

Terrain Assessment in a Mountainous Environment - A Swiss Austrian Contemplation

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Topographic mapping and terrain representation in Switzerland and Austria have an extensive history and their achievements are acknowledged worldwide. Not only are the Federal Topographic Agencies of these countries but also other institutions, such as the Alpenverein (Alpine Club) working on comprehensive programmes to improve and to disseminate their high quality topographic mapping activities. These results include a wide variety of analogue as well as digital products.

This contribution focuses on the specific situation in Switzerland and Austria dealing with large-scale topographic mapping and the utilisation of these commodities for terrain evaluation. It gives an impression of the current activities and deals with their limitations and problems. In order to evaluate these products it is important to understand their development process and the quality criteria connected to them. Quality in connection with topographic mapping is most often defined as a quantity, such as a number describing the RMSE of a digital elevation model. However, it is also important to consider quality as a description of what kind of information is derivable from the product and how this information can be utilised by the user.

INTRODUCTION

For more than 10 years the Department of Geography and Regional Research at the University of Vienna is regularly undertaking cartographic field trips to the Silvretta, a mountain range that is situated at the border between Austria and Switzerland. The goal of these excursions is to evaluate and analyse high mountain cartography from a scientific as well as practical point of view. A main emphasis is hereby to understand the manifold facets of cartographic terrain representation and to compare them with reality. In order to do so various analogue and digital geo-data sources, such as large-scale topographic maps as well as digital elevation and terrain models of the area are utilised. Furthermore it is also essential to understand the quality aspects of these components whether they are suitable for terrain assessment.

This paper deals therefore mainly with the analysis of various available Digital Elevation Models (DEM) of the area and compares them with terrain specific features using different large-scale topographic maps. From the following institutions DEM and maps were applied: BEV (Austria Federal Office of Metrology and Surveying), SwissTopo (Swiss Federal Office of Topography), Uni-Wien (Department of Geography and Regional Research, University of Vienna)

AREA OF INTEREST

The area of interest for this analysis was chosen in the western part of the Silvretta mountain range situated in the Austrian provinces of Vorarlberg and Tirol along with the Swiss province of Graubünden. It can be easily accessed from the north via the valleys of Montafon (Vorarlberg) and Paznaun (Tirol). From the south, the Silvretta is reachable via Unterengadin and Prättigau. Even though the highest peak in the range is the Southern Fluchthorn (3.399m), the most famous summit is the Piz Buin (3.312m). Its colossal rock face and imposing location at the end of the Ochsental glacier surely underlines this circumstance. Due to the fact that various interesting geomorphological features are also present within the vicinity makes this mountain range predestined for in depth cartographic terrain assessment.

