

# Cartographic Mountain Relief Presentation

## 150 Years of Tradition and Progress at ETH Zurich

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### **Abstract**

*The aim of this paper is to present the building up of the tradition of relief depiction at ETH Zurich since the mid 19<sup>th</sup> century. It is a logical consequence of the early works of the professors Johannes Wild and Fridolin Becker, culminating in the leading cartographic works and theories of Eduard Imhof and Ernst Spiess in the 20<sup>th</sup> century. Using the example of the „Swiss Style Coloured Relief Shading“, this paper shows the development of a widely known cartographic methodology, its development throughout the years and the adaptation to modern technologies and demands.*

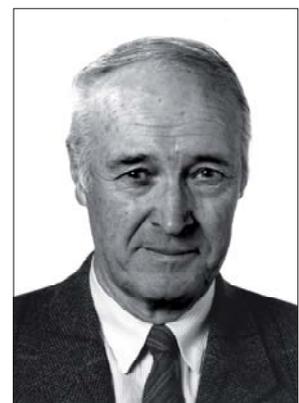
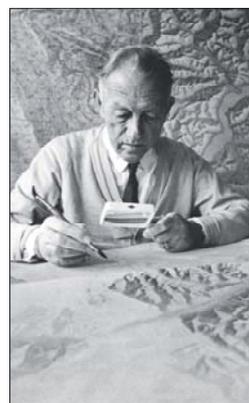
### **1. The political roots of cartography at ETH Zurich**

Following the Napoleonic occupation of Switzerland at the beginning of the 19<sup>th</sup> century, the country suffered from an increasing destabilisation. After 1813 the centralistic system was changed back into a decentralised, federalistic one, giving the Cantons more direct power. This finally culminated in the civil war between catholic and protestant cantons in 1847, which was actually the last war on Swiss territory. Due to the prudence and the tactical geniality of General Guillaume Henri Dufour, the catholic cantons were defeated

with a minimum of casualties. Nevertheless, a new political beginning was necessary and in 1848, the modern Swiss Confederation was founded, empowering on one hand the central government but also leaving well defined corrective measures to the cantons – a typical Swiss compromise.

Already in 1834, the same General Dufour was ordered by the “Tagsatzung”, the former Swiss government, to build up a new high-quality topographic map of Switzerland at the scale of 1:100,000. Gugerli (2005) interprets the role of that map as supportive of the “nation-building” of Switzerland. For the first time, the country as a whole was shown in a relatively large scale, with high geometric precision and in a well designed, comprehensible manner.

Another brick to this nation-building was the foundation of a polytechnical university, the Swiss Federal Institute of Technology (“Eidgenössische Technische Hochschule, ETH”) in Zurich in 1855. The technological progress and the needs for technical infrastructure such as railroads asked for specialists in engineering. Dufour already had an education as civil engineer from the “Ecole polytechnique” in Paris, which comprised also topographic compilation and depiction methods. The first professorship at ETH Zurich in that domain was also closely linked to civil engineering.



*Fig. 1: From left to right: Cartography professors at ETH Zurich: a) Johannes Wild (1814–1894, ETH 1855–1889); b) Fridolin Becker (1854–1922, ETH 1887–1921); c) Eduard Imhof (1895–1986, ETH 1922–1965); d) Ernst Spiess (\*1930, ETH 1964–1996)*

## 2. Wild and Becker – the beginning of cartography at ETH Zurich

Since the foundation of the Swiss Federal Institute of Technology in 1855, at least one chair was devoted to topography and/or cartography. The first professor of topography was Johannes Wild (Fig. 1a), who was among the first of about 45 professors and lecturers of the young ETH. Wild had an education in civil engineering and mapping from Munich and Vienna and had just finished the field work for his topographic map series 1:25,000 of the canton of Zurich, later known as the “Wild Map”. This map served as a cantonal base for the Dufour map and was one of the first multicoloured large-scale topographic maps with contour line depiction. Before, he was also involved in topographic and planning work for the first Swiss railroad lines between Zurich and Basel. In 1843, he produced an internationally renowned map of the Unteraar Glacier on which Louis Agassiz also based his research which finally led to the development of the ice age theory. Wild was assigned professor at ETH Zurich without having applied for the post, but finally accepted his designation.

