

# Mountain mapping and visualisation

Proceedings of the 6th ICA Mountain Cartography  
Workshop, 11-15 February 2008, Lenk, Switzerland

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## **Workshop Organisation**

Institute of Cartography, ETH Zurich, Switzerland.  
[www.karto.ethz.ch](http://www.karto.ethz.ch)

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Institute of Cartography, ETH Zurich, Switzerland.

## **Cover Picture**

Figure of the prototype Atlas of Switzerland 3. The image shows a virtual 3D panorama of the Wildstrubel massive, Bernese Oberland, seen from the Lenk valley. © 2008 swisstopo / ETHZ (BA2008RG)



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# Edition Notice

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# Foreword

## Dear readers,

I am very pleased to present you the proceedings of the 6<sup>th</sup> International Mountain Cartography Workshop "Mountain Mapping and Visualisation". The symposium was held under the auspices of the Commission on Mountain Cartography of the International Cartographic Association (ICA – ACI) and took place at Lenk/Simmmental (Switzerland) from February 11 to 15, 2008. It was organised by staff members of the Institute of Cartography at ETH Zurich.

The Commission on Mountain Cartography of ICA evolved from a working group of the German Society of Cartography in 1999. Since then, a very successful series of 6 bi-annual workshops were organised. It is in the nature of things that the symposia could always take place in a splendid mountain environment: at Bielerhöhe/Silvretta (Austria) in 1998, Rudolfshütte/Hohe Tauern (Austria) in 2000, Mount Hood/Oregon (USA) in 2002, Vall de Núria/Catalonia (Spain) in 2004, Bohinj (Slovenia) in 2006, and Lenk (Switzerland) in 2008.

As in the preceding workshops, most of the contributions in this volume belong to one of two major topic groups: a substantial part of the papers deals with cartographic, i.e. design-related aspects of mountain cartography. The special morphology, natural phenomena and land cover, but also the utilisation by men represents a special challenge for cartographers when visualising mountainous areas. The contributions in this volume demonstrate the application of existing techniques, as well as the further development of methods of relief representation on various media like paper, computer screen and mobile devices. Beside the cartographic visualisation methods, a second group of papers deals with methods of mapping and analysis of natural man-influenced spatially-related phenomena and processes in mountains. Here, too, the adequate cartographic representation of investigation results plays an important role, because it represents the interface to the addressee, i.e. the map reader. I hope that this volume demonstrates especially to scientists the added value of cartographic visualisations designed in a user-friendly manner.

Beside the organisers of the workshop, I would express my sincere thanks to the Swiss Society of Cartography and many others for supporting the workshop. The following members of the Commission on Mountain Cartography of ICA were reviewing the conference abstracts: Christian Häberling, Karel Kriz, Tom Patterson, Maria Pla and Dušan Petrovič. The editorial work of the volume was carried out by Christian Häberling, Bernhard Jenny, Melanie Kunz, Corina Pachlatko and Adrian Weber of the Institute of Cartography at ETH Zurich. A very special "Merci!" goes to Stefan Räber for the overall editorial work and for the diligent layout and design of this publication.

## Liebe Leserinnen und Leser

es freut mich, Ihnen mit diesem Band die Beiträge des 6. Internationalen Gebirgskartografie-Workshops unter dem Motto „Mountain Mapping and Visualisation“ vorstellen zu dürfen. Das unter der Schirmherrschaft der Kommission für Gebirgskartografie der Internationalen Kartografischen Vereinigung (ICA) stehende Symposium mit rund 60 Teilnehmenden fand vom 11. bis 15. Februar 2008 an der Lenk im Simmental (Schweiz) statt. Es wurde von einem Team aus Mitarbeiterinnen und Mitarbeitern des Instituts für Kartografie der ETH Zürich organisiert.

Die Kommission für Gebirgskartografie der ICA ging 1999 aus einer Arbeitsgruppe der Deutschen Gesellschaft für Kartografie hervor. Seither konnten im Zweijahres-Rhythmus sechs äusserst erfolgreiche Workshops durchgeführt werden. Es liegt in der Natur der Sache, dass diese immer in einer prächtigen Gebirgsumgebung stattfinden konnten: 1998 auf der Bielerhöhe/Silvretta (Österreich), 2000 in der Rudolfshütte/Hohe Tauern (Österreich), 2002 am Mount Hood/Oregon (USA), 2004 im Vall de Núria/Katalonien (Spanien), 2006 in Bohinj (Slowenien) und 2008 an der Lenk (Schweiz).

Wie bereits in den vorangegangenen Workshops können die meisten Beiträge in diesem Band einer von zwei Hauptgruppen zugeordnet werden: Ein wesentlicher Teil der Papers beschäftigt sich mit kartografischen, d.h. vor allem gestalterischen Aspekten der Gebirgskartografie. Die Beiträge in diesem Band zeigen sehr schön die Anwendung bestehender Techniken aber auch die Weiterentwicklung von Methoden der Geländedarstellung auf verschiedensten Medien wie Papier, Bildschirm und portablen Geräten auf. Neben der kartografischen Visualisierung werden in einem zweiten Schwerpunkt Methoden der eigentlichen Kartierung und Analyse von natürlichen und durch den Menschen beeinflussten raumbezogenen Phänomenen und Prozessen im Gebirge behandelt. Ich hoffe, dass dieser Band insbesondere Wissenschaftlerinnen und Wissenschaftlern den Mehrwert qualitativ hochstehender, benutzergerecht gestalteter kartografischer Visualisierungen aufzeigt.

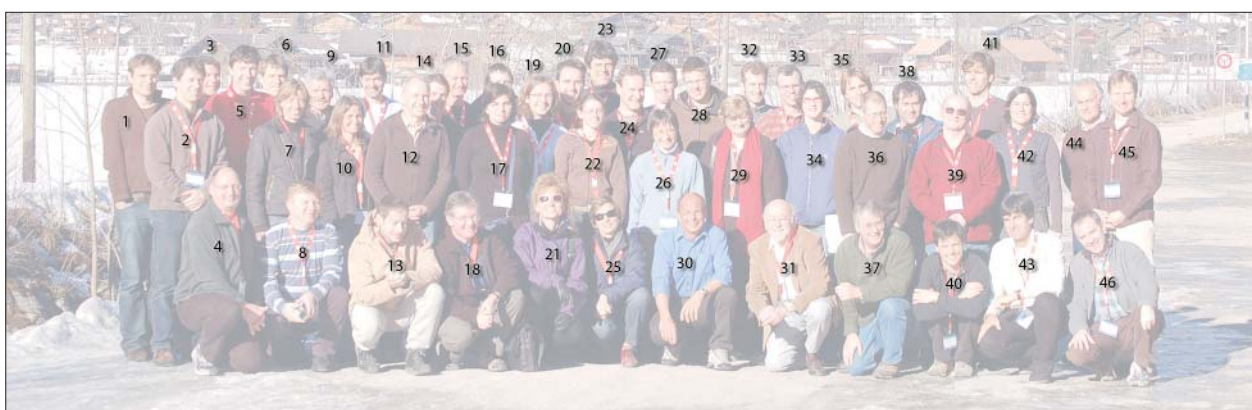
Neben den Organisatorinnen und Organisatoren des Workshops möchte ich der Schweizerischen Gesellschaft für Kartografie und weiteren Personen für die Unterstützung bei der Durchführung des Workshops danken. Folgende Mitglieder der Kommission für Gebirgskartografie der ICA haben die Begutachtung der Abstracts besorgt: Christian Häberling, Karel Kriz, Tom Patterson, Maria Pla und Dušan Petrovič. Bei der Redaktion des Bandes haben Christian Häberling, Bernhard Jenny, Melanie Kunz, Corina Pachlatko und Adrian Weber vom Institut für Kartografie der ETH Zürich mitgewirkt. Ein ganz spezielles "Merci!" geht an Stefan Räber für die Gesamtedition und die sorgfältige Gestaltung des vorliegenden Werkes.



Prof. Dr. Lorenz Hurni



## Group Photo



1 – Alexander Thimm  
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 3 – Igor Drecki  
 4 – Christian Häberling  
 5 – Dušan Petrovič  
 6 – Bernhard Jenny  
 7 – Claudia Trochsler  
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 9 – Hans-Uli Feldmann  
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 15 – Roger Smith  
 16 – Rafał Jońca

17 – Gabriela Ilies  
 18 – Alastair Pearson  
 19 – Constantin Beyer  
 20 – Loïc Gondol  
 21 – Blanca Baella  
 22 – Sabine Stäuble  
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 27 – David Schobesberger  
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 41 – Christophe Lienert  
 42 – Melanie Kunz  
 43 – Karel Kriz  
 44 – William Cartwright  
 45 – Stefan Räber  
 46 – Lorenz Hurni

### Not on the photograph:

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 48 – Costante Bonacina  
 49 – Jesus Miguel Garcia  
 50 – Berta Haselböck  
 51 – Helene Haselböck

52 – Ernst Hutzler  
 53 – Kevin McManigal  
 54 – Julita Petrovič  
 55 – Blaž Petrovič  
 56 – Oscar Schönenberger

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# The Rwenzori Trekking GIS

Costante Bonacina<sup>2</sup>, Giorgio Vassena<sup>1</sup>, Giuseppa Cipriano<sup>2</sup>, Susanna Bulferetti<sup>2</sup>, Bob Nakilesa<sup>3</sup>

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## Abstract

*The paper deals with the program of surveying of all the trekking routes inside the Rwenzori Mountains National Park (RMNP), of the main data related to the trekking route and to the main points of interest present into the Park. The structure of the geodatabase starts from the ProtSIS protocol (the trekking routes geodatabase structure defined by the Italian Alpine Club).*

*This database comes from the same structure realized in 2000 and 2006 for the survey of trekking routes in the Himalaya range (Nepal) and in particular in the Sagarmatha, Kangchenjunga and Annapurna National Parks.*

*From the 27<sup>th</sup> of July until the 2<sup>nd</sup> of August 2007 two researchers moved along the routes of the RMNP with a mono frequency GPS receiver and are now working to the final data processing.*

*The objective of the survey consists in mapping the position of the trekking paths and mainly in the data collection of the information related to the path that can be useful both for planning the maintenance of the pathways and for touristic purposes. The greenways inside the RMNP are often cover by mud and for reason require a frequent and constant maintenance, in particular for the some facilities as bridges, wood ladder, etc.*

## 1. Introduction

The main goals of the trekking route survey, besides the touristic one, are linked to the management planning and to the fruition of trekking route.

To do that it is necessary to achieve a convergence of aims between institutional and territorial institutions in charge of area management and then of the paths; besides is essential to unify the way of “approaching trekking route” and the way of spreading, consultation, management and data updating.

This unity of intentions and action is certainly favoured by the introduction of tools for common management, efficient and sheared, hence operative.

The GIS using in help to the decision concerning the territory, widely spread into the administrations and the territorial corporations, can properly be extended with appropriate integrations, to the management of trekking system, giving excellent data in the economic qualification of intervention of ordinary maintenance, hence constituting an excellent decisions support system.

## 2. The Italian Alpine Club (CAI)

In this context enters the CAI's activity that is historically involved in frequentation and respect of mountain. This is his big engagement officially confirmed by the Italian State with the 24 December 1985, n.776 art 2 comma/paragraph b) law that says:

*“... The Italian Alpine Club provides, in favour of both its members and other people, within the limits of the articles of the statute, and in the way established here: [...]*

*b) to the contouring, to the realization and the maintaining of trekking routes, alpine works and alpine facilities;*

*c) to the spread/diffusion/distribution of mountain attending and to the organization of alpine, excursionist and speleological enterprises...”*

Nowadays the network of Italian trekking routes is expanding along dozen and thousand kilometres; many of these has exclusively historical value, and is currently in disuse; the CAI estimates that approximately ninety thousand miles of paths are now used for purposes related to hiking tourism and about sixty thousand kilometres of these are somehow managed by CAI itself.

Despite the paths have often extended regional or even inter-regional only in a few cases, the management has been scheduled on a non-closely local criteria but in an overview.



In the absence of a national policy on paths, each fact is organized themselves and unfortunately often in disharmony with the neighbouring creating over time a palette of colourful signs and trekking routes numbers.

The Central Commission for Hiking of CAI has fixed in 1996 principles and criteria which must be followed about pathway carried out by sections of CAI and with 27.11.1999 resolution the Central Council of CAI has formalised the previous decisions of technical branch. He then set the institutional basis for implementing this long process that involves all the CAI and is increasingly method for Public Body.

In 1997 it was created a special working group for the trails, called SITCAI, which operates directly under the National Presidence Commission of CAI, and that is playing an important filtering role nationally, of technical and training proposal, but also support and connection with sections and technical committees on the territory.

This group is working for building a single large WEBGIS system, collecting all the data surveyed on the field by all the peripheral groups of CAI by using of a stand-alone software provided to them. The CAI by implementation of this project recognizes the importance and the help that the world and the virtual digitalization and the GIS system particularly can provide in the planning, management, maintenance of the network pathway.

The steps that have been made toward this digitalization are:

- Creation and distribution of a standard GIS protocol named PROTSIS
- Development and improvement of the SIWGREGI web-GIS software;
- Development and spreading to all the CAI groups of the SENTIERIGIS stand alone software

### 2.1. Protocollo Sistema Informativo Sentieri CAI (PROTSIS)

In 2006 SIT CAI has published a GIS standard protocol by which CAI defines the procedures to build a GIS for trekking routes. This protocol is called PROTSIS, an acronym for Information System “PROTocol Trekking routes”. This protocol is proposed to all the Italian community of users, as a standard database for trekking routes data managing.

## 2.2. SIWGRI: the webGIS for trekking routes network management.

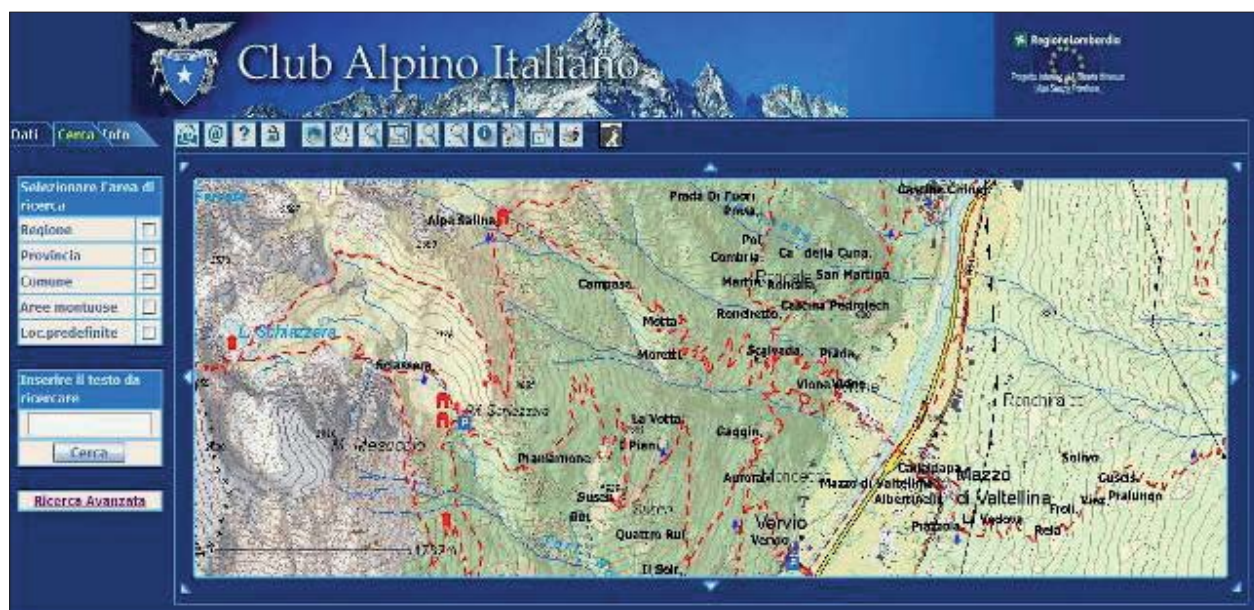
The CAI of the Lombardy Region, in collaboration with the Region Government within a EU founding programme INTERREG IIIa has developed an application, called SIWGREI (WebGIS Information System Italian pathway Network), by which it is possible to manage the pathways data collected in Lombardy and in the future in all Italy.

The SIWGREI information system is a completely manageable, at different levels, via WEB and therefore has all the characteristics to become the single platform management paths of Italy (Fig. 1).

SIWGREI is responds to different kinds of needs:

managerial/operational: the identification of the degradation and maintenance problems; properties of a path and the alternatives to routes no more proposable. The viewing of facilities, of equipment, but also of historical, cultural, environmental exigences, in order to check the usability. The design of new paths and evaluation of neglect for others over the extraction of data to track budgets and obtain financing;

- hiking: viewing the network of paths in a particular area and of emergencies and equipment related to, planning trips with description of the times run and of the gradients;



*Fig. 1: SIWGREI, the CAI WEBGIS.*

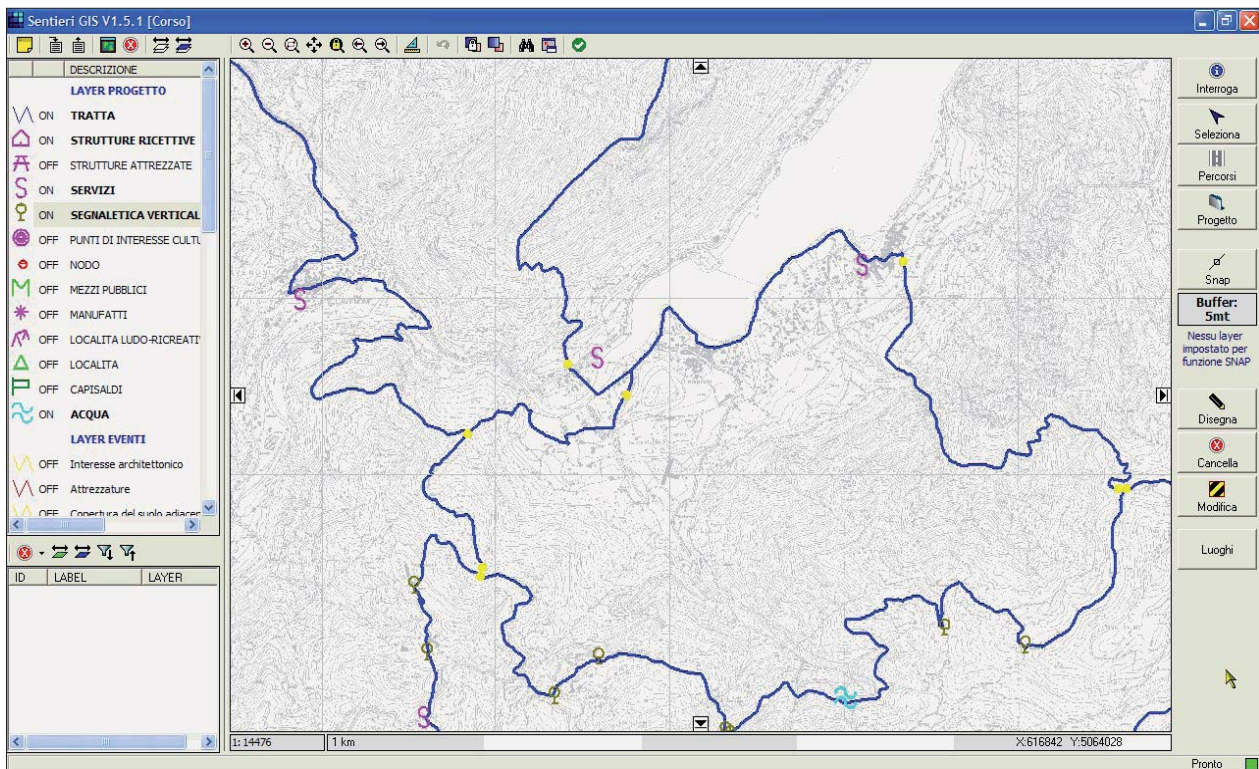


Fig. 2: A screenshot from SentieriGIS software.

- outreach: creation of an ON LINE database that can produce trekking maps, sharing and confluence of data to and from other Web GIS.
- institutional: it allows the exchange and the integration of data with other pathway network operators, regions, parks, mountain communities, provinces, municipalities, keeping/having the Italian Alpine Club as a reference point.

The SIWGREGI application is the set of different software components:

- a geodatabase resident on a centralized server;
- a Web Server for the publishing WEBGIS client data via intranet (*Sentieri WEB*)
- a traditional kind of GIS application Client> Servers (*Sentieri WEB*) installed on the local that receives and retransmits data to the database
- an application management (*Sentieri DOC*) that can talk with the central database.

### 2.3. SentieriGIS

The *SentieriGIS* software – owned by the CAI – operates in stand-alone mode and has been designed and developed in order to allow the upgrade and consulting pathways data in every section or groups of sections of the CAI.

The software is distributed free to all the organised group of the association CAI that request it. To every group is given an opportunity, within its own coordinating peripheral structure, to update pathways network data belong to its area of competence, and then to transmit this information to the central group of CAI, which will validate before publication on SIWGREGI.

The *SentieriGIS* program is a tool used to monitor the status of pathways network in order to schedule maintenance both ordinary and extraordinary, on a local scale, but in accordance with the specifications defined at national level. In SIWGREGI are stored cartographic information, use of the land, informations on the state of conservation of the paths, and several data related to topics of tourist interest. In addition, the software provides the ability to CAI member to use the system to create trekking routes, maps and reports with all relevant information for excursions (Fig. 2).

### 3. The role of the University of Brescia

The surveying group of the University of Brescia started the studies on the trekking routes surveying with GIS-GPS approach since 2000 inside the Sagarmatha National Park (Nepal) under the acronym of SATGIS (Sagarmatha Trekking GIS, Fig. 3). In 2002 started a collaboration also with Comitato Ev-K2-CNR. The surveying have been made by using a home developed GPS and the GIS standard. The complete surveying of the trekking routes of the Sagarmatha (Everest) National Park required three years of work, from 2000 until 2003.

In the following years started the Nepal Trekking GIS (NET-GIS) project and the survey activities has been extended to the Annapurna (2003) and Kangchenjunga (2004) ranges.

In the October 2005 and October 2006 the researchers returned in the Sagarmatha National Park to update the data surveyed in 2000–2002, and for teaching some local people to the data update of the surveyed data, using both GPS, digital cameras and pre-prepared standard documents.



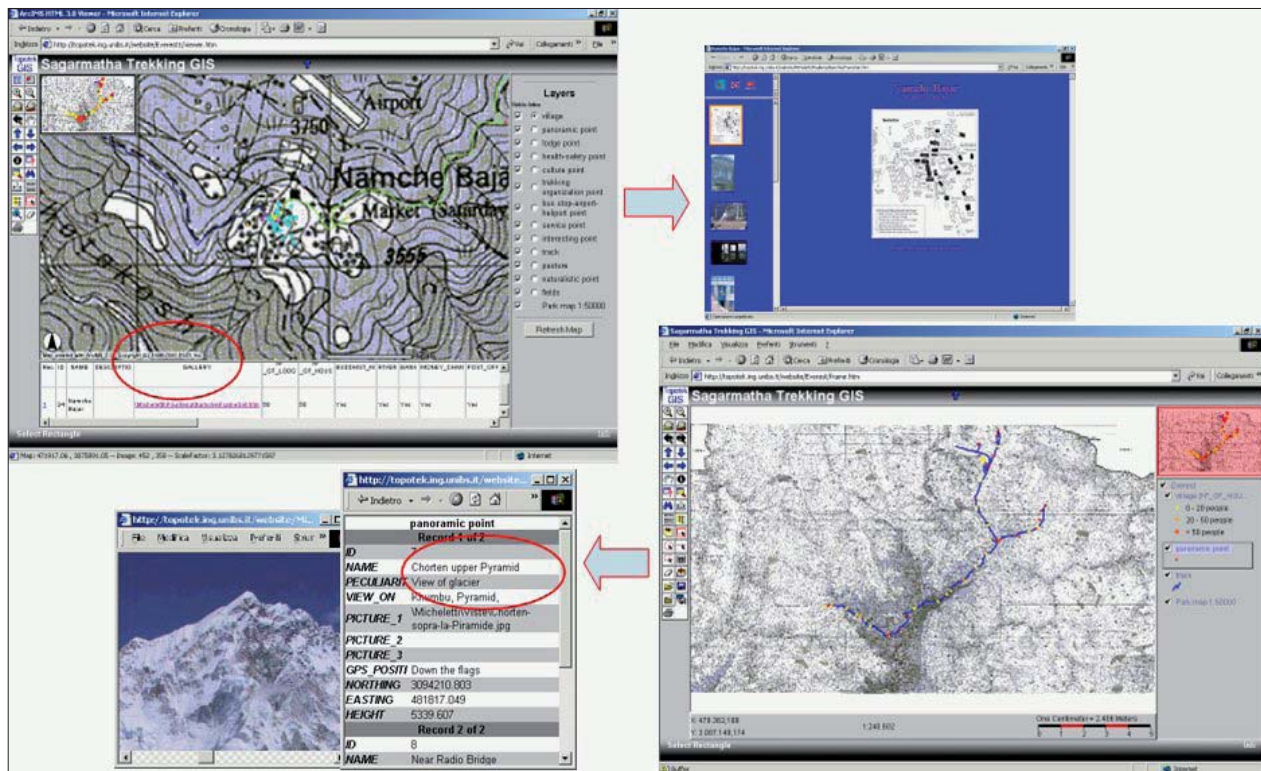


Fig. 3: Screen Shot of the Sagarmatha Trekking GIS developed on Open Source basis.

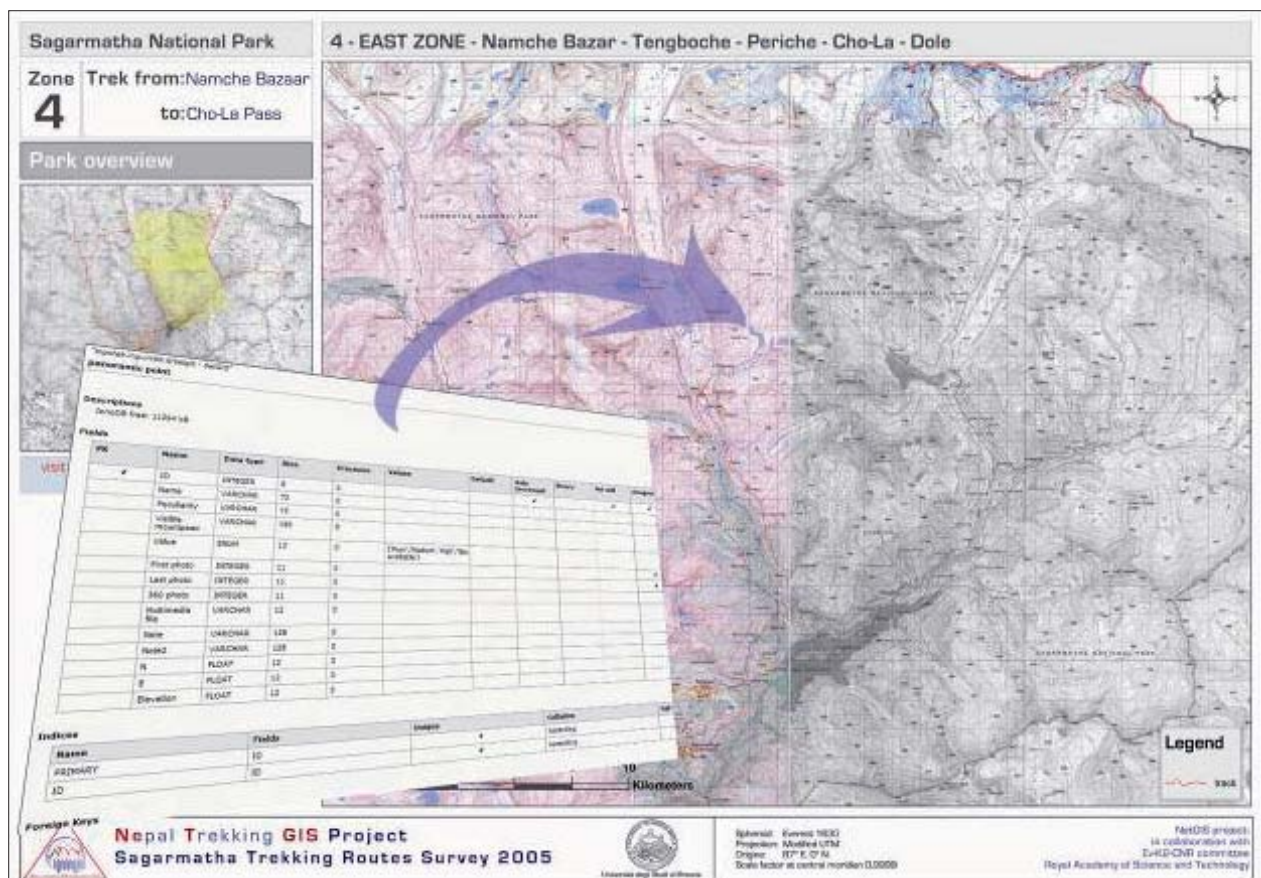


Fig. 4: Surveying update table for SATGIS project.



The data update and the new data surveyed could be loaded in the NetGIS server through an automatic via-web procedure, using the MySQL standard format and PHP pages, between the months of May and June 2007.

The field work in Nepal has been a good and valid experience to study how to apply European Survey Standards to developing countries needs and to evaluate how to use local people for the day by day surveying and data updates needs (Fig. 4).

The trekking routes, their management and organization, their support facilities on the park and the amount of information that arrive at people who cover a route are, indeed, different. The acquired experience has been used to plan the Rwenzori Trekking GIS project.

#### 4. The Rwenzori Trekking GIS

In 1906, inspired by Henry Morton Stanley's last wills, the Duke of Abruzzi led an expedition to the Ruwenzori Range in Uganda. He and the members of his expedition climbed sixteen summits in the range, including the main six peaks. One of them, Mount Luigi di Savoia, bears his name. The highest peak was reached on June 18, 1906 and was named Margherita, the Queen of Italy.

Luigi Amedeo of Savoy's team was made up of Captain Umberto Cagni who, with Lieutenant Edoardo Winspeare, assisted the Duke with geographical observations; the photographer Vittorio Sella (Fig. 5) and his assistant Erminio Botta; Dr Alessandro Roccati, director of the geominalogical laboratory of Turin Polytechnic, entrusted with geological and mineralogical research; Major Achille Cavalli Molinelli, naval doctor, who, among other things, has the task of collaborating with Roccati in the collection of zoological and botanical specimens.

In the Centenary of such an event the University of Brescia, in collaboration with the environmental association "L'Umana Dimora", registered at the Italian Ministry of Environment, and the Italian Alpine Club in order to celebrate that great event has organized a new expedition on the Mountains of the Moon together with an articulate scientific and cultural action; the outcomes may result into bringing out the environmental features of the Rwenzori range, and in the realisation of didactical and educational tools for Ugandan students, locally spread thanks to a close collaboration with the italian NGO AVSI (International Service Volunteers' Association) and through educational scientific initiatives also for the non-specialist public in Italy concerning the environmental peculiarities of the Rwenzori National Park, and Uganda in general.

This Project is a direct consequence of the scientific interest for the mountain territories of Central Africa and of an historical collaboration in the realisation of research projects shared by some researchers of the Department of Civil Engineering, Architecture, Land and Environment of Brescia University, together with the "Mountain Working

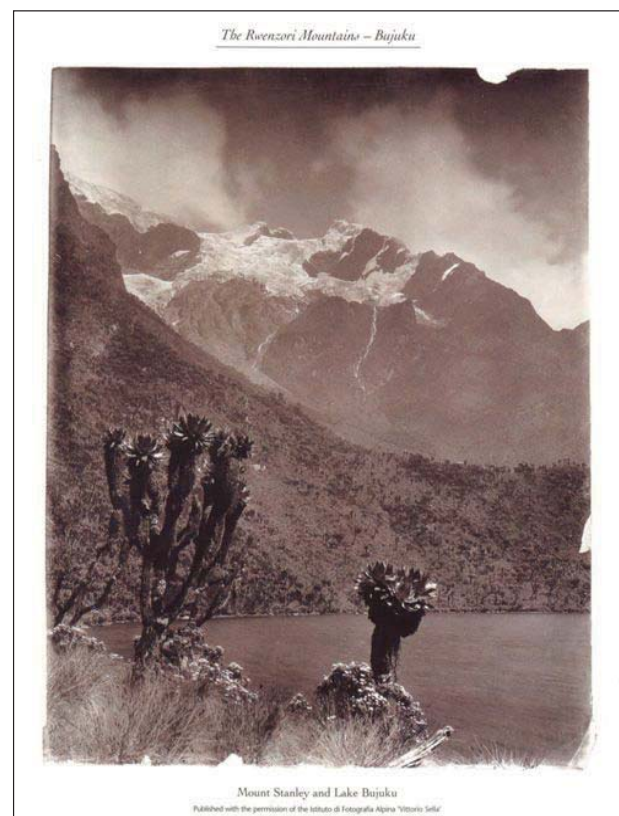


Fig. 5: Mount Stanley by Vittorio Sella



Fig. 6: Surveying in Rwenzori Range

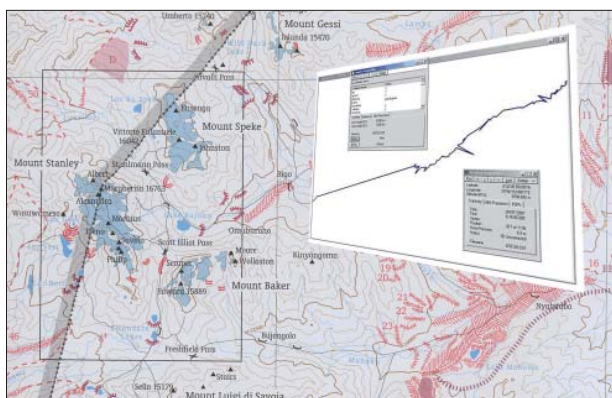


Fig. 7: GPS Raw data on the map

Group” (hereby called Mountain Group), active from many years within the association “L’Umana Dimora”.

From the 27<sup>th</sup> of July until the 2<sup>nd</sup> of August 2007, one year later, two researchers moved along the routes of the RMNP park with a mono frequency GPS receiver (Fig. 6) and are now working to the final data processing.

The paths surveyed are the following:

- Ibanda-Nyabitaba wasn’t surveyed because of the leaf cover;
- Nyabitaba-John Matte. There were big restrictions on this way because of the rich vegetation;
- John Matte – Bojuku was completely surveyed, for a overall length of about 7,5 km.
- Bojuku – Elena Hut, complete surveying for a distance of 4,1 km
- The stages/legs from Elena Hut – Kitandara and Kitandara – Nyabitaba weren’t surveyed because of the difficulties met with during the way (mud and slippery and very exposed plates).

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The data collected concern particularly:

- the positions of paths mapped out in the park;
- the position and the most important data related to the huts and the lodges in the area;
- the position and the state of maintenance of system of signs;
- the condition of places, particularly of stretch of road strongly degraded;
- the location of panoramic view/points;
- the points of naturalistic interest.

The GPS data have not been processed yet by the differential correction, either filtered or cleaned in any way (Fig. 7).

## 5. Conclusions

The expedition planned for December 2007 and January 2008, that must have provided all GPS data concerning the Rwenzori Park trekking routes, has not been realised because of the sudden ebola epidemic broken out in Uganda in December. Next data will collect in the next summer 2008 expedition.

