maps were regularly updated until the mid-1990s. Although the map content was reduced, cartographic portrayal of rock remained almost the same (cf. Fig. 3), suffering the same disadvantages as mentioned above.



**Figure 3.** The same areas as in the Figure 1 in ZM 10. Maps taken from Central Archives for Land Survey and Cadastre (*Ústřední archiv zeměměřictví a katastru*), © ČÚZK.

### 3. Digital Processing

Digital processing of Czech topographical maps started with scanning and georeferencing of printing masters of the latest edition of ZM 10. Large scale digital topographic database, called ZABAGED® (acronym for *Základní báze geografických dat*, Fundamental Base of Geographic Data), was based on vectorization of these maps. Work on ZABAGED® started in 1995 and was mostly finished in 2001, definitely in 2004. Since 2001, this database is regularly updated, using orthophotos, field work and external data. The rocks are represented as polygons; their total count exceeds 40,000. These originate from outline of hachured areas in ZM 10 and were made more accurate where possible by topographers.

Based on ZABAGED<sup>®</sup>, the basemaps in scale 1:10,000 were gradually created using digital technology since 2001. Last sheet of the first digital edition was completed in 2006 and since then the updates are made continuously. While processing the map, the cartographer had to fill a polygon from ZABAGED<sup>®</sup> with stylised hachures. For this purpose, several symbols are combined to achieve desired results (see Fig. 4).



**Figure 4.** Anatomy of digital rock drawing in digital edition of ZM 10: symbols used for drawing stylised hachures. In the first row from the left: symbols for a single rock, symbols for a single sandstone rock, symbols for upper part of a rock (narrow and wide variant). In the second row symbol for lower part of a cliff. Taken from legend of topographic maps produced by Land Survey Office, © ČÚZK.

Firstly, the symbols for a single rock were created. It resembles a stylised hachure. Two types of symbols were used, one for sandstone rocks (more rounded) and the other for other rock types. The notes from topographers distinguished them. In praxis this was not done quite consistently.

From these “base cells”, several lines were derived. The first consist of repeated symbols put sequentially like pearls on a necklace (although in slang often called “cartridge belts”). The second type included transitional strokes between the symbols, which helped to avoid undesired regularity to some extent. Variants for wide and narrow rock exist. When filling a polygon, these lines were drawn along upper edges.

Finally, the line for depicting lower part of a rock was utilised. It has short transverse strokes, irregularly distributed. These lines were drawn to fill the part of polygon, which was not covered by the previous ones and exactly met the first ones. This was used in case of larger (and especially wider) polygons. Typical representations of various rock terrains, created with the use of these lines, are shown in the Figure 5.

Processing data from ZABAGED<sup>®</sup> for the first digital edition, no automation was used and all lines were drawn by operators. As during vectorization, no details inside rocky areas (e.g. ridges or upper edges) were captured, the orientation of hachures needed to be inferred from the original analogue ZM 10. In case of more complicated shapes, the cartographer had to use these lines for creating a ridge or a valley (as in Figure 5 in the first example). For the next edition, data was adapted from the previous one and only

the minor changes were made (based on update of polygons in ZABAGED®).



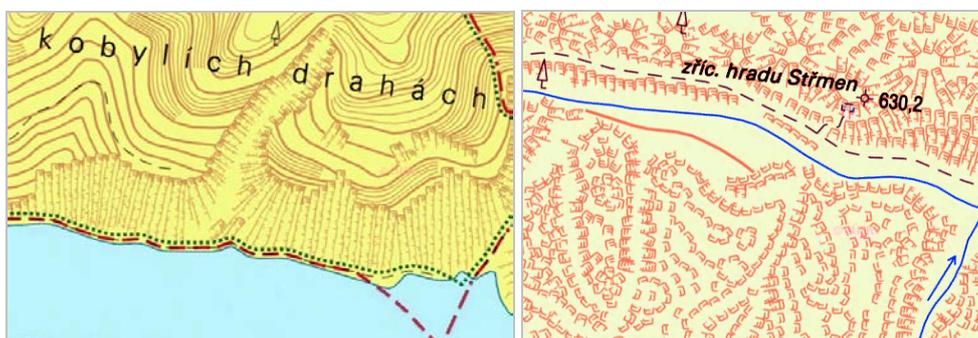
**Figure 5.** Examples of using combination of lines in praxis. Each pair shows on the left side geometry from ZABAGED® and in red and blue the lines and points drawn by cartographer; on the right the result for digital edition of ZM 10. Data ZABAGED® and maps taken from Geoportal ČÚZK, © ČÚZK.

