Existing rock representation in topographic maps and their suitability for digital generation

Tobias Dahinden

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Abstract

The representation of vertical rock faces and unvegetated rocky outcrops are one of the most difficult cartographic endeavors. This reputation has it's origins in the art of hand drawn rock hachures, which is a style used by the Swiss Federal Office of Topography. Hand drawn rock hachures are an expensive method to implement and can only be produced by specialists [Hurni, 1995].

Cartographers must use graphical tricks to give rock faces depicted on a map equivalent visual importance, as compared when an observer views the same feature in the field [Schrader, 1911].

1 Different styles of rock representation

The depiction of rock can be achieved by contour lines, colour tones (oblique hill shading), ridge lines, hachures, hairlines and orthophotos. Many combinations of the former elements are typically found on maps in addition to varying the proportions of ridge lines and hachures.

It is useful to group the different rock representation methods. When the groups were defined we looked at different drawings with the view of digital production.

Two main groups were formed according to the amount of slope information, the key criteria being the number of contour lines.

1. none of few lines
2. many contour lines

Rock drawing with none or with few contour lines

Representations belonging to this group usually contained slope information, as indicated by the direction of hachures or by the graytone relief. The density of slope information is not as high as the following group.

Historic cliff drawings

In maps published in early modern times mountains were shown in an upright projection, similar in appearance to a molehill, see figure 1 and figure 2.

In 1706 Johann Jacob Scheuchzer produced a sketch of lake Uri (figure 3), where the observer views the lake from a birds eye perspective but the cliffs remain in an upright projection. The map also shows many details of the cliffs, faults and nappes.

In the 19th century mountains were drawn in orthographic projection. Hachures were used to show the elevation as well as slope, light direction and rock depiction. A historic orthographic projection is shown in figure 4. The map represents rock hachures, although it is difficult to see the difference between slope and rock hachures.

Hachures

Many maps use hachures for rock representation. Although there are rules governing how they should be drawn, each cartographer has a different individual style. Therefore we have subdivided this group into three subgroups: fill hachures, shadow hachures and geometric hachures.

Figure 1: Mountains depicted as Molehills in the map Canton Unterwalden, drawn by G.Walser, 1767. Source: [Kraiszl, 1930]

Figure 2: A post-modern version of mountains depicted as molehills. Source: http://www.spiegel.de/almanach/laender/0 1518 CHE 00.html

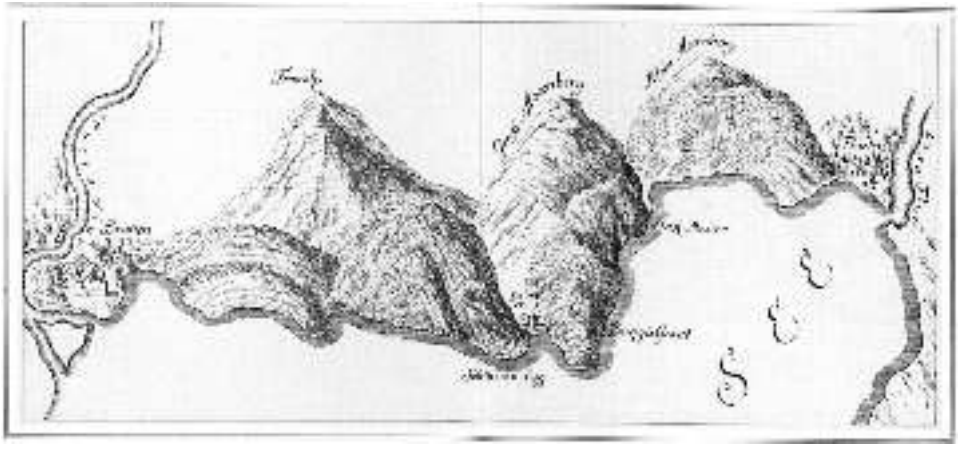

Figure 3: A section of Scheuchzers map of lake of Uri. Source: [Kraiszl, 1930]

Figure 4: Rock hachures as drawn in the early 19th century by Roverea and Grunder. Source: [Kraiszl, 1930]

Fill hachures style Rocks are drawn with a thin and simple fill hachure. Normally the hachures are short, bent but unshaken lines. Ridge lines are relatively thicker than the fill hachures and intersect them orthogonally. Ridge lines are always represented by a stroke.