We would give a special thanks to the AVSI ONG operating in Kampala, and particularly to the Dr. Filippo Ciantia for his collaboration and logistic support. A special thank to Mr. Pietro Averono chief of the cultural office and Dr. Pietro Tombaccini, lieutenant ambassador of Italy in Uganda. Thanks also to the Uganda Wild Life Authority and in particular to Nelson Guma, Warden in Charge of RMNP [guma\\_nelson@yahoo.co.uk](mailto:guma_nelson@yahoo.co.uk)

# Investigations into the Spatial Pattern of Annual and Interannual Snow Coverage of Brøgger Peninsula, Svalbard, 2000 – 2007

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## Abstract

*Two expeditions of the late cartographer and glaciologist Wolfgang Pillewizer from the Institute for Cartography (IfC) in Dresden in the 1960s gave motivation for nivological investigations in Pillewizer's former study area, the Brøgger Peninsula on Spitsbergen - Svalbard. Following the definitions of Carl Troll 1955 and Carl Rathjens 1982 the archipelago of Spitsbergen represents, despite its comparatively low altitudes, a terrain of highalpine nature. There, like in all arctic areas, the importance of snow is all encompassing. The evolution of regional biota is closely correlated with the variations of snow coverage, distribution and depth. Furthermore, snow is a major indicator of the impact of global warming on the vulnerability of the arctic environment. As (amongst others) stated in the "Fourth Assessment Report (AR4)" of the Intergovernmental Panel on Climate Change (IPCC) from February 2<sup>nd</sup> 2007, especially the polar areas show dramatic changes in their snow and ice cover under the influence of the global climatic change. This gave rise for an investigation of the snow cover on the well-studied Brøgger Peninsula on Svalbard. Snow-depth data based on both point measurements and terrestrial radar profiles have been made by the Norwegian Polar Institute (NPI) in Tromsø since the year 2000. NPI and IfC jointly carried out a correlation study concerning the correlation between point probings, ground-radar, and QuikSCAT and MODIS Albedo remote sensing data. Taking into account the particular climatological and geomorphological conditions, the results presented in this paper are meant to serve as a basis for further investigations into remote sensing-based monitoring of snow patterns and snow depth. Difficulties in setting up formalisable relationships are pointed out.*

## 1. Motivation and Objectives

It is no longer an issue of the scientific community, politicians and NGOs to discuss global warming, its origins and consequences – it is resounded in every stratum throughout the world these days. Since February 2007, the Intergovernmental Panel on Climate Change (IPCC) published several contributions to the "Fourth Assessment Report (AR4)",

which pointed out the serious condition our planet is situated in. Polar areas play a major role in the context of global warming due to their vulnerability and influence on the global climate. In the Arctic three major mechanisms occur which influence our planet's climate and may amplify the process of global warming. The cumulative melting of ice and snow results in changes of surface reflectivity and the oceans' circulation by adding more and more freshwater. Beside these two mechanisms the proceeding warming leads to an increased quantity of greenhouse gas emissions. High concentrations of carbon dioxide, methane and nitrous in the global atmosphere result in warming and in a dramatic change of the snow and ice coverage of the Arctic and Antarctica. This phenomenon shows retroactive effects on the worldwide temperature distribution and evaporation. The situation in arctic areas implicates an intensified research of its underlying processes and consequences. Further, the snow cover in arctic areas shows a declination of 10 % over the last 30 years with respect to the springtime maxima. This implies a reduction of the snow season in correlation with an earlier pulse of river runoff. In combination with a decreasing snow quality like thin ice layers, the animals access to food and nesting sites is restrained. The additional variations of snow distribution, depth and coverage represent a dramatic intervention in the regional biotas' evolution (ACIA Group 2004; IPCC 2007).

The work presented here was meant to contribute to the ongoing work of the Norwegian Polar Institute (NPI) to investigate the effect of global warming on polar areas. Further, it is representing a revival of the cooperation between IfC and NPI since the Spitsbergen expeditions of Wolfgang Pillewizer in 1962 and 1964/65. In the sense of the approaches made by the group around Rune Solberg (Oslo; Solberg et. al 2005 cum lit.) this study should constitute a contribution towards a more operational snowpack monitoring



## 2. Data

For the analysis of the spatial pattern of the annual and inter-annual snow coverage on Brøgger Peninsula, in-situ measurements, remote sensing imagery, as well as meteorological data were used.

In-situ snow-depth measurements were provided by the Norwegian Polar Institute (NPI) in the form of snow probing and ground-penetrating radar (GPR) data. Annual snow probing measurements were carried out in the lowlands and on the two glaciers Austre Brøggerbreen and Midre Lovén-

breen in the years 2000 till 2007. Using GPR, in the years 2000 and 2007 auxiliary snow depth measurements were conducted along several snow probing routes (Kohler 2007; Fig. 1).

Beside the in-situ measurements, imagery from the NASA Moderate Resolution Spectroradiometer (MODIS) was used. MODIS is mounted on the multi-instrument Earth Observing System satellites Terra and Aqua, which were launched in February 2000 and May 2002 respectively. MODIS provides a continuous, comprehensive and global



Fig. 1: GPR Equipment

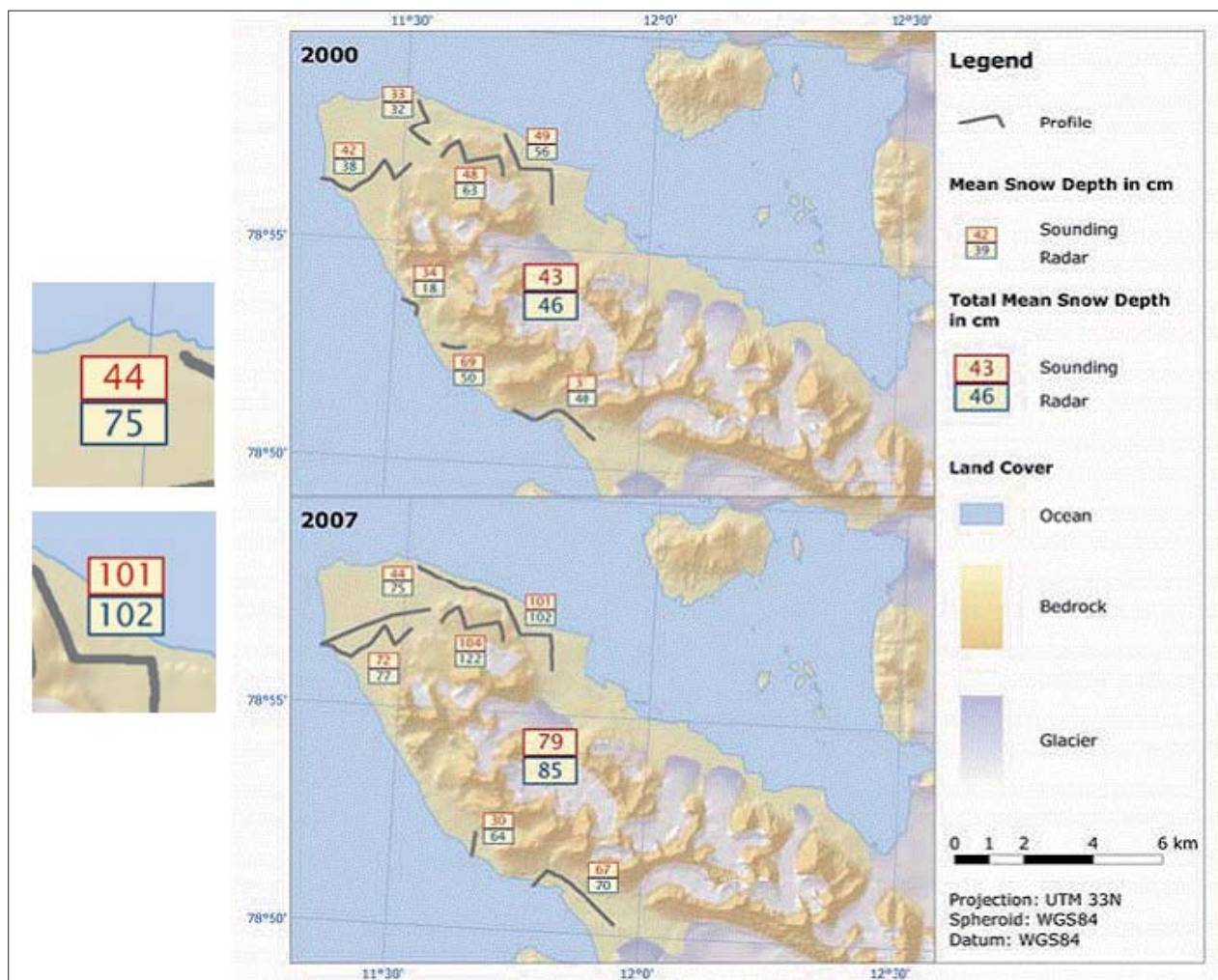


Fig. 2: Map of Brøgger showing the comparison of the results of manual snow-depth soundings versus GPR measurements.

coverage of biological and meteorological characteristics. From the wide variety of products, for the project the MODIS Albedo Product was chosen. This data provides black-sky and white-sky albedo for the spectral MODIS bands 1 to 7 and three broadbands (VIS, NIR, SW), wherefrom the white-sky SW was taken for the analysis (cf. Schaaf et al. 2002).

Other remote sensing data source used stem from the QuikSCAT/SeaWinds Scatterometer of NASA. A scatterometer is a radar system that determines the backscatter of the Earth's surface in function of the incidence angle. QuikSCAT was launched in July 1999 as the follow-up of the successful NASA Scatterometer (NSCAT) mission which was aborted in June 1997. QuikSCAT is providing different products as well, wherefrom the Normalized Radar Cross Section  $\sigma^0$  was chosen.

The  $\sigma^0$ -signal indicates the amount of the reflected energy per specified resolution cell and is derived from the radar equation referred to a unit area on the horizontal ground plane. QuikSCAT provides  $\sigma^0$ -values for horizontal and vertical polarization at 46° and 54.1° nominal incidence angle, which correspond to the inner and outer beam of the system. For the analysis, the vertical polarization (VV) was chosen (cf. Long 2000).

In addition to the in-situ measurements and remote sensing products, meteorological data from the local weather station in Ny-Ålesund was used for the analysis. Temperature and precipitation data covering the period from August 1999 until July 2007 were provided by the Norwegian Meteorological Institute. From these data, a snow model was used for the modelling of snow accumulation on Brøgger Peninsula. Thereby, the input parameters were optimized for the in-situ snow observations, regarding the location in the lowlands or on the glaciers (Kohler & Aanes 2004).

### 3. Methods

The snow depth measurements in the lowlands and on glaciers from the years 2000 till 2007 were statistically correlated with the relief parameters: elevation, aspect, and slope. Therefore, box-and-whisker plots were used, which represent one dimensional graphics of numerical data in five dimensions: the lower and upper quartile define a rectangular box which is divided by a central dot or line representing the value of the median. The so-called whiskers at each end of the box regard potential outliers by the limitation of the whisker length on the basis of a fixed multiple of the interquartile. For the statistical analysis of the correlation between snow depth and relief parameters, the data was differentiated by year and location, i.e. lowlands and glaciers. Moreover, the three variables were divided into typical intervals each in order to ensure the significance of the conclusion.

Further, the quality of the sparse sounding observations was compared to the radar measurements in the years 2000 and

2007 (cf. Fig. 2). For this purpose, the (arithmetic) mean snow depths of the particular profiles were analyzed.

Regional and local variability were assessed using the standard deviation of the mean, grouped into individual elevation intervals for the lowlands and the glaciers due to the relation between altitude and measured snow depth. The standard deviation of the means of each year shows the measurement dispersion on the basis of the standard deviation divided by the square root of the number of measurements (cf. Fig. 3).

The analysis of the annual and inter-annual albedo changes is based on the albedo mean values of each image covering the period of April until September for the years 2000 to 2007. The same procedure was used for the evaluation of the  $\sigma^0$ -signal (VV-polarization) in comparison to the meteorological data covering the years 2000 through 2006.

The correlation of remote sensing data with the in-situ snow depth did not lead to any reasonable relation. Therefore only a short insight in the applied method is given, although this was the most time-consuming process during the study. The

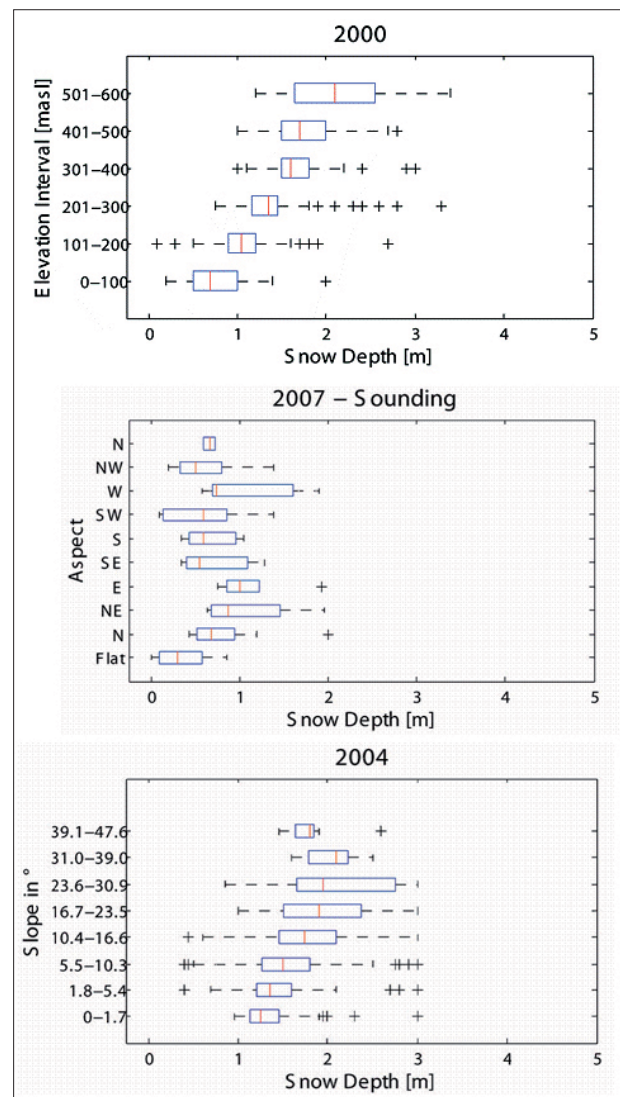


Fig. 3: Box-and-whisker plots showing the correlation between glacier snow depth, elevation, slope and aspect of the year 2000.



first step was the interpolation of the used MODIS data because of sporadically occurring data gaps. Further, the in-situ snow depth data was scaled in three steps, resulting in three matrices for the correlation with MODIS and QuikSCAT.

#### 4. Results and Conclusions

The analyses of relief parameters and in-situ observations showed a high correlation between elevation and snow depth for both the lowlands and the glaciers (e.g. Fig. 3). Further, regional variations in snow accumulation related to the aspect could be determined. Thereby, a relation between greater snow heights and a North-Northeast-East trend for the lowlands as well as a South-Southeast tendency for glacier regions respectively was identified. On gentle slopes, a proportional increase of snow depth was found which is reversing for steeper slopes. A combination of these relief parameters with prevailing wind directions could lead to the generation of snow avalanche hazard maps (cf. Buchroithner & Kostka 1990, Kinberger and Kriz 2007 cum lit.) for more remote areas.

The analysis of GPR versus manual sounding measurements led to a good accordance between the arithmetic means of radar and sounding for almost all profiles. Outliers could be excluded by determining median and trimmed values as well as circumjacent values which show continuous increases and/or decreases. Deviations in individual profiles could be assigned only to snow redistributions caused by e.g. aeolian processes which were, however, only detectable by dense GPR measurements.

Regarding the regional and local variability of the in-situ snow depths, a greater variation in altitudes above 201 masl for the lowlands and 501 masl for the glaciers was determined. For the inter-annual variability of glacier and lowland snow depths a high correlation was recognizable

(Fig. 4). Glacier measurements showed a low annual variation. MODIS and QuikSCAT data hold almost parallel show-height profiles for the inter-annual variability of the two regions, the lowlands listing lower values for both data sets.

Due to the polar night MODIS albedo data from 2000 to 2007 only cover the periods from April to September. Maximum and minimum values tend to a decrease over the years, even though minor deviations are observable. Annual trends show a strong decrease around the end of April or beginning of May implying snowmelt. Individual summer peaks indicate snowfalls which could be verified by meteorological data.

Melting periods were also analyzed using the QuikSCAT signal in combination with weather data. Hereby, warmer periods during the snow accumulation as well as refreezing during the snowmelt could be identified. Further, an always occurring pattern was found in the QuikSCAT signal indicating the start of the annual melting period in May or June, while two years additionally revealed a pre-melting phase in March or April. Based on the modelled snow accumulation a delayed melting in comparison to the QuikSCAT data was determined, showing, however, the same behaviour for refreezing periods (cf. Fig. 5).

The correlations between in-situ snow-depth measurements and remote sensing data led to a restricted suitability. Due to multiple influencing factors which, for various reasons, could not be regarded in the analysis, the results show no good correlation between in-situ observations and satellite imagery. MODIS albedo (cf. Fig. 6) is, however, slightly better correlated than QuikSCAT backscatter because of the complex composition of snow conditions influencing QuikSCAT signal. For a good evaluation of the snow accumulation with QuikSCAT, areas with continuous snowpacks

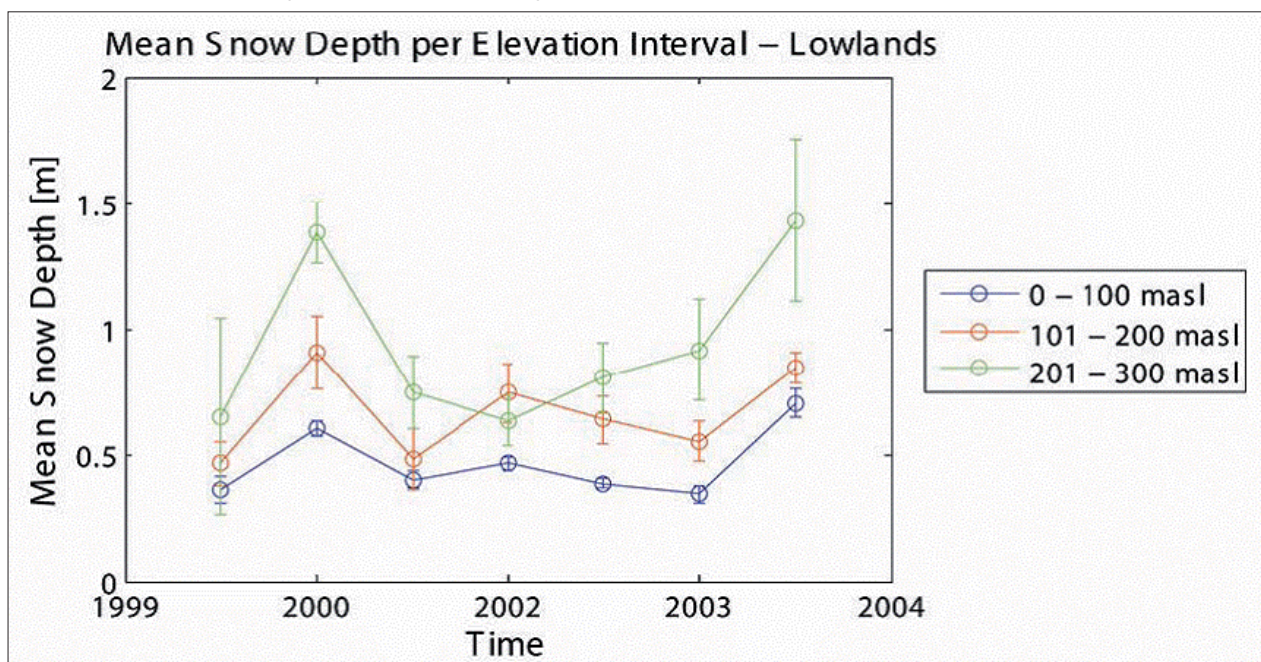


Fig. 4: Change of mean snow depth in the low lands (per elevation interval) from 2001 to 2007.

and information about the underlying layers are required (Drinkwater et al. 2001).

The inclusion of factors like snow density, grain size, liquid water content, microclimatic conditions, etc. can certainly enhance the suitability of the used remote sensing data sets. Additional measurements of in-situ albedo would provide a reference for the MODIS Albedo Product as assessed by Stroeve et al. (2005), in order to determine a better relation between snow depth and albedo.

All in all, an extension of the in-situ soundings on a regular grid covering the entire area instead of sparse profiles may provide a better basis for spatial and temporal variability studies of the snow patterns. Furthermore, it would be an advantage to gather in-situ observations three times a snow period.

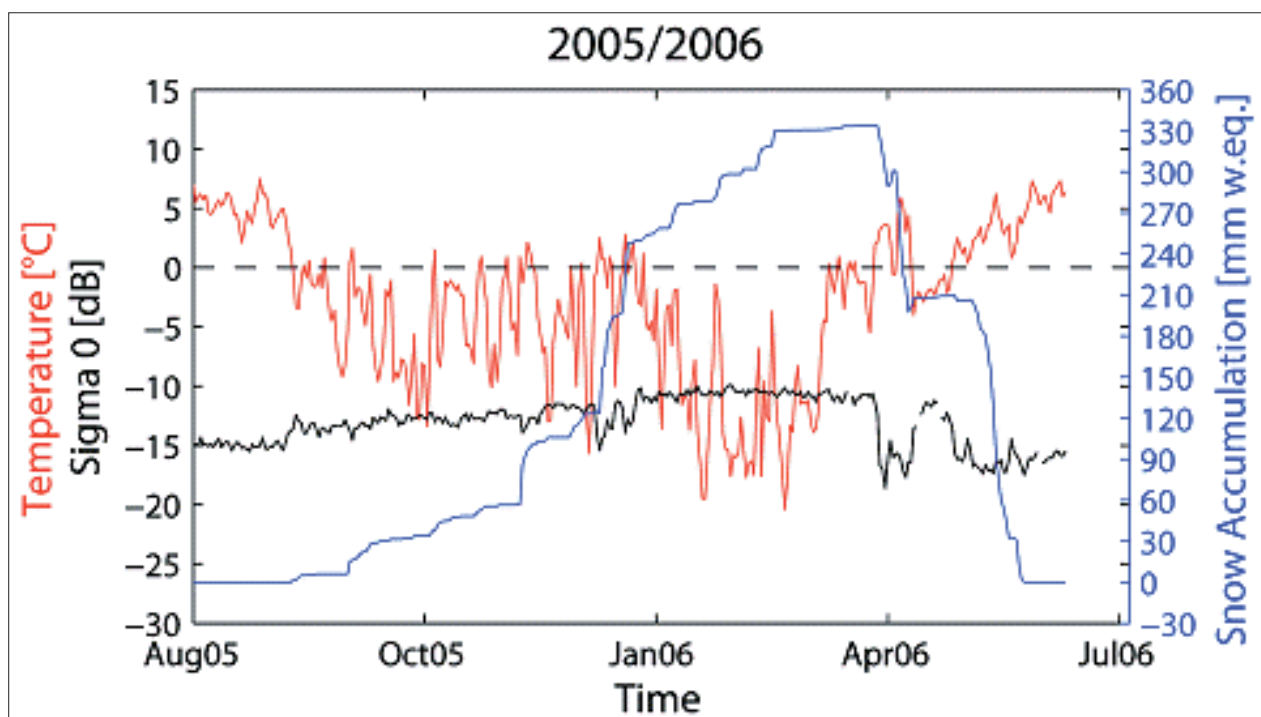


Fig. 5: QuickSCAT  $\sigma_0$ -signal, temperature and modelled snow accumulation of the winter period 2005/2006.

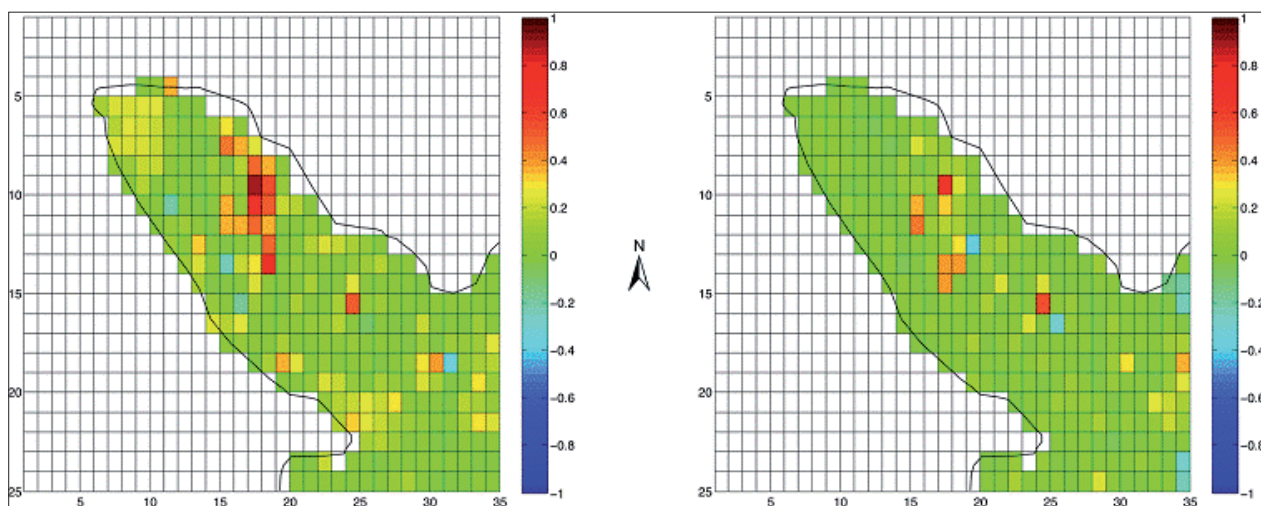


Fig. 6:  $R^2$  of correlation for MODIS data. Shown are snow depth means per elevation interval (left) and overall (right).

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# Evaluation of Cartographic Resources in Researching Landforms in High Mountains

## Case Study of Double Ridges in the Polish Part of the Tatra Mountains

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### Abstract

*Cartography has traditionally played an important role in advancing research in physical sciences. This has been even more pronounced in recent years due to the increased availability of high resolution and high definition cartographic resources, such as aerial photography, satellite imagery, large scale topographic and thematic maps and databases. These resources enable researchers to locate and identify ever finer landforms in difficult terrain, such as high mountains.*

*This paper examines the availability of cartographic resources and systematically evaluates their suitability for researching high mountain landforms in the Polish part of the Tatra Mountains. In particular, it considers methods for identifying and locating double ridges, relatively small longitudinal depressions along mountain ridge tops. The paper suggests that, although the available resources are not yet sufficient for comprehensive geomorphological studies, existing approaches are adequate for detecting larger depressions. It recommends the investigation and evaluation of other cartographic resources currently not available for the Tatra Mountains for more detailed analysis of high mountain landforms.*

### 1. Introduction

Cartography has traditionally played a significant role in supporting physical sciences research, from providing base maps and thematic databases for analysis to representing the results in spatial context. An important part of this support has been facilitated by cartographic products, both hard copy and digital, that deal with mountain environments. Researching geomorphological processes and landforms in difficult terrain can be a very demanding and challenging endeavour. Application of appropriate cartographic resources, reinforced by their systematic evaluation, could form a valuable aid in such studies. In particular, these resources could be used to identify and locate various landforms in high mountains.

Over the last decade, the mountain cartography research efforts have primarily focussed on representation and mod-

elling of mountainous terrain, including issues of design, tools, databases and visualisations (e.g. Haeberling, 2004; Heuberger and Kriz, 2006; Hurni et al., 2001; Kriz, 1999). Other areas of active research include high mountain hazard mapping, monitoring of snow cover and glacier dynamics, as well as cognitive aspects in mountain cartography (e.g. Kaufmann et al., 2006; Kriz, 2001; Trau and Hurni, 2007; Wood et al., 2005). Considerably less attention has been devoted to a systematic evaluation of cartographic resources that could be useful for identifying and locating landforms in high mountains.

An application of a detailed digital elevation model (DEM) to represent the Hellenic Volcanic Arc was described by Vassilopoulou and Hurni (2001). The model was thoroughly evaluated with regard to its positional accuracy and was found suitable as a basic tool for tectonic and geomorphological analysis. However, no examples were given to illustrate the performance of this model in identifying or locating landforms. A process for updating the rock and scree representation on Swiss topographic maps at the scale of 1:25,000 was illustrated by Gilgen (2006). A wide range of cartographic resources including existing maps, photogrammetric plots, and aerial photographs in colour and



Fig. 1: Double ridge at Starorobociańska Przełęcz (no 30, see Fig. 5 for explanation) with Starorobociański Wierch (2176 m) in the background. Photography: Justyna Żyszkowska

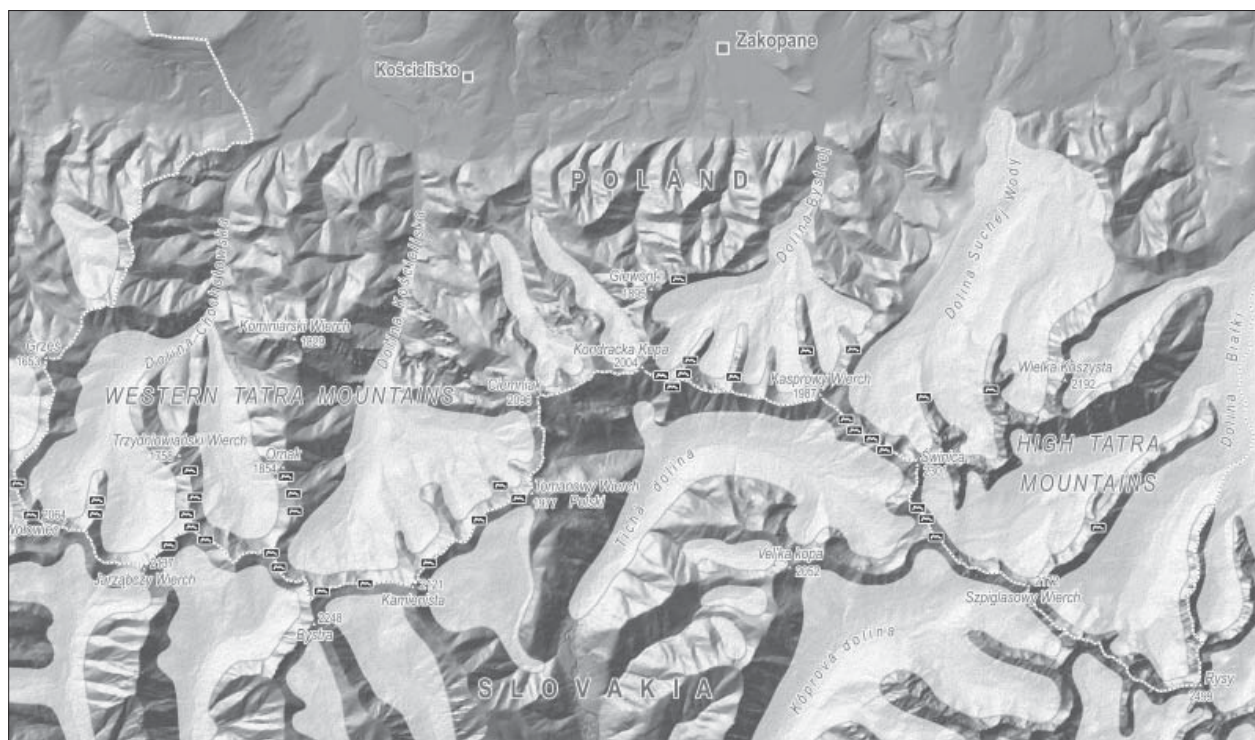


Fig. 2: The Tatra Mountains during Würm (Vistulian) glacial episode (~20,000 years BP) (adapted from Nemčok, 1993) and the current distribution of double ridges. Glaciers are represented by semi-transparent white polygons, while double ridges by solid black-filled symbols. Note the relationship between the locations of double ridges and heavily glaciated neighbouring valleys.

greyscale were used to perform this task. Gilgen (2006) reported that accurate distinction between landforms in mountainous terrain is sometimes difficult to make even for an experienced cartographer. The research did not perform any evaluation of the cartographic resources used in the updating process.

This paper aims to contribute to mountain cartography research by examining the available cartographic resources and systematically evaluating their suitability for identifying and locating high mountain landforms. In particular, it considers methods for detecting double ridges in the Polish part of the Tatra Mountains.

## 2. Double Ridges

Double ridges are relatively small longitudinal and often asymmetric depressions along mountain ridge tops (Jaroszewski et al., 1985) (Fig. 1). They are formed by a process called sacking which involves gravitational spreading of a mountain ridge and eventually a collapse of large blocks along structural rock fractures and faults. This process leads to the formation of trenches or double-crested ridges at the tops and in some cases a bulging of lower slopes (Barrett, 1997). It is often attributed to the glacial oversteepening of the neighbouring valley walls and removal of lateral support during deglaciation (Barrett, 1997; Żyszkowska, 2005). In some cases, seismic activity can be responsible for the formation of double ridges in high mountains (Jaroszewski et al., 1985).

Double ridges occur mostly in mountain ranges of the Alpine orogenic cycle, especially those built of igneous or

metamorphic rocks which were recently or are currently glaciated (Żyszkowska, 2005). The Tatra Mountains are an example of a recently glaciated mountain range where these landforms can be found throughout (Fig. 2).

The term double ridge is not well recognised in English geomorphological literature, despite being very fitting to describe this particular landform. Attempts in popularising this term (e.g. Rubín et al., 1986) were unsuccessful and the name double ridge remains rarely used today. It seems that for many years these landforms were subject of intensive scientific research in a non-English speaking countries where the term double ridge (or alternatively ridge top depression), in local languages of course, has been established and accepted among the scientific community. Examples include zdvojený hřbet (Czech), crête doublée (French), doppelgraten (German), podwójna grań (Polish) and zdvojený hreben (Slovak). The alternative term of ridge top depression has its equivalent in sdružený hřeben (Czech), rów grzbietowy (Polish) and zdrušený hreben (Slovak).

Double ridges are a common landform in high mountains on all continents. Apart from the Tatra Mountains, they have been found and documented on Svalbard and Greenland (Jahn, 1947, 1958), the Alps (Nemčok, 1982), Altay Mountains, Caucasus Mountains (Nemčok, 1982), the Southern Alps (Barrett, 1997), the Japanese Alps, the Andes and the Rocky Mountains (Barrett, 1997; Carson et al., 1997; Nemčok, 1982). They can also be found in the Low Tatra Mountains, Lesser Tatra Mountains (both in Slovakia), Fogaras Mountains (Romania), the Ural Mountains (Russia), the Pyrenees and Himalayas (Żyszkowska, 2005).



The size of double ridges in the Tatra Mountains varies and can be classified into three broad groups based on their morphometric characteristics. Small landforms are up to 2 m deep and up to 80 m long, while the medium size ones are 2–10 m deep and 80–300 m long. The large double ridges can be up to 30 m deep, 10–70 m wide and up to 830 m long. In other parts of the world even larger landforms can be found. For example, Źyszkowska (2005) provides an account of a very large, 100 m deep double ridge located in the Southern Alps of New Zealand near Manapouri (Fig. 3).

### 3. Polish Part of the Tatra Mountains: Study Area

The Tatra Mountains form the highest part of the 1,300 km long Carpathian Mountains. They cover an area of 785 km<sup>2</sup> and are located on the border between Poland and Slovakia in Central Europe. They are the only mountain range

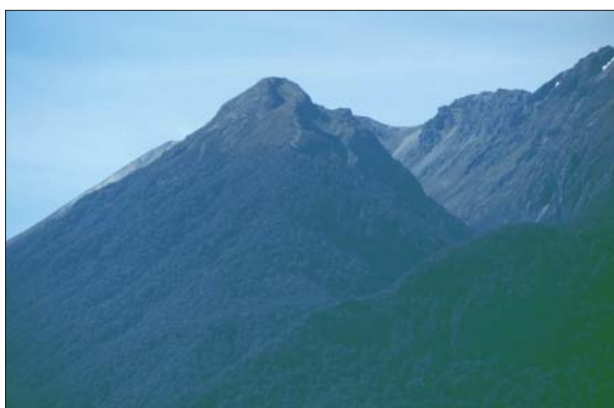


Fig. 3: A very large double ridge (below the left peak) in the Southern Alps near Manapouri. Photography: Jacek Drecki

having an alpine landscape between the Alps and the Caucasus Mountains. The highest peak is Gerlachovský štít in Slovakia at 2655 m. Due to the geological composition, and consequently landscape and land relief characteristics, the Tatra Mountains consist of (west to east) the Western Tatra Mountains with the highest peak of Bystra at 2248 m, the High Tatra Mountains and the Belianske Tatra Mountains with the highest peak of Havran at 2152 m.

The Polish part of the Tatra Mountains occupies only 175 km<sup>2</sup>, less than 25% of the entire mountain range and does not include any part of the Belianske Tatra Mountains. The highest peak is Rysy at 2499 m located in the High Tatra Mountains on the border with Slovakia. The highest peak of the Polish part of the Western Tatra Mountains is Starorobociański Wierch (Klin in Slovak) at 2176 m.

Although the occurrence of double ridges is common around the world (e.g. Nemčok, 1982; Barrett, 1997; Źyszkowska, 2005), the Tatra Mountains are an ideal study site due to their great accessibility for undertaking field surveys combined with availability of wide range of cartographic resources. In this research, field survey was limited to the Polish part of the Tatra Mountains covering about 30% of the area and including almost entire main ridge and numerous side ridges (see Fig. 4). The eastern and central part of the High Tatra Mountains, where geological structure of rocks was not favourable for the formation of double ridges, was excluded from the survey. Also the area of Kominiarski Wierch (1829 m) in the Western Tatra Mountains was excluded, as this region was already surveyed by the Tatra National Park rangers and no double ridges were found there.



Fig. 4: Distribution of double ridges in the Polish part of the Tatra Mountains and their relative sizes. Consecutive numbers, next to double ridge symbols, correspond to the listing in Fig. 5. Study area is shown by a grey, dotted line and a semi-transparent band on the inside.