Wild’s successor Fridolin Becker (Fig. 1b) published numerous maps covering areas in the Swiss Alps, but also abroad. He is considered one of the pioneers of relief depiction for topographical maps. The introduction of chromolithography in cartography in the second half of the 19<sup>th</sup> century allowed the introduction of continuous tone shadings in maps. In Switzerland, the Alpine Club published the first multicoloured relief maps which were further developed by Becker. He especially focused on the development of natural colour depiction (Schertenleib 1997) by applying hypsometric tinting combined with shading and representation of sun-lit faces. Becker also elaborated a number of plaster reliefs.

## 3. Eduard Imhof, the founder of the Institute of Cartography

Eduard Imhof (1895–1986, Fig. 1c) was Lecturer and Professor of Cartography at ETH Zurich from 1925 to 1965. After his diploma graduation in 1919, he was immediately appointed Lecturer to replace Fridolin Becker who was already severely ill at that time. After Becker’s death in 1924, Imhof was promoted to Professor in 1925. One of his first actions was the foundation of the Institute of Cartography, thus becoming the first academic cartographic research institute world-wide. According to the well-cultivated legend (Imhof 1990), Imhof simply asked a painter to write the designation “Institute of Cartography” above the entrance door of his office!

Imhof continued Beckers work by precisely defining design rules for hypsometrically tinted relief maps and applying the technique in many school maps and atlases. His main contribution was the further refinement of Becker’s colour scales, finally leading to his famous Swiss Style Colour Relief Shading (Jenny and Hurni 2006). He developed a hypsometric tinting starting with a grey-bluish green in the

lowlands, then into an olive, brown-red, yellow and finally fading into a white in the highest area.

At the time of Imhof’s studies, first studies for a new National Map Series which should replace the old Dufour and Siegfried maps from the 19<sup>th</sup> century, were starting. The introduction of the new National Map however started only in 1938, and ended 1978. Imhof had a major influence on the definition and the design of the new maps. He especially urged to introduce a metric map scale series consisting of scales of 1:25,000, 1:50,000, 1:100,000, 1:200,000, 1:500,000 and 1:1,000,000. A fortunately unsuccessful counterproposal postulated a scale of 1:33,333, replacing both the scales 1:25,000 and 1:50,000 (Imhof 1979).

Later on, Imhof concentrated much more on Atlas cartography by creating the “Atlas of Switzerland” and the “Swiss World Atlas”. Nevertheless, he still worked on numerous mountain maps, terrain sketches, paintings and natural colour relief maps. The legacy of Imhof was on one side published in his book “Cartographic Relief Presentation”, but also disseminated in two international academic advanced training courses in 1957 and 1960.

## 4. Ernst Spiess – Maintaining Imhof’s legacy and mastering the technological leap

The theories of Imhof on relief depiction were further taught and developed by his successor Ernst Spiess (Fig. 1d), who applied them successfully in his 1960 expedition map of the Panta range in Peru. He also applied and developed the techniques of natural colour reliefs in his school atlas maps as well as cliff drawing techniques for topographic mapping. Spiess’ main focus of work however was the further development of the “Atlas of Switzerland”, the Swiss national thematic atlas and the re-conception of Imhof’s secondary school atlas into the current “Swiss World Atlas”. Besides, he introduced digital production technologies and methods into cartography and successfully applied them in his atlas and map projects. Today a major focus at the Institute is the further development of those methods and their extension and adaptation to new media such as Electronic and Web Atlases and mobile devices.