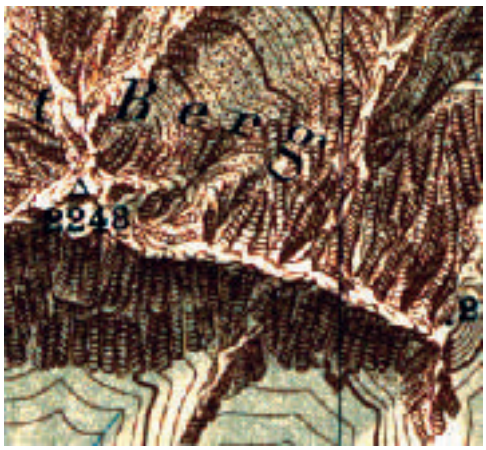

Figure 5: Fill hachures style, as drawn by Geyer. Source: Mittenwald map of the ”topographisches Bureau des K.B. Generalstabes”, Austria (1904)

Shadow hachures style Hachures and ridges show the influence of a virtual light source, which means they are sometimes not represented. The contrast between hachures, ridges and background is of major importance. The hachures are often drawn slightly staggered and bent.

Shadow hachures style is one of the most common styles used on Swiss maps. Cartographers who have used this style are: Stengel, Bétemps, Leuzinger (see figure 7), Imfeld, Becker, Imhof, Oberli, Nelles, Mi Desheng, Gilgen, ...

Geometric hachures style In this style hachures are straight and not shaken or they represent small basic shapes such as rhomboids and triangles. They are not

Figure 6: Fill hachures style, as drawn by Yates. Source: Karakoram Himalaya map of the Royal Geographical Society, 1939.

Figure 7: Shadow hachures style, as drawn by Leuzinger in 1893. Source: Map of Albulapass, Swiss Federal Office of Topography.

exact in their form because they are mostly drawn by hand [Pla, 1998].

This style is used in maps from the Institut Cartogràphic de Catalunya, Spain (see figure 8).

Ridges

Ridges are represented by strokes which vary in thickness. The rocky area is filled with a single colour, which can be the background colour of the map (e.g. taken from the relief).

This style is common in maps from Austria. Another example is the map of Pik Lenin, Russia [Hauser, 1998] or figure 9.

Colour tones

On some maps special colours, textures and reliefs are used for rock representation (see figure 10, 11 and 12). Colours tones can have the same effect as hachures if the map is viewed from a distance. The boundaries and the ridges of the cliffs are not sharp, therefore this style should only be used for synoptic maps.

Figure 8: A map with hachures in 'geometric style'. Source: Institut Cartogràpic de Catalunya, Spain, 2001.

Figure 9: A test map with ridge lines from the Swiss Federal Office of Topography of 1926.

Figure 10: Map of the US National Park Service of 1972 (Canyonlands National Park). Note the the rocks are depicted in the same colours as the relief.

Figure 11: Rocks and relief in the same colour (the large dark areas are rocks). Source: Mapa de Tenerife; Anselmo J.Benitez, San Francisco,6y8, Santa Cruz de Tenerife; (no year).

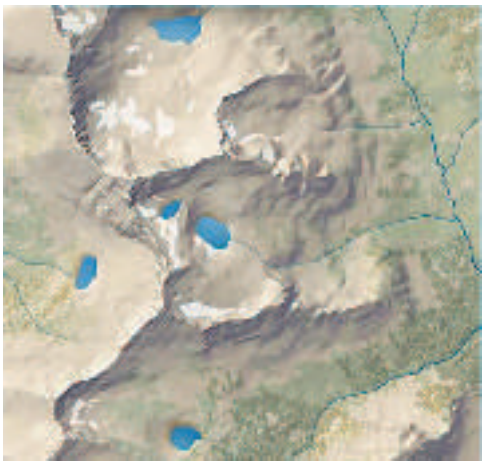

Figure 12: Map with textured rock areas by Tom Patterson. The final version has contour lines [Patterson, 2002].