No	Name	Size
	<b>Wierch, Turnia – a Peak, Przełęcz – a Saddle, Grzbiet – a Ridge</b>	
1	Opalone ( <i>next to Opalony Wierch</i> )	M
2	Gładki Wierch	L
3	Between Gładka Przełęcz and Walentkowy Wierch	M
4	Next to Walentkowy Wierch	M
5	Żółta Turnia	M
6	Mały Kościelec	L
7	Behind Skrajna Turnia - Pits	S
8	Behind Przełęcz Liliowe ( <i>towards the first eastern peak</i> )	S
9	Przełęcz Liliowe	S
10	Between Przełęcz Liliowe and Beskid	S
11	Uchrocie Kasprowe	S
12	Kasprowy Wierch, Suchy Uplaz ( <i>a ridge between Dolina Goryczkowa and Dolina Sucha Kasprowa</i> )	M
13	Kondratowy Wierch	M
14	Łopata	M
15	Suchy Wierch Kondracki	M
16	Przełęcz pod Kopą Kondracką	M
17	Przełęcz pod Kopą Kondracką ( <i>in the direction of Suchy Wierch Kondracki</i> )	M
18	Next to Długi Giewont	M
19	Between Tomanowy Wierch Polski and the arm of Zadni Smreczyński Grzbiet	S
20	Zadni Smreczyński Grzbiet	L
21	Between Smreczyńska Przełęcz and Smreczyński Wierch	S
22	Hlińska Przełęcz	L
23	Pyszniańska Przełęcz	M
24	Between Pyszniańska Przełęcz and Błyszcz	S
25	Baniste	L
26	Siwy Zwornik	L
27	Ornak	S
28	Ornak – Siwe Skały	L
29	Ornak – Kotły	L
30	Starorobociańska Przełęcz	L
31	Trzydniowiński Wierch	S
32	Czubik	S
33	Between Czubik and Kończysty Wierch	S
34	Kończysty Wierch	M
35	Jarząbca Przełęcz	M
36	Czerwony Wierch	S
37	Czerwony Wierch II	S
38	Wołowiec	M
39	Between a saddle next to Wołowiec and Rakoni	S

Fig. 5: Summary of double ridge systems in the Polish part of the Tatra Mountains. The first column (No) refers to the number on Fig. 4 and the third column (Size) to a size of a particular landform, i.e. large (L), medium (M) or small (S).

Fig. 5 (above) lists all double ridges that were identified and located during the survey. There are a total of 39 double ridge systems, including 9 large, 15 medium and 15 small ones. They became a benchmark in evaluating the suitability of cartographic resources for researching double ridges in this study.

#### 4. Cartographic and Non-cartographic Resources

The Tatra Mountains are very well covered by a multitude of cartographic and non-cartographic resources for undertaking research in physical sciences. They include topographical maps, geological maps, specialised geomorphological maps, aerial photography, satellite imagery, digital spatial databases and a wide range of scientific articles and reports. Their suitability for identifying and locating double ridges varies greatly. Discussed below are only those cartographic materials that are relevant in researching double ridges in the Polish part of the Tatra Mountains. They provide a full coverage of the study area at their respective scales and were reasonably easy to access, either from the Warsaw University

Library or the Tatra National Park headquarters in Zakopane.

##### 4.1. Topographical Maps

An excellent source of topographic information for the purpose of identifying and locating double ridges is the Polish Tatra Mountains map series (Zarząd Topograficzny Sztabu Generalnego WP, 1984, 1991) at the scale of 1:10,000 (14 sheets). Two editions of these maps were examined, i.e. Edition 1 from 1984 and Edition 3 from 1991. Apart from their currency, the significant difference between these editions is that the 1991 edition shows contour and rock drawing details for entire sheets, while the 1984 one shows these features only up to the national border with Slovakia. Since significant number of double ridges is located on the main mountain ridge along the national border, only the 1991 maps were used in this study because they show topographic information consistently on both sides of the national border.

### 1:10,000 Polish Tatra Mountains, Edition 3 1991 (labelled TOPO in Fig. 7)

This set of maps provides the most detailed topographical information available for the Polish part of the Tatra Mountains (Fig. 6a). The contour interval is 5 m except the rock drawings and cliffs where 50 m interval is used. Double ridges are represented by either contour lines, or a configuration of rock drawing symbols, or a combination of both. Some landforms are very hard to interpret and require cartographic and geomorphological expertise, often coupled with *a priori* knowledge to be successfully identified on these maps.

### 4.2. Geological Maps

There are two geological maps that were found suitable for this research. They include the Geological Maps of Polish Tatra Mountains (Guzik and Sokołowski (eds), 1958) at the scale of 1:10,000 (14 sheets) and the Geological Map of Polish Tatra Mountains at the scale of 1:75,000 included in the Polish Tatra Mountains. Geological guide for tourists (Bac-Moszaszwili and Gąsienica-Szostak, 1989).

### 1:10,000 Geological Maps of Polish Tatra Mountains (GEOL 1)

These maps provide a detailed account of the complex geology of the area. Double ridges are represented by a series of black lines with ticks facing the inside of the landform (Fig. 6b). This symbol can be easily identified on the map by any reader.

### 1:75,000 Geological Map of Polish Tatra Mountains (GEOL 2)

The map represents generalised geology of the Polish part of Tatra Mountains. A separate symbol, consisting of two black, roughly parallel lines with ticks facing the inside, is used for representing double ridges (Fig. 6c). This symbol can be easily identified on the map by any reader.

### 4.3. Atlas of Tatra National Park

The Atlas of Tatra National Park (TPN and PTPNoZ, 1985) contains 32 thematic maps including 12 dedicated to physical sciences. Of particular interest for this study is Plate 9 Geomorphology - Western and High Tatra Mountains printed on two facing pages (Klimaszewski, 1985).

### 1:30,000 Geomorphology - Western and High Tatra Mountains (ATLS)

The map provides a detailed account of various types of landforms present in the Tatra Mountains including fluvial, erosional, glacial, periglacial, karst as well as those shaped by anthropogenic processes (Fig. 6d). Double ridges are represented by a dedicated symbol of two parallel dashed lines in dark blue colour. Their identification on the map is very easy for any reader.

### 4.4. Aerial Photography and Orthophotomap

There are two image-based cartographic resources available for the Polish part of the Tatra Mountains. They include aerial photography at the scale of approximately 1:29,000 (CODGIK, 1999) and the Tourist Photomap of Polish Tatra Mountains, an orthophotomap at the scale of 1:20,000 (Drachal, 2002). Since the above orthophotomap was digitally compiled using the above aerial photographs, and the necessary orthorectification process introduced some radial displacements of land features (Drachal, 2004), it was decided that there is no real advantage of using this cartographic resource. Therefore, only the aerial photographs were used in this study.

### 1:29,000 Aerial Photographs of Tatra Mountains (PHTO)

A set of cloud-free aerial images for the Tatra Mountains was taken on 15 September 1999 (Fig. 6e). Because of the flight occurring in mid autumn, the images are subject to long cast shadows and only limited image enhancement procedures were possible to improve their legibility. However, identification of double ridges was possible, although good photo-interpretation skills were required in some instances.

### 4.5. Other Cartographic Resources

Other cartographic resources considered for this research included the Topographical Map of Slovakia (VKU, 2002, 2007) at the scale of 1:25,000 and the Slovak Orthophotomap of the High Tatra Mountains at the scale of 1:20,000 (VKU, 2003).

The Topographical Map of Slovakia was deemed not suitable for identification of double ridges, mainly due to its scale. A thorough examination revealed that none of the landforms were represented on this map, even the largest 830 m long and 51 m wide double ridge on Hlińska Przełęcz (Hlińska

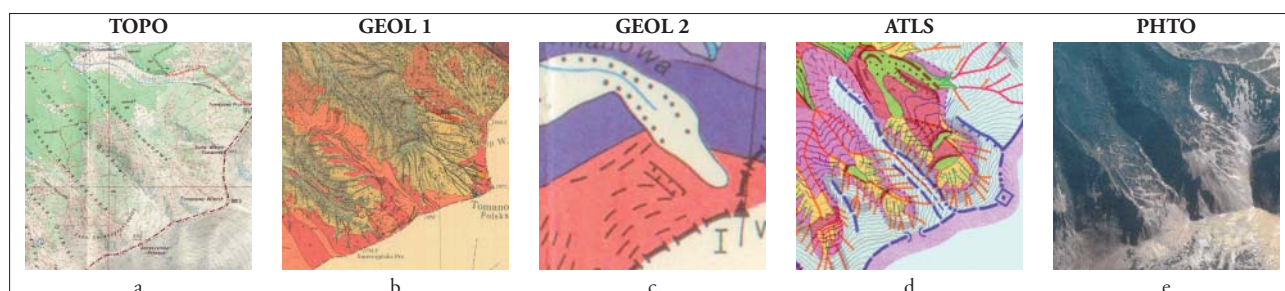


Fig. 6: A series of small samples of cartographic resources used in this study. Their scale is ~1:50,000 and they cover approximately 2.25 km<sup>2</sup> (1.5 × 1.5 km). The area shown spans between Tomanowy Wierch Polski and Zadni Smreczyński Grzbiet. Please note that the Fig. 6e (PHTO) shows the relief in reverse due to the south-eastern sun illumination.



Saddle) in the Western Tatra Mountains (double ridge no 22 on Fig. 4).

The Slovak Orthophotomap of the High Tatra Mountains was also found not suitable as none of the double ridges were shown. It is rather surprising, as both the scale of the orthophotomap and the image-based nature of this resource should allow at least the largest forms (no 2, 4 or 6 on Fig. 4) to be identifiable.

#### 4.6. Non-cartographic Resources

A geomorphological textbook (Klimaszewski, 1988) was referenced in this study as an example of a non-cartographic resource (labelled KLIM in Figure 7). It contains a table (p. 97) of 31 double ridge systems found in the Polish part of the Tatra Mountains. Only general textual descriptions are given without any map (or illustration) that is showing their locations. The table was also included in the evaluation process described below.

### 5. Evaluation

An evaluation process can take two possible general approaches. The first approach involves establishing a solid benchmark based on a detailed field survey and then evaluating cartographic resources against it. The other approach involves identifying and locating landforms using the available resources and then undertaking a detailed field survey for evaluation purposes. In this research, the first approach was adopted due to an existence of a suitable benchmark.

The *Genesis of Ridge Top Depressions in Polish Tatra Mountains* (Żyszkowska, 2005) is the most comprehensive study of double ridges in the Polish part of the Tatra Mountains available to date. The research was undertaken between 2002 and 2004, and included an extensive field survey of the study area (see Fig. 4). The work contains a detailed description of each of the existing 39 double ridge systems, including their geology, morphometric characteristics and detailed cross-sections. Most of the cartographic resources described above were not significantly used for identifying or locating double ridges. Exceptions include the 1:10,000 topographical maps (TOPO) employed for field survey logistics and for marking all double ridges within the study area, the 1:75,000 Geological Map (GEOL 2) for identifying and locating a double ridge next to Opalony Wierch in the High Tatra Mountains (no 1 on Fig. 4), and the 1:29,000 aerial photographs (PHTO) for illustrating the distribution of all landforms (as an Appendix).

Żyszkowska's (2005) study was found appropriate and fitting to serve as a benchmark for evaluating the suitability of all cartographic and non-cartographic resources described above. The systematic evaluation process involved an assessment of these resources in terms of their performance against data quality components described in the Spatial Data Transfer Standard (SDTS) (NIST, 1992) and in more recent research (e.g. Thomson et al., 2005; Drecki and Maciejewska, 2005; Drecki, 2007). In this study, completeness, accuracy (both spatial and attribute), and logical

consistency were particularly relevant. Other data quality components are also briefly discussed below.

#### 5.1. Completeness

Completeness deals with issues of missing information. In this research it is applied to measure the number of double ridges marked on the cartographic resources against the benchmark, i.e. the 39 landforms identified by Żyszkowska (2005). Fig. 7 gives a summary of findings.

Topographical maps (TOPO) were found to be the best cartographic resource with 51.3% of all double ridge systems identified on these maps. Aerial photographs (PHTO) and generalised geological map (GEOL 2) showed just above 25% of all landforms, while geomorphological map (ATLS) just 8 double ridges. On the detailed geological map (GEOL 1) only eight landforms were found, a rather disappointing result considering its scale. One explanation could be that majority of double ridges are located along the main ridge which forms part of the national border. Since the map design forced the authors to show the data only up to the border with Slovakia, they decided against marking only one side of the landform on the map and not the other. The geomorphological textbook (KLIM) was the most complete resource with 64.1% of all landforms listed.

#### 5.2. Positional Accuracy

Positional accuracy is a measure of discrepancy between geographical location of an object and its location on a map. In this research it describes the discrepancy of double ridge locations on all cartographic resources (taking into account their scale) and their true locations in the field. Topographical maps (TOPO) were superior to all other resources with regards to representing double ridges with accuracies of  $\pm 0.5$  m in x and y, and  $\pm 0.7$  m in z direction. These results were more than satisfactory for describing landforms of this size. Other resources, despite being less accurate, were found at least satisfactory considering their scale. The non-cartographic resource of KLIM was not evaluated for obvious reasons.

#### 5.3. Attribute Accuracy

Attribute accuracy refers to the degree of conformity between graphic description of an object on a map and the attribute of a corresponding object in the field. Considering its pure definition, only TOPO maps were subject to this evaluation. The contour lines were most helpful in identifying double ridges, with 12 landforms interpreted purely from their graphical configuration. Rock drawing was useful in 4 instances, while 4 double ridges were identified using both contour lines and rock drawings.

Furthermore, attribute accuracy was used to check whether double ridges identified on a particular resource had their equivalent in the field. From all identified landforms, only two resources posed some problems. On GEOL 2, two separate double ridges identified by Żyszkowska (2005) (no 30 and 34) were shown as one landform, while KLIM describes

No	TOPO	GEOL 1	GEOL 2	ATLS	PHTO	KLIM	# matched
1			Y(es)				1
2					Y	Y	2
3	Y <sub>c</sub>						1
4					Y	Y	2
5							-
6							-
7							-
8						Y	1
9						Y	1
10	Y <sub>c</sub>						-
11							-
12		Y				Y	2
13						Y	1
14	Y <sub>c</sub>			Y			2
15	Y <sub>c</sub>	Y		Y	Y	Y	5
16	Y <sub>c</sub>			Y	Y	Y	4
17	Y <sub>c</sub>					Y**	2
18							-
19							-
20	Y <sub>c</sub>	Y	Y	Y	Y	Y	6
21	Y <sub>c</sub>					Y	2
22	Y <sub>c</sub>		Y	Y	Y	Y	5
23	Y <sub>c</sub>				Y	Y	3
24						Y	1
25	Y <sub>s</sub>		Y		Y	Y	3
26	Y <sub>c</sub>				Y		2
27							-
28	Y <sub>cs</sub>	Y				Y	3
29	Y <sub>cs</sub>	Y	Y			Y	4
30	Y <sub>cs</sub>		Y*	Y	Y	Y	5
31	Y <sub>s</sub>	Y				Y	3
32						Y	1
33	Y <sub>s</sub>	Y		Y			3
34	Y <sub>cs</sub>	Y	Y*		Y	Y	5
35	Y <sub>c</sub>			Y		Y	3
36	Y <sub>s</sub>		Y			Y	3
37			Y			Y	2
38			Y			Y	2
39							-
Σ	20	8	10	8	11	25	
%	51.3	20.5	25.6	20.5	28.2	64.1	

Fig. 7: A summary of matches between double ridges marked on evaluated resources and the benchmark (Żyszkowska, 2005). Light grey column indicates a non-cartographic resource, i.e. a geomorphological textbook (KLIM). **c**: interpreted from the contour lines; **s**: interpreted from rock drawing; **Y\***: double ridges no 30 and 34 are shown as one landform; **Y\*\***: double ridge no 17 is described as two separate landforms.

Size	bnchmk	TOPO	GEOL 1	GEOL 2	ATLS	PHTO	KLIM
L	9	7	3	5	3	6	7
M	15	8	3	3	4	5	10
S	15	5	2	2	1	-	8
Σ	39	20	8	10	8	11	25

Fig. 8: A relationship between landform sizes and their appearance on the evaluated resources. None of the resources show all large forms, i.e. over 300 m in length and over 10m in width (Żyszkowska, 2005). Light grey is used to indicate a non-cartographic resource, i.e. a geomorphological textbook (KLIM).

# of resources	Large	Medium	Small	Σ
0	1	2	5	8
1 (KLIM only)	-	1	4	5
1	-	2	1	3
2	2	5	2	9
3	1	2	3	6
4	2	1	-	3
5	2	2	-	4
6	1	-	-	1
Σ	9	15	15	39

Fig. 9: A summary of matches between the size of double ridge systems, i.e. large, medium and small and the number of resources that identify them.

two double ridges at Przełęcz pod Kopą Kondracką, while in the field only one was identified. Also, KLIM lists further five double ridges which were not found in the field during the survey.

#### 5.4. Logical Consistency

In general terms, logical consistency assures that there are no contradictory relationships between a map and field survey data. Since double ridges were classified into three broad classes based on their size, it was expected that all large landforms should be represented first, before medium and small ones. Logical consistency was employed to check whether this is the case.

The results of this exercise are rather surprising. TOPO is missing two large forms (no 2 and 6), but shows several small ones (e.g. no 10, 21, 31, 33 and 36). GEOL 2 misses four large double ridges (no 2, 6, 26 and 28), but shows two small landforms at the same time (no 36 and 37). The most consistent resource was PHTO which shows only large and medium size landforms in a consistent proportion. Fig. 8 summarises the results for all resources.

Fig. 10 gives an overview of a relationship between the position and size of double ridges and the number of resources that identified them. A total of eight landforms are not identified on any of the resources including one large (no 6!), two medium (no 5 and 18) and five small ones. There are five more double ridges, including one medium and four small ones, which are identified only on the non-cartographic resource (KLIM).

There is only one double ridge system that is identified on all six evaluated resources, i.e. Zadni Smreczyński Grzbiet (no 20). Four further landforms, two large (no 22 and 30) and two medium (no 15 and 34) ones are mentioned by five separate resources. All results including four and less matches are given in Fig. 9.

#### 5.5. Other Data Quality Components

Lineage information (NIST, 1992) had little relevance in evaluation process, although it helped to determine which edition of the topographical map (TOPO) to use (see discussion above). Currency (Drecki, 2007) was not evaluated as double ridges have not changed enough in the last 50 years to create difference in their representation on any of the evaluated resources. Credibility, subjectivity, interrelatedness and even precision (Thomson et al., 2005) were not considered. Regrettably, there was not enough information to perform a systematic and thorough evaluation based on these data quality components.

### 6. Conclusions

This research focused on examining the availability of cartographic resources and evaluating their suitability for researching landforms in high mountains. In particular, it considered methods for identifying and locating double ridges in the Polish part of the Tatra Mountains.

There are several cartographic resources currently available for the Tatra Mountains to assist research in physical sciences. The most useful in this study were topographical (TOPO) and geological maps (GEOL 1 and GEOL 2),



Fig. 10: A relationship between the position and size of double ridges and the number of resources, marked as concentric circles centred on a double ridge symbol, that identify them. Double ridges that are marked by a solid black-filled symbol are not identified by any of the evaluated resources, those marked by a grey-filled symbol are only identified by a non-cartographic resource (KLIM), and those marked by a white-filled symbol are shown on at least one cartographic resource.

a geomorphological map (ATLS) and aerial photographs (PHTO). Accessing these resources was reasonably easy, either at better libraries or at the Tatra National Park headquarters in Zakopane. Their coverage was complete for the entire study area.

A systematic evaluation of cartographic resources used in this study involved the assessment of their performance against data quality components described in SDTS (NIST, 1992), with completeness, accuracy (both spatial and attribute), and logical consistency being particularly relevant. The TOPO scored well against all categories, although some landforms required substantial cartographic experience and *a priori* knowledge to be identified. The PHTO performed well with regards to logical consistency where many large and several medium double ridges were identifiable. A poor performer in the completeness category included GEOL 1 with only 8 out of 39 landforms shown. The geomorphological textbook (KLIM) scored very poorly with regards to attribute accuracy, with several identification mismatches against the benchmark. Unfortunately, it was rather difficult or even impossible to use other data quality categories for evaluation purposes due to the lack of appropriate meta-data.

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This research demonstrates that many current cartographic resources are not yet sufficient for comprehensive studies of relatively small landforms in high mountains. Ideally more detailed resources from both scale and resolution perspective are required to support such studies. Examples might include high resolution satellite imagery or aerial photography, an optical remote sensing technology such as LIDAR, or large scale topographical or geomorphological maps. Their systematic evaluation, based on the procedure proposed above, is critical in assessing their suitability for researching double ridges or other similar landforms in high mountains. However, it is strongly believed that even high quality resources and rigid evaluation processes would not completely remove a need for a comprehensive field survey.

The adopted approach for studying double ridges was satisfactory in detecting large and medium size depressions. This could potentially help in reducing the time needed for field surveys and in targeting specific areas for logistical planning and field investigation. The key is to use multiple cartographic resources as well as to cross-reference them against relevant literature.



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# Cartographic Analysis of Avalanche Hazard Maps

## A Comparison of Relevant Cartographic Factors for the Visualization of the Avalanche Bulletin

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### Abstract

*We cartographically analysed the avalanche hazard maps of 26 avalanche warning services. The range of the cartographic products reaches from high quality visualizations over simple bitmap-pictures to hazard charts. A survey involving 167 protagonists was conducted. Alpinists indicated that a map with detailed hazard levels for small, well-defined areas is indispensable, while a map with the hazard level dissolved over a large area is dispensable. Because of extensive data measuring, every avalanche warning service is able to differentiate the hazard level by region, height and daily temperature curve.*

*This paper will give a clear picture of what is needed and easily understood by an inhomogenic user group and will demand a high-quality standard for avalanche hazard maps, following common cartographical rules as well as technical constraints. The results will be addressed in a catalog of requirements.*

### 1. Introduction

The Alps comprise 73,4% of Austria's surface (61,500 km<sup>2</sup>), with almost 50% of all Austrians (4 million people) inhabiting regions categorized as alpine. About 60 million tourists visited Austria in the last winter season, nearly 8 times more than the Austrian population counts (Statistik Austria, 2007).

In ever increasing numbers tourists, mountaineers and alpinists explore untouched nature and take more risk. Alpine touring received a real boost in the last few years and this trend goes along with a growing number of avalanche victims among these people as a result of a careless attitude towards avalanche hazard, a general neglect of investing time in tour planning and a deficit in cartographic knowledge (Mair, 1998).

Due to the fact, that in mountain regions the snow cover is persistent for more than six months of the year, it is becoming important to deal with avalanches. Some of the most well-known touring areas count nearly 500 ski mountaineers on sunny days. Statistics prove, that 22 people died in an avalanche and 52 were injured last winter season in Austria.



Fig. 1: Crown face of a dry slab avalanche at Hochtennboden, Axamer Lizum, Tyrol, 2003.

In the season 2004/2005 48 people died in an avalanche and 72 people got hurt. A total of 95% of all victims trigger the avalanche themselves. (Würtl, 2005) Consequently it is absolutely essential to be well trained, educated, prepared and equipped to minimize the risk of getting buried by an avalanche.

### 2. Avalanche basics

The following assumptions will give a clear picture: If you travel in avalanche terrain 100 days per year, cross 10 avalanche slopes per day and the snow is stable enough to cross on 95 percent of the slopes, for every avalanche you accidentally triggers, you get caught every third time and killed every tenth time! (Tremper, 2001) It is essential to comprehend the nature of avalanches in order to be aware of their potential danger.

For nearly most of all deadly accidents the dry slab avalanche (Fig. 1) is responsible. A "slab" is a cohesive plate of snow that slides as a unit on the weak layers underneath. Typically a slab is about 150 m long, about 50 cm deep and accelerates to around 130 km/hr after the first few seconds. Because of very sensitive weak layers, the rapid addition of the weight of a person can easily initiate the fracture on

a slope. Both meteorological and topographical factors are responsible for such terrible threats. The weather deposits snow in layers, creates and changes the snowpack within its weak layers and bad surfaces. The most important meteorological factors are wind, temperature and solar radiation. But the weather has different influence on different kinds of terrain, aspect, height and slope. These topographical factors make the condition for slab avalanches and are more easy to understand because of their constancy. Weather changes every day and is a major determinant of avalanche risk, expertise is solely derived from years of monitoring it and its effects on the snowpack. (Tremper, 2001) Hence it takes a lot of experience to minimize the risk of avalanches, because avalanches are not easily predictable but often enough can produce devastating results.

### 3. Avalanche danger

Generally speaking, the word “danger” means the potential occurrence of a dangerous process such as an avalanche. But it does not indicate whether the process will take place. Avalanches become a “risk”, until people or physical assets are situated within the reach of the “dangerous process”. “Avalanche danger” describes the likelihood of occurrence of avalanches in a specific region. The exact moment of an avalanche’s triggering cannot be precisely determined. (SLF, 2005)

### 4. Avalanche Bulletin

The avalanche bulletin combines both meteorological and topographical factors and relates them to avalanche danger. It is the main item every avalanche warning service provides. The avalanche bulletin contains information about the current avalanche danger and how it may develop within the following days with regard to the weather forecast.

Relative frequency of the avalanche bulletin-check	
Avalanche bulletin-Check	Percentage
Several times a week	43 %
Only while planning a tour	32 %
Every day in winter	22 %
Rare	2 %
Never	1 %

Fig. 2: Relative frequency of the avalanche bulletin-check.

Over 40% of the alpinists check the avalanche bulletin several times a week, 32% while planning a tour, only 1% of the alpinists do not check the bulletin at all. But the avalanche bulletin as well as the weather forecast are the most popular tools for tour planning, a total of 96% of the interviewed mountaineers read the bulletin before starting a tour (Eckerstorfer, 2007).

Defined by the variables snow pack stability and avalanche probability, the avalanche hazard is rated according to the

European avalanche hazard scale into a progressively rising scale of five classes (“low”, “moderate”, “considerable”, “high”, “very high”) (SLF, 2005). The text of the bulletin is standardized to facilitate orientation. The avalanche bulletin contains information about (Land Tirol, 1988):

- Avalanche hazard level according to the European avalanche hazard scale
- The composition / condition of the snow blanket (setting, layering, wetting)
- The past and present weather situation and the snow blanket resulting from it
- The assumed further development of the situation (prognosis)

One main draw-back of the current avalanche warning system is that isolated slopes cannot be evaluated in the bulletin and local details are not considered. Therefore areas that are particularly dangerous are characterised in the bulletin by slope, aspect, height and type of terrain. Despite its limited scope, the bulletin must reach a variety of user groups with different alpinistic knowledge. The majority of the alpinists are hobby mountaineers and not professionals, as also depicted in the online questionnaire (only 15% were professionals) (Eckerstorfer, 2007). Therefore, it is indispensable to provide clear and comprehensible information about parameters which are relevant for avalanche formations, especially danger areas, fresh snowfalls, wind, temperature and the formation of the snow blanket.

Generally spoken, the avalanche bulletin becomes more and more important. The common security philosophy of

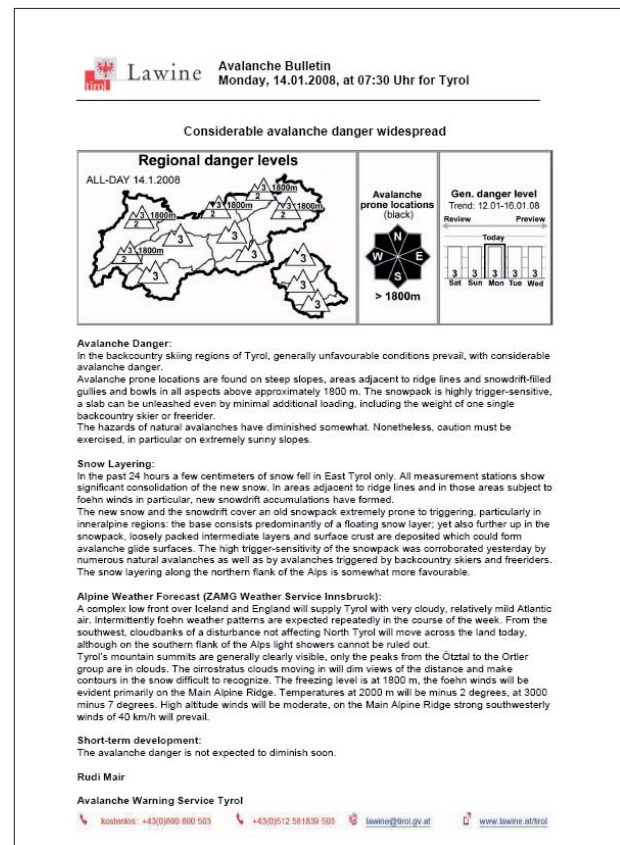


Fig. 3: Avalanche Bulletin of Tyrol, from 14.01.2008.

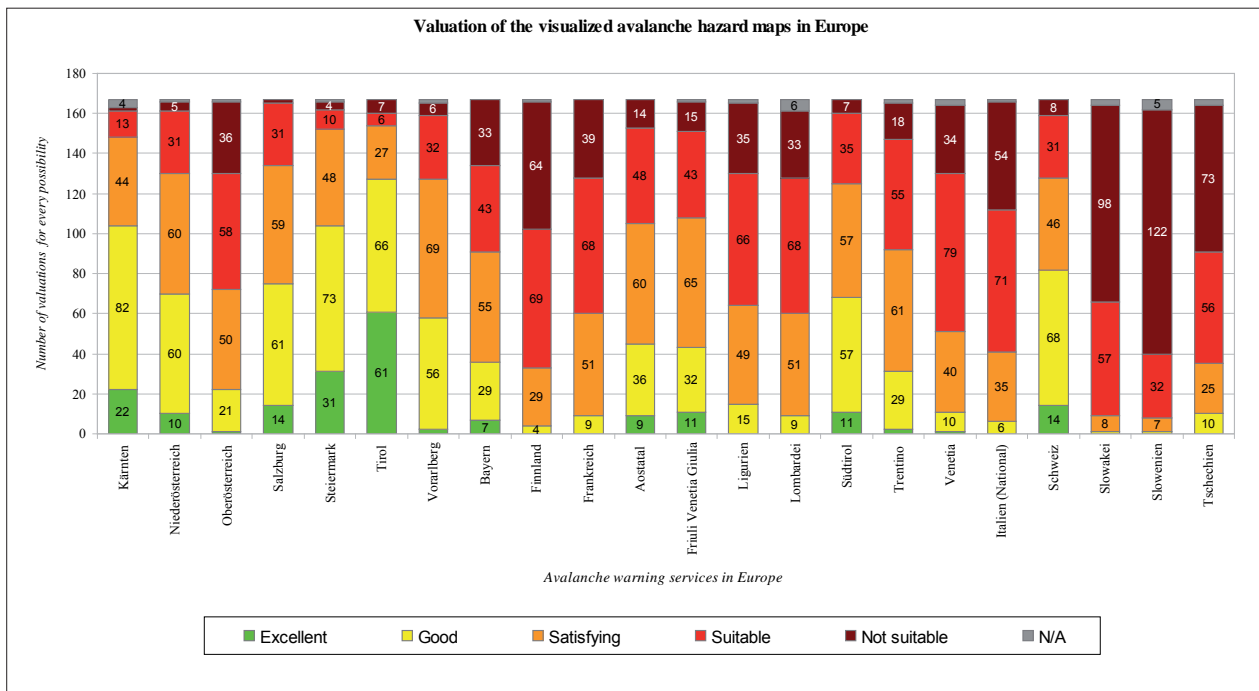


Fig. 4: Valuation of the visualized avalanche hazard maps in Europe.

the 1970s and 80s, which claimed that the snow blanket as the main scientific object is a homogeneous structure and has therefore no danger zones in it, has become obsolete. Furthermore, experts like Werner Munter, a pioneer in the field of practical avalanche research, introduced a conscious risk management. He suggests guidelines to facilitate the decision-making and planning process and invited the mountaineers to “deal with probabilities in a playful way” (Munter, 2003). Risk management deals with the avoidance of steep slopes depending on the hazard level. Risk management methods (StoporGo, SnowCard, Method of reduction) aim to provide a maximum risk reduction.

Therefore the Consortium of the European Avalanche warning services (ARGE EAWS) introduced a new design for the avalanche bulletin (Fig. 3). The most important information should be on top, less important information at the bottom of the text. As a result, the actual regional hazard level is explained on top, followed by avalanche prone locations and information about the general avalanche hazard, snow pack, weather and avalanche hazard trend. (Eckerstorfer and Nairz, 2007)

## 5. Avalanche hazard map

The cartographic visualization of the current avalanche hazard level can be seen in a close relation to the written avalanche bulletin. “The so called avalanche hazard map incorporates mainly a topographic map with thematic avalanche features” (Kriz, 2001). A concise, easy-to-understand representation is able to communicate the information quickly. The avalanche bulletin is often too complicated to understand for lay people, the avalanche hazard map is able to show the current hazard level, divided by height, region, daily temperature curve and aspect. Unfortunately,

this ideal case is not always given and the information is not always processed satisfyingly.

In a questionnaire I asked if the visualization of the avalanche bulletin is dispensable. 64% protagonists use the avalanche hazard map to gain all the information needed, people with poor alpine education rely on the cartographic visualization to a higher degree (50%) than people with alpine experience (80%). Mountaineers and alpinists also trust the written bulletin much more (nearly 95%) than winter tourists and hobby-mountaineers (60%). (Eckerstorfer, 2007)

And therein lies the challenge. From the cartographer’s point of view, meteorological and topographical factors have to be portrayed in their context on a map. It is a tricky task, to simplify real world three-dimensional phenomena into a spatial model, so to consider a map as a model of reality. To show the terrain-specific parameters that influence the avalanche paths a large-scale topographic map is well suitable. (Kriz, 2001). Slope and aspect, the most important topographic features can be derived easily from topographic maps. The various meteorological factors are much more difficult to visualize for cartographers and defy an easy visualization with conventional (static) cartographic tools. The main objectives of avalanche hazard mapping are therefore (Kriz, 2001):

- Cartographic design, layout and presentation using multimedia technology
- Digital Terrain Model (DTM) assessment for high quality feature derivation
- Combination of various fields of study (avalanchescience, risk research, web design, psychology of perception)

As a result, a consistent high-quality standard for avalanche hazard maps, following common cartographic rules should be achieved, so that the avalanche hazard map will fulfil



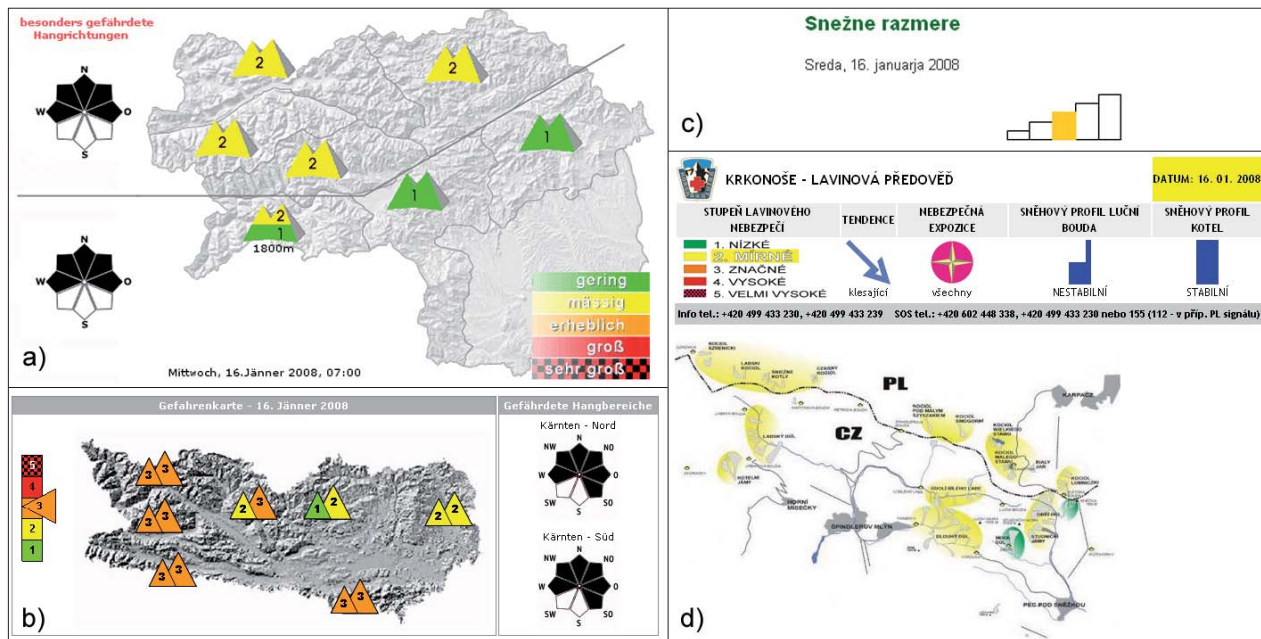


Fig. 5: Sample of 4 different avalanche hazard maps in Europe.

its role as a carrier of communication and information in the sense of the cartographic communication process. The principles of cartographic communication enable efficient methods to disseminate up-to-date information and offer a direct connection between the cartographic product and the user as well as the possibility to respond immediately.