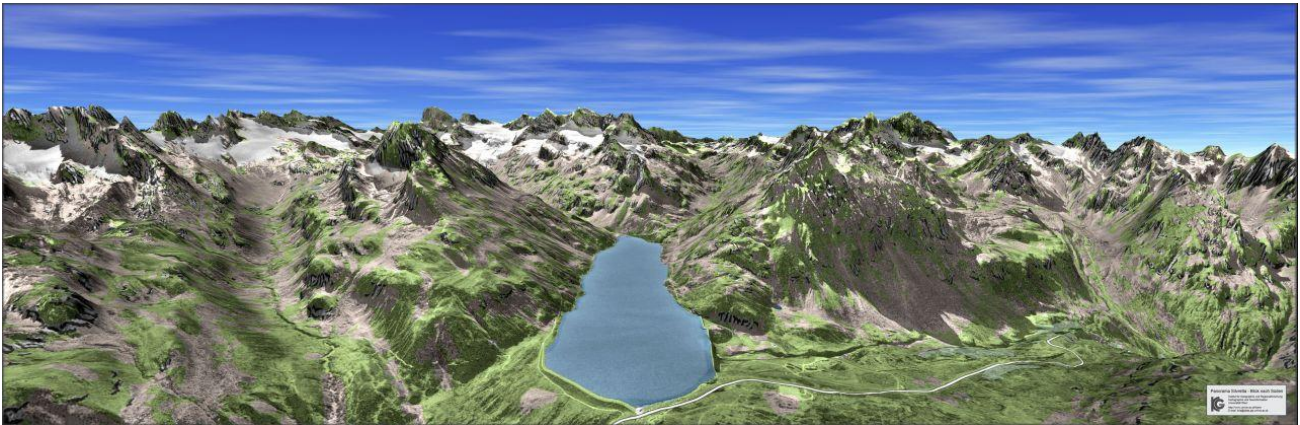


Figure 1: Area of interest Silvretta – Panorama Bielerspitze - View to the south

LARGE SCALE ANALOGUE MAPS

The speciality of the Silvretta from a cartographic perspective, particularly concerning detailed terrain and map analysis, is the coverage of various large-scale topographic maps. However, even though numerous cartographic products are being produced in this area for recreational purposes, not all available large-scale maps are of high quality and useable for terrain assessment. Topographic basic elements that are essential for orienteering purposes play hereby an important role and underline the quality of the available cartographic products. These elements are amongst others the isoline quality and equidistance, quantity and accuracy of height points, rock depiction as well as terrain representation utilising hill shading. Under these circumstances, the following high quality maps were chosen and used for further evaluation:

- Austrian base map 1:50.000 (sheet 169, 170)
- Alpine Club map 1:25.000 (sheet Silvrettagruppe)
- Swiss base map 1:25.000 (sheet 1178, 1198)

Austrian base map 1:50.000

The Austrian base map 1:50.000 (ÖK50) is the official topographic base map of Austria. It replaced the original map series 1:25.000 that was concluded in the late 1950-ties. It resembles the largest scale covering the whole nation. There is also currently a full coverage in scale of 1:25.000 however, this map series is only a photographic enlargement of the base map 1:50.000 and does not include any extra features. This enlargement is only possible due to the fact that the information density of the base map 1:50.000 coincides to the scale 1:30.000. The isolines are depicted in two colours – brown for vegetation, rock and scree, blue for glacier and water bodies. The equidistance of the isolines is 20m – 10m for intermediate lines. Forest is visualised as a continuous tone in green were as scrubs and mountain vegetation are symbolised through point symbols.

Rock depiction in the Austrian base map is always to be seen in combination with the isolines and resembles a geometric conform representation method. The isolines represent the primary element. All other elements are seen as secondary rock depiction elements. One of the main objectives is to include as many – if not all – isolines in the rock depiction. The rock face is then visualised schematically trying to resemble the perspective view a map-reader would have if he were standing in the terrain (compare Kriz 1998).

Alpine Club map 1:25.000

The Alpine Club (Austria OEAV - Germany DAV) has been producing for more then 100 years high quality maps of many European as well as worldwide selected mountain regions equally for alpinists and scientists. The main goals and tasks of the cartographic section have therefore been to proclaim high mountain cartography to the public, to survey remote mountainous areas, to explore new methods of depiction and to produce high quality cartographic products for its members. The benefit in comparison to the official federal topographic mapping agencies is the flexibility of

cartographic representation such as adapting to new rock depiction methods or experimenting with new techniques. Furthermore, the variable map format that is adjusted to the size of the surveyed mountain region so that all important features and localities are included is also an important and unique feature (compare Brunner 1998, Gartner 1998).

The Alpine Club has used over the years various terrain depiction methods. The method used momentarily in the edition of the Silvrettagruppe (1:25.000) that was published by the German section of the Alpine Club (DAV) is based on the Austrian topographic map series. However, the base for this map is derived from the original map 1:25.000. The depiction method resembles in most cases the Austrian base map 1:50.000.

Swiss base map 1:25.000

The Swiss base map 1:25.000 (LK25) is the official topographic base map of Switzerland. Isolines are depicted in three different colours – brown for terrain with vegetation, black for rock and scree and blue for glacier and water bodies. The isoline equidistance in high mountain areas is 20m with 10m for intermediate lines. Forest is visualised as a green area where as a distinction between continuous and uncontinuous forest boundaries is made. Furthermore, sparse vegetation in these areas is depicted mainly through point symbols.