## 5. Cartography at ETH Zurich 1855–2007: Tracks of tradition and development

Overlooking 150 years of cartography at ETH Zurich, one can identify a number of tracks of domain developments which were built up, maintained and further developed throughout the years:

- The mapping for engineering track
- The relief track
- The perspective and 3D track
- The map design track
- The thematic and the atlas track
- The technological track
- The international track

Since the beginning of cartography at ETH some mapping activities were closely related to or a significant part of engineering activities such as road and railroad construction. Perspective drawings, panoramas, and plaster reliefs supported the visualisation by two-dimensional maps; today, due to the technological possibilities, they gain an increased importance for similar purposes. Eduard Imhof laid the foundation of modern academic cartography by defining rules for map design which can be applied on numerous types of maps including modern interactive map information systems. Through two applied atlas projects, atlas cartography is a major core competence at the Institute of Cartography since the beginning of the 20<sup>th</sup> century. The institute has always been in a leading position by mastering major technological leaps in reprography and digital production methods. Furthermore, the institute was and is involved in setting up international cartographic networks for collaboration, standardisation and exchange. The most prominent of these tracks, the development and further application of the “Swiss Style Coloured Relief Shading” is the topic of the next chapter.

## 6. The “relief track”: From Becker’s multicoloured maps to the “Swiss Style Coloured Relief Shading” and its digital implementation

Influenced by the relief maps issued by the Swiss Alpine Club in the 1860ies, Fridolin Becker elaborated numerous relief maps of areas in Switzerland and abroad, either in grey-scales or in colour. Fig. 2 shows two watercolour sketches of Mount Rigi with Northwest and Southeast illumination and the final map with the light source at lower right.

As one can easily imagine, manual relief shading is a time consuming task which aims at depicting a terrain model modulated based on a specific illumination model (Jenny 2001). Only specially trained cartographers are able to interpret and generalise the often complex topography. Thereby the terrain should not be depicted in its geometrically correct form, but an easily interpretable image should be created. Imhof (1965, 1982, 2007), lists the following techniques to achieve this:

1. Locally, the light direction is slightly turned out of the main light direction in order to emphasize and clarify topographic features. Landforms that lay in the main light direction are thereby accentuated.
2. Moreover, flat areas are filled with a bright grey tone to build a relationship between hillsides separated by flat lowland. The applied tint is brighter than the physically cor-