## 6. Questionnaire

I cartographically analysed the avalanche hazard maps of 26 avalanche warning services (Eckerstorfer, 2007). The range of the cartographic products reaches from high quality visualizations over simple bitmap-pictures to hazard charts. A survey carried out on 167 protagonists was made. Alpinists indicated that a map with detailed hazard levels for small, well-defined areas is indispensable and a map with the hazard level dissolved over a large area is dispensable.

Fig. 4 shows the number of valuations given by the protagonists for every avalanche warning service in Europe. The avalanche hazard map of Tyrol (cf. Fig. 6a) is the best rated as “excellent” by 67 individuals, followed by the maps of Steiermark / Styria with 31 (Fig. 5a), Kärnten / Carinthia with 22 (Fig. 5b), Salzburg and Switzerland with 14. The hazard map of Slovenia with 162 “not suitable”-mentions received the lowest rating of the tested maps (Fig. 5c). Also the Czech Republic with 73 and Finland with 64 (Fig. 5d) did not achieve a good result, because either they do not provide a hazard map or the cartographic visualization is incomprehensible.

To receive a ranking, I calculated the overall average grade for every avalanche warning service (1 = “excellent”, 2 = “good”, 3 = “satisfying”, 4 = “suitable”, 5 = “not suitable”). Outstanding winner was Tyrol with an average grade of 1,99, because the protagonists valued the clear topographic representation and the classification of the various mountain regions. Both ensure a good and fast overview and orientation. Other cri-

teria for a good ranking were the differentiation of the avalanche hazard level by height, daily temperature curve and aspect, which are offered for example in Sytria with 2,30 (Fig. 5a), Carinthia with 2,33 (Fig. 5b) and Switzerland with 2,71 (Fig. 6a). Slovenia (Fig. 5c) was ranked last with an average grade of 4,70 due to the insufficient information of the stacked bar graph without key.

## 7. Catalog of requirements

Because of extensive measuring data every avalanche warning service is able to differentiate the hazard level by region, height and daily temperature curve. Therefore a clear cartographic visualization should be aspired. This could be achieved with a catalogue of requirements for a high quality avalanche hazard map:

### 7.1. Differentiation and cartographic visualization of the avalanche hazard level

The analysis of all 26 avalanche hazard maps in Europe showed that different regions require a varying cartographic visualization and differentiation of the avalanche hazard level (Eckerstorfer, 2007). A differentiation of the hazard level by region, height and daily temperature curve depends on the topographic and climate conditions in the region:

- Differentiation by region
  - For widespread areas with different meteorological influences.
- Differentiation by height
  - For mountain areas with great heights and big altitude difference.
- Differentiation by daily temperature curve
  - Especially for spring time with distinctive daily temperature curve as well as strong cooling in the night and strong warming the next day.

- Differentiation by aspect
  - Because of meteorological factors wind and solar radiation. Always in connection with the altitude at which avalanche prone locations take place.

The four possibilities of differentiation of the avalanche hazard level need several, complex cartographic solutions. The avalanche hazard level can be visualized by colorizing the area or by using multilayer, coloured symbols. The colour correlates the colour of each hazard level according to the European avalanche danger scale. It is absolutely necessary to picture both, colour and the hazard level by number. By using symbols (mountain symbols are common and clearly understood) it is important to pay attention to its size. Small symbols are hard to distinguish/read but oversized symbols can hide important topographic information underneath and make the map look overloaded and unclear. Color codes pose a problem to achromates, who cannot distinguish the hazard level, therefore additional black & white avalanche hazard maps are required.

- Differentiation by region
  - By using a multilayer, coloured symbol with the hazard level as a number for every region.
  - By colorizing the different regions, separated by the region borders. (Fig. 6a)

- Differentiation by height
  - By using a multilayer, coloured symbol (the hazard levels for lower and higher altitudes are indicated on the bottom and top, respectively, as well as the height, at which the hazard level changes. (Fig. 6b)
  - By colouring the different altitudes using a DTM. (Fig. 7a)
- Differentiation by daily temperature curve
  - By using a multilayer, coloured symbol (on the left side the hazard level for the morning situation is indicated, on the right side for the afternoon situation). (Fig. 5b & 6c)
  - By colorizing the different regions and using two maps, one for the morning situation and one for the afternoon situation. To avoid any confusion it is absolutely necessary to label each map.
- Differentiation by aspect
  - By using a wind rose displaying avalanche prone locations for the indicated altitudes. Usually endangered aspects are shaded in black and explained in a text above the wind rose. (Fig. 6d)

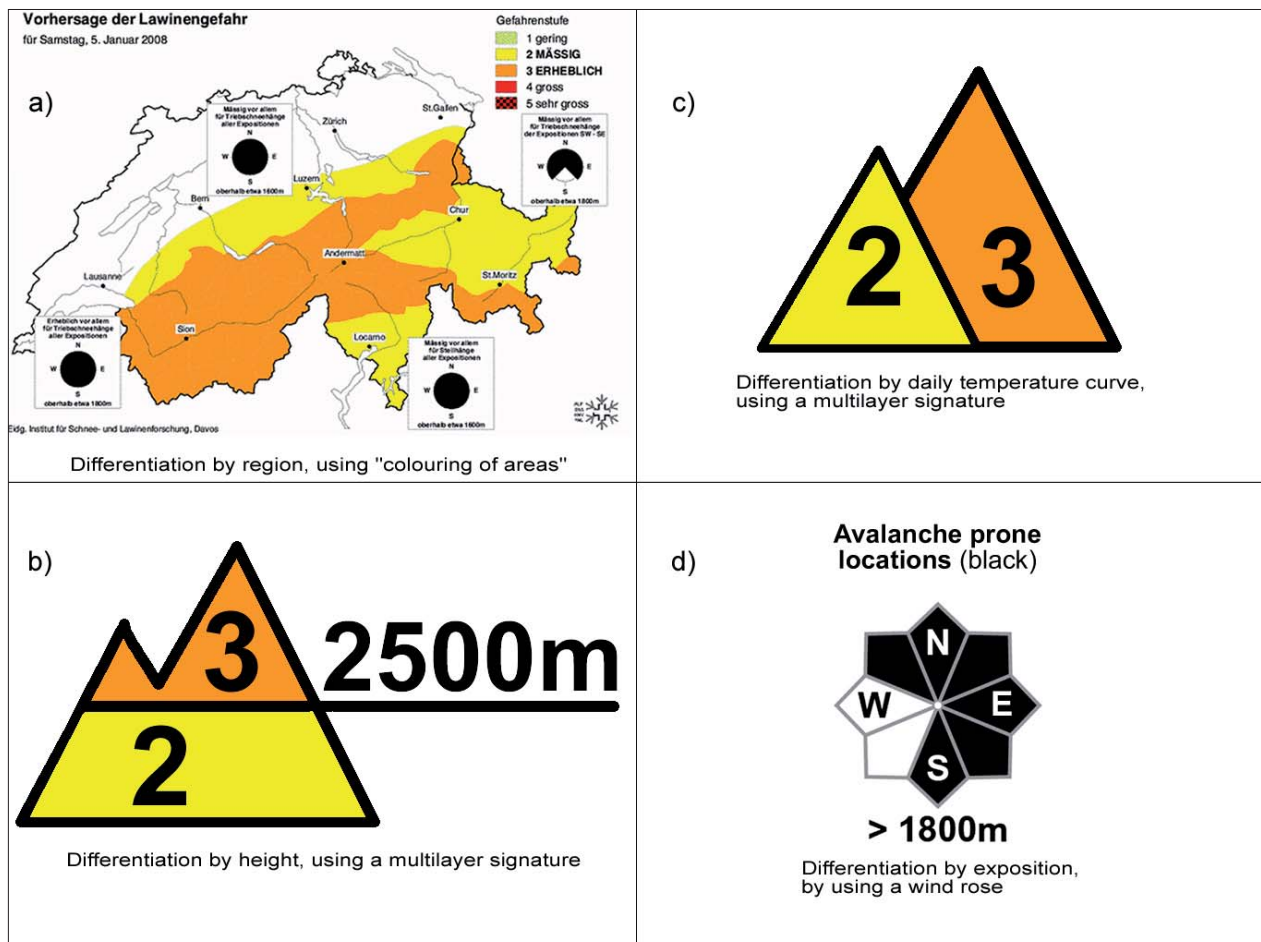


Fig. 6: Four possibilities of differentiation between the avalanche hazard level

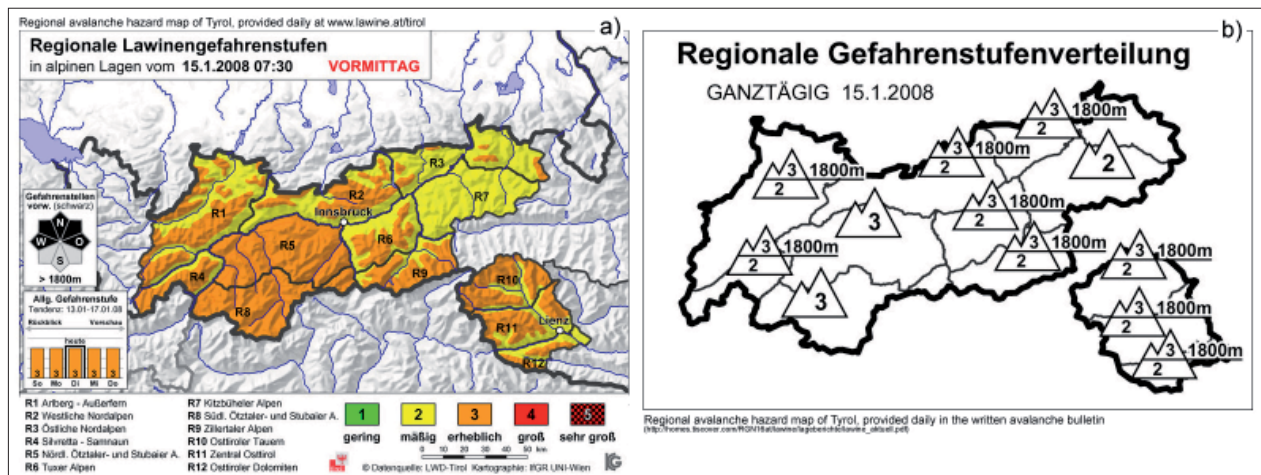


Fig. 7: Comparison of the regional avalanche danger maps provided as different products in Tyrol.

## 7.2. Topography

In order to use slope and aspect for avalanche classification and to give the user a good overview and orientation over the region, it is important to have a high quality base digital elevation model (DEM). DEMs can be derived from digital terrain models (DTM) in different ways. Using isolines from topographic maps with breaklines and high points is very common. (Kriz, 2001) It is essential to be aware of the quality and the resolution of the produced DEM to achieve the best results, standards and guide-lines for the implementation of DTMs and DEMs should be determined.

## 7.3. Map elements and cartographic visualization

Cartographic design issues as well as the visualization of the thematic elements play an important role, especially in the fields of understanding the given topic. They are essential for spatial communication and effective perception of information. An avalanche hazard map always consists of a title, a frame, a key, furthermore a wind rose to display avalanche prone locations, a catchline with the most important information, date and time to make sure, that the map is up-to-date and a hazard level trend, symbolised by arrows or a t. Therefore, high quality cartographic visualization is fundamental to ensure an optimum usability.

Because of technical constraints it is sometimes necessary to provide a less high quality cartographic product without all its technical possibilities in compiling and visualizing. As a result, the avalanche cartographer has to adapt the map or several map elements to ensure, that its target group is able to gain the information provided. For example a hazard map with a shaded relief and a hazard differentiation visualized by colouring the particular areas is impossible to read after it was sent per fax. So the cartographic visualization has to be smart, simple (KISS) and hit the nail on the head (Fig. 7a & 7b).

## 7.4. Technical implementation and web design

Nowadays technical implementation (Kinberger, 2003, Pichlbauer, 2007) and web design is becoming more and more important. This “trend in cartography” demands new rules and basic conditions. Kraak and Brown (2001) supported this view and commented that technical constraints hamper the visualization of data. There are some adjustments necessary in the sense of visualizing data and utilising interactivity and dynamic. The advantages of cartographic representations on the Internet can be seen in up-to-date-ness, interactivity, spatial communication as well as efficient and cost-effective dissemination. Four premises are important for a web based avalanche prediction tool (Kinberger et al., 2003):

- An Internet interface as a portal for visualization
- Cartographic expertise for geospatial representation
- Automatic weather data retrieval from external locations
- The use of automatic cartographic procedures

For example at the avalanche warning service of Tyrol, the map compilation is totally automatic. Tyrol has a very complex and powerful database driven online decision support system for cartographic visualization and analysis of current avalanche relevant factors in the Tyrolean Alps. All information, reaching from meteorological and spatial data to the avalanche danger situation can be interactively made accessible to the user (Kriz et al., 2004).

## 7.5. Colour and Cartography / psychology of perception

The representation of the five levels of the European avalanche danger scale must communicate critical consequence and support understanding. Visualization can be successfully accomplished by applying a set of cartographic guidelines according to the desired understanding of the avalanche danger scale (Low – green, moderate – yellow, considerable – orange, high – red, extreme – red w/black). Colour perception is not easily analysable but indispensable



to create an initial feeling of alertness with the first view of the avalanche hazard map. Dealing with colours to show the hazard level is quite complicated and leads to accurate analysis about colour and cartography as well as the psychology of perception.

The use of green correlates with the widely used decision support description of “green light terrain” (Fredston, Fesler, 1994). Neither the colour yellow nor orange are emotionally assigned to levels of risk and thus do not provoke alert behaviour (CAA, 2002). In contrast, red is the widely accepted colour of danger and risk. Additional research to validate the actual colour code and the understanding of the effect of different colours to different map users need to be conducted.

## 8. Outlook

An important task of my work is to analyse the gateway between map and user. As mentioned above, an inhomogeneous user group makes demands on the information the avalanche warning services offer. More and more people explore the mountainous regions but only a few of them know about the risks and dangers of a beautiful snow covered landscape. When investigating avalanche accidents the most consequential question is not one of slope angles, aspect and weather conditions, but one about the victim's cognitive skills. “What interfered with the person's judgement at the crucial moment?”

The avalanche hazard map has to be easy to understand for people with less alpinistic knowledge and experience and should as well offer enough specific information for mountain guides and professionals.

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# Charles Jacot-Guillarmod – One of the Pioneers of the Swiss Style of Rock Representation

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## Abstract

*The topographer Charles Jacot-Guillarmod (1868–1925) was responsible for cliff representation in the Topographical Atlas of Switzerland and thus also in the modern national maps. His name is almost absent in the technical literature of the time which leads to the assumption that he was bullied at work. He created two "topographical sketches" of the Chogori or K2 and Kangchenjunga which are the first exact maps of the Himalaya massif. He also drew various large-format panoramas and in 1923 the cliff representation for the Carte du Mont Olympe, and in 1925 was a topographic map of Mount Everest in the scale 1:63,360 in commission of the Royal Geographical Society.*

## 1. Introduction

Charles Jacot-Guillarmod [C.J.G.] (1868–1925) was a very talented topographer (Fig. 1). It is thanks to his knowledge that he was jointly responsible for rock representation in the Topographical Atlas of Switzerland 1:25,000 and 1:50,000 (the so-called Siegfried Map) and thus also in the modern national maps (Fig. 2 + 3). Even though over a period of 24 years (1890–1914) he was active in the Federal Topographic Office and contributed a great deal to the representation of the large-scale mountain maps, his name is remarkably absent in the technical literature of the time. This fact as well as the procedure of his dismissal leads to the assumption that he was a victim of bullying at the workplace.

## 2. The K2 and Kangchenjunga maps

Following his dismissal from the federal services in 1914, he created two "topographic sketches" of the Chogori ou K2 and Kangchenjunga based on terrestrial photographs taken by his cousin and Himalaya researcher Jules Jacot-Guillarmod (1868–1925), and on marvelous photographic material from the Italian Vittorio Sella (member of the Duke of Abruzzi's expedition). The two original drawings at the scale of 1:50,000 with 100 m contours are the first exact maps of the Himalaya massif. They were lithographed by Kümmerly & Frey in Bern and published in the Bulletin de la Société Neuchâteloise de Géographie in 1925.

C.J.G. reported some interesting details about the two maps. For the map of K2 (Fig. 4) the author used observations made by Filippo de Filippi who had accompanied the Duke of Abruzzi's [Luigi Amedeo from Savoy] research expedition in 1909 as a topographer. The positions of the photographic stations had been carefully calculated through triangulation using a photo theodolite, which yielded a very precise network of control points. Based on this triangulation network, all C.J.G. had to do was to draw the rocks and the contour lines using the photographs. Thanks to this



*Fig. 1: Charles Jacot-Guillarmod, topographer and cartographer (1868–1925). Photograph approx. 1890. (© swisstopo map archive).*



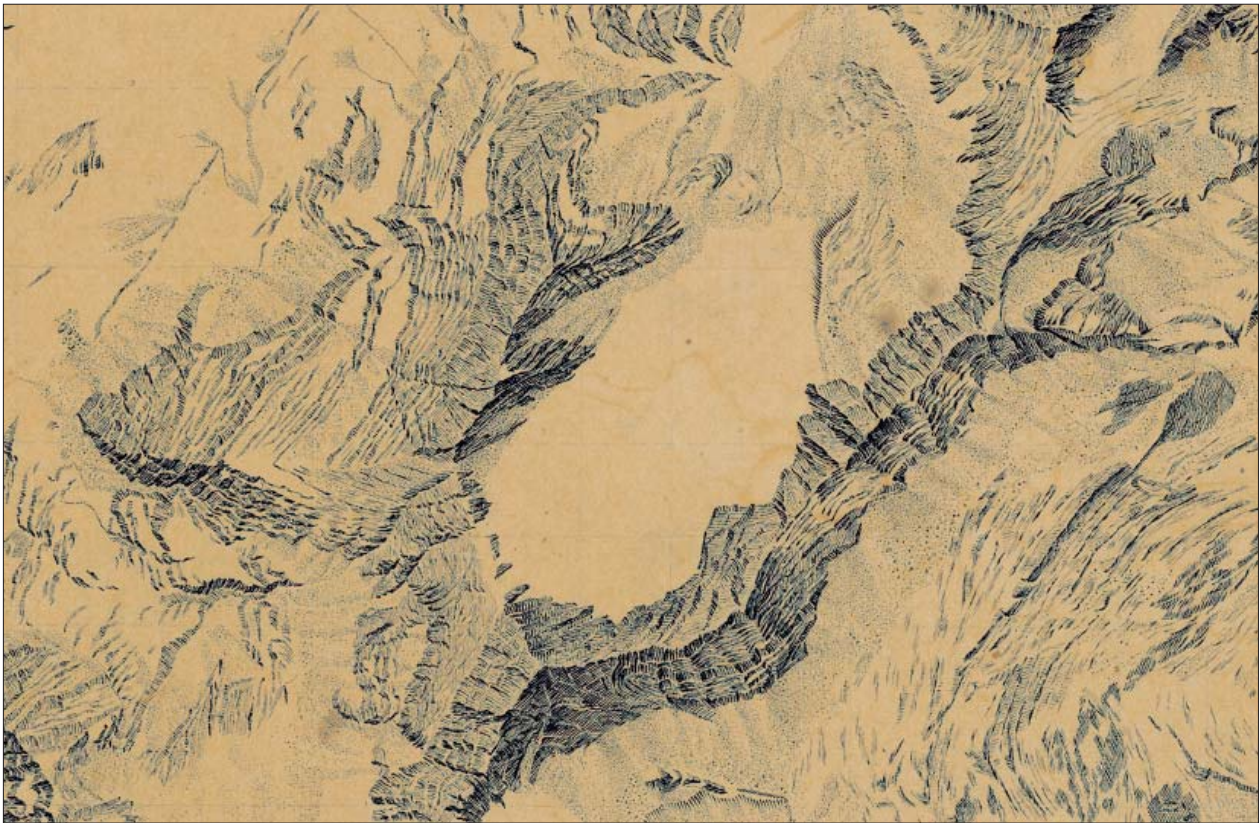


Fig. 2: Map specimen for the Siegfried Map, sheet 480 Anzeindaz, 1:25,000. Rock drawing by Ch. Jacot-Guillarmod (approx. 1906). (© swisstopo map archive).

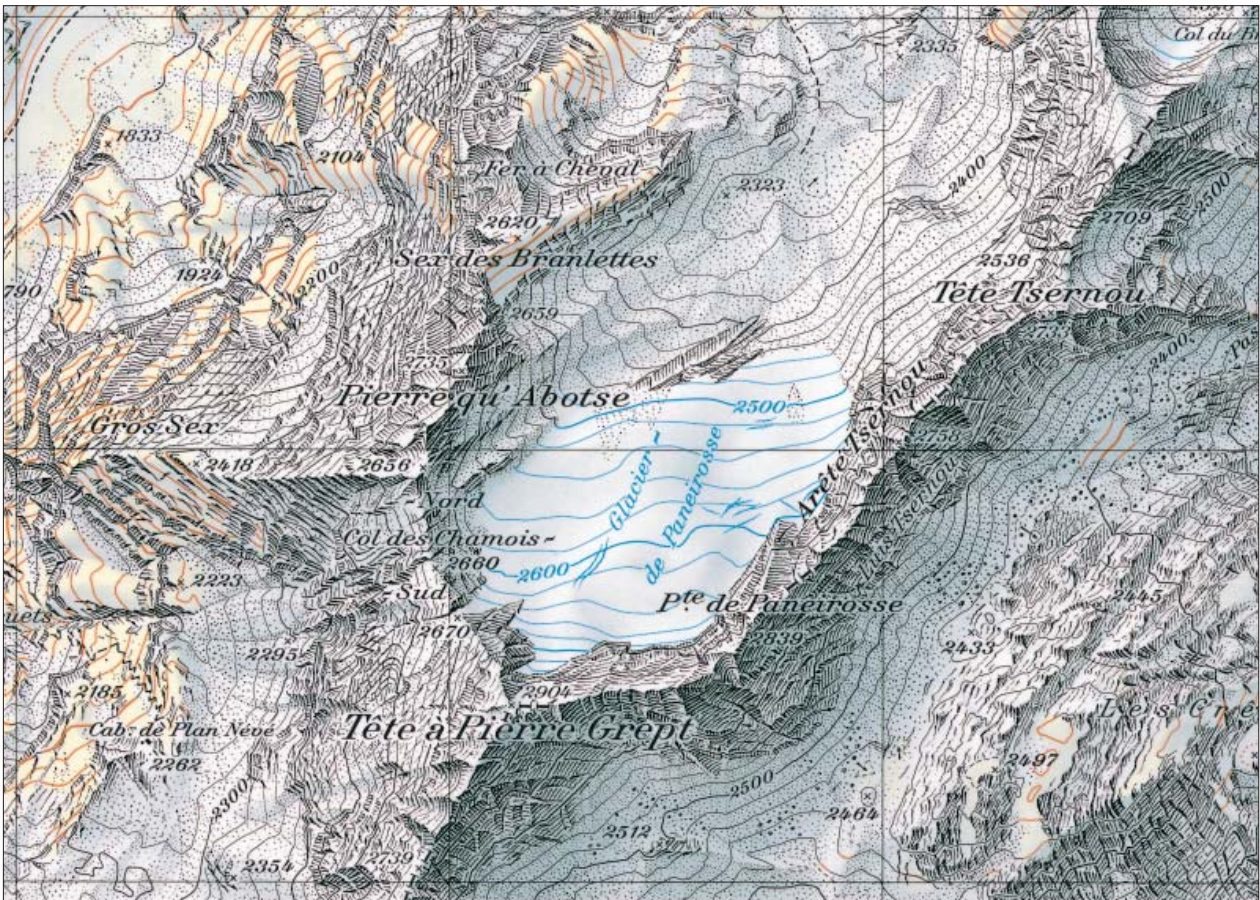


Fig. 3: Swiss National Map, sheet 1285 Les Diablerets, 1:25,000 (1998). A comparison of this map with Fig. 2 shows how Ch. Jacot-Guillarmod succeeded in creating an extraordinary terrain representation – even though he did not have any perpendicular aerial photographs at his disposal (© Federal Office of Topography swisstopo).



reliable base, his drawings are absolutely comparable to an Alpine survey.

The map of Kangchenjunga, however, is much less precise (Fig. 5). The photographs from Jules Jacot-Guillarmod's expedition in 1905 were taken by a hand-held Véroscope (stereo camera) and were usually not perpendicular. The positions and height of the stations were calculated by a graphic construction based on four triangulation points in India: the Jannu, the two summits of the Kangchenjungas and the Kabru. Fortunately, a complete view of the horizon was observed with the Véroscope mounted on a tripod on point 4973, located in the center of the Yalung cirque. Even though the instrument height was not measured, it was still possible to determine the position of the station using the four above-mentioned summits. The approximate inclination angle was interpolated by means of the heights of the summits. From there on it was easy to calculate the points. They are shown in blue on the map. The values are rounded to the nearest 10 meters, indicating that the heights of these points are only approximate.

The north face of the Kangchenjunga was drawn using a good photograph taken by Vittorio Sella in 1899 during the Freshfield expedition. The position of the station, the instrument height, the orientation and even the focal length of the camera were all unknown. It was necessary to use

the distance between the summit of the Kangchenjunga and point 7863 which was known from the triangulation of India. C.J.G. describes how vast experience is necessary to be able to determine the positions of points or the contour intervals using only the slope inclinations from photographs. For that reason the south face had to be drawn first so that the results of the interpolation could be compared to the other two faces.

### 3. The Mon Olympe map

From 1916 to 1922 C.J.G. taught geodesy and topography at the Central Army Surveying School in Peking. After his return to Switzerland he drew various large-format panoramas and in 1923 the rock representation for the Carte du Mont Olympe, the first topographic map of this mountain massif at the scale of 1:20,000 with 20 m contour intervals (Fig.6).

### 4. The Mount Everest map

His last achievement in 1925 was a topographic map of Mount Everest commissioned by the Royal Geographical Society in London. The map was based on terrestrial photographs and surveying results made by two British expeditions and published at the scale of 1:63,360. Besides the work itself, it is fascinating that he even received the man-

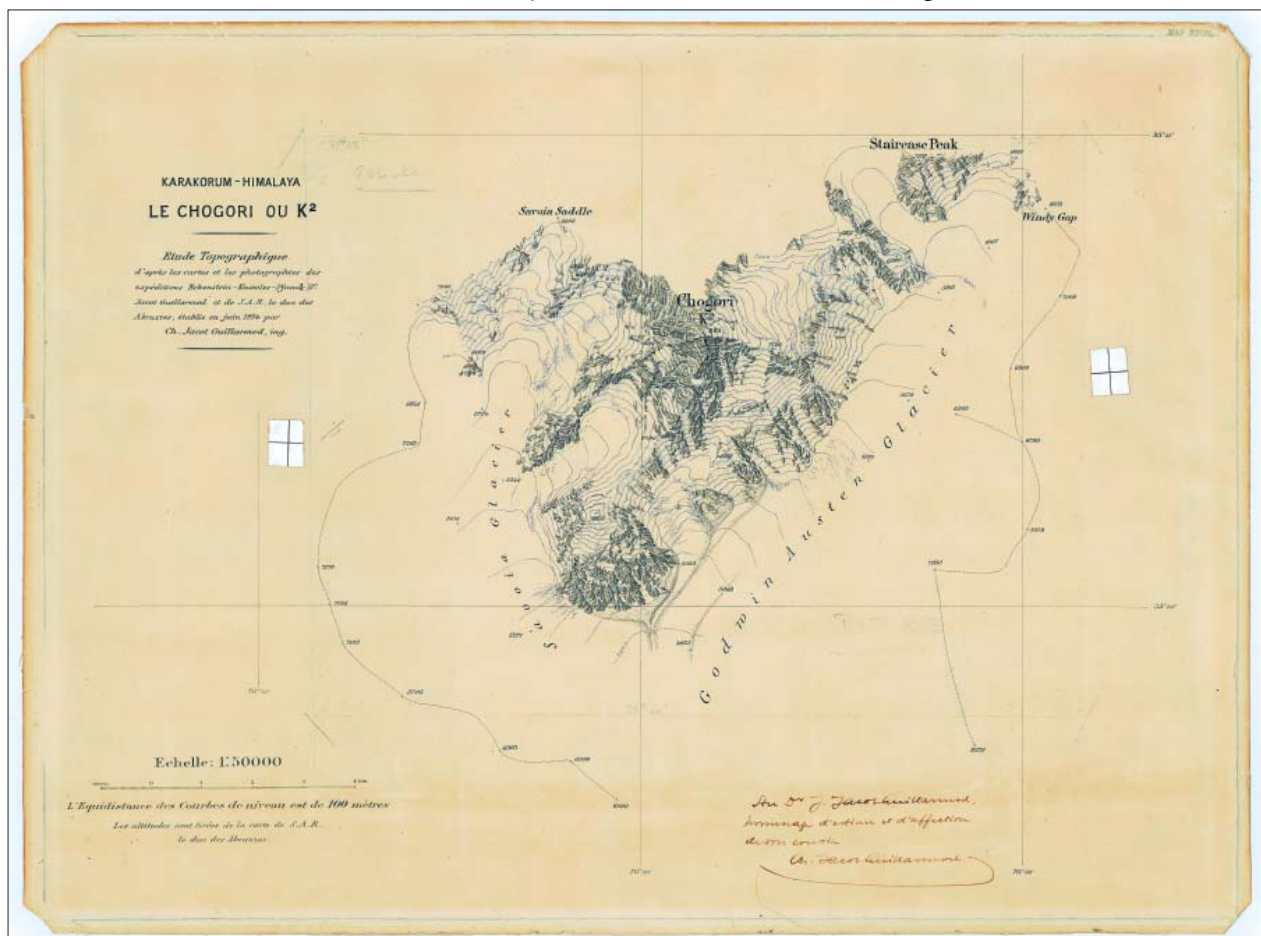


Fig. 4: Le Chogori ou K2. Etude Topographique d'après les cartes et les photographies des expéditions Eckenstein – Knowles – Pfannl – Dr. Jacot Guillarmod et de S.A.R. le duc des Abruzzes, établie en juin 1914 par Ch. Jacot Guillarmod, ing. Original drawing at the scale 1:50,000, contour interval 100 m. Extract reduced. (Private collection).

date in the first place, and also to realize in what short a time the undertaking was achieved. The various aspects that were involved are very impressive:

- quality awareness
- entrepreneurial commitment and risks
- time factor
- costs
- logistics
- language problems
- human relationships

This effort can be only highly regarded in light of the situation at that time without a phone, fax or the Internet, and the railroad being the only means of public transportation. The story of how this mandate to draw a map of Mount Everest came into being began on

4.2.1925. Letter Hinks → Montagnier:

Arthur R. Hinks, Secretary of the Royal Geographical Society (RGS) wrote Swiss publisher Henry F. Montagnier, whom he knew, a letter. The RGS wants to publish a book about Major Wheeler's Everest expedition. Because the cartographers at the RGS were already overloaded with work, he asks Montagnier to find out if C.J.G. would be willing

to draft a map of Mount Everest using surveying data and photographs by Wheeler, and what that would cost.

5.2.1925. Memorandum Hinks → Mount Everest Committee:

1. Hinks points out the lack of human resources at the RGS. 2. He had heard from Mr. Montagnier that C.J.G. had drawn a panorama for him, but otherwise didn't have many orders. Hinks proposes to commission C.J.G. with creating a map of Mount Everest if his offer were not too costly. 3. *C.J.G. is undoubtedly the world's most gifted draftsman for topographic maps of high mountains. Besides a map of the Kanchenjunga, he had also made one of Mount Olympus for Marcel Kunz.* The Committee disposes of the necessary financial means and the expenses would guarantee the best possible map, not only for the book itself but also for geography in general.

7.2.1925. Letter Montagnier → Hinks:

Writes that he has written C.J.G. and is certain that he is the right man for this task. Montagnier invites Hinks to visit him in Geneva where he will be staying at the Hotel de Russie from February 25 for a month.

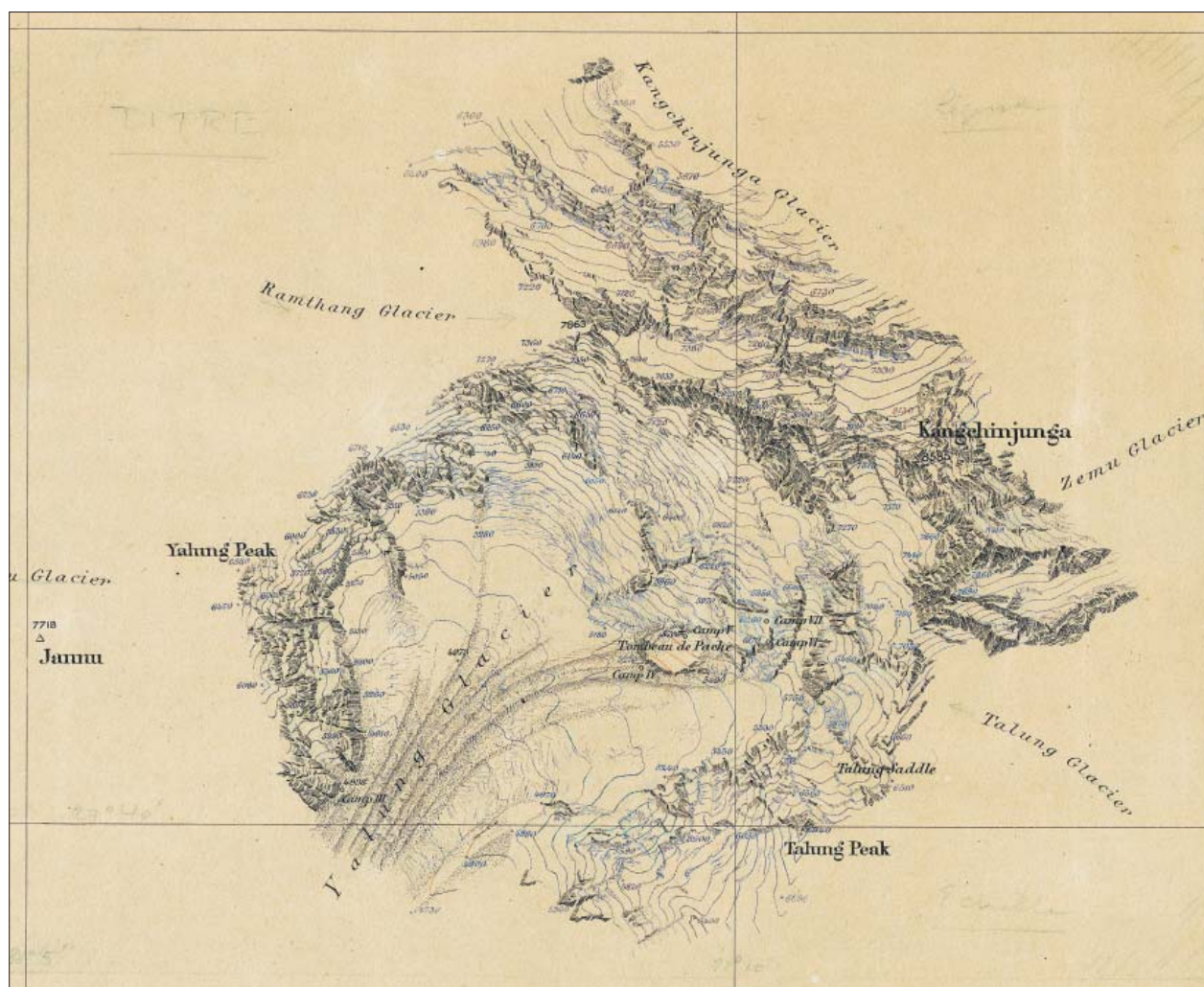


Fig. 5: Kangchenjunga 1:50,000, May 1914. Extract reduced. (Private collection).



14.2.1925. Letter Montagnier → Hinks:

Writes that C.J.G. had made a favorable price estimate of 10 pounds per English square foot.

17.2.1925. Letter Hinks → Montagnier:

*I cannot understand his estimate of price at all. It seems too ridiculously cheap, and I think there must be some mistake, but we can discuss all that, and I shall not be surprised if he finds it better to come to London.* He also thanks Montagnier for the technical description of C.J.G.'s construction theory for making panoramas.

17.2.1925. Letter Hinks → C.J.G.:

Returns the sketches and proposes to meet C.J.G. in Switzerland to show him the material and then to decide if the map should be drawn in Switzerland or in England. They will meet in Vevey.