Figure 13: Rock representation with few contour lines and colour tones. A test map of Dent du Midi, Swiss Federal Office of Topography, 1938.

Rock drawing with contour lines

Rocks faces are often very steep and hence contour lines are very closely spaced and may intersect. The result is an almost unreadable image. It is normal therefore to remove some lines in this group. The difference to the former group (none or few contour lines group) is the cartographer has tried to fill the rocky area with regular equidistant contour lines. In the former group, the equidistant contour lines are reduced by default.

Contour lines only

It is possible to represent rock areas with contour lines only if the contour lines have a separate colour for rocky areas. Thus it is difficult to recognize the structure of the rocks. Figure 16 shows a test example with contour lines only.

Figure 14: Rock representation with contour lines only. Part of a test map of Dent du Midi, Swiss Federal Office of Topography, 1937.

Hachures

There are two kinds of hachures: fill hachures and slope hachures.

Shadow hachures style Here hachures and ridges look like the shadow hachures with none or few contour lines but are combined with contour lines.

The shadow hachures style is seldom used in maps. An example is shown in figure 15. Several test maps, e.g. [Imhof, 1965] Table 3 and figure 16. The rock drawing of Ebster (see figure 17) can also be put into this group, although he used hairlines instead of hachures[1].

Slope hachures style In this style the contour lines show the main information. If the rock faces are so steep that the contour lines become too closely spread the lines are replaced by vertical hachures. Hachures in flat areas can be used to increase

[1] From a programmers view the difference between hachures and hairlines is difference in stroke width.

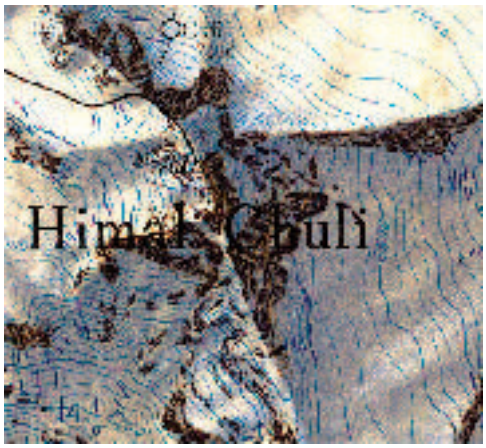

Figure 15: Rock representation with hachures and red contour lines. Source: Himal Chuli map, Keio University, Alpine Club, Japan, 1964.

Figure 16: Rock representation with contour lines and shadow hachures. Part of a test map of Dent du Midi, Swiss Federal Office of Topography, 1938.

Figure 17: Rock representation by Ebster. Source: Alpenvereinskarte Geigenkamm, 1953.

the effect of striation. Ridges and edges are normally drawn with thin lines and a break in the contour lines.

The slope hachures style was originally used in the map of “Glärnisch” by [Blumer, 1954] which was published in 1937 by “Kümmerly und Frey”. The style has been used and adapted since then by Brandstätter (see figure 18) and his successors Moser, Geiss and Fischer (all Cartographers of Alpenverein).

Figure 18: Rock representation after Brandstätter. Source: Alpenvereinskarte Steinernes Meer, 1969.

Ridges

In this style rocks are represented by their ridge lines. Behind the ridge lines there is often a relief or a background colour.

This style is used in test maps of the Swiss Federal Office of Topography and by [Hurni, 1989], (see figure 19 and 20). Maps of Aschenbrenner and Krottendorfer (Institute of Geography, University of Salzburg) such as ”Hohe Riffel” (1993) and ”Alpinzenturm Rudolfshütte” (1993) also use the ridges style.

Figure 19: Rock representation with ridges and contour lines. Part of a test map of Dent du Midi, Swiss Federal Office of Topography, 1938.