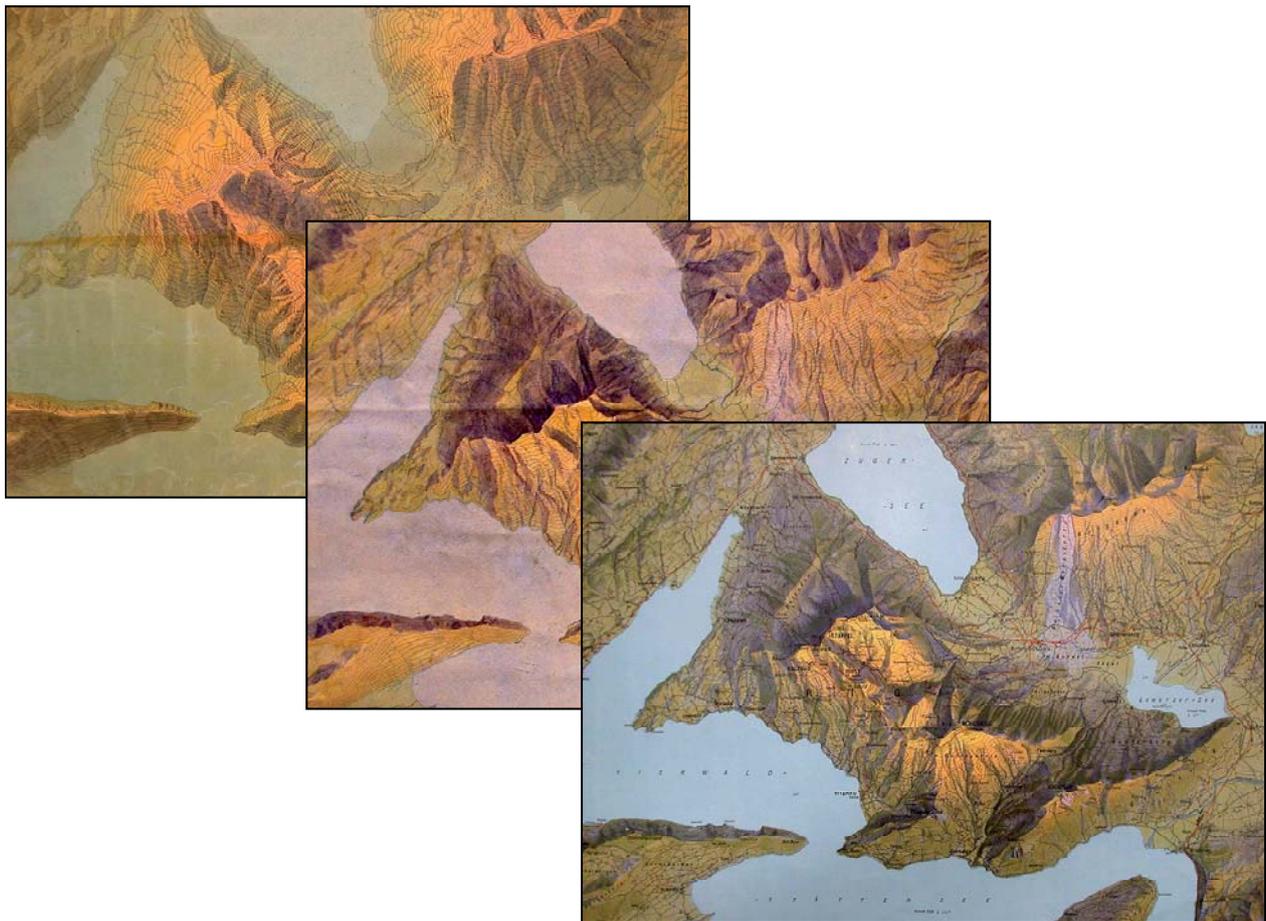


Fig. 2: Two watercolour sketches of Mount Rigi by Fridolin Becker with Northwest and Southeast illumination and the final map with Southeast illumination at lower right.