19.3.1925. Letter Hinks → C.J.G.:

It is now time to make definite plans. C.J.G. should come to London as soon as possible after April 1 because Hinks will not be there from April 7h to 17. The idea is that C.J.G. would work on the map in London for 5 to 6 weeks and then return to Switzerland to finish the work.

Comfortable accommodations have been found for C.J.G. at the Marlborough Hotel in Lancaster Gate, for [...] *three guineas per week (63 s.), full board and lodging.* The hotel is located about 12 minutes by foot [...] across Kensington Gardens [...] from the RGS building. [...] *You spoke of your terms for the work in Switzerland as 250 francs for what you estimated to be a week's work, that is to say a little over £ 10. Would you be content to receive 12.10s. per week for work in London? I think that the additional £2.10s. would cover the additional cost to you of working here instead of in Vevey. We would of course also pay your railway fare.*

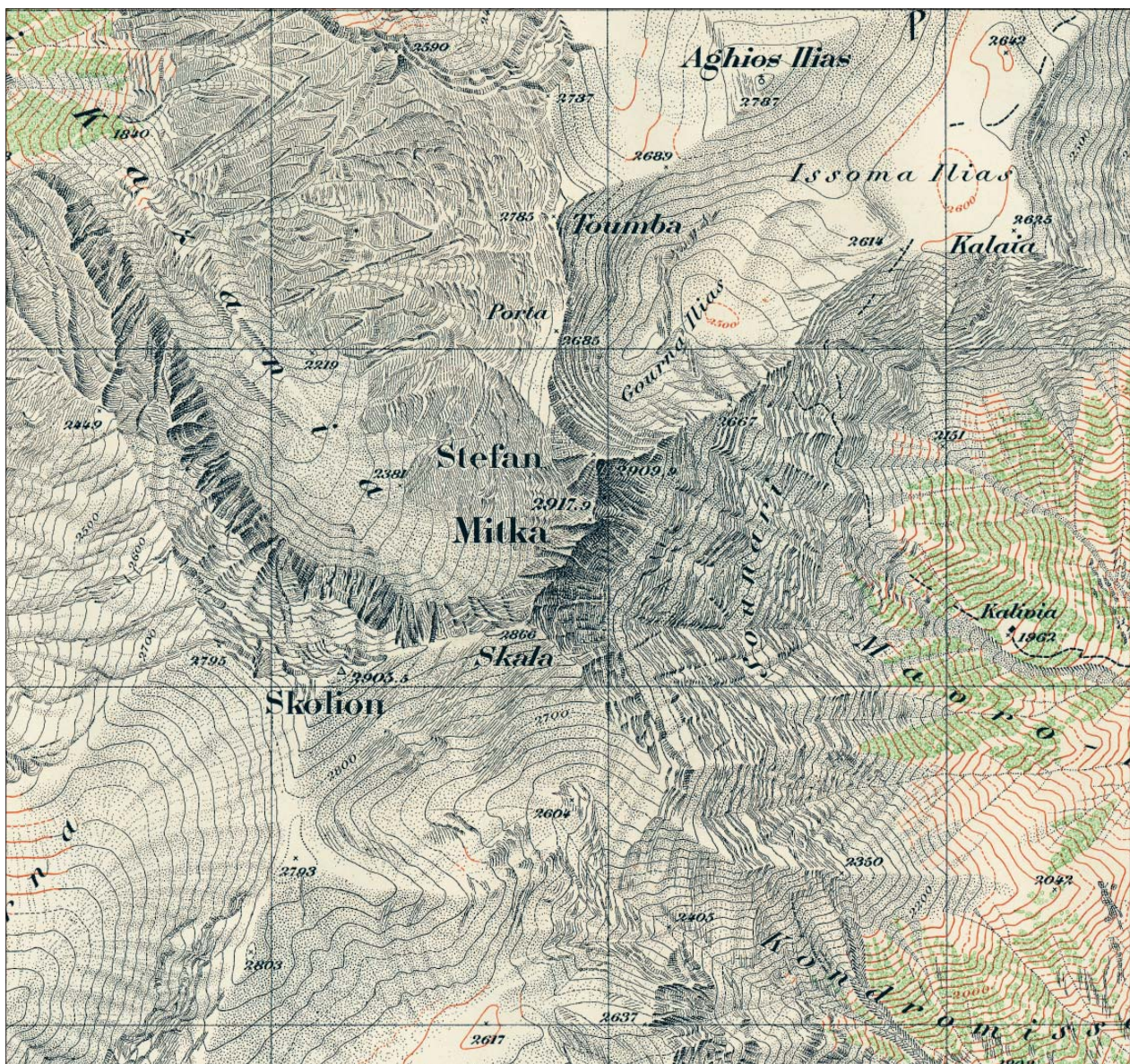


Fig. 6: Carte du Mont Olympe. Rock drawing by Charles Jacot-Guillarmod (1923). Lithography in 3 colours. 1:20,000, contour interval 20 m.



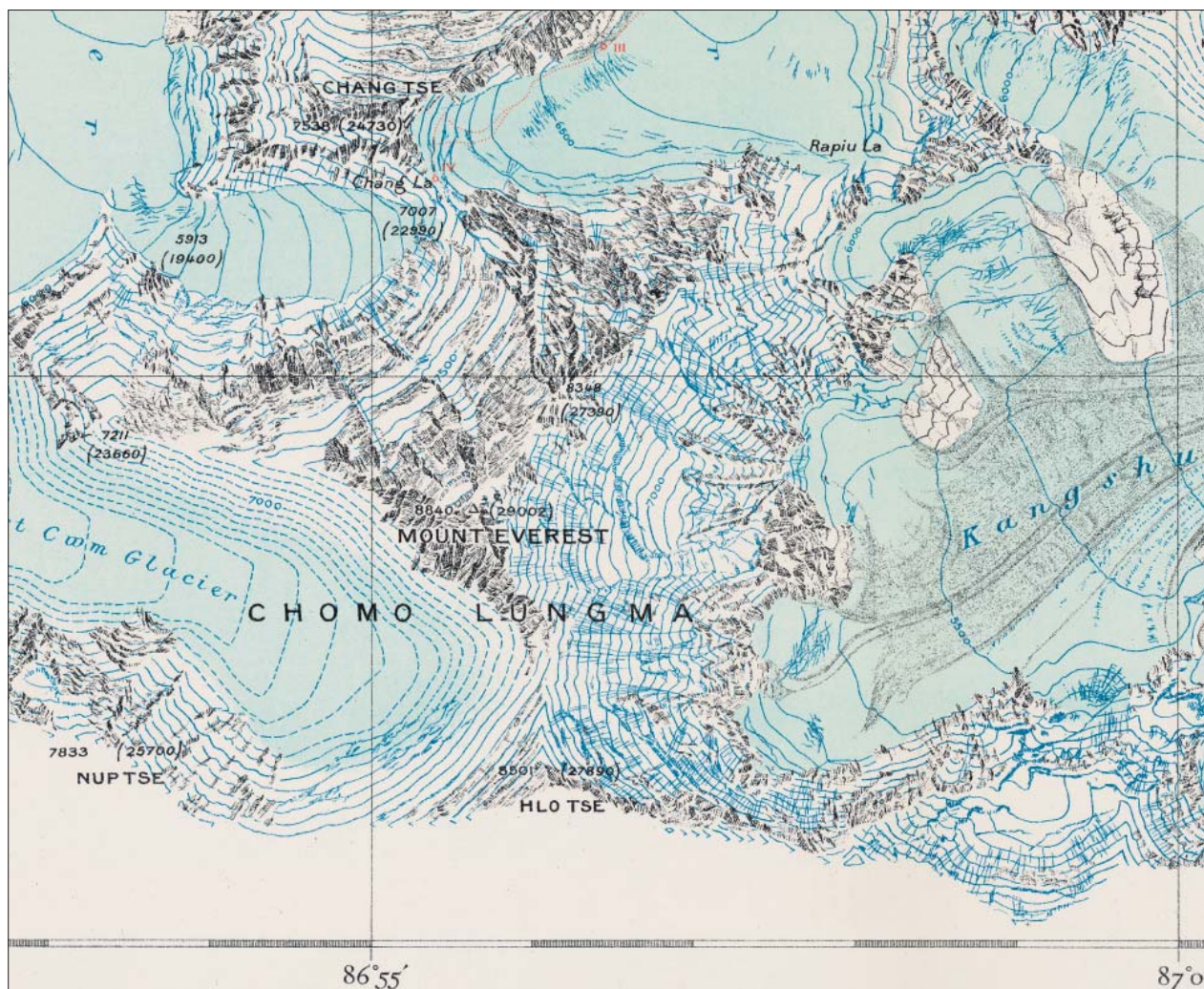


Fig. 7: The map Mount Everest & the Group of Chomo Lungma lithography printing in 4 colors. Scale 1:63,360, contour interval 100 m. Original drawing by Ch. Jacot-Guillarmod (1925).

23.3.1925. Letter C.J.G. → Hinks:

It is a great honor to create an "oeuvre cartographique de l'Everest". He is entirely satisfied with the financial offer. He is only now able to reply because he first had to find out if he would be able to finish a project before leaving for London on April 2 or 3. This will not be possible because he has to finish the Vevey–Montreux map first. Should he come to London already on April 14 or 15, or should he wait until April 20?

His train would arrive in London around 3:20 pm, and he would then proceed to the Marlborough Hotel immediately to meet his RGS colleagues.

25.3.1925. Letter Hinks → C.J.G.:

April 20 will be fine to start work. He will take care of the hotel reservation in writing.

*[...] I am sure that the Committee will count themselves fortunate in having secured your services. Believe me, yours very truly [...].*

2.4.1925. Letter C.J.G. → Hinks:

Confirmation: I will leave here on April 18, spend Sunday in Paris and arrive in London on Monday, April 20 approx. 3:20 pm.

6.4.1925. Memorandum Clerk Mount Everest Committee → C.J.G.:

*Mr. Hinks has asked me to let you know that he duly received this morning your letter of the 2<sup>d</sup> April, and is pleased to hear that you will arrive in London on the 20<sup>th</sup>.*

6.4.1925. Letter Clerk Mount Everest Committee → Manager of Marlborough Hotel, London:

*[...] With reference to Mr. Hinks' enquiry on the telephone some little time ago, Mons. Jacot-Guillarmod is arriving in London from Switzerland in the afternoon of Monday, 20<sup>th</sup> April, and we should be glad if you would reserve for him as nice a room as possible as from that date [...].*

1.7.1925. Letter Hinks → C.J.G.:

Apologizes that he was tied up with business on Friday and was not able to bid farewell to C.J.G. *[...] But I take an early opportunity of thanking you on behalf of the Mount Everest Committee for the admirable work you have*

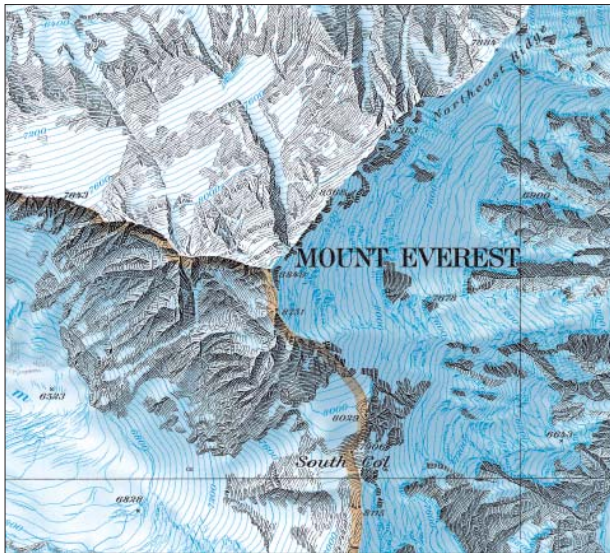


Fig. 8: Mount Everest Map 1:50,000, contour interval 40 m. (© Federal Office of Topography swisstopo, 1988).

*done on the Mount Everest Map. There is no one in the world who could have interpreted the photographs so well and I shall always be personally happy that I had some share in persuading the Mount Everest Committee to entrust the work to you. I am very sorry to read in the papers this morning of the death at Aden of your cousin who was on his way to Central Africa. Will you please accept my most sincere condolence. I shall hope to write again in a few days on the technical questions of the reproduction of the maps, but meanwhile I am very busy after four days absence from London [...].*

5.7.1925. Letter C.J.G. → Hinks:

Actually it is he who would like to express his gratitude at the warm reception in London. He includes a few notes in the letter which might possibly be of use for his article about the geology of Mt. Everest.

15.8.1925. Obituary C.J.G.

Charles Jacot-Guillarmod passed away on August 14, 1925. The cause of death was a stroke which he incurred during surveying work along a road. Charles Jacot-Guillarmod was one of the pioneers of genetic rock representation as it is still found in today's Swiss topographic maps. He never saw the printed product of his most significant piece of work, the Mt. Everest Map.

The original drawing (2 sheets) of his work which lasted 8 weeks was engraved in stone in the same year and printed in 4 colours (lithography, Fig. 7). The map *Mount Everest & the Group of Chomo Lungma* measuring 50 x 36 cm was bound in a book about the third Mount Everest Expedition.

The quality of the map and especially the rock representation in the style of today's Swiss topographic maps is excellent. A comparison with the present Mount Everest Map at the scale of 1:50,000 by the Federal Office of Topography from 1988 is impressive (Fig. 8). Among other information, C.J.G.'s map shows the position of the photo theodolites as well as the ascent route of the third Mt. Everest Expedition led by Wheeler. C.J.G.'s original drawing is archived at the RGS library in London. The west sheet shows the Kangshung-Glacier, which was not represented on the printed map because of the format.

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# Multidate Mapping Approach to Determine Alpine and Subalpine Vegetation Variations on Mount Jacques Cartier, Quebec, Eastern Canada (1973–2004)

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## Abstract

*Recent global warming trends have affected mountainous areas, especially in mid-latitude regions where the cryosphere component has shrunk rapidly over the last century. Among the potential impacts of warming, a shift from alpine to subalpine vegetation habitat has been observed by many researchers in Europe and Western Canada and the United States through changes to snow cover duration and distribution and to the timber line. The effects of global warming on the mountainous regions of Eastern Canada have been insufficiently studied. The Gaspé peninsula in Quebec has a particular climate and ecosystem that is typically found in areas further north (for example there are areas of tundra and herds of caribou).*

*This paper evaluates the magnitude of changes to alpine and subalpine vegetation cover over the last three decades in this region. A multidate mapping approach was used to delimitate the alpine and subalpine habitat on a local scale, through an analysis of factors such as the mosaic of land cover types. The mapping technique used for this case study is based on digitalized aerial photographs and combined with a Geographical Information System. The results show no major altitudinal shifts of the timber line toward the hilltop, in contrast to what has been reported by many other researchers for other mountainous regions. However an increase of the surface covered by vegetation patches was observed, together with a reduction in the surface area of the block field. These preliminary results are meaningful for the mountain climate and ecosystem of the region that constitutes a biogeographical island of alpine tundra at this latitude.*

## 1. Introduction

Among the potential impacts of global climate change on the alpine and subalpine areas are an increase of the air temperature and a greater amount of snow during the autumn and winter season. The alpine vegetation is also affected and recent research already shows that the snowbeds communities species composition has changed (Björk and Molau, 2007) and that timberline have shifted many meters toward the higher mountain areas for certain regions (Beniston,

2003; Kullman, 2007). Different approaches can be used to quantify the spatial vegetation migration or landscape fragmentation for different environments including alpine and subalpine areas. A classical approach consists of making quadrats and transects, which represents an efficient way to describe the floristic composition at a local scale (Pfeffer et al., 2003). At a regional scale remote sensing images or aerial photographs can be used to extract information for mapping alpine vegetation. The image classification can be made manually by a user or automatically. The latter is less appropriate for a heterogeneous terrain where the vegetation distribution follows a patchy pattern (Lindblad et al., 2006).

Another key factor for mountain studies is the scale at which the studies are made. The spatial variability is one of the main challenge for researchers who work on heterogeneous environments such as mountains (Jones et al., 2001). As mentioned previously, the latitudinal factor is important. In the presence of a high vertical gradient, however, the spatial features can change rapidly in a short horizontal distance. The scale is then a crucial factor that must be chosen with care to ensure that the main purpose of the study will be clearly addressed. In alpine and subalpine environments the abiotic factors that influence the vegetation cover distribution vary, but the slope (angle, form and aspect), the surface roughness, the soil type and humidity and the snow conditions (snow depth, snow duration,...) are important at both mesoscale (100 m to 10 km) and microscale (1 m to 100 m).

For Eastern parts of Canada and the United States very few studies about the potential impacts of recent warming on mountain areas are available. Even fewer studies climate of the Gaspé peninsula have been conducted. The lack of knowledge about the climate can be explained partly by the lack of complete meteorological datasets in the interior of the country, as most of the meteorological stations are located along the coast where the influence of continentality and the altitudinal gradient are small or non-existed. Since the work of Gagnon (1970) no major studies about the Chic Choc climate have been published. On the other

hand, the alpine and subalpine vegetation habitats of the Mount Jacques-Cartier have been studied at the end of the 1970's by Boudreau (1981). This sector is a fully preserved area that is used by the caribou (*Rangifer tarandus caribou*) an endangered species (Mosnier et al., 2003).

At the regional scale (southern Quebec) the mean annual temperature has slightly increased (Yagouti et al., 2006) during the 1960-2003 period. However, due to the lack of complete meteorological datasets for the inland part of the Gaspé peninsula, the magnitude of the temperature variability is still difficult to evaluate. Assuming that alpine vegetation is particularly sensitive to climate changes (Keller et al., 2005), a multidate mapping approach was then used to determine the magnitude and size of vegetation cover changes. The vegetation here is used as a potential indicator of a recent warming climate (since the early 1970's).

In the summer of 2007, different temporal series of air photos were acquired for the area, specifically the summit plateau, and a short field work campaign was done at the end of the summer. In this study monochrome air photos were digitized and integrated into a GIS, and manual classification was carried out. The main goal of this study is to evaluate whether habitat changes happens, and if so what is the amplitude of such change, for the highest summit of the region (Mount Jacques Cartier) between 1973 and 2004. We discuss the limitation of the using this method and propose some processes that can explain why changes happened.

## 2. Study area

The Gaspé peninsula is located on the eastern part of southern Quebec in Canada between New Brunswick in the south, on the other side of the Baie des Chaleurs and the Côte Nord region on the other side of the Saint Lawrence river in the north (Fig. 1). The mountains of the Gaspé peninsula are a part of the Appalachian Chains that is subdivided in the Chic Choc mountains in the west and McGerrigles mountains in the east separated by the Sainte Anne river. Mount Jacques Cartier is the higher peak in the Gaspé peninsula (1268 m) and the second highest peak in Quebec province. The mid-latitude climate characterizing the region is a humid continental climate with no dry season following the Köppen climate classification. The mean annual precipitation is above 1600 mm ( $\pm 60\%$  fall as snow) and the mean annual air temperature is 2.1°C.

The influence of air masses is greatly changes greatly with season cycle in the region a fact which explains and it can explain the precipitation and temperature of the region. Hufty (2001) shows that the main air masses affecting the region are from Continental Polar and Polar Pacific Modified (W), Polar Return (SW) and Arctic Modified (NW, W) the latter being usually associated with strong winds during the winter period. Secondary air masses are the Maritime Tropical (SW), Arctic (NW) and the Atlantic Maritime Polar (E,NE), the latter often the source of snowstorms and heavy snowfall during the winter season. The influence of the air masses are important in order to understand the climate and the ecoregion of the area because synoptic climatology is directly coupled with surface conditions. Following

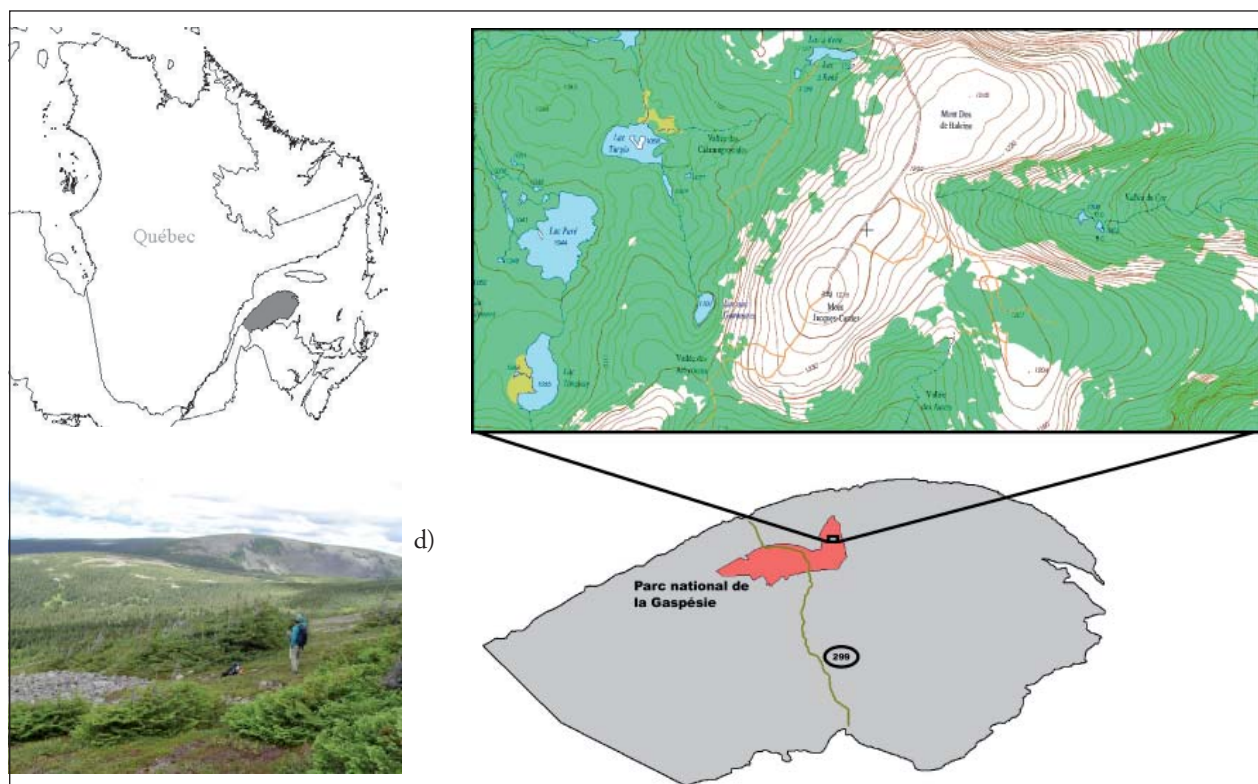


Fig. 1: The Gaspé peninsula is located in the southern Québec (a); Mount Jacques Cartier summit (1268 m) is located at 48°56,26" N; 65°56,33" W (b) the Gaspé provincial Park is located in the peninsula, less than 30 km from the northern coast (c); a view of the Mount de la Passe from the N-E slope near the Mount Jacques-Cartier summit (d).

Boudreau (1981) three altitudinal zone can be defined for Mount Jacques Cartier : the alpine zone (above the timberline, 975-1268m), the subalpine zone (900-975 m) and the montane forest (250-900 m). The subalpine zone is a transitional zone between the two others that is mainly covered by krummholz.

### 3. Methods

This work is part of a larger project consisting of evaluating the potential impacts of a warming temperature in the study area. We did not have a long-term data on either vegetation description or meteorology directly at the study site. The available data are sparse in time and space. Hence our work utilizes two series of aerial photos to explore the potential effects of warming climate on vegetation cover response.

#### 3.1. Photo interpretation and vegetation mapping

The plateau of Mount Jacques Cartier is relatively flat and covers almost 80 km<sup>2</sup>. Initially seven time-series (1948; 1970; 1973, 1975; 1986; 1992; 1994; 2004) have been investigated to evaluate the vegetation cover distribution through the time period from the 1970's to the beginning of the 21<sup>st</sup> century. The 1986 and 1992 series are infrared images but all the others are black and white photos. The scale is 1:15,000 for all images except that for 1994, which is 1:50,000. After a first overview of the changes that can be seen by standard photo interpretation methods several were discarded mainly because of poor images quality due for example to the presence of clouds or the presence of snow on the ground, despite the fact that the images were taken during the summer. Finally two time series, 1973 and 2004, were used to evaluate the vegetation cover changes for four predetermined zones that are all located on the plateau of Mount Jacques Cartier (Fig. 2). Having finalized our choice of images, the second step was to digitized them. MapInfo™ (version 9.2), a geographic information system software, was then used to create a map for each dataset.

Provencher and Dubois (2007) suggest that it is preferable to use colour and high resolution images (e.g. 1:15,000) when a vegetation inventory is made by photo interpretation. In the case of the present study monochrome contact prints were enough detailed enough to establish the vegetation limits. Colour prints can be useful for vegetation identification but this is not essential to get the edge and limits of vegetation patches.

Moreover if an attempt at vegetation identification is made it requires detailed field work that is usually obtained by traditional vegetation sampling such as transect and quadrat as has already been done by Boudreau (1981) for the study area. At the scale used in our study the species identification for each zone it is not relevant because we want to evalu-

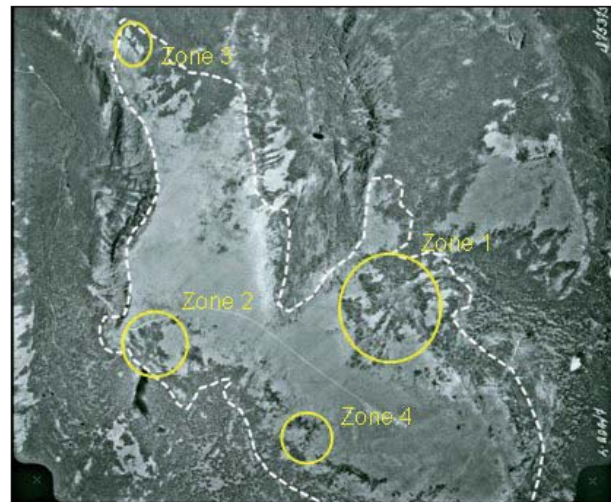


Fig. 2: Four zones location on the plateau of Mount Jacques Cartier.

ate the spatial variation of the alpine vegetation area cover rather than the community's species composition.

Initially eight different classes of vegetation were chosen, but there classes were not all present in the study area. Although vegetation description is not detailed here, a simplified classification containing only three classes was finally kept for the vegetation mapping. Vegetation classes are all located in the alpine tundra and the most common plant communities are summarized in Fig. 4 (in accordance with Boudreau, 1981).

The merging of different classes is mainly explained by the difficulty of clearly distinguishing the limits between some vegetation classes (gradual transition without evident edge or cut) and the small size of the study area where many of the previous classes are simply absent. Another interesting approach, described by Keller et al. (2005), consists in using the habitat zones rather than alpine plant species. This second approach used five classes for the habitat zones for alpine plant species : 1- snowbeds; 2- ridges; 3- swards (relatively flat areas); 4- scree; 5- rocks. Nevertheless, because the study area contained only classes 3 and 5, this approach was not used. Two snowbeds (class 2) were observed during the field work (see field data collection section) but they are out of the study area on the SW slope. The fact that the plateau is relatively flat means that classes 2 and 4 are absent.

#### 3.2. Field data collection

The field data was conducted in mid-August 2007, a period similar to the acquisition period of the two air photos datasets (meaning a similar phenological stage for the vegetation can be assumed). About 40 points were reached in the field using a GPS (Garmin Explorer) with a vertical precision of  $\pm 4-7$  meters. Air photos were brought in field for validation

Classes	Plant communities
Meadows / Alpine / Grassland	Carex bigelowii, Polytrichum juniperinum, Vaccinium uliginosum
Shrubs	Diapensia lapponica, Ledum groenlandicum, Empetrum nigrum, Phyllodoce caerulea
Rocks	Mainly recovered by different lichens and moss species

Fig. 3: Vegetation class description.



purposes, and the surface area of approximately ten different patches have been measured in detail using a metric tape. No detailed vegetation inventory had been done.

#### 4. Results and discussion

Different kinds of vegetation changes, whether expansion or contraction, can occur in alpine areas. A shift of the timber line was first considered but no evidence of such a shift was observed. Nevertheless other behaviour can occur for example Tape et al. (2006) observed three types of shrub expansion in an arctic environment: new colonization, patch in-filling and individuals getting larger. Our results clearly show new colonization and patch in-filling for all the study area (Fig. 4).

The results derived from the four zones in the study area are summarized in Figure 5. The results indicate a decrease of meadows (-0.11% per year) and rocks (-0.27% per year) classes for the four zones from 1973 to 2004. By contrast the shrub's expansion proceeded at +0.28% per year during the same period. The changes for the meadows areas are almost all negative except for zone 2 where a positive growth was observed. The rocks areas indicate a decline of the area in three zones and no changes for one zone. The shrubs area show a clear expansion for all zones with a large growth rate for zones 1 and 3 and subtle changes for zones 2 and 4.

In the arctic environment an increase of both the mean winter air temperature and the snowpack depth increases the nutrients available and thus soil conditions are more favourable to vegetation colonization or expansion (Tape et al., 2006). This situation seems also plausible for temperate cold environments even if some differences need to be taken into account such as an increase of the occurrence of rain-on-snow events, thaw-refreeze cycles, etc.

##### 4.1. Restricting factors

For the Gaspé peninsula the threat of plant migration and even extinctions could be serious in regard to the very small altitudinal gradient (a few hundreds meters only). The predominance of rocky surfaces means that soil is either absent or poorly drained, except for a few depressions. These factors are negative for plants propagation at least for short and mid-term periods. Another restricting factor for vegetation expansion is the presence of permafrost at the top area on the Mount Jacques Cartier. In the early 1970's Gray and Brown (1979) showed that a relic permafrost is present at the top of the Mount Jacques Cartier. The current situation is unknown, but if the permafrost is still in place, as is probably the case, this is another obstacle for the vegetation expansion toward higher elevations.

Löffler (2007) has shown that the high variability of the local temperature in high mountain environments, mainly associated with the local topography, altered the functionality of the ecosystem. The work of Keller et al. (2005) demonstrates the same thing and they posit that the precipitation, temperature, wind and radiation are not sufficient to explain a change of the vegetation pattern in mountain areas. The snow cover and relief are also crucial factors for plant phenology and distribution. Other factors such as nutrients, soil characteristics (organic content, pH, moisture, etc.) also play an important role in vegetation growth and spatial distribution (Jones et al, 2001).

##### 4.2. Expanding factors

The presence of heavy snowfalls for this region (Gagnon, 1970) could represent an insulation factor that might be favourable for the survival rate of the plants in the harshest areas. The plateau is a significant fetch for wind that removes the snow from the top area and deposits the redistributed snow on the lee side creating large snowbeds on the south-eastern side because most of the snowstorm and bliz-

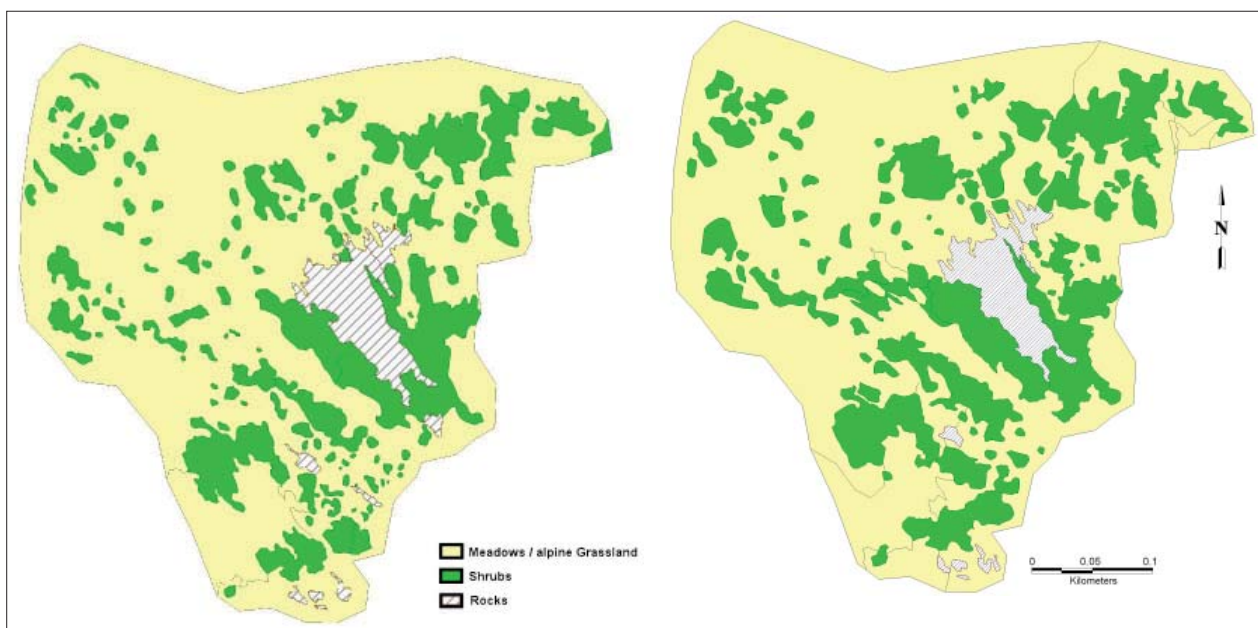


Fig. 4: Example of vegetation modification for zone 1.

1973 / Classes	Area (m <sup>2</sup> )	Zone 1	Zone 2	Zone 3	Zone 4
Meadows	97 476	17 150	2 702	28 486	
Shrubs	31 830	37 130	8 463	7 494	
Rocks	6 794	21 950	3 965	0	
Total	136 100	76 230	15 130	35 980	
2004 / Classes	Area (m <sup>2</sup> )	Zone 1	Zone 2	Zone 3	Zone 4
Meadows	91 520	18 903	2 242	28 387	
Shrubs	38 210	38 150	9 517	7 593	
Rocks	6 370	19 177	3 371	0	
Total	136 100	76 230	15 130	35 980	
Classes	Area changes (m <sup>2</sup> ) / %*	Zone 1	Zone 2	Zone 3	Zone 4
Meadows	/ -6.11	/ 10.22	/ -17.02	/ -0.35	
Shrubs	/ 20.04	/ 2.75	/ 12.45	/ 1.32	
Rocks	/ -6.24	/ -12.63	/ -14.98	/ 0	

\* + : area increase or – : area decrease.

Fig. 5: Analyses results of land surface cover for each class from aerial photographs of 1973, 2004 and the changes (%) between the two periods.

zard come from the northeast. Germain et al. (2005) have studied the region and they hypothesize that vegetation is trapping the blowing snow. The snowpack has a feedback effect because snow trapped by vegetation protects it from desiccation and low temperatures. The structural character of the snowpack is another important factor that controls plant survival rates because ice features, such as ice layers through the snowpack, might affect the gaseous exchanges between the plant and the atmosphere (Jones et al, 2001). Moreover alpine plant species and communities are highly sensitive to an increase of temperature.

In regards to predicted local or regional warming, even a small increase for the study area can mean a modification of the snowpack which will thus modify climatic variables to a critical level. Groisman et al. (1994) target sensitive regions, calling them snow transient regions, that might be particularly sensitive to climatic change. Gaspé peninsula can be consider a sensitive region where the interannual standard deviation of the presence of snow cover for each season varies from 0.20 to 0.25 (calculated for a 20 year period) during the spring period (April-May). Yagouti et al. (2006) analysed climatic trends for southern Québec between 1960 and 2003 period, and argued that the warming trend for Gaspé peninsula is not clear. This situation is partly explained by the large size of the peninsula and the small number of meteorological stations over the region. Most of the stations are located along the coast at a low altitude, which obscures the altitudinal gradient and continentality effect of the mountainous areas in the middle of the peninsula. Nevertheless the Saint-Jean-de-Cherbourg meteorological station (44.84°N, -66.47°W; 358 m), which seems to be the more representative of the central area, showed a slight increase of the maxima and minima air temperatures during both winter (max.: +1.5°C; min: +1°C) and spring (max.: +0.5°C; min.: +1°C) for the 1960–2003 period. This situation could be favourable to a vegetation expansion assuming a statu quo of the edaphic conditions.

Conducting intensive research in the early 1990's, Grabherr (1994) observed an altitudinal increase of high alpine species toward the summit of different mountains in the Alps.

He concluded that for his study area (western Austria and eastern Switzerland) a shift of the altitudinal vegetation belts happened at a rate of 8–10 per decade, assuming a mean air temperature increase of 0.7°C for a period of 7–9 decades. Yagouti et al. (2006) estimated a similar trend for the mean annual air temperature increase of about 0.5°C from 1960 to 2003 (Saint-Jean-de-Cherbourg station). However, as mentioned previously, no evidence of an altitudinal shift has been observed at our study site.