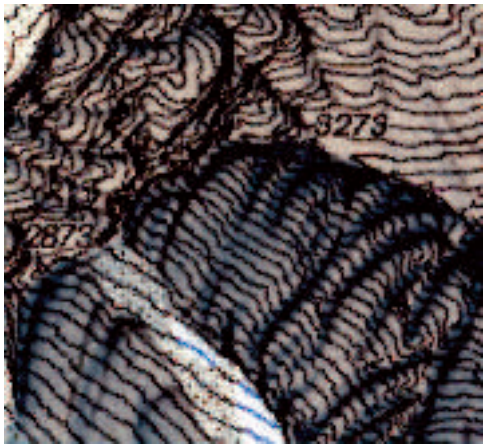

Figure 20: Rock representation with ridges and contour lines by [Hurni, 1989].

Colour tones

This style contains rock representation with special colours, textures and hill shading. It is equivalent to the colour tones without contour lines.

The style is often used in synoptic maps such as that shown in figure 21, although sometimes it is difficult to recognize the rock area, e.g. see figure 22. Some tests were made by [Finsterwalder, 1925] and [Finsterwalder, 1928] (see figure 23 for examples). Another test example from the Swiss Federal Office of Topography is shown in figure 24.

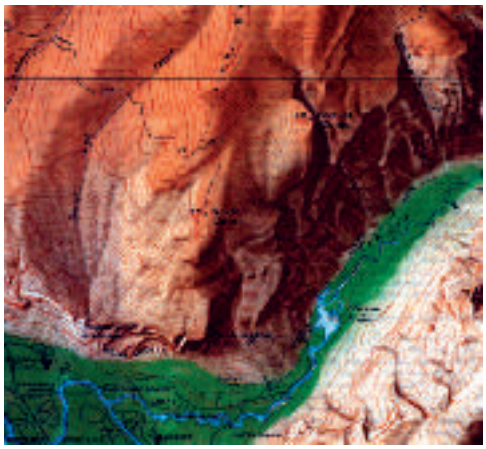

Figure 21: Map of Yosemite Valley, US Department of the Interior, Geological Survey, 1938 and 1949.

Orthophotos

Orthophotomaps usually have contour lines, but for rock representation they have no other information (see e.g. figure 25). In some orthophotomaps rock is represented by symbolization, although it is rarely used. An example is shown in figure 26. In this example ridges have been combined with the orthophoto.

Figure 22: A test of a very simple rock representation (”Fels in reiner Kurvendarstellung”). Original scale 1:10 000, 1922. Source: [Kraiszl, 1930].

Figure 23: Grey rock area. The steeper the rock the darker the colour. Source: Alpenvereinskarte Loferer Steinberge, wissenschaftliche Ausgabe [Finsterwalder, 1925].

Figure 24: Rock representation with contour lines and a colour tone. Part of a test map of Dent du Midi, Swiss Federal Office of Topography, 1938.

Figure 25: Orthophotomap of Monte Leone. Source: [Hurni, 1989].

Figure 26: Orthophotomap with ridge lines, drawn by Hölbling. Source: [Pillewizer, 1976].

A general classification

The grouping of rock drawings will never be complete because the representation of rock can be individualistic. We have attempted to group all known representations. Figure 27 shows an overview of the groupings we made. Sometimes it was difficult to put a map into one single group, e.g. the Russian map of Switzerland 1:50 000 has a mix of fill and shadow hachures. Some Chinese maps[2] have used mainly ridge lines but have shadow hachures as well.

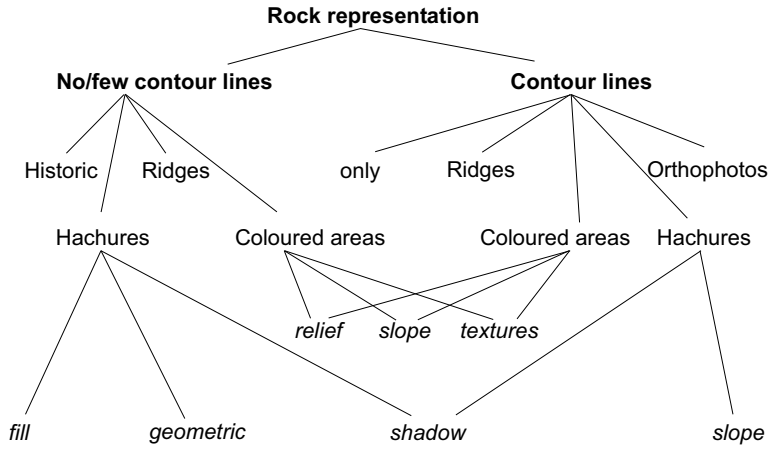

Figure 27: Different styles of rock representation.