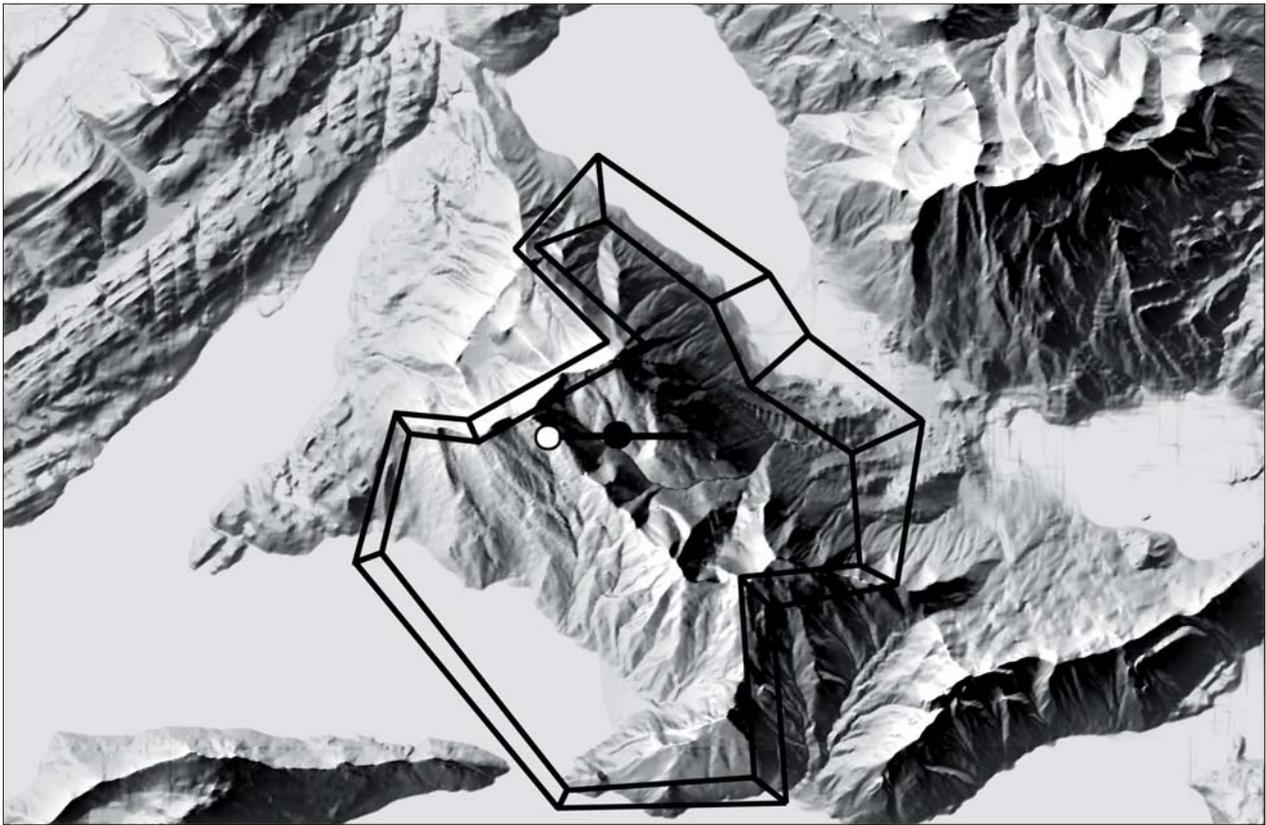


Fig. 3: Local adjustment of light direction. Elevation data (DHM25) © Federal Office of Topography, Wabern, Switzerland.

rect value, in order to avoid any darkening of these usually densely settled zones.

3. A brightening of local shadows on the light side of hills, and a darkening on the shadow side, is used to emphasize large landforms, to structure the landscape and to accentuate characteristic forms

4. Aerial perspective is used by cartographers to depict differences between high mountain summits and lower, more distant lowlands. Hence, contrast is sharpened towards the topographic peaks and softened towards the lowlands.

Analytical relief shading is the digital process of generating a shaded terrain relief from a digital elevation model (DEM). During the last 50 years, a great variety of methods for analytical shading to fulfil the needs of cartographers have been developed. Grey values of the relief image depend on slope and aspect; both parameters are calculated out of the DEM data. Yoëli (1959, 1965, 1966, 1967, 1967a) was the first to produce an analytical relief shading by applying the “Diffuse Reflection” illumination model on a DEM. Thereby the grey value of each pixel is determined by calculating the cosine of the angle between the surface normal and the light vector. Later, numerous efforts have been made to adapt the different shading algorithms to the specific needs of cartography; prominent examples are the first experiments with local adjustments of the light direction, made by Yoëli (1967) and Brassel (1974).

Comparisons of analytical and manually shaded reliefs of mountainous areas show that the numerically processed versions often contain too many details, whereas the manual

shadings accentuate vertical transition. In manual hill shading, smooth vertical transition is applied to emphasize aerial perspective and to structure the topography. This manual style can be simulated if the slope information is ignored and shading is based on aspect only. A bright grey tone has to cover flat areas since aspect is undefined in these regions. Using a coded mathematical function or an interactive control panel, the grey tone can be mixed with the aspect based shading in function of the slope. This shading type produces almost random values in nearly flat, but slightly undulating areas.

By help of a computer programme developed at the Institute of Cartography (Jenny 2001), aerial perspective can be simulated. Thereby, three components are transformed into a weight for each pixel. The relative elevation of the considered point determines the first weight, whereas second weight is proportional to the exposition towards the light direction (= aspect). To calculate the third weight the relative position of the point within a hillside, that is identified using slope lines, is considered. The previously calculated grey value is corrected by these weights. After a first reduction in contrast of the grey value, a definable constant value is multiplied by the three weights and added to it.