## 5. Conclusion and future works

The results presented here must be interpreted with care and more in-depth analysis of both the vegetation classification method and the climatic trends is necessary. An increasing trend of the vegetation cover area for the four zones is still insufficient to get a complete picture of the situation because species changes are more relevant than community changes in order to the impacts of climate change (Becker et al., 2007). However this study represents a first attempt to estimate the vegetation modification for the higher summit of the region. As already mentioned, little information is available about the climate of the Eastern Canada mountainous areas. The main conclusion of this study is that new colonization and in-filling of the vegetation patches happened during the study period in the Mount Jacques Cartier plateau. The climate conditions are more susceptible to explain the vegetation expansion than edaphic conditions which are less prompt to occur, i.e. about 30 years.

This study is a part of a more comprehensive project that consists to evaluate the climate changes in the Chic Choc Mountains since the end of the 1940's. A particular effort is made to understand the main consequences of a warming climate of the region in regards to the altitude and the continentality. Future research is still needed in many areas. Our future efforts will be on:

1. establishing more monitoring datasets of the geographical and meteorological processes along an altitudinal gradient to reconstruct all the alpine vegetation habitats instead of being limited to the plateau;

2. creating a detailed DEM in which existing information could be integrated to facilitate data management and spatial surfaces changes through time;
3. updating plant species diversity monitoring at Mount Jacques-Cartier and expanding the observations to other summits in the region (e.g. Petit Mont Saint-Anne where a meteorological station is present);
4. applying a simple logistic growth model (as suggest by Tape et al., 2006) to quantify more exactly the rate of increase of shrub patch through time;
5. proceeding to homogenization of temperatures and precipitations over the region (Fortin et al., 2007).

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# Mobile Mountain Mapping

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## Abstract

Map visualization is an important tool to make mountainous areas easily understandable to visitors. This article suggests to turn from classical printed maps to the digital cartography presented on PDAs (Personal Digital Assistant) or on handheld GPS (Global Position System) device. Nowadays mountaineers and hikers have many possibilities to plan their excursions, instead of going to the bookshop, they make their plans by using internet. As an example, the following tools are already available on the net: Google Earth, free online map or for more expert cartographers - the currently spatial data infrastructure (SDI) which allows to visualize an image of multi-sources cartography through WMS services (web map services). Nevertheless, it is most fashionable for current adventurers to take their GPS device and all the tracks available, and perhaps why not to get some additional information about the interesting sites, they will pass through.

This article deals with mobile mountain cartography and its representation on portable electronic devices, where due to the factors: size of the screen, location based services (LBS) and current customers of mountain cartography, new solution should be considered for an innovative design. Additionally a pilot project of mobile mountain cartography has been designed for the project "La mirada circular" ([www.lamiradacircular.com](http://www.lamiradacircular.com)).

## 1. Introduction

The implementation of many projects proves the importance of mountain cartography and its scope within different environments which it is related to. Moreover mountain cartography has a great range of application and its demand is not only focused on the developing countries. A list of the thematic variety related to the mountain environment is presented in Hurni et al. (2003).

The solutions and developments in mountain cartography have been several in the last years. Today it is possible to go for a walk without a printed map. Moreover much of the geographical technology, which was not specially designed for mountain cartography, may be used for it, like for example GoogleEarth or VirtualEarth. Many tracks, photos, mountain huts are included on the web and they can be easily founded by googling. Even new terms are commonly used like geovisualization. Geovisualization provides methods and tools for the visual exploration and presentation of the geographical information. Altogether, these new approaches enlarge the idea of mountain cartography.

## 2. La mirada circular

The opened variety of mountain cartography, together with the currently range of geovisualization opportunities have made possible to create this project called "La Mirada Cir-

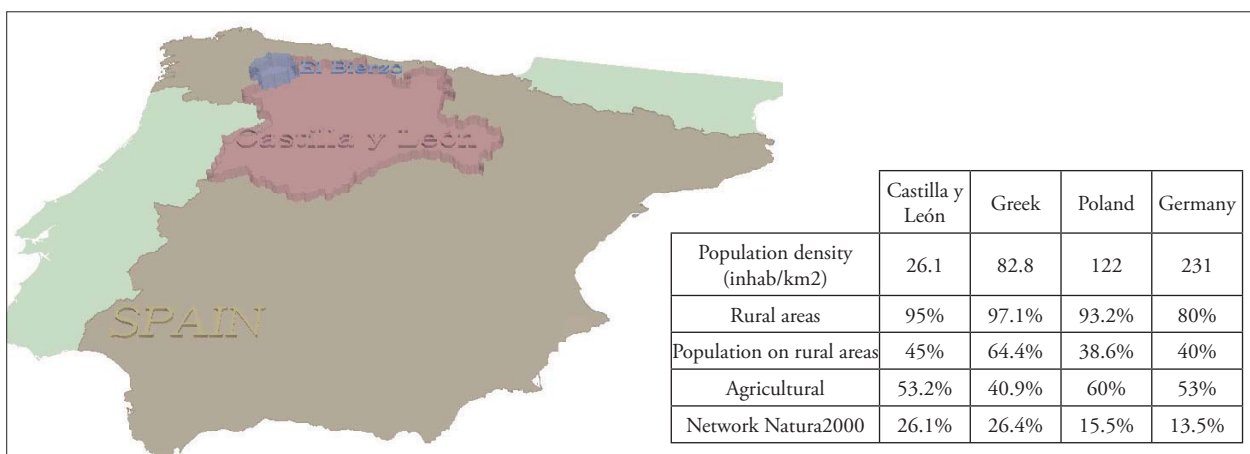


Fig. 1: Geographical location and data of Castilla y León



cular". La Mirada Circular is a project of sustainable and intelligent tourism based on the beauty and isolated rural areas of a region called El Bierzo.

El Bierzo is a region in the Northwest part of Spain which belongs to an autonomous region called Castilla y León. Fig. 1 describes the location of El Bierzo and some geographical features of this region compared with other EU countries. Some conclusions from Fig. 1 are the low population density of the region and the big areas of natura2000 network. Based on this data El Bierzo is a good area for relaxing and forgetting the stress of crowded cities as well as a sightseeing place to be in contact with nature.

Mountain paths and roads have always been the base on economy and partnership between cultures. This idea is the starting point of "La Mirada Circular". By renovating these lost roads and following these old traces a walking route has again become a solution for the economy of the region.

As an important part of the project the cartography is not only the spatial information but also the use of many others technologies; like animated maps, videos, and an attractive web design. One of the main functions of the web-mapping is the real time access to a great scale of information. Tourists nowadays collect information through the Web; at this stage they are called virtual tourists. They visit the earth just by being in front of their computer. By navigating through [www.lamiradacircular.com](http://www.lamiradacircular.com) as a virtual tourist you will understand more all the geographical aspect of the region as well as you will feel like coming to visit us. Comments through the webpage are always welcome to improve the project.

Belinchón (2005) proposes that rural tourism is an effective tool for the promotion and conservation of the rural heritage. As soon as the virtual tourist decides to come to visit El Bierzo, one of the main objectives of this project

is already fulfilled. At this point a new stage of the project begin, the virtual tourist become and active tourist by visiting the region. New technological approaches are still on design to satisfy the expectancies of the active tourists on El Bierzo.

Active tourist involves mobility around the territory, personalization of activities and hobbies and context awareness. One solution gathering these ideas is the development of mobile cartography for the region, as it is shown in Fig. 2.

### 3. Mobile Cartography

After the success of the Internet, web mapping is a further step for the traditional use of geographical information. The importance of Internet is undoubtedly enormous. La Mirada Circular is already included in this wide web world.

Geographical technology is nowadays easier available but at the same time this technology is rapidly changing from the classic desktop applications into web mapping and into the latest applications based on mobile computing. Mobile devices such as Personal Digital Assistants (PDA), mobile phones or GPS handhelds are some examples of appliances used in mobile environments.

This evolution on cartography brings new terms and the discussion to implement solutions. Telecartography and the Location Based Services (LBS) are terms related with mobile cartography. Telecartography means the exchange and transmission of spatial information through cartographic products that are transmitted by telecommunication technologies and are accessible by mobile query and display devices (Gartner 2000). Location Based Services (LBS) are wireless 'mobile content' services to provide location-specific information to mobile users moving from location to location. Within the LBS concept a cartographic visualization is already understood. Finally mobile cartog-

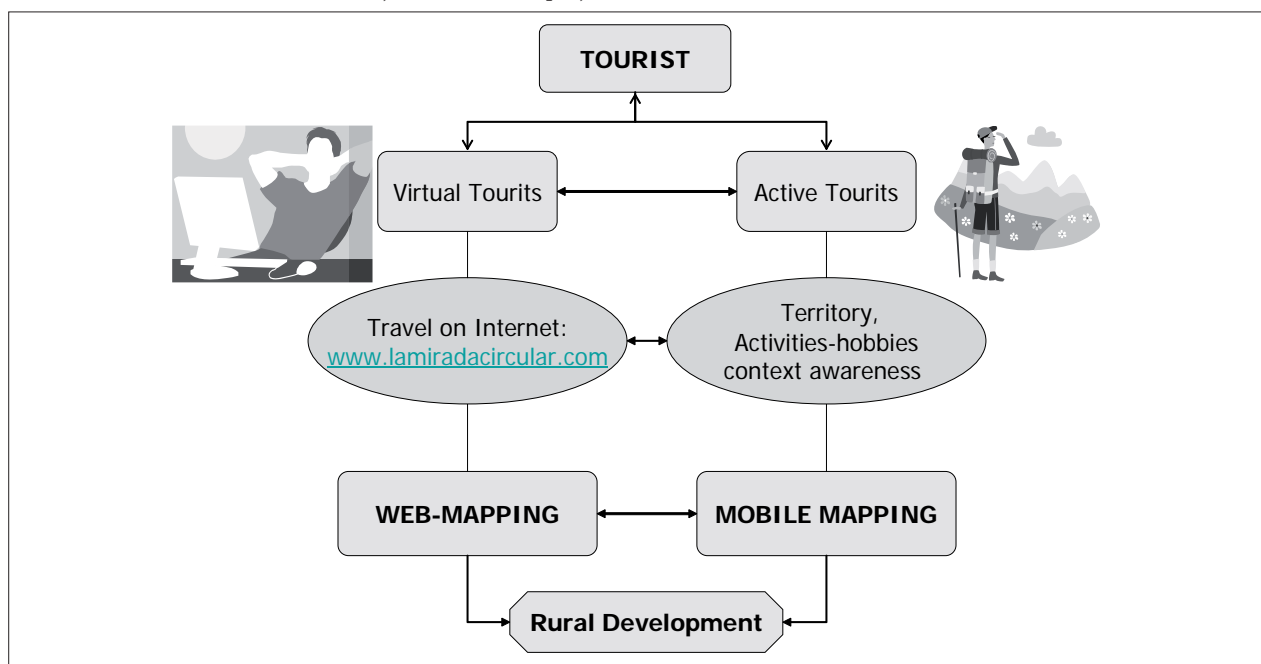


Fig. 2: Workflow from virtual tourists to an active tourist

raphy deals with theories and technologies of dynamic cartographic visualization of spatial information on mobile devices. Mobile cartography is the geovisualization on LBS devices (Reichenbacher et al. 2003)

Fig. 3 describes the characteristics of the main map groups. It shows the complexity of mobile cartography as it contains all the characteristics of digital and printed maps.

Cartography Characteristics	Printed	Digital	Mobile
Mobility	x		x
Positionable			x
Adaptive/Adaptable		x	x
independent		x	x
Interactive Location	x		x

Fig. 3: Characteristics of different cartography (adapted from Reichenbacher 2004)

There are many solutions for mobile cartography, even for industry and commercial purposes. Perhaps the most success device is the navigation systems performed for the motorizing market. New ways of geovisualization are established, as an example the navigation on a road network is very well accepted by many users. Fig. 4 illustrates the well-known visualization of a Tom-Tom.

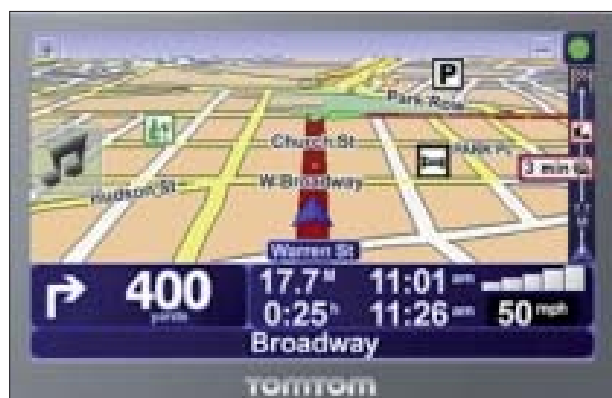


Fig. 4: Example of car navigation systems

### 3.1. Generalization and Adaptation

Many cartographers consider the mobile cartography a representation of the digital cartography in a small display; as a matter of fact map generalization will improve the geovisualization. Others authors consider mobile cartography a new display of cartography, and the process of generalization and adaptation are both necessary. In fact both terms overlap each other, generalization is more objective: characteristics of map elements: takes into account scale and map purpose. And the adaptation process is more subjective it implies the most relevant elements for the user and it takes into account the context of the map usage (location, time, activities, goals and etc...). (Reichenbacher 2004).

## 4. Mobile Mountain Mapping

Mobile mapping by means of mountain cartography has also several solutions, especially in national parks and tourist areas. A good example is the WebPark project, funded by the European Union (Webpark 2004). It consists on a mobile information system that provides visitors of natural areas and parks information about their surroundings using PDA and GPS. The success of the project has brought a new market and some companies are nowadays working on digital guides for tourisms. On the other hand there are also cartography companies commercializing their printed products on a digital raster format for desktop and mobile applications. Fig. 5 illustrates two ways of managing the cartography data.

Many of the developed projects have focused their attention especially on telecartography and the telecommunications protocols which are important for the interoperability between different platforms. However, Konecny 2001 mentions that there are many other challenges for cartography in this millennium. One of them regarding the impact of the computer is the importance on the basis of visualized spatial data in order to take the right decision.

Cartographic visualization on screens has a number of advantages over the paper maps. However, as there are a big number of different devices with their own screens and characteristics, the visualization of cartography on digital devices can not be so easy summarized.

Fig. 6 shows the differences characteristics of geovisualization between the map groups:

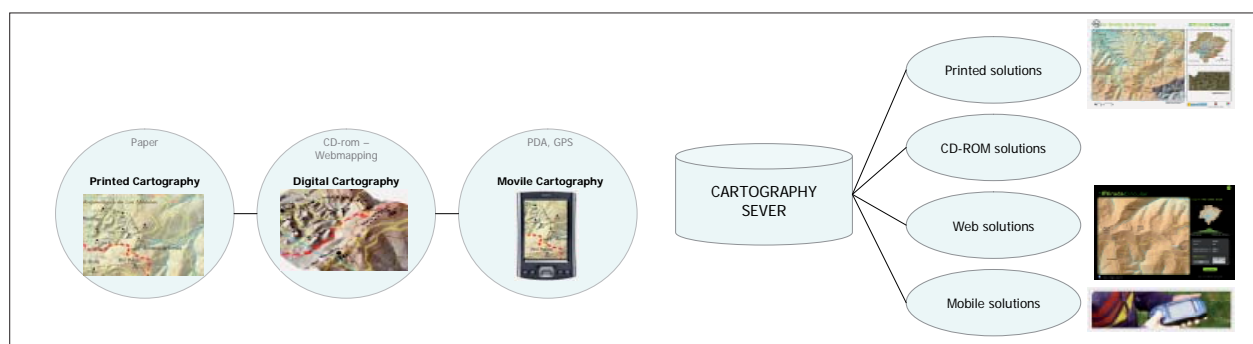


Fig. 5: Two different workflow for managing cartography information

	Printed Cartography	Digital Cartography	Mobile Cartography
<b>Size</b>	700 x 1000 mm	228 x 304 mm (15 inch) 1024 x 768 pixels	60 x 80 mm 240x320 pixels
<b>Legend</b>	Limited	Interactive	Limited/Interactive
<b>Scale</b>	Fixed	Scalable	Scalable
<b>Coverage</b>	Limited	Seamless	Seamless
<b>Queries</b>	Unable	Available	Available
<b>Processing / Battery</b>	Independent	Great capacity of processing / Electrical Energy.	Lack of processing power memory / Battery lifetime

Fig. 6: Technical characteristics of the different map groups

#### 4.1. Devices for mobile mountain cartography

There are already available on the market several products for mountain cartography. PDAs and GPS are the combination most used but they are not the most robust solution for hard mountain terrains.

The company Magellan already commercializes robust GPS units with Windows mobile 6.

#### 4.2. Examples and recommendations for mobile mountain cartography

The major limitation for the geographic information visualization on mobile devices is their small display. This lack of space on the map implies that auxiliary elements such as a map legend would be display only if it is demanded.

Additional design should be implemented on mobile mountain cartography. As it was discussed before visualization, generalization and adaptation have to be taking into account for the representation of mobile mountain cartography. This ideas are managed by the GUI (Graphical user interface), which provides the interaction between the computer and the user. For that, mobile mountain cartography is focused not only on the visualization of cartography but also on the design of an easily to use device.

One of the main advantages of GPS devices for hikers and alpinist is the knowledge of the direction, which guide them to their goal. However, there are more important necessities factors to move on mountain terrain. The weather, the distance and difference in height to the goal, snow conditions, sunrise and sunset calendar, vegetation and animals are additional information that can also be implemented in a mobile mountain device.

The most commonly solution for representation objects on mobile cartography is the use of POI (Points of interest) through icons. Fig. 7 shows POI of a village placed in El Bierzo.

New algorithms to process Generalization and Labelling automatically must be implemented. It is shown on Fig. 7 the height of the contour lines automatically labelled on the screen. However, the algorithm has placed the texts on the different directions.

The displaying of the next step of the track gives the users an idea of the direction, as it is shown on the right image of Fig. 7.

Sounds for warning or information, Photos, Route Profiles are several extra techniques available to be used in mobile mountain cartography.

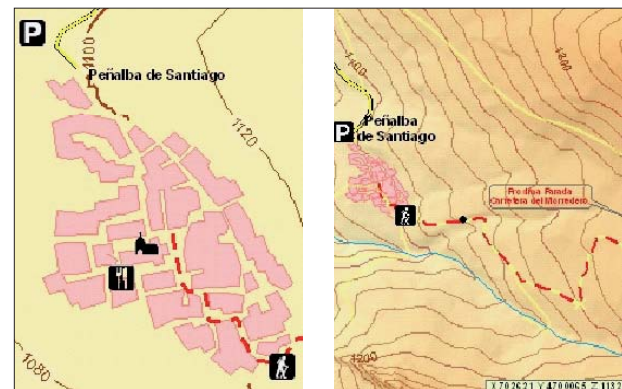


Fig. 7: POI for mobile cartography



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# Aerial Photos + Photogrammetric Plot = swisstopo's Rock Representation: Caricatured Mountains?

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## Abstract

*The Federal Office of Topography swisstopo's rock and glacier representation is based on aerial photos and the photogrammetric plot. Like all other map content, the terrain representation is generalized. The importance of caricatured or exaggeratedly drawn rock is illustrated by probably the most extreme example in a swisstopo map and the resulting benefit for the map reader is explained. Finally, the necessity of 3D aerial photos in the swisstopo's rock and glacier drawing is stated.*

## 1. Introduction

The Federal Office of Topography swisstopo has introduced a series of optimizations in the map production process. In 2007 swisstopo moved from analogue to digital aerial photography, and in 2008 map production starts switching from a CAD system to a geographic information system. Before the introduction of these optimizations, the visualisation equipment for 3D aerial photos in the cartography department was put in question. The uncertainty was based on the fact that the analogue stereoscopic aerial photos that had been used thus far were no longer available. Therefore, orthophotos and 3D aerial photos as source for mapping of rocks and glaciers were compared to each other. It was decided that 3D aerial photos are still necessary in the rock and glacier revision. This paper illustrates why 3D aerial photos are still essential for rock drawing.



Fig. 1: Rowan Atkinson alias Mr. Bean as a caricature

The representation of rock, scree and glacier is generalized like all other map content. Important terrain features are emphasized, complicated forms are simplified, and less important ones are omitted. The terrain is virtually caricatured so that the map reader can easily identify the mapped area and can relate the spatial pattern to recognizable physical features.

## 2. Rock drawing

A photo is a precise representation of reality, while an artistic caricature not only shows the physical appearance of a figure, but also adds information about its character and traits. For example, Fig. 1 shows a photograph and a caricature of Rowan Atkinson, alias Mr. Bean, where the caricature accentuates Mr. Bean's waggish and doltish character.

In rock drawing, it is the same — but with the difference that cartographers aim at accentuating important landforms. Take for example an orthophoto that very accurately portrays small details of a rock formation (Fig. 2). Unfortunately, orthophotos are very bad at showing the character of large terrain forms. In the area depicted in Fig. 2, the most important landform is the impressive cliff of Fig. 5, which dominates the view in nature with its almost vertical face. In the orthophoto, however, it remains completely invisible. Another problem of orthophotos are cast shadows, which can disguise entire mountain slopes, as for example the rock faces oriented in north-western direction in Fig. 2.

Contour lines are an alternative means to show major and minor landforms (Fig. 3). Narrow contour lines are able to indicate the location of the impressive cliff of Fig. 5. However, their technical nature is too abstract for many map readers, who are not able to easily interpret a contours-only representation. Orthophotos and contour lines depict relief from a vertical viewing point above the terrain. Hence, the impressive vertical cliffs cannot be rendered as seen by a mountaineer neither by an orthophoto nor by a contour-lines-only representation.

The rock hachure representation, on the other hand, caricatures the terrain (Fig. 4). The cartographer accentuates main features of rock faces and glaciers and works them out to show them more clearly than on an orthophoto or on a





Fig. 2: Swissimage orthophoto, southern part of Mürtschenstock, sheet 1154 "Spitzmeilen", year of flight 2003. © swisstopo 2007 (BA071335).

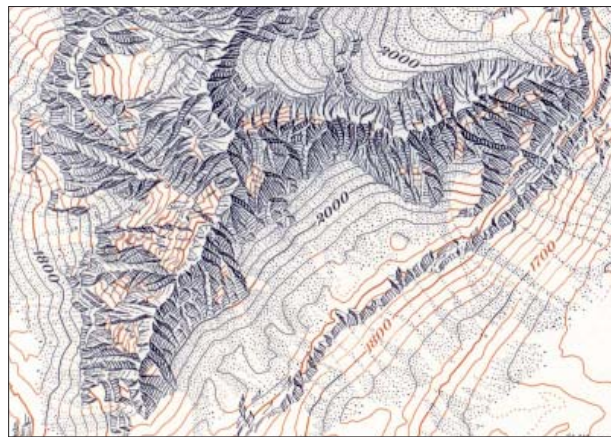


Fig. 4: Rock hachures. Same area as Fig. 2. Rock drawing by Paul Ulmer (Imhof 1982).

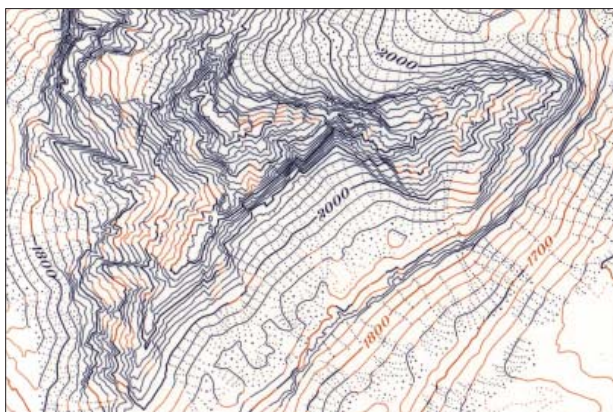


Fig. 3: Contour lines. Same area as Fig. 2. 1:25,000, enlarged. (Imhof 1982).

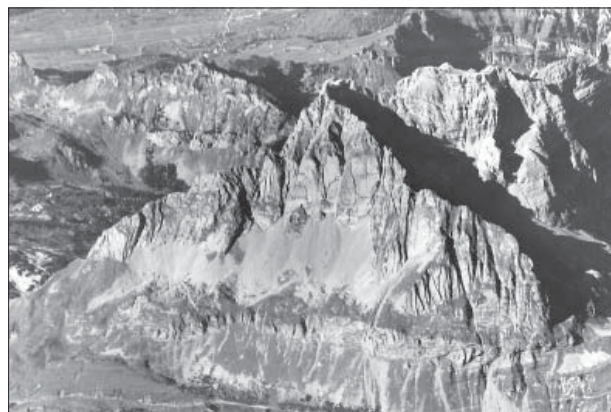


Fig. 5: Oblique aerial photo of the rock face in Fig. 2 to 4, looking in western direction.

contour-only map. Rocks faces are drawn from a side view and appear as seen when walking straight towards the rock face. A side view requires more space than an orthogonal view, which is the reason why the cartographer enlarges the footprint of a cliff.

Fig. 4 shows a masterpiece of rock hachuring by the late Swiss cartographer Paul Ulmer. Rock features are crisply and well depicted; rock masses are distinctly outlined; the crest and gully lines are clearly indicated; and the vivid modulation of brightness imitates three-dimensional shading effects that simplify reading of the third dimension. The map shows the cliff with the merited prominence due to the exaggerated footprint, the side view, and the darkness of the rock drawing. This exemplary piece of rock hachuring clearly achieves its goal to give the map reader an accurate and authentic "natural" impression of the mountain.

At swisstopo, the revision of rock hachures is based on (1) photogrammetric contour lines, (2) polygons delimiting areas of rock, scree and glaciers, and (3) 3D-aerial photos. The cartographer generalizes a skeleton of the main rock features to the scale of the map and outlines them on the map. Within this skeletal framework, the rock hachures are added with an average density of about 7 lines per 2 mm. Each hachure line is jittered, imitating the rough texture of a rock surface, and its line width varies to imitate

a shading effect. Where space permits, hachures are added inside the finely detailed and lightly portrayed skeletal outline framework in such a way that their combined effect corresponds to the tonal values of a previously prepared, or merely assumed, shaded image. In this way the rock hachure produces a detailed image with a vivid three-dimensional effect (Imhof, 1982).

Besides its merits, rock hachuring also has disadvantages. For example, only skilled and trained cartographers are able to produce satisfactory results. Rock drawing is also very time-consuming and production costs are therefore extremely high.

### 3. Photogrammetric compilation

Rock drawing starts with a photogrammetric plot. The photogrammetric operator compares the new stereoscopic aerial photos (Fig. 9) with the map being revised (Fig. 6). Differences are marked in the photogrammetric plot (Fig. 7) – the blueprint for the cartographer. The rock, scree and glacier areas are rather difficult to plot. Therefore, the operator should have some knowledge of high mountain cartography to well serve the cartographers' needs.



#### 4. Cartographic revision

A detailed and accurate photogrammetric plot (Fig. 7) is crucial for the revision of rock areas and glaciers. A good rock and glacier representation takes advantage of the smallest movements in the photogrammetric contour lines to characterise the terrain features (geomorphology). The contour lines in the area of rock drawing must correspond to the generalized rock features. swisstopo uses an equidistance of 100 m at the scale of 1:25,000. Maps at smaller scales do not contain contour lines in rock areas. Contour lines in rock areas must match with adjoining contour lines in areas of meadows, scree/shingle or ice. In fact, it is still necessary to consult the aerial photos (Fig. 9) while drawing rocks, even when the blueprint has contour lines of very small equidistance. The geomorphology of rock and glaciers is only interpretable after examining the relevant photos.

A map revision based only on photogrammetric contour lines (Fig. 7) would result in a wrong representation. Although the abraded look of the rock representation in Fig. 10 might seem logical – glacial polish – the depiction of the revised area is geomorphologically incorrect. Upon

comparing the blueprint (Fig. 7) to the aerial photos (Fig. 9), it is clear that the photogrammetric contour lines are not detailed enough for rock drawing (Fig. 8). A quick look at the pair of 3D aerial photos (Fig 9) reveals the definitive connections between the movements of the contour lines marking the crest and the gully lines in the rock drawing.

The example above confirms Eduard Imhof's statement that "contours alone, even very exact photogrammetric contours with a small interval, are not adequate as a basis. Good aerial photos and terrestrial photography, taken at different times of the day, and stereo-photos, in particular, are indispensable. On the basis of geological maps and profiles, one should take into account the type of rock and rock bedding, in order to be able to recognize certain, perhaps blurred relationships and characteristic distinctions more easily" (Imhof 1982). Imhof lists here the ideal bases for rock drawing from scratch for shaded rock hachuring.

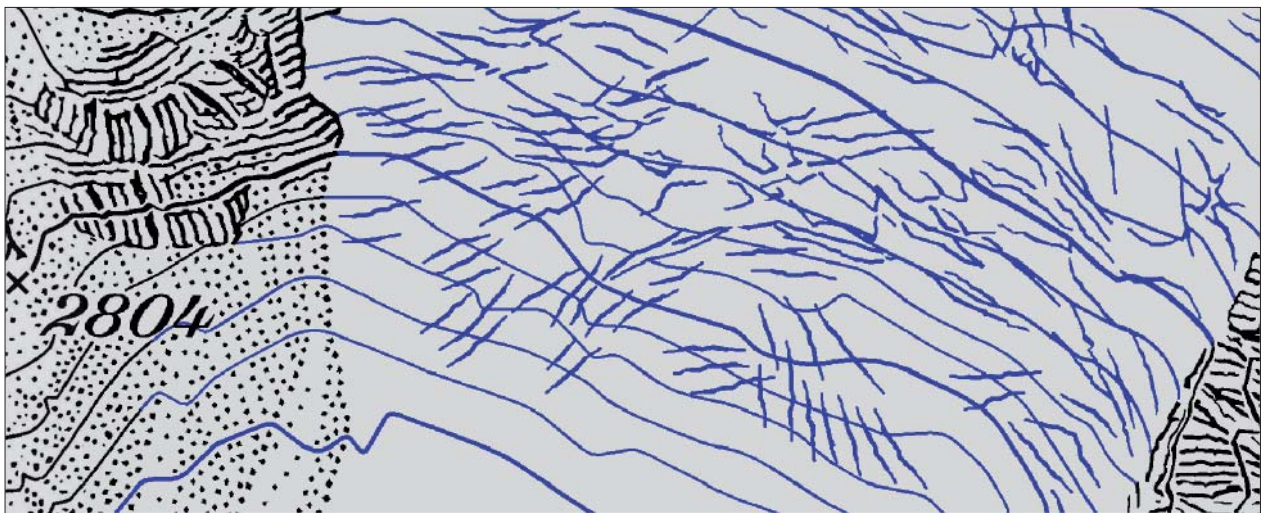


Fig. 6: Enlarged extract from the swisstopo map 1269 "Aletschgletscher", 1:25,000, 2002 (status of the map content 1999), © swisstopo 2007 (BA071335).

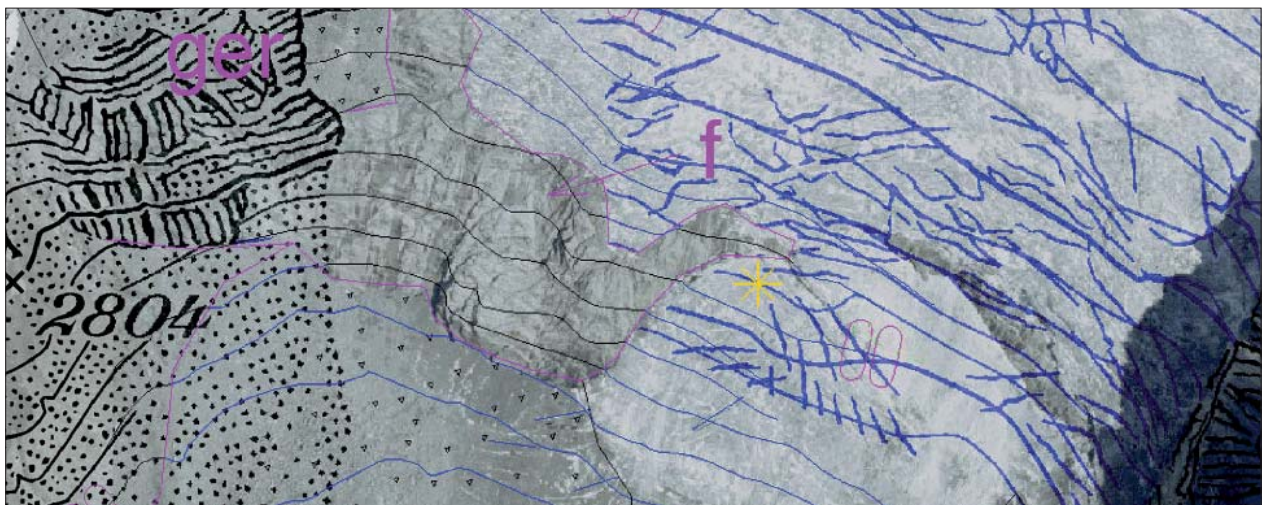


Fig. 7: Aerial photo (year of flight 2005), photogrammetric plot combined with enlarged extract of the map of Fig. 6 with the obsolete map content already deleted. © swisstopo 2007 (BA071335).



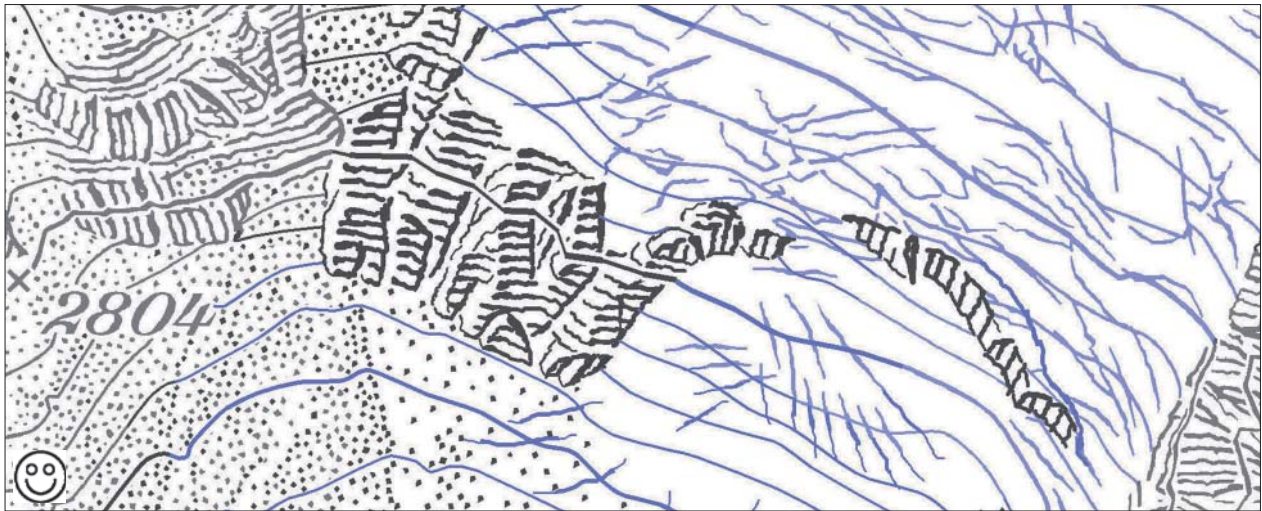


Fig. 8: The map of Fig. 6 with correctly updated rock drawing published in 2007. The map revision is in black and dark blue. The existing map content is in grey and light blue. The map revision is based on the photogrammetric plot and the 3D aerial photographs. © swisstopo 2007 (BA071335)



Fig. 9: Aerial photograph (year of flight 2005). Only a single photograph of the 3D set is shown here. Rock formations, glaciers and scree areas clearly appear as three-dimensional objects when pairs of photographs are viewed with stereo restitution. © swisstopo 2007 (BA071335).