A very similar approach for rock portrayal is used in the base map in scale 1:25,000. For the scales 1:50,000 and 1:100,000 there exists only lines for depiction of upper edges in various widths, i.e. lines for finishing lower part of a rock are not used here. Point symbols that represent a single cell are used more often in these maps. At scale 1:200,000 there is only one type of line for upper edges used.

Between 2001 and 2010, the digital processing was carried out using MicroStation and MGE. Since 2010 are maps produced in a new technological line called IS SMD (abbreviation from *Informační systém státního mapového díla*, Information System of National Map Series) based on ESRI software, which expedited and simplified map production. All the user lines for filling of polygons were migrated from MicroStation to ArcGIS, keeping the symbology almost the same.

Although described solution does not reach the clarity and beauty of the hand-drawn rock portrayal, its production is by far not so time-consuming. For small rocky outcrops, this method is quite appealing and showing almost the same information as stylised hachures in the analogue ZM 10. Pure vector processing without the need to combine with raster image can be considered as another advantage. Despite higher level of stylisation, it is visually better than simple filling with a regular (or irregular) pattern, so often visible in contemporary geoportals and poor digital maps. However, it is quite unsatisfactory for bigger polygons and / or more complicated shapes inside. The limits are evident: drawing is too stylised and fades out

the information about structure of rock, which sometimes was in ZM 10 expressed (see Fig. 6).



**Figure 6.** Digital rock drawing for large polygons (left side) and for a complicated sandstone relief (right side). Maps taken from Geoportál ČÚZK, © ČÚZK.

#### 4. Future Development

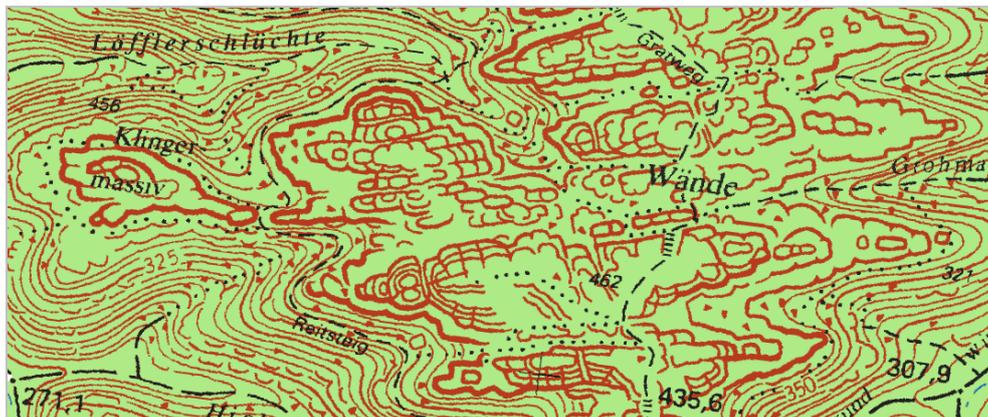
From the facts mentioned above, there is evidently some space for enhancement of rock drawing in the Czech topographic maps. The new impulse for discussion these issues arise in connection with a new project of mapping hypsography of the Czech Republic using airborne laser scanning, which started by 2009. Three state agencies cooperate on it: the Czech Office for Surveying, Mapping and Cadastre (ČÚZK), the Ministry of Agriculture, and the Ministry of Defense (Brázdil, 2009). The project has numerous outcomes, but to the cartography is DMR 5G (abbreviation for *Digitální model reliéfu 5. generace*, Fifth generation digital terrain model) of greatest importance. It has the form of triangular irregular network (TIN), semi-automatically derived from the point cloud with average density about 1.5 points per sq. m, with a complete standard elevation error of 0.18 m in open terrain and 0.30 m in forested terrain. These parameters allow mapping of rocky terrains to unprecedented detail, never reached before. Innovations of rock representation also take the feedback from map users into account, as they point out that contemporary too stylised rock depiction is inadequate for their purposes.