A speciality of the Swiss base map 1:25.000 is the impressive plasticity of the terrain. This spatial impression is achieved by using hill shading combined with a north-west orientated sun tone that is only adapted on areas with vegetation. Furthermore, the rock depiction is realised in a very schematic fashion however, emphasising delicate features and terrain ridges that are visualised depending on their exposition using hachure technique (compare Gilgen 1998, Kriz 1998).

MAP COMPARISON

Isolines in topographic maps are significant information carriers and are utilised to depict the third dimension. Their equidistance, the height difference between neighbouring isolines, defines how exact the terrain can be reproduced. This measure is dependent on the graphical conceivability as well as map scale and steepness of the terrain. Isolines are therefore the most important elements of terrain depiction in large-scale topographic maps.

The following elements, isolines and rock depiction, were compared in all three maps (Austrian base map 1:50.000 ÖK50, Alpine Club map 1:25.000 AV and Swiss base map 1:25.000 LK25) under the specific consideration of their accuracy and terrain representation. Through this comparison, it was interesting to see what priority and accuracy requirements each institution follows. Figure 2 shows the combination of the original ÖK50 isolines (brown 100m isoline, red 20m isoline) based on the geocoded AV-map. It can be clearly seen that the AV-map isolines show a slight systematic error towards the South. This anomaly is however not constant over the entire map and is in average 10m in some extreme cases up to 25m. An explanation for this misalignment can be seen in the fact that the base for the AV-map is the older original topographic map of Austria 1:25.000 surveyed using terrestrial methods in the first half of the past century. Even greater mismatching can be registered when comparing the Swiss base map 1:25.000 with the ÖK50. Here the horizontal displacement of the isolines is between 15-25m. Especially in glaciated areas, the misalignment can be significantly larger, because the acquisition time of the glaciers is different.

Rock depiction in all three maps is based on form drawing that does not depend solely on geometric construction. In general, it should resemble the individual feature of rock in reality trying to emphasise on major peculiarities. This is realised by general construction guidelines combined with individual artistic features. In most cases, it can be seen graphically as a fine line drawing (compare Gilgen 1998). Figure 3 shows a comparison of rock depiction based on the Swiss LK25 with the rock depiction of the ÖK50 superimposed in red. The methods of representation are different. Areas without rock depiction in the ÖK50-map in comparison to the Swiss LK25 are noticeable. The Swiss depiction method is in general the same as the Austrian, however more schematic hachure and clearer geometric delineation is used. One reason for the rock omission is that the final map scale of the ÖK50-map is smaller than the LK25.

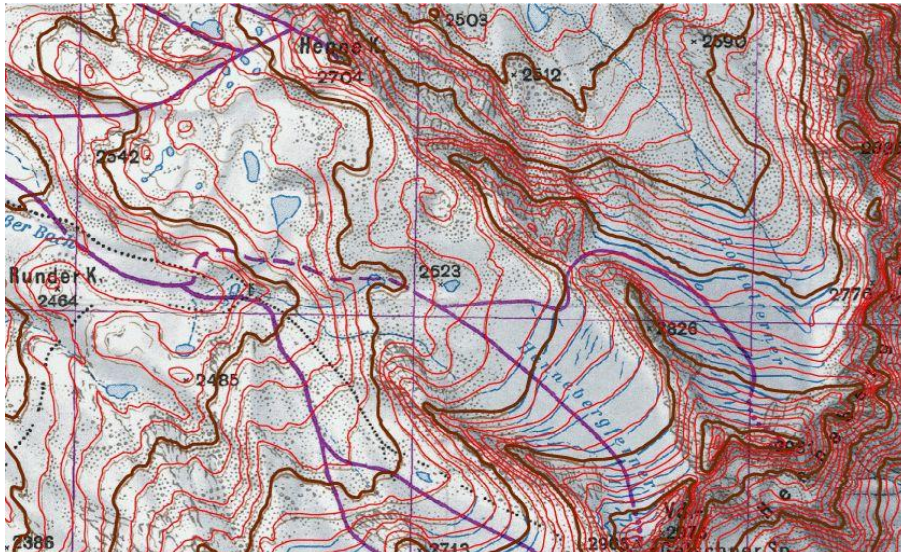


Figure 2: Alpine Club Map Silvretta with superimposed ÖK50 isolines (brown 100m, red 20m)