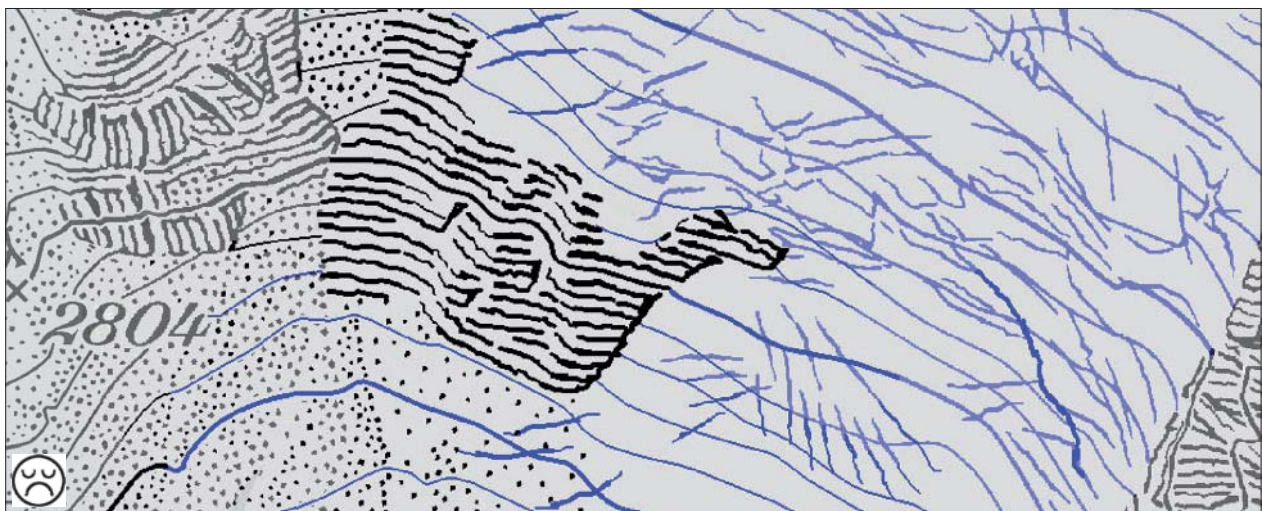


Fig. 10: The map of Fig. 6 with incorrectly updated rock drawing. Rock areas are graphically nicely represented, but the depiction is geomorphologically incorrect. The index contour line in the rock area (equidistance 100 m) has been smoothed and the rock area is too polished. The map revision is in black and dark blue. The existing map content is in grey and light blue. The revised part is based only on the photogrammetric contours without consulting the aerial photos. © swisstopo 2007 (BA071335).



## 5. Mapping geomorphologic features: Rock, scree and glacier areas

A well-drawn caricature portrays the appearance and the character of a person in a simplified way. For example, Fig. 1 shows the mischievous, googly-eyed and bourgeois-clothed Mr. Bean as a “humorous simpleton”. A well-done rock representation, on the other hand, also shows the appearance and character of rocks in a simplified way so that the map reader can easily identify the mapped terrain and can relate to it in nature. The idea to apply caricatural techniques in digital cartography is not new, for example Lecordix et al. (1997) present caricature algorithms for the generalization of road lines.

The reader is invited to have a look at Fig. 11 to 14 and answer the following question: Which one of the representations in Fig. 12, 13 and 14 is most easily related to the terrestrial photo of Fig. 11? Is it the map at 1:50,000 in Fig. 12, the map at 1:25,000 in Fig. 13, or the orthophoto in Fig. 14? The question will be answered at the end of this paper from the author's perspective.



Fig. 11: Rock face “Hardermandli”, Interlaken.

A good rock drawing depicts the geomorphology well adjusted to the scale. The main rock features (visible in aerial photos) drawn at 1:25,000 are:

- Demarcation lines (limits of rock masses, particularly those associated with scree, vegetation or permanent snow and ice)
- Crest lines (watersheds = positive skeletal lines)
- Ravine or gully lines (drainage ditches = negative skeletal lines)
- Cliffs (= main feature, as they look impressive to the mountaineers and can only be ascended by well equipped climbers)
- Flat, or almost flat, rock areas (= minor feature, as they are not perceived as a barrier by mountaineers)
- Sedimentary rock, the bedding might be folded and contorted (layers of different kinds of material called beds or strata)
- General appearance of surface (eroded angular or polished round)



Fig. 13: swisstopo map 1208 “Beatenberg”, © swisstopo 2007 (BA071335). 1:25,000, 2001, enlarged. The rock representation is based on the photogrammetric plot and the aerial photos only. The impressive cliffs (barriers for mountaineers) are well depicted.



Fig. 12: swisstopo map 254 “Interlaken”, 1:50,000, 2003, enlarged. Rock drawing by Friedrich Siegfried. The cliff, a tourist attraction, is exaggerated in size and drawn as it is seen outdoors, according to the terrestrial photo (fig. 11). © swisstopo 2007 (BA071335).



Fig. 14: Orthophoto, Swissimage (year of flight 2000), The impressive cliffs are hardly recognizable. © swisstopo 2007 (BA071335).



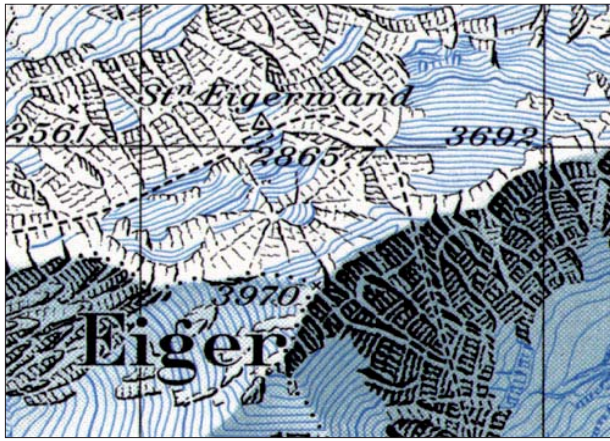


Fig. 15: swisstopo map 254 "Interlaken", 1:50,000, 1980, enlarged. Rock drawing by Othmar Wyss. The (White) Spider (a name well known to alpine climbers) was deleted in the following edition because it was considered to be too exaggerated as a representation. © swisstopo 2007 (BA071335)

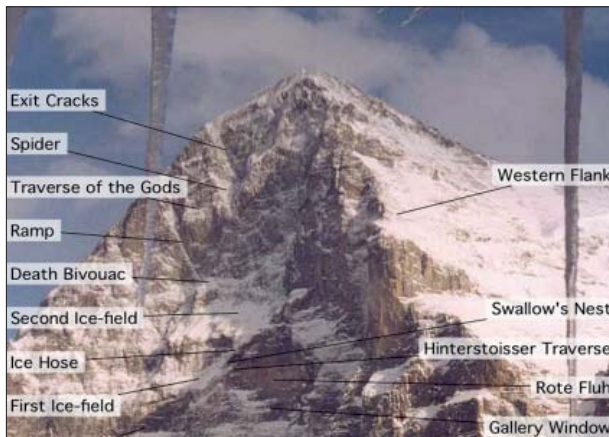


Fig. 16: North face of Eiger. The (White) Spider is only visible at certain snow and light conditions.

The perfect scree representation depicts the features in nature according to the scale. The typical and recognisable features in aerial photos are:

- Trenches (straight, often cut sharp by streams and landslides down the steepest slope in the debris cone)
- Moraines
- Deltas
- Glacial erratics (boulders)
- Inclination of terrain (steep to flat)
- Finer-grained materials generally lie at higher elevations, while the larger blocks come rather to rest on the valley bottom or even on the opposite slope

A well-done glacier representation shows the features of the ice generalized to the map scale. As glacial features change much faster than rock or scree, the cartographer's goal is to represent zones of phenomena, rather than to depict the reality exactly.

- Crevasses
- Séracs (a pinnacle, sharp ridge, or block of ice among the crevasses of a glacier)
- Ice cliffs

Difficult to depict are sometimes the blending of:

- Small rock forms with scree and/or earth surface
- Scree on glaciers

## 6. Understanding caricatures to improve recognition

From Wikipedia – Caricature: “Caricatures have been studied in experimental psychology, with interesting results. Rhodes and collaborators [...] (Rhodes 1997) compared recognition of caricatures to anticaricatures. The latter are created using the Brennan formalization [Brennan (1985) formalized the process of caricatural exaggeration as the difference from a mean face] but instead of exaggerating the individual differences from the mean, the individual differences are deemphasized (moved toward the mean face) by an equivalent amount. The anticaricatures were much more difficult to recognize, taking four times longer than the caricatures on average. More surprisingly, her study found that caricatures are recognized twice as fast as the default veridical (uncaricatured) drawing” (Fig. 17).

It is unknown to what extent these findings can be applied to cartography and specifically rock hachuring. However, personal observation has shown that a caricatured rock drawing following the guidelines outlined above can be successfully interpreted by many map readers.

## 7. A personal answer to the question in section 5

Section 5 invited the reader to have a look at Fig. 12 to 14 and to identify the representation that is most easily related to the terrestrial photograph in Fig. 11. (Fig. 18 to 21 show enlarged sections and will be used to answer the question).

The author of this paper can relate the map of Fig. 19 at a scale of 1:50,000 very quickly to the terrestrial photo, the default veridical, as it is the map reader's usual perception of the landscape. The mapped rock face helps the observer to orient and locate the position from where the rock face is observed. The map of Fig. 20 at 1:25,000 is more difficult to relate to the terrestrial photo, since the face is not depicted

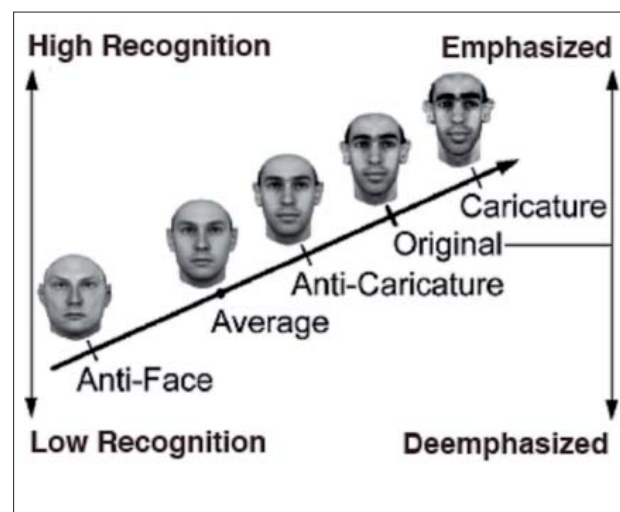


Fig. 17: Emphasized / deemphasized portrait.

in the map. The orthophoto (Fig. 21) is certainly the most difficult one to relate to the terrestrial photo (Fig. 18).

Note: The rock area in the map at 1:25,000 (Fig. 20) was considered to be too large for a pictographic representation as in the 1:50,000 map (Fig. 19). For this reason, the rock representations differ from each other. However, the name of this rock face ("Hardermandli", with "Mandli" meaning short man) is labelled on the 1:25,000 map, which was considered to be sufficient (see Fig. 13).

The author's result seems to be in accordance with the study by Rhodes (1997). The most exaggerated and caricatured cliff representation (Fig. 19) is the one that is easiest to recognize.

What is your answer to my question, dear reader?

## 8. Conclusion

The rock hachure representation has its cartographic advantages compared to other methods. A good rock representation gives the reader the necessary information to easily identify the mapped area. The depicted spatial pattern relates to recognizable physical features.

To date, the stereoscopic aerial photos have been essential in rock drawing and will continue to be indispensable in the future. Together with detailed photogrammetric plots, they are indispensable in rock and glacier revision at swisstopo. Certain details to be mapped are invisible even in the best photogrammetric plot as well as in orthophotos. Currently, the applied multispectral (RGB + PAN + IR) stereo aerial photography of remote sensing, unveils important information necessary in the process of rock and glacier map revision.



Fig. 18: Terrestrial photo. Default vertical = usual perception of landscape by walking, hiking or biking map readers.



Fig. 19: Map 1:50K, 254 "Interlaken", enlarged.



Fig. 20: Map 1:25K, 1208 "Beatenberg", enlarged.



Fig. 21: Orthophoto Swissimage.



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# Cartography of High Mountain Areas

## Testing of a New Digital Cliff Drawing Method

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### Abstract

*From now on, the French National Mapping Agency (IGN France) is set up with the BD Topo®. This is a topographic vector database that covers the whole national territory. IGN decided to produce base maps at 1:25k and 1:50k from this database. On topographic mountain maps, rock areas are among the map elements that are the most difficult to produce with digital cartography. In the past, they have been drawn manually by experienced cartographers, using graphic means and working with aerial photographs. Now, we need to focus on 2 points with a digital approach. The first one is the detection and an automated classification of concerned areas. The next one is the development of an adapted cartographic representation of rocks and scree areas. This article presents the first results on these problems. As far as possible, we aim at having automated high mountain cartography with lower production costs. Also, we would like it to be as expressive as it was in previous maps. This is to keep the same cartographic quality of the current base map at 1:25k and 1:50k.*

### 1. Context

#### 1.1. The BD TOPO®

The French National Mapping Agency has decided to create a topographic database for several years. This is the BD TOPO®. This vector database provides some geographic information about road, rails, electric and hydrographical networks, but also about buildings, administrative boundaries, toponymy, land use and relief. The first version of the BD TOPO® (V1) was mainly acquired by digital restitution, and it included all the needed information for the map at 1:25k. However it required a huge workload and therefore too much time to realise this database on the whole territory. In 2000, IGN France chose a new lighter specification for the BD TOPO® that allowed its completion on the whole territory by the beginning of 2007.

Beyond various applications linked to GIS, the BD TOPO® is also useful to derive the base map, produced and diffused by IGN France. The base map includes a topographic map at 1:25k and another one at 1:50k. Since 1993, 450 out of 1800 maps at 1:25k have entirely been digitized from the BD TOPO® V1 on several areas of the national territory.

Nevertheless, up to now, no map covering a high mountain area has been done from the BD TOPO® V1. In fact, the cartographic representation of these areas is knotty dealing with a digital production. On high mountain areas, all current base map versions come from revisions of former versions drawn manually years ago. They are not originally from BD TOPO®. As a result, we currently have 2 distinct processes to collect data, update the database and the topographic map.

#### 1.2. The New Base Map Project

In 2004, IGN France decided to launch the New Base Map Project in order to derive the base map from the BD TOPO® with its new specifications, and to reduce update costs of next base map versions. The process is planned to work on the whole territory, and then on high mountain areas.

Among other issues, this project has to provide solutions to retrieve the needed information for the map that is lacking in the new specifications of the BD TOPO®. In particular, the land use is one of the main incomplete themes. This recovery issue is especially perceptible in high mountain areas where a paramount part of the map information deals with mountain land use: rocks, scree, glaciers... Without these themes, mountain maps would appear uncluttered and could not satisfy users.

It is not enough to recover the needed information in high mountain areas. Indeed, another issue arises that has to be carried out by the New Base Map Project. It deals with the digital representation of these specific themes, in order to get the most expressive possible result on concerned areas.

#### 1.3. From manual to digital drawing

During the history of cartography, a lot of solutions have been tested out for the cartographic representation of mountain areas on topographic maps. In (Imhof, 1982), a literature review of these solutions is presented. The relief aspect often comes from a combination of different techniques: hill shading, graphic means, contour lines with a colorimetry depending on areas (glaciers, rocks...), etc. But up to now, the solutions that have been carried out and the best provided results are only the outcome of traditional graphic techniques. Fig. 2 shows an extract of an IGN topographic

map at 1:25k, where an example of this cartographic result on the Alps is shown.

In the beginning of the 2000's, IGN France launched the first studies with the purpose of considering the feasibility of substituting digital solutions by traditional methods (Le Men et al., 2002). These works focused on the automatic extraction of needed map information (rock areas, scree, glaciers) and provided the first steps for data representation. These study results provided in a digitally manner are presented on fig. 3. This is the same area that was used in fig. 2, where results are obtained manually.

The New Base Map Project has been continuing these first works. In particular, it looks at improving final cartographic results. Dealing with data retrieval, the MATIS, a research laboratory of IGN in image processing, has been carrying out the study.

## 2. Information retrieval

### 2.1. Problem presentation and proposed solutions

Two ways of getting back landcover information that lacks from BD TOPO® but is necessary to obtain the topographic map are possible since it can be extracted either from aerial (ortho-)images (through (semi-)automatic classification) or from present maps (owing to removing moiré patterns techniques). As the cartography of these missing landcover themes is not up to date in present maps, the first solution has been given up. So, the chosen solution consists in extracting landcover information out of aerial orthophotos from BD ORTHO® through a supervised classification method. The only lacking landcover themes necessary to make the map are rocks, scree and glaciers. However, the classification legend must contain more items than these three lacking themes to obtain a landcover classification of whole mountainous areas. In this instance, the legend classification consists of the six following classes: rocks, scree, glaciers, forests, high mountain pastures and water areas (lakes).

In high mountain areas, landcover extraction using aerial photographs is bothered by several phenomena:

- Shady areas are often spread out.
- The radiometry of a same theme can widely vary from one image part to another. This phenomenon can be due to lighting differences related to the rough relief. It can also be "artificial" (since the image is in fact a mosaic of orthorectified aerial images which have not been captured at the same time and have undergone several different radiometric treatments) or natural (as for instance in case of changes in geology).
- Some of the land use themes have a very close radiometry; they look like each other on the aerial photograph. For instance, scree (especially torrent bed scree) are sometimes as vivid as glaciers. Similarities between rocks and scree, shadows and water areas can also be quoted. This last phe-

nomenon is deepened by the radiometry variance phenomenon, explained above.

As a consequence, image information is not sufficient to extract landcover using a semi-automatic classification. That's why complementary knowledge has to be introduced in the classification process. Two different kinds of external information are useful:

- On one hand, this is knowledge depicting relief since landcover strongly depends on altitude, slope and orientation in mountain areas. This information can easily be computed from a Digital Terrain Model.
- On the other hand, knowledge from another data base can also be used. In the present case, the European data base CORINE Land Cover 2000 (CLC2000) dealing with land use has been employed (Bossard et al., 2000). This data base is more generalised than the base map: the smallest mapped area is 25 hectares and the better scale to use the data base is 1:100k. Its legend is different as well: its semantic precision varies depending on cases. For example, a difference exists between kinds of forests whereas rocks and scree are contained within a unique class. In other cases, some CLC2000 classes are related to intermediate situations between several of our classes: "forest and evolving shrubby vegetation" is linked both to forest and high mountain pastures.

As the shadow areas are important on the image, they must also be taken into account to obtain a classification of the whole area. It is possible either to correct shadows (it means to detect shady areas and then to adjust the radiometry there) or to divide each landcover class "c" in two and then to get a class "c in shadow" and another one "c in light". Of course, these two classes are aggregated at the end of the classification. This last solution has been chosen since, in fact, a shadow correction would suffer from the consequences of DTM imprecision and doubts linked to the orthoimage. Remind us that the orthoimage is a mosaic of merged orthorectified aerial photographs captured at different times (and thus the precise capture time of each pixel of the orthoimage can not be known precisely) and having undergone different radiometric treatments. However, a method using radiometric correction in shady areas has been successfully developed by (Le Men et al., 2002) during the first studies about this issue.

Thus the technique described above is not used. Nevertheless, an approximate knowledge about shady areas can be taken into account. Even though the available information is not sufficient to precisely detect and correct shadows, it can be used to compute an approximate prior probability for each pixel of the image of being in shadow knowing the DTM (since the beginning and final time of data capture of all the images are known even if the exact capture time of each pixel of the orthoimage is not precisely known). It could help to discriminate dark themes (such as water) in light from themes in shadow. After its computation, this probability can be reintroduced in the classification process.



## 2.2. Method

The landcover extraction method encompasses two steps: segmentation and then classification.

First, the image is segmented, which means it is split up in several homogeneous regions (Fig.4). A description of the used segmentation tool can be found in (Guigues, 2004) and (Guigues et al., 2006).

The second step is classification strictly speaking: a class is given to each region of the segmentation. The main interest of classifying regions is to prevent from obtaining too noisy results. The classification method carried out in this case is a MAP classification method. All explanations about this technique are presented in (Trias-Sanz, 2006) and (Trias-Sanz and Boldo, 2005). Information is processed in terms of probability. The final class given to a region is then its most likely one.

The way image information is used by the classification algorithm is explained in details in (Trias-Sanz and Boldo, 2005). First, a model is computed from training data previously captured on the image by an operator. This is an  $n$ -dimensional radiometric and statistic model (with  $n$  standing for the number of channels used for the classification). To achieve this, for each class, a radiometric distribution, i.e. a histogram, is computed from training data before being modelled by statistical distributions such as simple histograms (raw or obtained by kernel density estimation) or parametric statistical laws (as Gaussian, Laplacian or even uniform laws). At the end, one of these models is chosen for each class by two criteria: its ability to describe ground truth (it means to fit to training data) and its complexity (Schwarz, 1978). The more complex the model is, the more degrees of freedom it has, the better it is able to describe training data. However, a complex model is also at risk to “stick” too much to training data without describing the whole ground truth as well as a simpler one. So, at the end of this model estimation step, a model allowing to compute for each pixel  $s$  its probability of belonging to class  $c$  knowing its radiometry  $I(s)$  is available. By deduction, the probability for region  $R$  of belonging to a class  $c$  knowing the radiometry  $I(R)$  of its pixels can also be computed.

Useful channels for classification are not necessarily original image bands; that is to say red-blue-green-near infrared, but derived ones such as intensity, hue, vegetation index “NDVI”, or channels in another colorimetric space like the Karhunen-Loève one. An association of derived channels can bring better results since some channels are in fact more efficient than others to separate some classes.

External information is introduced in the classification process as prior probabilities in relation to this probability knowing image (Le Bris and Boldo, 2007). This requires an interpretation of this knowledge in terms of probability.

In mountainous areas, landcover is strongly related to relief. Thus it depends on altitude, slope and orientation, making it possible to compute the probability of finding the differ-

ent themes knowing these three parameters. Such a model is proposed by (Le Men et al., 2002) from physical geography knowledge (such as the lowest and highest limits of the landcover themes...) presented by (Elhai, 1968) and (Lacambre, 2001). It consists of two distinct models (made of piecewise linear mathematical functions illustrated on figure 7) depending on the altitude and the slope. Orientation has a significant influence only on forests and glaciers areas. So this parameter is taken into account only for these themes.

CORINE Land Cover 2000 (CLC2000) information must also be introduced into the classification process as prior probability. This database is more generalised than the expected results: as a consequence, a CLC2000 area is likely to contain several classification themes. Besides, as its legend is not the same, several themes of our classification can be related to one specific CLC2000 legend item, and vice versa. Therefore the introduction of information from CLC2000 in the classification process must deal with those two kinds of uncertainties. An empiric probability model has been put forward to cope with this: a correspondence probability value  $P(T_{\text{classif}}|T_{\text{clc}})$  has been empirically assigned to each CLC2000 item  $T_{\text{clc}}$  and to each classification class  $T_{\text{classif}}$ . For instance, for the CLC2000 class named “forest and evolving shrubby vegetation”, the probability of finding water areas and glaciers is null. It equals 77% for forests, 20% for high mountain pastures, 1% for rocks and 2% for scree areas.

In the same way, shadow knowledge is taken into account using probabilities of being in shadow knowing the relief, i.e. the DTM, and the time interval of image capture.

A balance between these different information sources is applied. This allows to give more or less strength to some of them but also to modify the degree of generalisation of the result (the higher the CLC2000 weight is, the more generalised the result is).

To sum up, the class  $c$  given to a specific region  $R$  is the one that maximises the product of the probabilities for this region of belonging to  $c$ , knowing the different information sources. In fact, region  $R$ 's final class is its most probable class according to these different information sources.

## 2.3. Results

This method has been tested in two study cases. The first test zone located in the Alps, near St-Christophe-en-Oisans has already been the test zone of the preliminary study (Le Men et al, 2002). All the classification themes are present there, but only an old 3-bands (red-green-blue) orthoimage made from argentic scanned photographs is available. Due to large radiometry variations within the image, it was sometimes difficult, even for an operator, to identify classes. The second test area is situated in the Pyrenees, around the Ossau peak. Orthoimages have been produced from 4-bands (red-blue-green-infrared) digital photographs. All classification themes, except for significant glaciers, were present.

Results have been visually evaluated by looking at the whole area revealing no major errors (Fig. 7 and 8). In addition, most of the classification regions have a meaningful size to be relevant on the topographic map. Results have also been numerically evaluated (on smaller test zones in the image), by computing confusion matrices comparing test data captured by an operator to classification results. More details about these results can be seen at Fig. 1. On the second test area, almost 88% of pixels are classified in a right way whereas without any external knowledge, 75% of them are well classified. On the first test zone, results are not so good, which can be explained by the poorer quality of images, leading to the case where it is sometimes difficult even for a human operator to identify classes. Us-ac corresponds to the probability for a classified pixel of being really part of its class whereas Pr-ac stands for the probability for a ground pixel belonging to a given class of being well classified.

For this classification, several parameters have been tested. In particular, these tests have shown that many channel combinations are able to provide satisfying results that are almost equivalent. The channels association “intensity - hue - NDVI (Normalized Difference Vegetation Index)” and the three channels of the Karhunen-Loève colorimetric space (Wang, 2003) are among the channels combinations giving the best results. The significance of the external knowledge and the importance of the balance between them have also been proven.

At the end of the classification, the divided classes “c in the shadow” and “c in the light” are aggregated in a unique class “c”. Then, we only keep missing themes from BD TOPO®, it means rocks, scree and glaciers since information dealing with other themes is either already available or manually digitized. So all needed land use information is available in order to make the 1:25k-scale topographic map. Now, it needs to be mapped.

## 2.4. Further processes for the cartographic representation

Additional processes have been carried out in order to enrich and simplify data for cartographic requirements.

For instance, on one hand, too small areas are filtered out because they would be irrelevant and unreadable at a given scale, i.e. 1:25k in this case.

On the other hand, some processes aim at extracting more information from relief and the previous classification in order to improve the final cartographic representation. So steep slope areas, slope orientations, upper borders of rocky areas and steepest slope lines are retrieved in scree areas. Each one of this additional data is obtained using a specific process.

The aim is to represent scree in steep slopes (where slope is greater than 50%) with growing points along the slope. That is why steepest slope lines are gotten back in these areas taking into account density constraints. Here is the way of doing this: each node of a mesh covering the area is visited.

The current node is then considered as a starting point of a slope line along which we go down until being situated outside of a scree area or nearby another existing line.

Upper borders in rocky areas characterised by a steep slope (i.e. where the slope value is higher than 100%) have to be extracted since this is relevant to get back these linear objects so that map readability can be improved. To get these lines, only outline sections of rocky areas with their slope angled within the area are kept. Besides, pixels of these sections must have a higher altitude than at least half of their neighbours and these sections have to be longer than a threshold.

Another classification depending on the slope orientation is performed. This is to suit cartographic requirements and it only concerns rocky areas, which are split up one more time following their orientation with a 20° step. Then several rocks classes between  $n \times 20^\circ$  and  $(n+1) \times 20^\circ$  (with  $0 \leq n \leq 18$ ) are gotten. A particular representation is applied to each of these classes, as explained in the next paragraph.

## 3. Cartographic representation

### 3.1. Data and tools used

To complete these digital cartography tests, several data sources were needed. All data have been retrieved with tools developed by the MATIS laboratory. They have been presented in the previous paragraph.

Scree and rock areas are among the different land use areas detected on aerial photographs. They form the heart of the cartographic representation. They delineate areas we are interested in here, in the present study. In fact, the mapped area for this test is located in the Pyrenees, nearby the Ossau peak, and does not include any significant glacier. So, they have not been taken into account for these tests, but we have to know they contain specific problems, dealing with cartographic representation.

A Digital Terrain Model (DTM) allows us to superpose these land use areas with slope information, which is provided by the DTM. Then, it is possible to separate rock and scree areas depending on the slope value. Thus, we can associate a proper symbolisation to these different kinds of areas. A threshold allows us to distinguish steep slopes from gentle ones: a 100% slope is the limit for rock areas and it is 50% slope for scree ones.

Of course, this is only an interpretation of terrain characteristics.

A rock area classification following the slope orientation criterion has been done. The target of this classification is the same as previously, as we aim at differentiating the cartographic representations depending on areas. On one side, this classification has to contain enough details in order to illustrate as best as possible the terrain diversity and complexity. On the other side, areas have to be big enough if we want them to be readable on a map at 1:25k. After sev-

eral tries, it has been agreed that the creation of 18 classes at 20 degrees regular intervals was the best choice in our case. However, be careful not to generalise without any cares this result. The first point is to respect qualitative criteria explained above.

Finally, rock areas are divided in 36 different classes, depending on the slope orientation and the slope value.

Linear data complement the set of data within land use areas. Scree areas are characterised by steepest slope lines inside steep slope areas. Those lines are useful as they can be considered as the symbolisation skeleton in these areas. In addition to that, other lines are at the top of steep slope rock areas. They illustrate breaks in slopes. They are considered to be especially dangerous for hikers.

Two different software applications have been necessary in order to match data and have a resulting paper map. The first one is the GIS Geoconcept, produced by Geonconcept SA Ltd. Data were prepared thanks to this software. They were imported and georeferenced. Then, they were exported and integrated in a cartographic symbolisation software. This second product is Mercator, produced by Star-Apic Ltd. It enables us to manage all data representation with layers in order to do map-printing. This software has been used at IGN France for a long time to manage the end of topographic maps production lines, until maps are printed.

### 3.2. Method

In the previous paragraph, we looked at useful data for cartography in mountain areas. Now we need to assign a symbolisation to these data. This is what the user really sees and reads on the map. The whole issue is to represent in the best possible way the terrain complexity. The main point is to understand accurately the map, so that users can not be mistaken and thus avoid dangerous zones for example. When most users look at the topographic map at a big scale, they trust in its accuracy. This kind of map has to keep this asset.

Besides reflecting the reality, the representation has to be as automatic as possible, as one of the main purposes of this study is to reduce the map production cost. Up to now, rocks have been drawn manually by experienced cartographers, using graphic means and working with aerial photographs. This technique produces very good results but the point is that it is very expensive. Hurni et al. (2002) have studied some methods to automate the cartographic representation. However, they advocate the combination of manual tasks with automatic ones. According to them, digital methods can be applied only in a limited spectrum of tasks. Control of the full process by an experienced operator is still necessary and desirable, in order to keep the graphic quality that is characteristic of Swiss maps. At IGN France, we wonder as well how we can improve current results in digital cartographic representation. So we have kept carrying out some researches about this issue.

According to several case studies done in mountain areas, hachures seem to be a relevant way for rocks representation. They provide both a good perception of relief and an appreciated graphic result. This technique outcomes from a former more general one, used historically to depict the relief with hachures. They were generally drawn along the steepest slope so that the user could mentally think mounts and valleys. In our study case, we judge necessary to have ridge-lines depicting major contours and ridge crests so they complement hachures representation. Maps from the Swiss National Map Series produced by the Federal Office of Topography illustrate this way of representing rocky areas. Fill hachures are plotted manually either along the steepest slope where this one is steep or along contour lines. An operator estimates the slope value looking at aerial photographs. As the human eye is a subjective tool, there is no mathematic threshold to determine if a slope is steep or not.

This way of representing rocky areas has been adapted in this study, trying to incorporate it in a digital process. A hatched pattern has been designed to fill in rocky areas where the slope exceeds the given threshold of 100%. In order to have a fine visual perception, (Imhof, 1982) gives in particular some advices dealing with hachures design and related parameters. They have been taken into account to draw up this pattern. Following the different orientation slope classes, this one is always angled according to the steep slope. For instance, rocky areas with a slope angled from 0 to 20° will have a 10° angled hatched pattern. The classification depending on the slopes orientation is necessary to let the pattern follow the neighbour steep slope, whatever the slope orientation value is.

Another hatched pattern has been defined for rocky areas with gentle slopes. In this case, hachures are more spaced. Added point symbols and areas randomly disposed are part of the pattern to mean the presence of isolated rocky blocks. The pattern is angled following the average tangent to the contour line for each class. The hachures logic spacing used in this case is the same for contour lines. The denser they are, the steeper the slope is, and vice versa.

Hachures are voluntarily irregular to better imitate the real world. In fact, structure lines and the general rocks texture are hardly ever regular and geometric. Thus, when we had to design a pattern, we paid special attention to the possibility of reproducing it without any spatial discontinuity. An off-setting on the edge of the pattern does not produce a satisfying visual effect. This is especially true if there are no structure lines to hide it.

The scree representation is characterised by point symbols. There are small round points and irregular round shapes that mentally suggest to the map reader stones or rocks. Where there are steep slopes, scree tends to form streams because of unsteady rocks rolling down. These rocks crumbling leave a trace on the ground that can be observed on aerial photographs. We tried to duplicate as precisely as possible those characteristics. Depending on the slope value, we differentiated the scree representation.



Lines along the steepest slope are only extracted in scree areas where the slope rises above 50%. They are necessary for the representation support in these zones. In fact, round points symbols are computed and placed at regular intervals along these lines. The symbols diameter increases in a linear way when we go down along the slope. Visually, the crumbling effect appears thanks to the lines support. They are not visible on the map but we can easily imagine them.

Dealing with scree representation located in slopes under 50%, a pattern has been drawn. It is made up of point symbols and irregular round shapes, and suggests rocks randomly disposed. On the contrary of pattern used in rocky areas, this last is not angled. This is to keep the randomness of these zone structures.

Upper borders in rocky areas complement the cartography and give a global structure of these mountain areas. They are useful to mean cliff tops and broken grounds. They are drawn with two lines. The first one is black to underline the break; the other one is dark grey to mean the shadow, which is a frequent characteristic within these zones. The black line has a varying width. This is to avoid a symbolisation that would appear too geometric. Besides structuring the map in mountainous areas, these upper borders warn against potential dangers that may have not been clearly seen with hachures.

Previously listed elements are put together with more classic and often used ones: I mean contour lines and hill shading.

### 3.3. Results

For the time being, we only tested this representation in a unique zone, in Pyrenees nearby the Ossau peak. Nevertheless, we got some results that seem to be hopeful. The map has a good global readability. The whole coherency between themes is satisfying as no layer overrides others. Furthermore, we can easily distinguish the different kind of symbolised zones. The representation rationale and the patterns used here allow the map reader to associate the ground nature. Finally, this is promising all the more that this cartography has been entirely done in a digital way, which was one of the goals.

A comparison has been made with the former map manually produced. It enables us to identify a weakness dealing with the digital hill shading. In fact, it is far less expressive than the old one drawn manually. So it still needs to be improved, given that there are a lot of current researches in this field.

Of course, this method is to be reproduced on other mountain areas. Remind us that the New Base Map project aims at producing a homogeneous representation on the whole territory, and in particular concerning rocky areas. Currently, this is not the case in France. The result is different and depends on both cartographers and when it has been produced. In order to test the reliability and the scalability of this method, we understand better why this kind of test has to be generalised to other areas. Soon, it is planned to draw up Modane region and the Vanoise national park, in Alps. This test enables us to appreciate the general survey of large rocky areas. We would be able as well to give rise to specific problems linked to glaciers.

## 4. Conclusion

The New Base Map project carried out several studies dealing with image processing and mountain cartography. One of the main purposes is to get an automated digital high mountain cartography as good as the one we had before with manual processes. This study has been done combining several data sources, i.e. orthophotos, DTM and external knowledge, an automated extraction of rock, scree and glacier areas, and additional relief-related data. These data allow to realise an automated cartographic representation that aims at improving the relief and the “expression” of high mountain zones.

The first results obtained in Pyrenees are hopeful. So it has been decided to test this experimental method on another bigger area, located in the French Alps. Further tests could include a customer survey, especially concerning mountain map users. Remarks from clients could enable us to improve the final process and specific stages, in particular the hill shading. Then, we might be able to introduce this global solution within the IGN base map production line.