For future development, a thorough inspection of work concerning rocks representation and digital cartography was carried out. Although this is a not very active area of cartographic research, digital cliff drawing has been already studied, especially at ETH Zürich. The pioneer works in this field are summarised in Hurni & Dahinden & Hutzler (2001). The article contains in-depth description of digital ridge-line representation and implementation of shadow hachures in Swiss style. Further studies of different

aspects of digital cliff drawing were introduced (Dahinden & Hurni, 2007; Gilgen, 2007; Gilgen & Jenny, 2010).

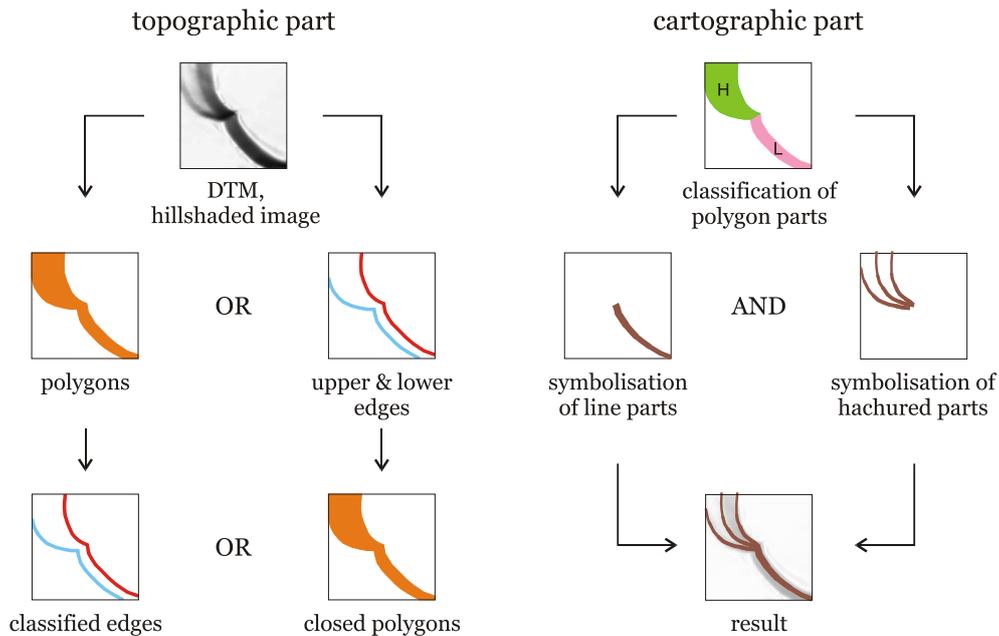
Also articles from authors outside Switzerland should be mentioned: Gondol & Le Bris & Lecordix (2008), focused on automation, and Yang & Guo & Shen (2009), whose results are a bit closer to the Czech style representation. Also the research regarding hachures in general are particularly useful; from these Regnaud & Mackaness & Hart (2002) can be noticed. Most of these papers aim to design of representation of large rock masses in the high mountains and thus are applicable to the sandstone landscapes to a limited extent only. From this point of view, an older work (Ullrich, 1969) is noteworthy, even if it does not deal with digital cartography at all.

His method was designed especially for steep escarpments of sandstone landscapes and utilised in topographical maps of Saxony (see Fig. 7). In general, rock formations are represented with lines, whose width varies according to their relative height following the rule the higher, the thicker. It lets enough space in the map to express detail of sandstone relief (e.g. rock pillars as closed lines, passages as gaps between lines etc.) For those cliffs that are too wide to be represented by a single line, the hachures in the style similar to TM 10 can be used (see Fig. 7, at the bottom part). Clarity of the map image and also relatively simple producing without need of experienced artists are the main advantages of this method. As a drawback, these rock "contours" can be confused with contour lines. This approach is used in contemporary large-scale Saxon topographic maps. The lines were re-drawn digitally from original analogue sources.



**Figure 7.** Contour method used in topographic map of Saxony in scale 1:10,000. © Staatsbetrieb Geobasisinformation und Vermessung Sachsen. Raster image retrieved from WMS of Landesvermessungsamt Sachsen.

Experiments regarding this method, digital cartography and laser scanning data have been carried out (Lysák, 2010). The focus is put on high degree of automation, in order to require as little manpower as possible (although human interaction is often inevitable). Key steps of experiments are described briefly. The scheme of the whole process is in Fig. 8.