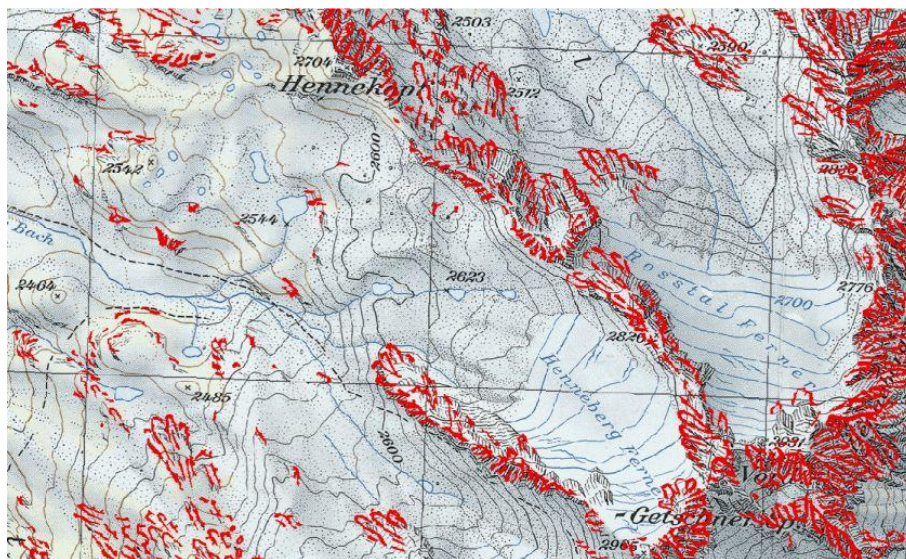


Figure 3: LK25 of Switzerland 1:25.000 with superimposed original BEV ÖK50 rock depiction (red)

DIGITAL ELEVATION MODEL (DEM)

A Digital Terrain Model (DTM) is similar to an analogue topographic map. They both incorporate a method of storing spatial relevant terrain information in a formalised way. In the case of an analogue map, the storage medium is paper opposing to a DTM that stores information in a digital numeric fashion. In both cases, the basic elements are alike. The essential topographic elements integrated in a DTM are above all isolines, height points, structure lines, ridgelines, break lines and a variety of thematic point, line and area forms. All terrain specific information can therefore be integrated in such a model. The goal of such models is to produce an exact, scale dependent resemblance of reality and to access this information in a cohesive formalised way. One derivation of such a model can be a Digital Elevation Model (DEM) that includes primarily unified height information. These models are very often used for further terrain assessment.

Crucial for the quality of a DEM is the geodata acquisition from secure primary resources. This can be for example retrieving height information from a photogrammetric campaign. Secondary resources, such as maps, are more easily available and contain abundant graphical – mostly generalised – terrain information. Providing the resource is comprehensible, these geodata suppliers can be appropriate. Especially the retrieval of height information from these resources based on the extraction of isolines is a very common task. Depending on the map scale as well as isoline

accuracy and equidistance, utilising this method obtains reliable results. Based on a large-scale topographic map with an isoline equidistance of 20m and combined with auxiliary terrain information, such as ridgelines and extra height points, it is possible to derive a quality DEM with an accuracy of up to 10-15m. This model is the foundation for further extraction of terrain relevant information, such as exposition, aspect or even hill shading.

DEM COMPARISON

The Silvretta area accommodates several different DEM. Even though these models have different backgrounds and resources, they are all exploitable for cartographic terrain assessment. The following evaluation deals with a comparison of these available DEM. All models were geocoded according to the Austrian base map 1:50.000 and adjusted to the same resolution (25m).