A possible grouping order can also be determined by light direction and the use

[2]Such as the Mount Qomolangma (Mt. Everest) map 1:100 000 by Mi Desheng, Chinese Academy of Sciences

of colours. Further the group 'shadow hachures' can be subdivided because there are many maps using this style.

Several styles presented in this paper were only produced for test purposes. Such test maps are often made by researchers and not by cartographers[3], e.g. [Finsterwalder, 1928]. They are therefore not comparable to other maps, because of the following reasons:

- the graphical quality of a researchers work is not equivalent to a cartographers [Imhof, 1938],
- researchers places emotions in their style [Arnberger, 1970],
- researcher draw on their own style, whereas a the cartographer must reproduce the style of someone else, e.g. compare [Finsterwalder, 1925] to [Gilgen, 1998],
- every style has made an evolution[4] [Finsterwalder, 1928], in a test map this evolution is missing.

2 Effectiveness

It is interesting to consider which style is the most effective. From this we can determine a representation that could be generated digitally.

An effective rock representation is (amongst other things) "gute Lesbarkeit, Vollständigkeit, geschmackvolles Äusseres, [...] anschaulich, für jedermann lesbar" [Finsterwalder, 1925] page 232. The former translates into English as: 'readable, completeness, tasteful appearance, [...] descriptive, readable for everybody'.

To say which representation is the most effective we must measure and order the values of the terms. A simple measurement scale is to assign a true or false value.

Out of these expressions completeness could be measurable but only if there is an idea what completeness means. Unfortunately no rules exist concerning completeness. Several rules exists for readability. One such rule is to have enough contrast between elements, e.g. [Räber, Jenny, 2001]. But it's not not really measurable if this rules are fullfilled. For the other parameters we have no rules. For example in considering clearness, light direction will influence clearness. For [Brunner, 1998] a change in light direction is not clear enough[5]. Finsterwalder prefers an orthogonal light source. In his opinion it is easier to see how steep a rock actually is (see [Arnberger, 1970] page 101).

[Brandstätter, 1983] wrote that his style is more accurate than the common shadow hachures style. There are several reasons why rock representations with none or few contour lines can be preferred to the group with contour lines in map production:

[3] Richard Finsterwalder called one of his test maps 'wissenschaftliche Karte'. This does not mean that a 'normal' map can't be used for research and that it was not done with the knowledge of research. But a 'normal' map is not cartographic research. Here [Imhof, 1938] is in error.

[4] An example of evolution is in 'slope hachures style' from Blumer, Brandstätter to Moser, Geiss and Fischer [Brunner, 2001].

[5] a view supported by the author of this paper.

- Information concerning height are sometimes not accurate enough to be able to draw contour lines.
- It is not required to produce a map that is more accurate (an increase in accuracy often results in cost [Ingensand, 1997]).
- The map can be more readable. This means the distance between the contour lines is too small [Brandstätter, 1983].
- Map users are not well trained in reading contour lines.

For the former we do not have an *a priori* rule to demonstrate which representation is more effective.

In fact there are no rules to indicate which presentations are more effective hence we cannot incorporate the different styles in an order.

3 Suitability of digital generation

Everything that can be drawn by hand can also be digitally drawn. The question is whether the costs for drawing are high or low. Four levels of costing are used to to group the representations. A representation can be assigned to a level if at least one of the following points is true.

1st level

- The representation can be drawn easily with standard graphic software.
- There is a full automatic software to produce this representation.

In this level costs are low.