Furthermore, the user has the possibility to define sub-areas of the DEM for local adaptations of the shaded relief. He can provide them with adapted parameters. The software allows the adjustment of the following parameters:

- Light direction
- Vertical exaggeration

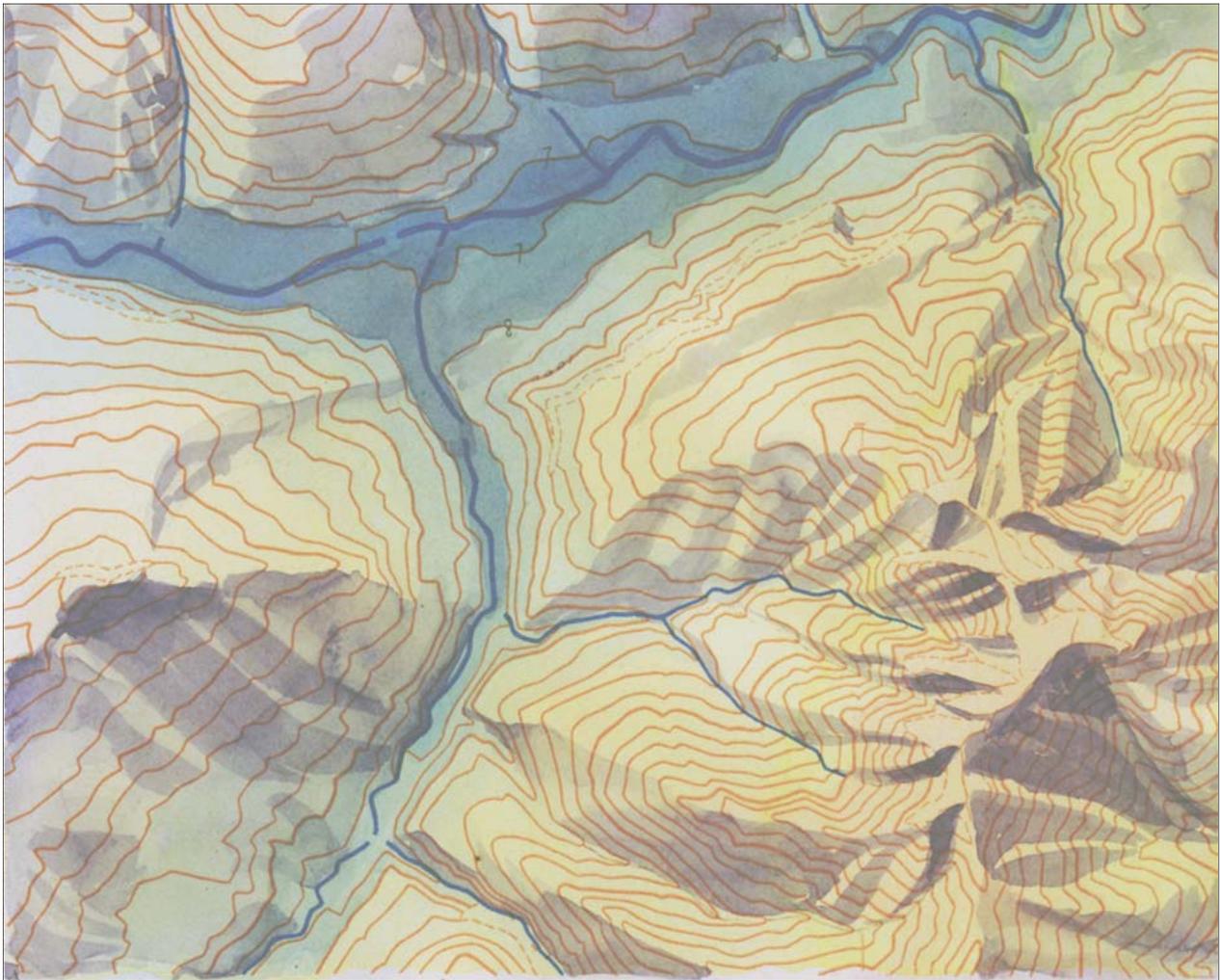


Fig. 4: Manual watercolour painting with the combined shading and hypsometric tinting method. Original painted by E. Spiess, 1951.

- Brightness
- Elevation dependant contrast
- Interpolation between diffuse reflection and aspect based shading

The effect of a local adaptation of the light direction is illustrated in Fig. 3. A light source from west locally replaces the main light source from north-west. The user digitises a polygon of the affected perimeter. Then, the programme automatically generates a second polygon inside the first one and the grey values between them are interpolated.