**Figure 8.** Scheme of a proposed processing from DTM to cartographic representation.

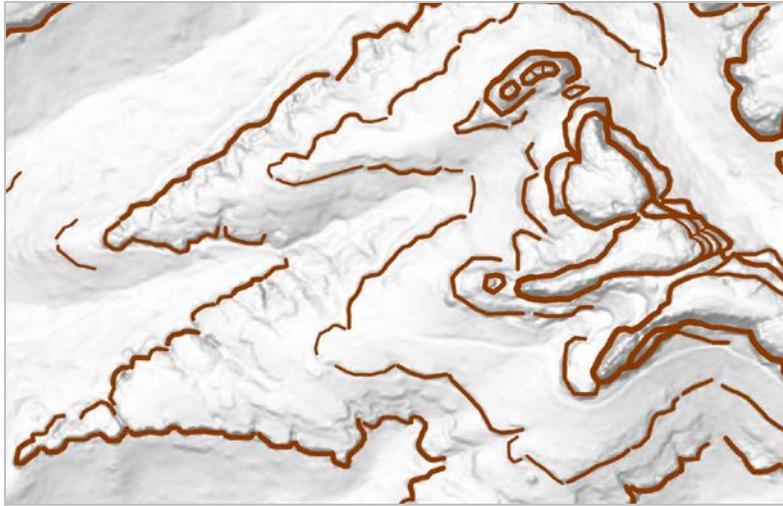
**Detection of rock walls.** As polygons from ZABAGED® are too exaggerated and not-well positioned (compared to precision and detail of models from airborne laser scanning data), rocky terrain for cartographic symbolisation needs to be extracted / refined first. Delineation of break-lines in a sandstone relief using digital image filtering (high pass and morphological filters) is described in Csaplovics & Naumann & Wagenknecht (2001). Combination of slope, semi-automatically extracted terrain break lines, manual editing with the use of hillshaded DEM and other external sources (e.g. early topographic maps mentioned in the first section or rock climbing guidebooks) seem to be useful. Orthophotos have only a limited usability, as the most rock outcrops is hidden under the canopy. This is a task more likely for a topographer rather than for a cartographer, but essential for further processing. The output of this phase are polygons, in sandstone areas with a typical elongated shape, or set of correctly oriented upper and lower edges.

**Classification of lines forming outline of a rock polygon.** The aim of this task is to distinguish between upper and lower edges. This can be done automatically using algorithms from computational geometry, comparing position of fall vector with a single line segment. Only minor manual corrections are needed. Several approaches to this task have been tested: classifying outline of a polygon, forming a closed polygon from digitized upper and lower edges, checking of correct orientation of upper and lower edges, checking for topological errors. The classification is a key feature for further cartographic processing.

**Design of appropriate means of map representation.** For each polygon or its part, it has to be decided whether single line or hachures will be used. This depends on “width” of a polygon, i.e. narrow polygons will be represented with lines, the wider ones with hachures. There are two thresholds used to keep the symbology more coherent. One threshold represents maximal width of a polygon that can be symbolised with a line; the second represents a minimal width of a polygon to be filled with hachures. The former value is less than the latter. Minimal length of sections for a certain type of symbolisation also has to be met. If not, these parts will be eliminated and get the same type of symbolisation as their neighbours.

**Determination of relative heights of walls.** In this part, height difference between upper and lower edge are computed. The key problem is to find corresponding pairs of points. As concerning parts of polygons are narrow, the solution is based on measuring a profile corresponding to the centerline between upper and lower edges. The centerline is part of medial axis of a polygon, found using 2D Delauney triangulation. Relative heights are further classified into categories. Each category has corresponding line width for its cartographic representation.

**Drawing shaded hachures for wide objects,** i.e. for those, which cannot be depicted by a line. Firstly, objects must be split into smaller parts according to breaklines (mainly the significant cracks). For each part, illumination model is computed separately. Hachures are drawn as horizontal lines, forming fluent transition between upper and lower edge. Their spacing corresponds to the local changes of slope. Finally, line parts are shaded according to northwest illumination, taking into account values calculated for the whole part as well as local position of each part of a single hachure. Illumination model from Hurni & Dahinden & Hutzler (2001) is used. Outputs of this phase are polygons, simulating variable widths of strokes. The main advantage is that resulting layer can be symbolised easily without setting properties of lines and transition between hachures is controlled easily. However, refinement of such representation requires total recalculation of polygons.