2nd level

- The representation can be drawn with a special tool using standard graphic software.
- A semi-automatic software to produce this representation exists.
- A software extension (Plug-in) to produce the representation exists for a standard graphic software.

3rd level

- Partly drawable with standard graphic software
- The representation can be drawn with special tools or semi-automatic software, but needs post-editing.
- There is no special software but a clear description of how to paint (like a cookbook). Therefore software can be written.

4th level

- There is no software to produce this representation, this means they have to be drawn pixel by pixel
- The representation is painted by a specialist or artist using a high level of intuition. It is therefore difficult to write a software program.

In this level costs are high.

Examples

By comparing the rock representations with the former levels produce the results shown in table 1.

level	style	comment
1st	contour lines	simple Bezier curves
	coloured areas	very simple
	coloured relief	program 'shadow' [Hurni et al., 2001]
	orthophotos - without editing	a simple raster image
2nd	historic (molehill)	
	coloured textures	needs some experience
3rd	old style hachures	Plug-in [Hurni et al., 2001], needs edits
	ridge lines (partly)	Plug-in [Hurni et al., 2001], needs edits
4th	romantic hachures	partly solved [Hurni et al., 2001]
	geometric hachures	
	ridge lines	
	slope hachures	
	orthophotos - with editing	is an artists work

Table 1: Levels and styles

If representations are mixed, there is more work to do, therefore costs become higher. We counted the level of each part. E.g.:

- The costs of representation for figure 22 are: simple background colour and contour lines. This means we have twice the work of level 1.
- The representation of figure 2 has only molehills projections. Therefore we have the equivalent of level 2.
- The representation of figure 20 has contour lines and ridges. This results in a combined equivalence to level 1 and level 4.

Unfortunately values cannot simply be added because the levels are not linear in costs. But we can compare the representations at least in some parts.

4 Conclusions

Rock representation exist in different symbolization. These representations can be grouped in different styles. The most common style is rock representation with

shadow hachures.

Looking at the effectiveness we are not able to compare the representations because the principles for effectiveness are not measurable.

A possibility to group different rock representation styles is to determine how difficult it is to generate them digitally. The most common styles are rather difficult to generate.

References

[Arnberger, 1970] ARNBERGER, E. *Die Kartographie im Alpenverein*, Wissenschaftliches Alpenvereinsheft 22. Deutscher Alpenverein und Österreichischer Alpenverein, 1970. München und Innsbruck.

[Blumer, 1954] BLUMER, W. *Die Felsdarstellung mit Höhenkurven und Schraffen*. Die Alpen, p. 153–158, 1954. Bern.

[Brandstätter, 1983] BRANDSTÄTTER, L. *Gebirgskartographie*, Band 2 of *Die Kartographie und ihre Randgebiete, Enzyklopädie*. Erik Arnberger, 1983. Wien. 319 p.

[Brunner, 2001] BRUNNER, K. *Die Kartographie im Deutschen Alpenverein*. www.bauv.unibw-muenchen.de/institute/inst10/wwwSites/Kartographie/Professurseiten/PDF-Dateien/DAV-Kartographie.PDF, Mai 2001. München-Neubiberg. 11 p.

[Brunner, 1998] BRUNNER, K. *Kartographische Felsdarstellung unter besonderer Berücksichtigung der Alpenvereinskarten*. In: KRIZ, K., Editor, *Hochgebirgskartographie - Silveretta '98*, Wiener Schriften zur Geographie und Kartographie, p. 207–217. Institut für Geographie der Universität Wien, 1998.

[Finsterwalder, 1925] FINSTERWALDER, R. *Begleitworte zur Karte der Loferer Steinberge*. Zeitschrift des Deutschen und Österreichischen Alpenvereins, p. 225–232, 1925.

[Finsterwalder, 1928] FINSTERWALDER, R. *Neue Aufgaben der Kartographie*. Zeitschrift der Gesellschaft für Erdkunde zu Berlin, Sonderband, p. 447–458, 1928. Tafeln XXVI–XXXI. Berlin.