The definition of a scale of tints for colour shaded reliefs was another one of Imhof's major scientific achievements in cartography. Thereby, a compromise must be found between natural resemblance and symbolic colours. Jenny and Hurni (2006) – besides a purely hypsometric tinting – mention a possible colouring combining hypsometric tinting by elevation and a modulation according to exposure to illumination. Continuing the work by Fridolin Becker, Imhof developed such coloured relief shading. It is based on a hypsometric colour scale which starts from a bluish-greyish green for lowlands by olive and brownish-yellowish tones for mid-altitude areas to even white tones for the highest, snow covered peaks. Imhof also developed a photomechanical

method to derive this kind of a tinted depiction from one single greyscale shaded relief. Several copies of the relief were made with different contrast levels; they were then tinted in different colours representing the separation colours of the overall relief. The result was also combined with a negative of the shaded image in yellow (representing the sun illumination) and with a hypsometrically graded plate in order to represent the different altitude levels. This so-called Swiss Style Colour Relief Shading is until today applied in many maps of e.g. the Swiss World Atlas ("Schweizer Weltatlas", the official Swiss school atlas), in Cantonal school maps and also in official small scale topographic maps. It can also be painted "directly", as manual watercolour painting with the combined shading and hypsometric tinting method in Fig. 4 shows.

A new method for digital production of Swiss-style colour relief shading and a corresponding computer programme were developed recently at the Institute of Cartography of ETH Zurich (Jenny and Hurni 2006). The production of a new edition of the school map of the Swiss Canton of Schaffhausen was the starting point for this implementation. After a long search in various archives, Imhof's original relief from the 1950 were found, but unfortunately not the derived colour plates. The colour tint at a specific place in

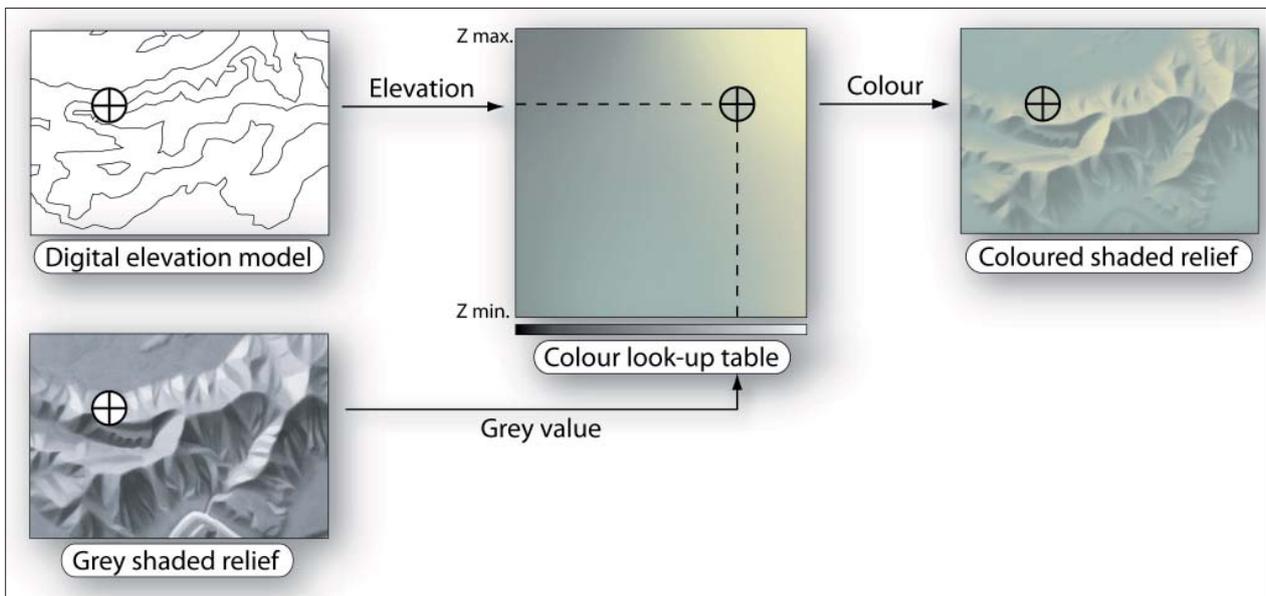


Fig. 5: Generating a coloured shaded relief by choosing the colour from a two-dimensional look-up table built up by elevation and exposition parameters (after Jenny and Hurni, 2006).