- Austria Federal Office of Metrology and Surveying – BEV DEM 25m
- Federal Office of Topography SwissTopo – SwissTopo 25m DEM
- University of Vienna, Department of Geography – UNI-Wien 25m Isoline DEM

BEV DEM 25m

Data acquisition of this 25m DEM was achieved by photogrammetric extraction and post processing computation. After data caption the survey data is then transformed to a regular 50m raster, where various raster resolutions can be calculated. Initially this elevation model was used to compute orthophotos. Since 1990, the survey uses colour aerial photographs in a scale 1:15.000 with a fix raster resolution of 50m to fulfil this task. Besides the orthophoto production, other terrain information is now being acquired. Additional height information and ridgelines are also being captured. This information plus the original survey data is then combined using the software product SCOP (from the Technical University of Vienna) to produce the desired raster resolution (10-50m). The accuracy of these computed elevation models depend therefore mainly on the terrain relief, land cover and most of all the raw data acquisition method as well as included extra terrain information. The accuracy of the model in mountainous areas lies between +/- 5-20m depending on the resolution and integrated terrain information (compare BEV 2004).

SwissTopo 25m DEM

The SwissTopo 25m DEM is a dataset that describes terrain in a three dimensional form. Essentially all height information is derived from the Swiss base map 1:25.000. The digitised isolines and height points build the foundation of this model. Furthermore, line elements such as shorelines and break lines as well as selected peaks and other terrain relevant height points are integrated. The computation of a 25m raster model is then calculated out of this information. The accuracy of the model and the mean positional deviation according to SwissTopo in alpine areas is +/- 3m (compare SWISS 2004).

UNI-Wien 25m Isoline DEM

Base for the UNI-Wien 25m Isoline DEM was the Austrian base map 1:50.000 (ÖK50). All terrain information such as morphological structures, height points, break lines and ridges were extracted from this source and integrated in the model. The model creation began with the isoline caption. The isolines were geometrically adjusted, topologically structured and all attributes were assigned. Thereafter, all significant height points, ridgelines as well as form lines were incorporated. This information is relevant for all regions that have low coverage of isolines, such as areas in flat terrain. Subsequently a Tringulated Irregular Network (TIN) was calculated. Using this model a regular raster of 25m was interpolated using a quintic interpolation method that considers the surface model to be continuous and smooth. The accuracy of the model in mountainous areas lies between +/- 10-20m.

DEM Comparison

One way of verifying the quality of a DEM is to derive isolines and to combine the results with a topographic source, such as a map. This geodata retrieval provides information over certain scale dependent terrain characteristics as well as

vital information regarding morphological features. This method requires however, a high quality topographic base map. In figure 4, the overlaid isolines were derived from the BEV DEM 25m with an equidistance of 20m and are superimposed over the official topographic base map of Austria 1:50.000 (ÖK50). For the most parts of the map, there is a sufficient coherence. However, larger discrepancy can be localised in glaciated areas as well as in regions with high relief energy. The mean deviation lies between 15-20m. In extreme cases up to 80-100m. These peculiarities are mainly due to different surveying dates of the area and varying glacier extensions.

Figure 5, shows the LK of Switzerland 1:25.000 with superimposed derived 100m isolines from BEV DEM 25m in violet and SwissTopo DHM25 in red as well as the original 100m ÖK50 isolines in brown. The high correspondence of the derived SwissTopo DHM25 isolines with the base map is clearly perceived. This is explainable that the isolines were derived mainly from the isolines of the original map LK of Switzerland 1:25.000. Slight deviations can be localised, however they are all less than 15m. A similar conformity and terrain form resemblance is achieved by the derived 100m isolines from BEV DEM 25m, nevertheless larger conflicts can be located in glaciated regions as well as in areas with high relief energy. Here deviations of up to 20m are found. However, greater inconsistencies can be seen in the original 100m ÖK50 isolines of up to 40-50m.