[Gilgen, 1998] GILGEN, J. *Felsdarstellung in den Landeskarten der Schweiz*. In: KRIZ, K., Editor, *Hochgebirgskartographie, Silvretta '98, High Mountain Cartography*, Band 11 of *Wiener Schriften zur Geographie und Kartographie*, p. 11–21. Institut für Geographie der Universität Wien, 1998.

[Hauser, 1998] HAUSER, M. *Kartenprojekte im Pamir und auf Kamtschatka*. In: KRIZ, K., Editor, *Hochgebirgskartographie, Silvretta '98, High Mountain Cartography*, Band 11 of *Wiener Schriften zur Geographie und Kartographie*, p. 11–21. Institut für Geographie der Universität Wien, 1998.

[Hurni, 1989] HURNI, L. *Verschiedene Felsdarstellungsarten für Gebirgskarten 1:25 000*. Diplomarbeit, Institut für Kartographie, Eidgenössische Technische Hochschule, Zürich, 1989. 23 p.

[Hurni, 1995] HURNI, L. *Modellhafte Arbeitsabläufe zur digitalen Erstellung von topographischen und geologischen Karten und dreidimensionalen Visualisierungen*. Dissertation, Institut für Kartographie, Eidgenössische Technische Hochschule, Zürich, Januar 1995. 190 p.

[Hurni et al., 2001] HURNI, L.; JENNY, B.; DAHINDEN, T.; HUTZLER, E. *Interactive Analytical Shading and Cliff Drawing: Advances in Digital Relief Presentation for Topographic Mountain Maps*. Vorabdruck, 8 p., 2001.

[Imhof, 1938] IMHOF, E. *Die Felsdarstellung auf Grund photogrammetrischer Aufnahmen*. In: *Comptes rendus du congrès internation de géographie Amsterdam*, 1, p. 117–121, 1938. Amsterdam.

[Imhof, 1965] IMHOF, E. *Kartographische Geländedarstellung*. Walter de Gruyter, 1965. Berlin. 425 p.

[Ingensand, 1997] INGENSAND, H. *Geodätische Messtechnik I + II*. ETH-Hönggerberg, Zürich, 1997. Vorlesungsskript.

[Kraiszl, 1930] KRAISZL, W. *Historische Entwicklung der Felsdarstellung auf Plänen und topographischen Karten unter besonderer Berücksichtigung schweizerischer Verhältnisse*. Schweizerische Zeitschrift für Vermessungswesen und Kulturtechnik, Heft 1 und 2, Januar 1930. Separatabdruck. 17 p.

[Patterson, 2002] PATTERSON, T. *Photo-realistic Map Design at the U.S. National Park Service*. In: PATTERSON, T., Editor, *Workshop of the Commission on High Mountain Cartography 2002*, Mai 2002. Mt. Hood, Oregan, USA.

[Pillewizer, 1976] PILLEWIZER, W. *Felsdarstellung aus Orthophotos*, Heft 9 of *Geowissenschaftliche Mitteilungen*. Studienrichtung Vermessungswesen Technische Universität Wien, Institut für Kartographie und Reproduktionstechnik, Wien, Österreich, Juni 1976. 81 p.

[Pla, 1998] PLA, M. *Experience in modelling and representing the relief at the Institut Cartogràfic de Catalunya*. In: KRIZ, K., Editor, *Hochgebirgskartographie, Silvretta '98, High Mountain Cartography*, Band 11 of *Wiener Schriften zur Geographie und Kartographie*, p. 11–21. Institut für Geographie der Universität Wien, 1998.

[Räber, Jenny, 2001] RÄBER, S.; JENNY, B. *Attraktive Webkarten - ein plädoyer für gute Kartengraphik*. In: ASCHE, H.; HERRMANN, C., Editoren, *Symposium Web.Mapping.2001*, p. III.1–III.25. Fachhochschule Karlsruhe, 2001.

[Schrader, 1911] SCHRADER, F. *Essai sur la représentation topographique du rocher*. La commission de topographie du Club Alpin Français, 30, rue du bac, Paris, 1911. 35 p.