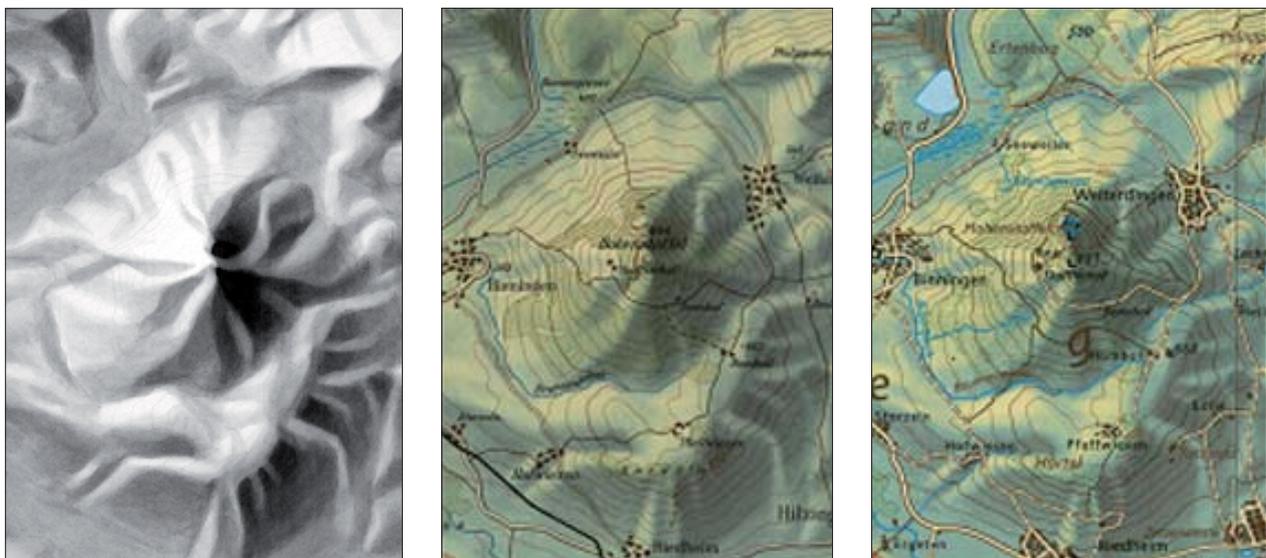


Fig. 6: New school map of Schaffhausen: The coloured shaded relief (right) combines the greyscale value of the relief (left) with the height dependent colour of the specific point. Centre: Old school map of Eduard Imhof from 1954.

the terrain, e.g. yellow in higher areas, of the illuminated north-western side of a hill or a blue-green-grey in lower shadowed areas can be defined using the software. The programme sets up a two-dimensional look-up table with the elevation on the y-axis and the greyscale values on the x-axis after the user has defined a number of significant points with their respective tints. The input parameters elevation (from a digital elevation model DEM) and grey value (from an existing shaded relief, representing the exposition to illumination) are shown in Fig. 5. Finally, the greyscale value of the relief and the height dependent colour of the specific point are combined in the resulting coloured shaded relief (Fig. 6).

### 7. Conclusion

The adequate representation of relief features is a major and demanding task since the beginning of high quality topographic cartography in the 19<sup>th</sup> century. The work of Eduard Imhof was a consequent continuation of his fore-runners' activities. It was continued by his successor and it laid the base for modern topographic mapping not only in Switzerland, but also on an international level. We therefore propose a thorough examination of the history of cartography in Switzerland and of its international implications in the 20<sup>th</sup> century in the framework of a research project.

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