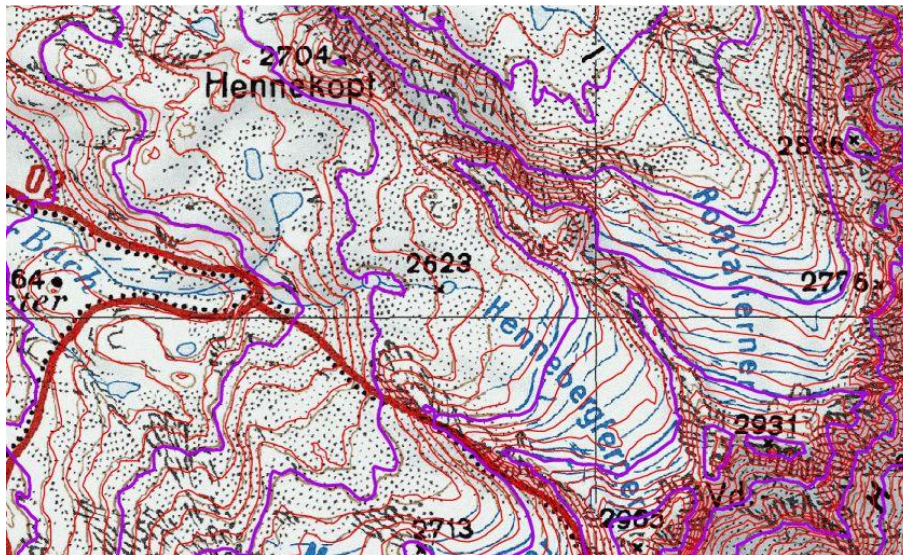


Figure 4: ÖK50 with superimposed isolines (violet 100m, red 20m) derived from BEV DEM 25m

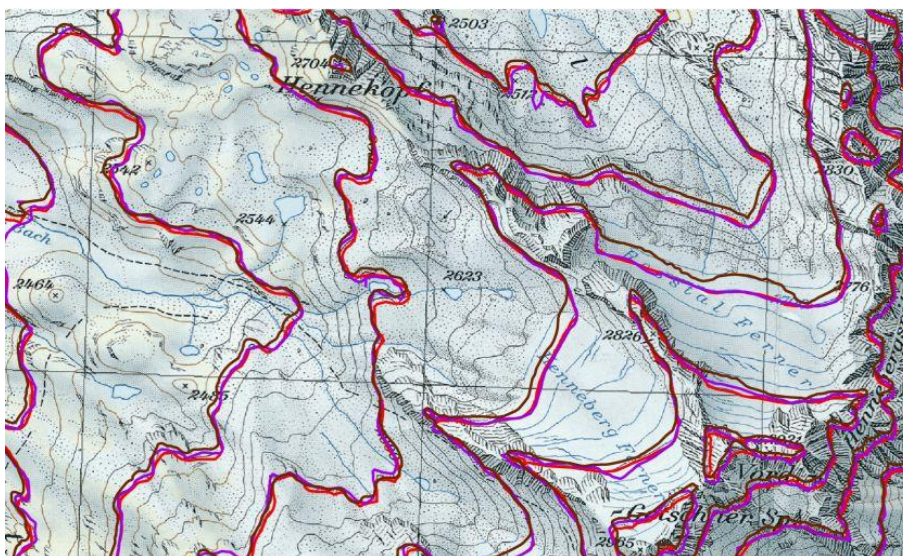


Figure 5: LK of Switzerland 1:25.000 with superimposed derived 100m isolines (violet BEV DEM 25m, red SwissTopo DHM25, brown ÖK50 original 100m isolines)

CONCLUSION

In general the overall coherence of all analysed geodata (analogue maps as well as digital elevation models) is given. They all possess within the defined scale adequate topographic quality and acceptable terrain form resemblance. Discrepancies are possible merely in extreme areas, such as in steep rock faces or in glaciated regions. This is however mainly due to the different surveying methods and caption dates. Deviations of up to 25m are therefore tolerable if the use of terrain specific geodata is in a scale of 1:50.000 or smaller.

Increasing interest on topographic base data for terrain assessment and analysis is leading to a massive demand for high quality cartographic geodata. Maps and elevation models can fulfil these requirements providing the available resources are correctly checked and defined by originator and user equally.

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All figures and utilised DEM with allowance of the Alpine Club Cartography, SwissTopo and BEV

Biography

Karel KRIZ, born 1962, studied geography and cartography at the University of Vienna and graduated in 1989. For the first few years, he worked in the fields of digital cartography, GIS and computer science developing various scientific and commercial applications. Since 1992, he is an Assistant Professor at the Department of Geography and Regional Science at the University of Vienna. In 1994, he completed his PhD on the topic of “Requirements on Digital Cartographic Systems”. His major areas of interest lie in web-based cartography, GIS and thematic aspects of mountain cartography. He is currently working on various projects dealing with web-based cartographic applications.