**Figure 9.** Results of processing of a small portion of sandstone relief in the National park of Bohemian Switzerland. Hillshaded image with rock contours and hachures, without contour lines. DTM © Technische Universität Dresden, Institut für Photogrammetrie und Fernerkundung (data from the project INTERREG IIIA "Geoinformation Networks for the Crossborder National Park Region Saxon-Bohemian Switzerland" from April 2005, kindly provided by the Bohemian Switzerland National Park Administration, as DMR 5G has been not yet available for this locality).

Preliminary results of the process for a real terrain after manual editing are shown in Fig. 9. We showed only key ideas of proposed processing. More testing is needed and a lot of must be solved to make this procedure really usable / operational. Other than sandstone terrain must be also considered.

## 5. Conclusion

In the previous lines, we tried to show one of interesting problems, which the local Czech cartographers face to, including its solution and future perspectives. Despite all its drawbacks, it is usable in most cases and appears to be a good compromise between processing time and graphical quality of result. Described digital portrayal and proposed enhancement are obviously imperfect in comparison with glamorous hachures created by the skilled mountain cartographers, but that is not where we primarily head to. Different type of relief would seem to require dissimilar means of map representation. Although new technologies are without any doubts extremely useful for digital cliff drawing, there is still a long way to a fully automated and

operational solution. Digital cliff drawing, with the focus put on sandstone landscapes, remains a subject of authors' further research.

## References

- Brázdil K (2009) Projekt tvorby nového výškopisu území České republiky. *Geodetický a kartografický obzor*, 55, 7: 145–151.
- Csaplovics E, Naumann K, Wagenknecht S (2003) Beiträge zur Extraktion von Felskanten aus Airborne Laser Scanner Daten am Beispiel der Eibsandsteinformationen im Nationalpark Sächsische Schweiz. *Photogrammetrie, Fernerkundung, Geoinformation*, 2: 105-114.
- Čapek R (1973) *Znázorňování skal*. Rigorous thesis. Praha.
- Čapek R. (1985) Československé topografické mapy. *Acta Universitatis Carolinae, Geographica*, 20: 33-47
- Dahinden T, Hurni L (2007) Development and quality assessment of analytical rock drawings. In *Proceedings of the 8th meeting of the ICA Commission on Mountain Cartography*, Moscow, Russia.
- Gilgen J (2007) Aerial Photos + Photogrammetric Plot = swisstopo's Rock Representation: Caricatured Mountains?. *Mountain Mapping and Visualisation*, 63.
- Gilgen J, Jenny B (2010) Digital Rock and Scree Drawing in Vector and Raster Mode. *Geographia Technica, Special Issue*, 12: 24-31.
- Gondol L, Le Bris A, Lecordix F (2007) Cartography of high mountain areas, testing of a new digital cliff drawing method. In *Proc. 6th ICA Mountain Cartography Workshop*, pages 71–80, 2008.
- Härtel H et al. (2007) *Sandstone Landscapes*. Academia, Praha.
- Hurni L, Dahinden T, Hutzler E (2001) Digital Cliff Drawing for Topographic Maps: Traditional Representations by Means of New Technologies. *Cartographica*, 38, 1&2: 55-65.
- Kavan G (1965) Kresba skal, ssutí a ledovců. *Vojenský topografický obzor*, 3, 2: 203-206.
- Lysák J (2010) Skalní útvary v kartografii a GIS. *Geodetický a kartografický obzor*, 56/98, 3: 52-58.
- Regnauld N, Mackaness W A, Hart G (2002) Automated relief representation for visualisation of archaeological monuments and other anthropogenic forms. *Computers, Environment and Urban Systems*, 26: 219–239
- Ullrich K (1969) Die Kartographische Darstellung der Felsen des Elbsandsteingebirges. *Vermessungstechnik* 17, 10: 388–395.
- Yang N, Guo Q, Shen D (2009) Automatic Modeling of Cliff Symbol in 3D Topographic Map. *Proc. SPIE 7492, International Symposium on Spatial Analysis, Spatial-Temporal Data Modeling, and Data Mining*; doi:10.1117/12.837760