	St-Christophe-en-Oisans (Alps)		Ossau (Pyrenees)	
	with complementary knowledge			
	us-ac	pr-ac	us-ac	pr-ac
Water (Lakes)	/	/	100.0	76.4
Forest	81.9	65.2	89.0	95.8
Pasture	71.1	52.2	96.3	85.1
Rocks	76.4	69.9	71.0	87.2
Scree	54.7	73.3	88.0	83.1
Glaciers	58.6	69.5	98.3	72.2
Well classified pixels	67,0 %		87,4 %	
	only image information			
Well classified pixels	55 %		75 %	

Fig. 1: Evaluation of the classification results on the three test zones



Fig. 2: Example of a handmade topographic map at 1:25k in Alps

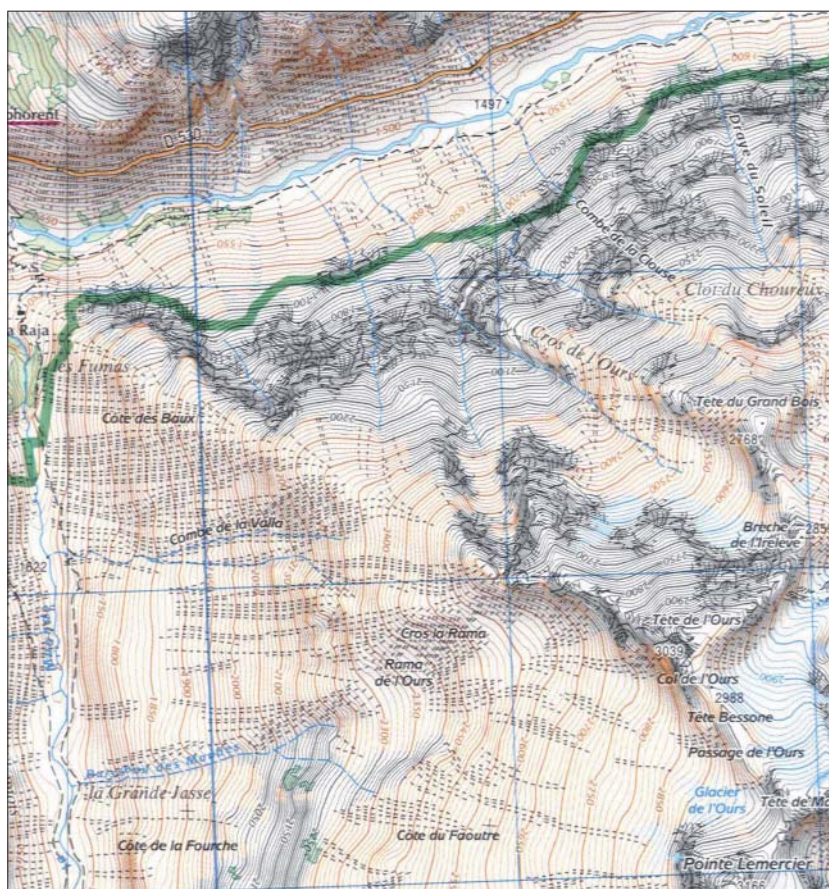


Fig. 3: First map digitally obtained by Le Men et al (2002) of the same area





Fig. 4: Extract of orthoimage used during the process



Fig. 5: Extract of Corinne Land Cover land use on the same area

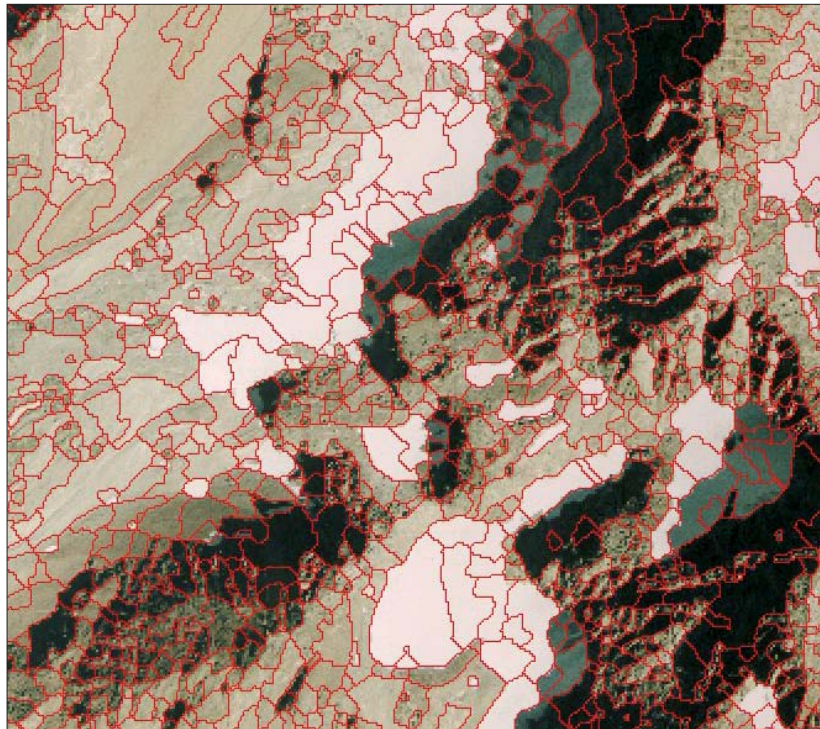


Fig. 6: Segmentation of the orthophoto in homogeneous regions

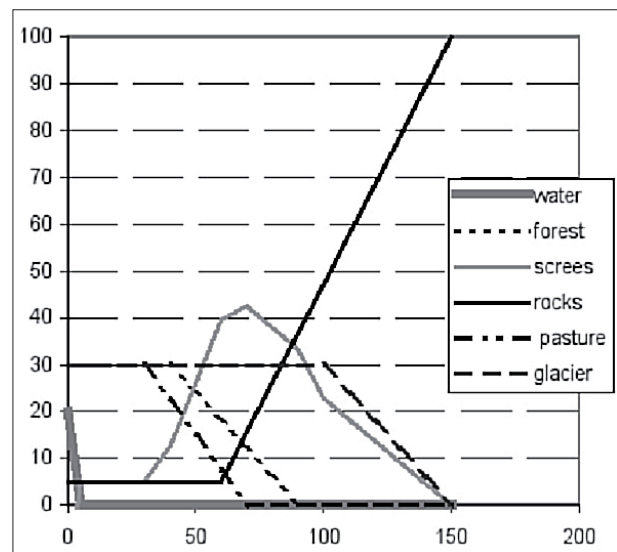
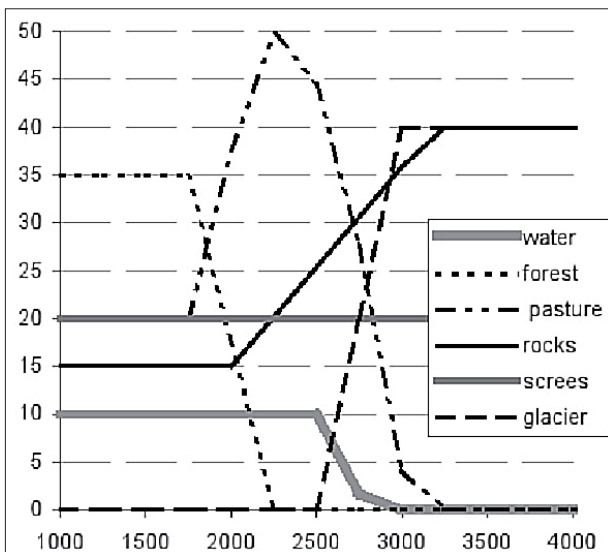


Fig. 7: Probability of finding themes knowing altitude (left) and slope (right)



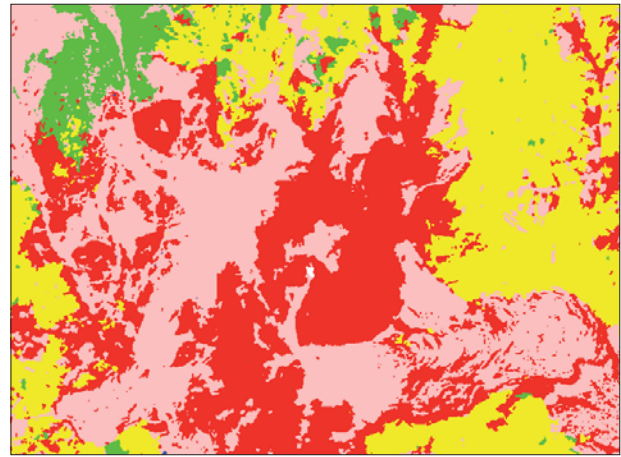


Fig. 8: Orthoimage (left) and classification (right) in Pyrenees (Ossau peak region)  
(Red = Rocks; Green = Forests; Yellow = Pastures; Pink = Scree)

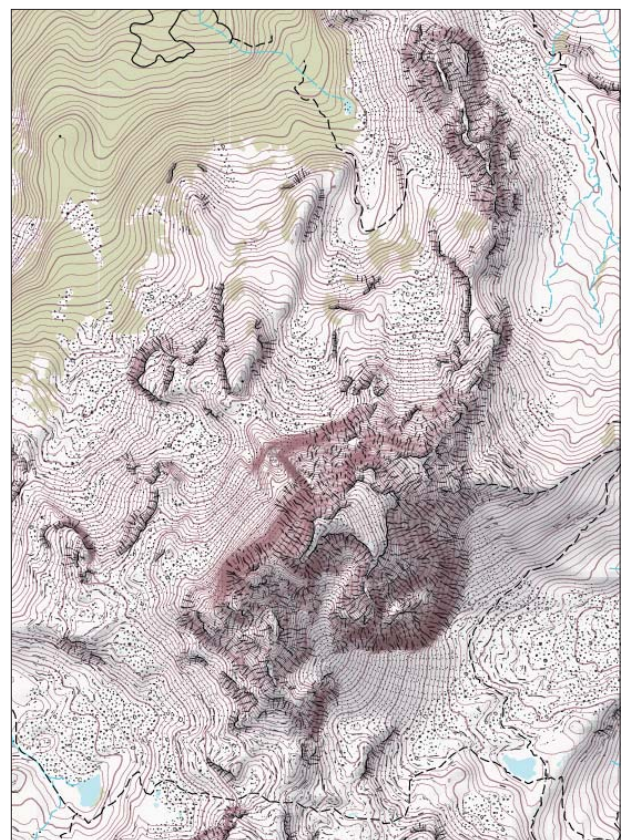
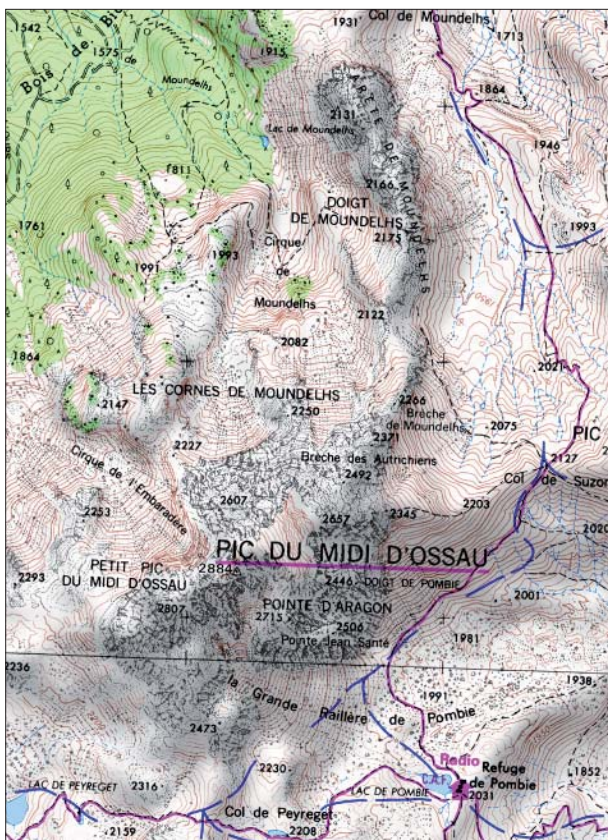


Fig. 9: Present handmade topographic map (left) and the new fully digital made map (right) in Pyrenees (Ossau peak region) at 1:25k

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# The Swiss Alpine Club SAC and its Role in National Mapping

Martin Gurtner

## Abstract

*Which came first, the hen or the egg? Tourism (including alpinism) or mapping? Fact is that the two are strongly connected. The Alps were discovered as a “playground” around 1850, and at the same time, many other fields developed rapidly: science, technology, transport... The alpinists needed maps, and the newly established national mapping agency was (more or less) able to fulfil this wish. Even nowadays, there are strong links between the SAC and the Federal Office of Topography*

## 1. Threatening mountains

In the old days, people were afraid of the mountains. Gruesome monsters and dragons were reported to live there. Nevertheless, farmers in the valleys made their living with agriculture – and some of them specialized in the transport of goods across some passes. While hunting a chamois, one or the other of them may have climbed a ridge or a peak in his neighbourhood.

## 2. The people at the beginning

It was Albrecht von Haller, a bernese scientist, who promoted a different look at the mountains with his poem „Die Alpen” in 1729. Later, Jean-Jacques Rousseau took up his ideas, saying that children should stay outside far more to gain strength. Father Placidus a Spescha was the first real alpinist in Switzerland; he climbed many peaks around Disentis at the beginning of the 19<sup>th</sup> century.

## 3. Tourism

With these new ideas in the background, travelling became a very popular pastime for rich people. The German writer Goethe came to Switzerland for the first time in 1779 and admired the Staubbach waterfall at Lauterbrunnen. The existing trade routes were used. The Alps were no longer a threat, but something to be admired. The locals realized that they could make some money with the gentlemen (or the rare ladies) who visited the country.

## 4. Alpinism

Many British climbers came to central Europe around 1850 and discovered the Alps as a “playground” (Leslie Stephen). The “battle” for the Matterhorn lasted several years – and ended tragically for half of Edward Whymper’s party. But the locals wanted to climb their own summits too; in 1863 the Swiss Alpine Club was founded. It was a very upper class association these days, “ordinary” people were accepted only after the first World War. The assembly of 1907 excluded specifically women from membership (!) – until 1981, when the Women’s Alpine Club and the SAC merged.

## 5. Science

The theory of the ice ages may serve as an example for the development of science: in 1815 a farmer of the Val de Bagnes (Valais) brought up the idea that the valleys had been carved out by glaciers to a geologist. The National Academy of Natural Sciences discussed the theory at their assembly in 1822. Louis Agassiz published it in 1836, as a proof he established a bivouac on the Lauteraar glacier, called “Hôtel des Neuchâtelois”.



Fig. 1: The “Hôtel des Neuchâtelois” the Lauteraar glacier around 1840





Fig. 2: The project for the new Monte Rosa hut near Zermatt

## 6. Accommodation

When the early tourists came to Switzerland, there were no guest houses in the mountain villages. The first hotel at Zermatt was built in 1850. The early climbers slept in farmer's huts or had to bivouac under a rock. Shortly after its foundation, the Alpine Club built a small hut on the east side of the Tödi. Today there are 150 huts forming the "highest hotel chain". Together with the ETH Zurich a spectacular building is planned near Zermatt: the new Monte Rosa hut.

## 7. Transport

Napoleon built the first road across the Simplon Pass "pour faire passer le canon". Before, most of the goods were carried on horse (or men's) backs. More and more roads were built, stage coaches linked the main cities together, and travelling became easier. Not very long after the first rail connection between Zurich and Baden was built (1847), the first mountain was "conquered" by a rack railway: the Rigi in 1871. The first aerial passenger line opened up near Grindelwald just before World War 1.

## 8. Mapping

### 8.1. National Mapping

A few month before the SAC was officially founded, some of its representatives wrote to the government to rename the "Highest Peak" of the country to honour the general of the civil war of 1847 and the chief of the first accurate map, Guillaume-Henri Dufour. Four Days later (!), the motion was accepted and subsequently the map was updated. Since 1863, the highest rise of the Monte Rosa massive is called "Dufourspitze". At the first general assembly of the SAC, Dufour was elected an honorary member. Until the turn of the century, the club subsidised the publication of the so called Siegfried map!

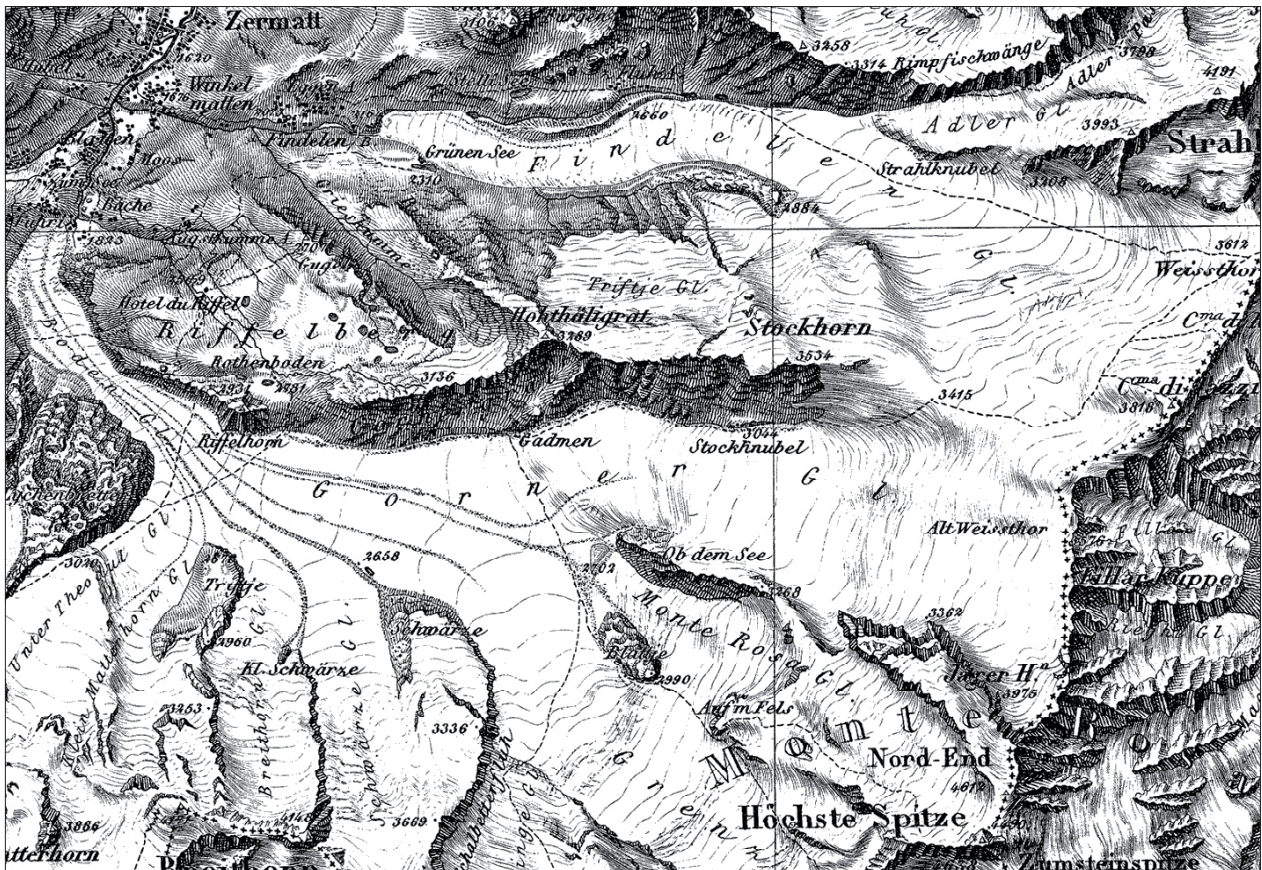


Fig. 3: The Topographic Map of Switzerland 1:100,000, showing the "Highest Peak"



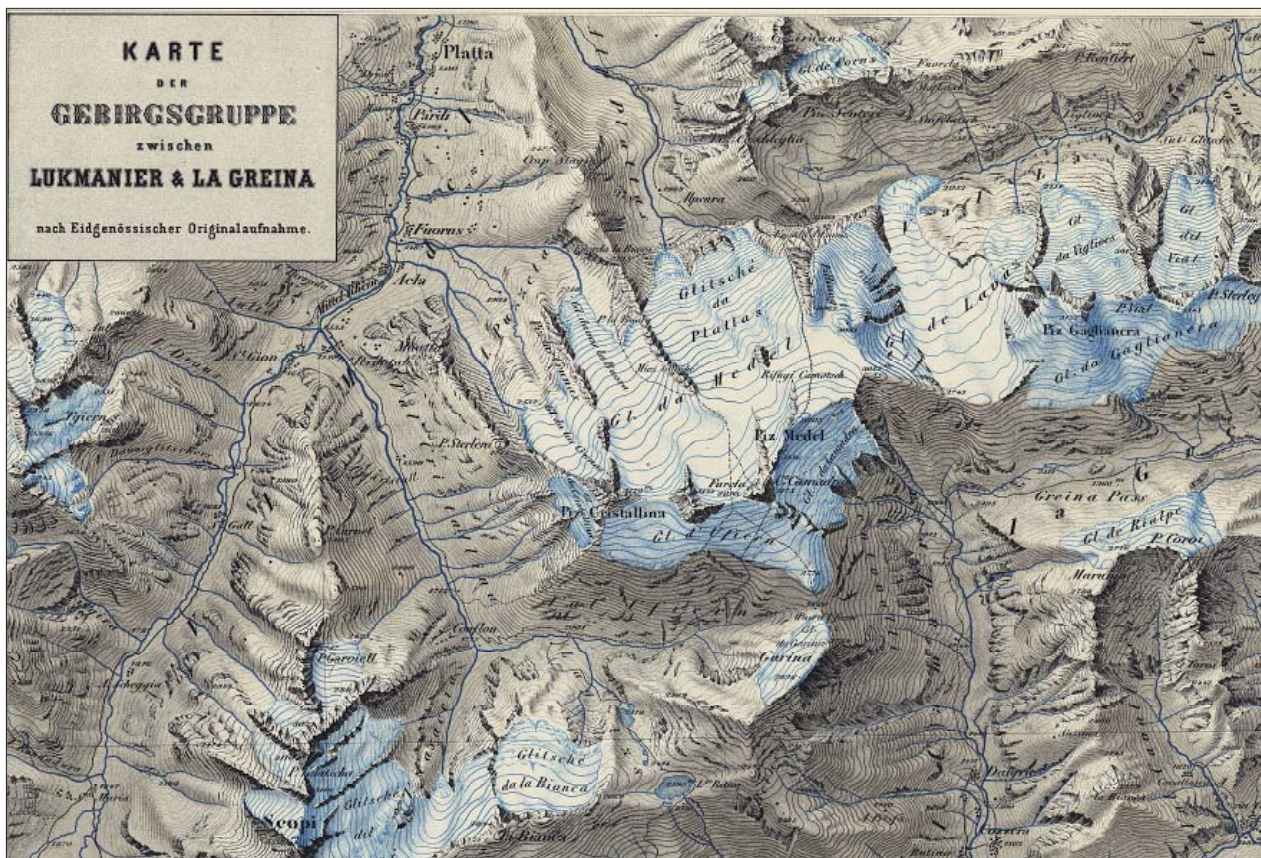


Fig. 4: Map of the Greina region 1:50,000, by R. Leuzinger

## 8.2. Private mapping

Since the scale of 1:100,000 was not really sufficient, the Alpine Club and the Academy of Sciences soon pleaded for the publication of the original surveys, with contour lines and at scales of 1:25,000 for the plateau and the Jura, 1:50,000 for the Alps. In his yearbook of 1864, the SAC published a first map at own costs, based on the official surveys. One year later, the cartographer Rudolf Leuzinger finished the map for the Greina region, the first one with continuous tone hill shading.

## 8.3. Three experts

The Alpine Club produced 35 maps until 1900, many of them made by Leuzinger. He also worked for the government. Xavier Imfeld surveyed 23 sheets of the national maps after his studies and he is well known for his detailed rock drawings. Later he had a small private company and published maps, panoramas and produced 3D-models – and was elected honorary member of the SAC in 1901.

Eduard Imhof was a professor at the Federal Institute of Technology in Zurich (ETH) for 46 years. Between 1927 and 1934, he was the spokesman of the Alpine Club in the discussion about the future National Map Series. He



Rudolf Leuzinger  
1826–1896



Xavier Imfeld  
1853–1909



Eduard Imhof  
1895–1986

Fig. 5: Three experts in Swiss cartography



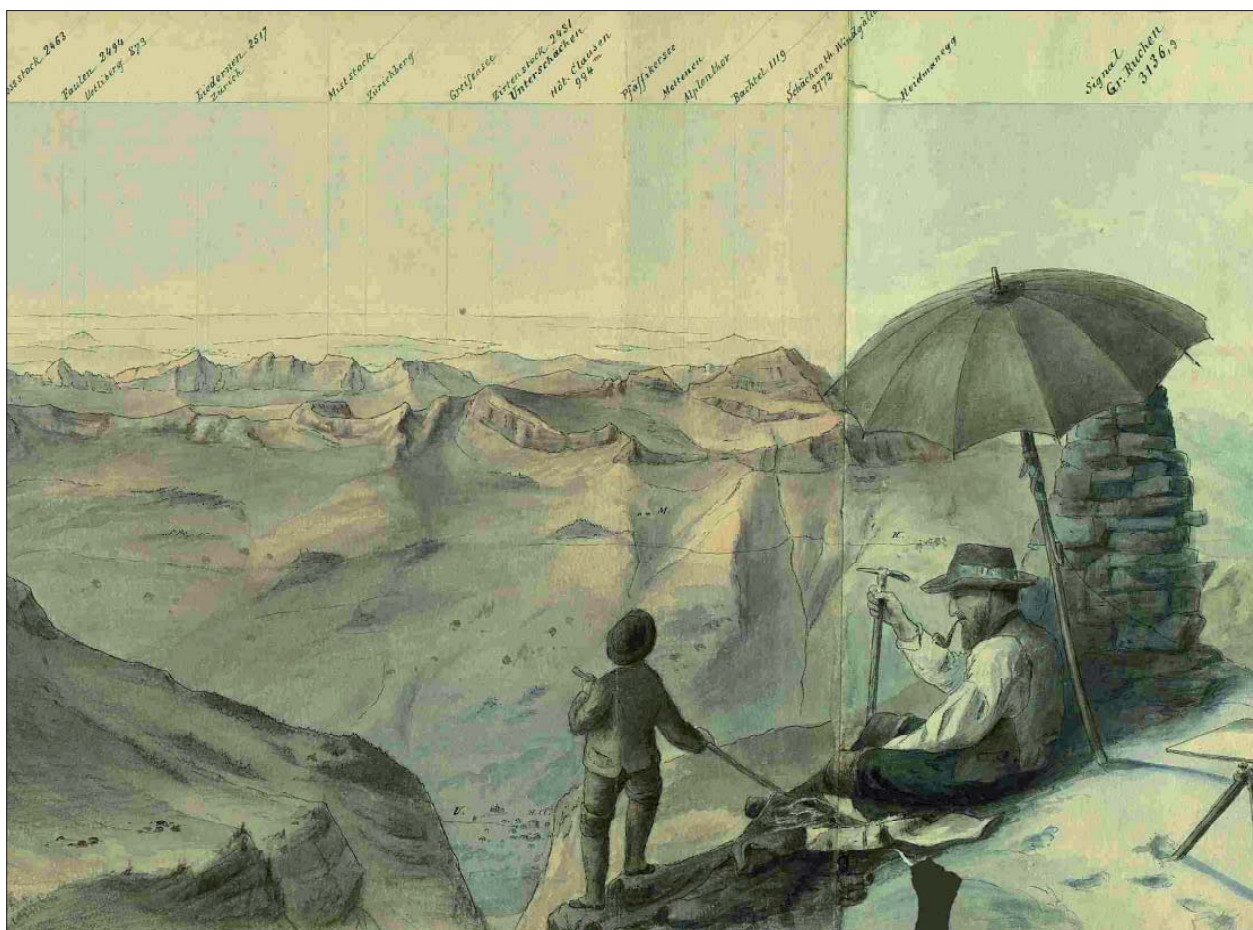


Fig. 6: A small fragment of a panorama drawn by X. Imfeld at top of the Gross Ruchen

pleaded for larger scales covering the whole country. He convinced the minister of defence, because of what he is called the “father of the National Maps”. His school maps are the base of geography lessons in hundreds of classrooms. He also worked on a guidebook for the Alpine Club and was named honorary member in 1958

## 9. Guidebooks

Traditionally, the authors of the Alpine Club’s guidebooks are the ones who use the topographic maps most intensely. Therefore swisstopo (the Swiss Federal Office of Topography) was always interested to keep close contacts to them. Besides the conventional summer guides, the sales of hiking and skiing books have increased considerably during the last years. The map reading manual was a joint publication of the SAC and the Federal Office of Topography.

## 10. New publications

Two CDs were produced together: route descriptions, photos and maps for the most popular climbs in the Bernese Alps and the Valais. Since 2006, the SAC is a joint editor of the ski touring maps 1:50,000, being responsible for the yellow overprint with the protected sites: game and nature reserves. The maps are published by swisstopo, however the routes on them have the same numbers as the descriptions in the SAC guidebooks.

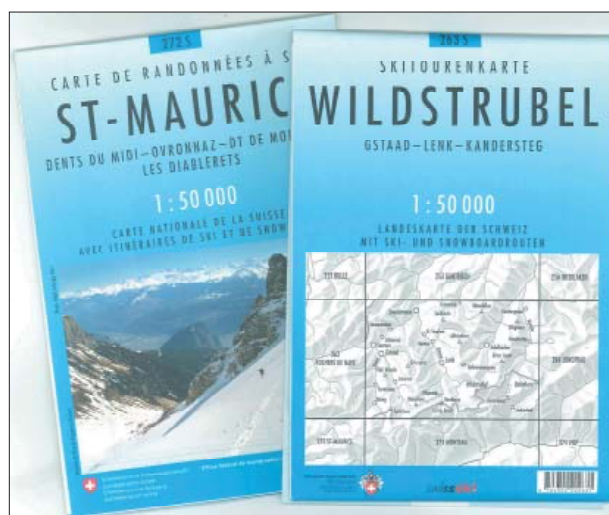


Fig. 7: The ski touring maps 1:50,000 are a joint product of swisstopo, Swiss Ski and SAC.

## 11. The future

swisstopo will take up the production of the new topographic landscape model TLM in 2008. With this data – updated every year – navigation will be much more reliable. As the download rates increase, alpinists will be able to get the latest map (and maybe the aerial photography as well) on his GPS. But he will still carry a paper map as well: it provides a far better overview and it needs no batteries!



# 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.*

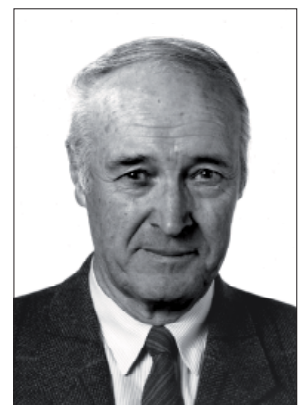
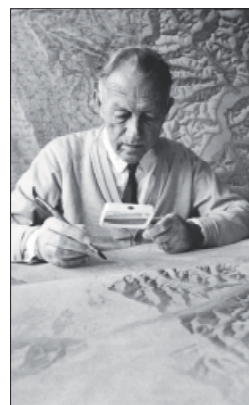
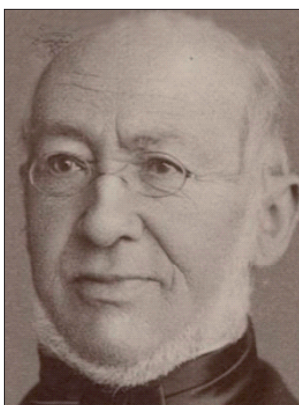
### **1. The political roots of cartography at ETH Zurich**

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 Becker's 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-

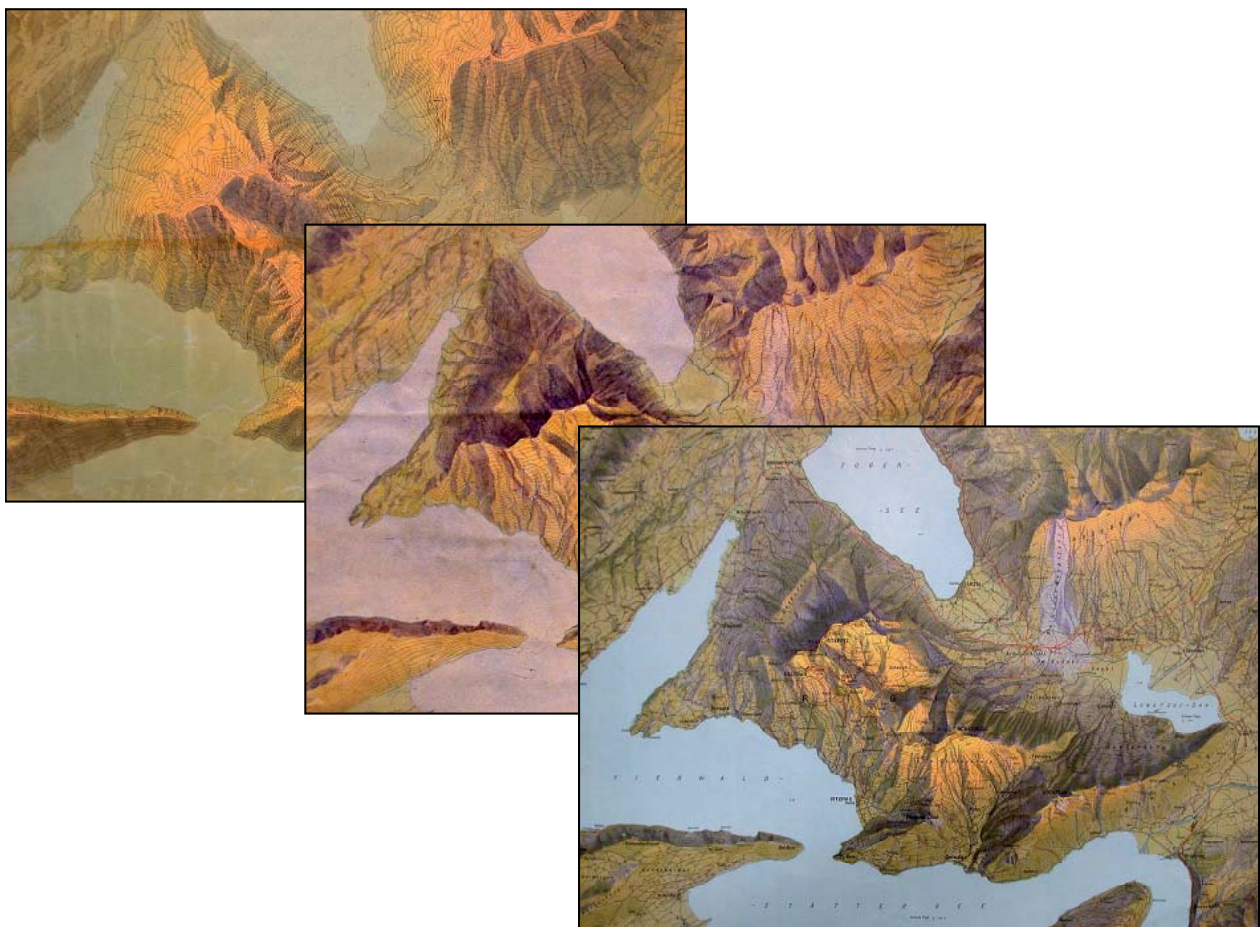


Fig. 2: Two watercolour sketches of Mount Rigi by Fridolin Becker with Northwest and Southeast illumination and the final map with Southeast illumination at lower right.



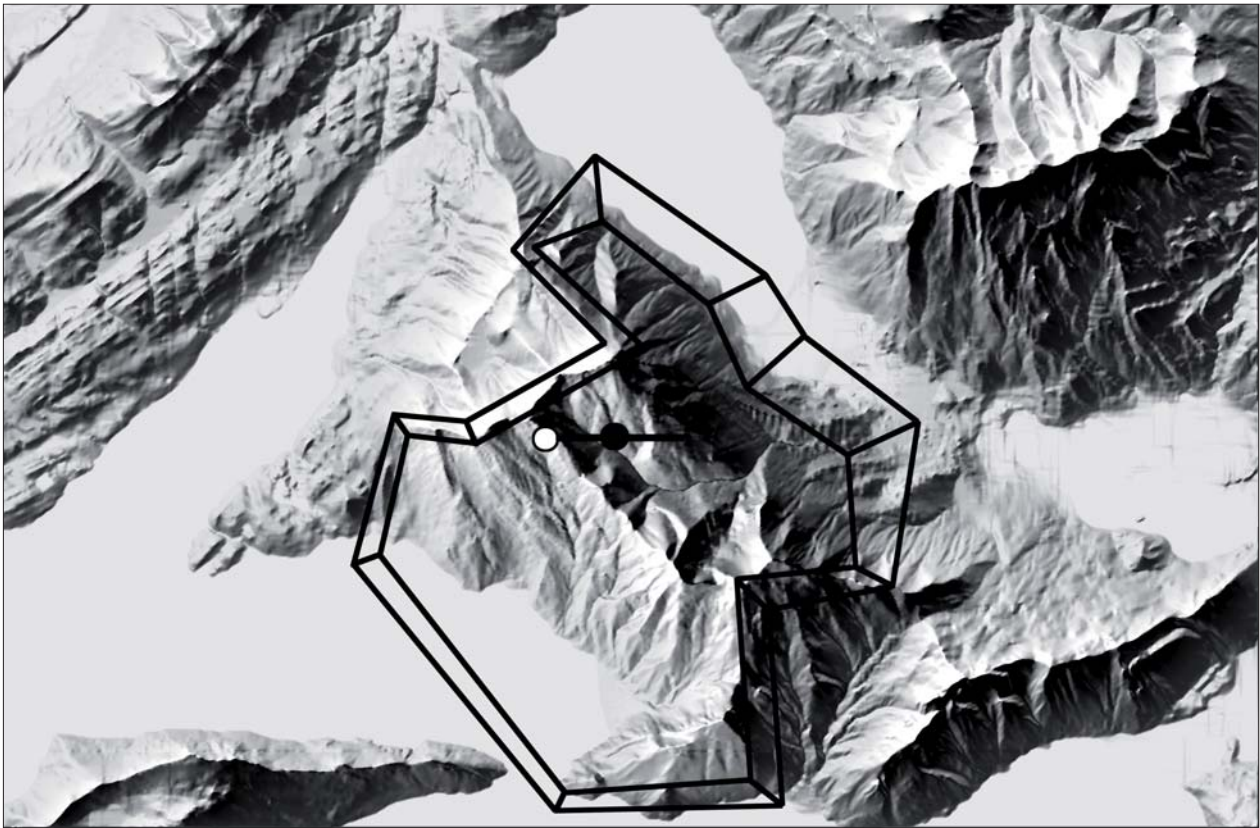


Fig. 3: Local adjustment of light direction. Elevation data (DHM25) © Federal Office of Topography, Wabern, Switzerland.

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).

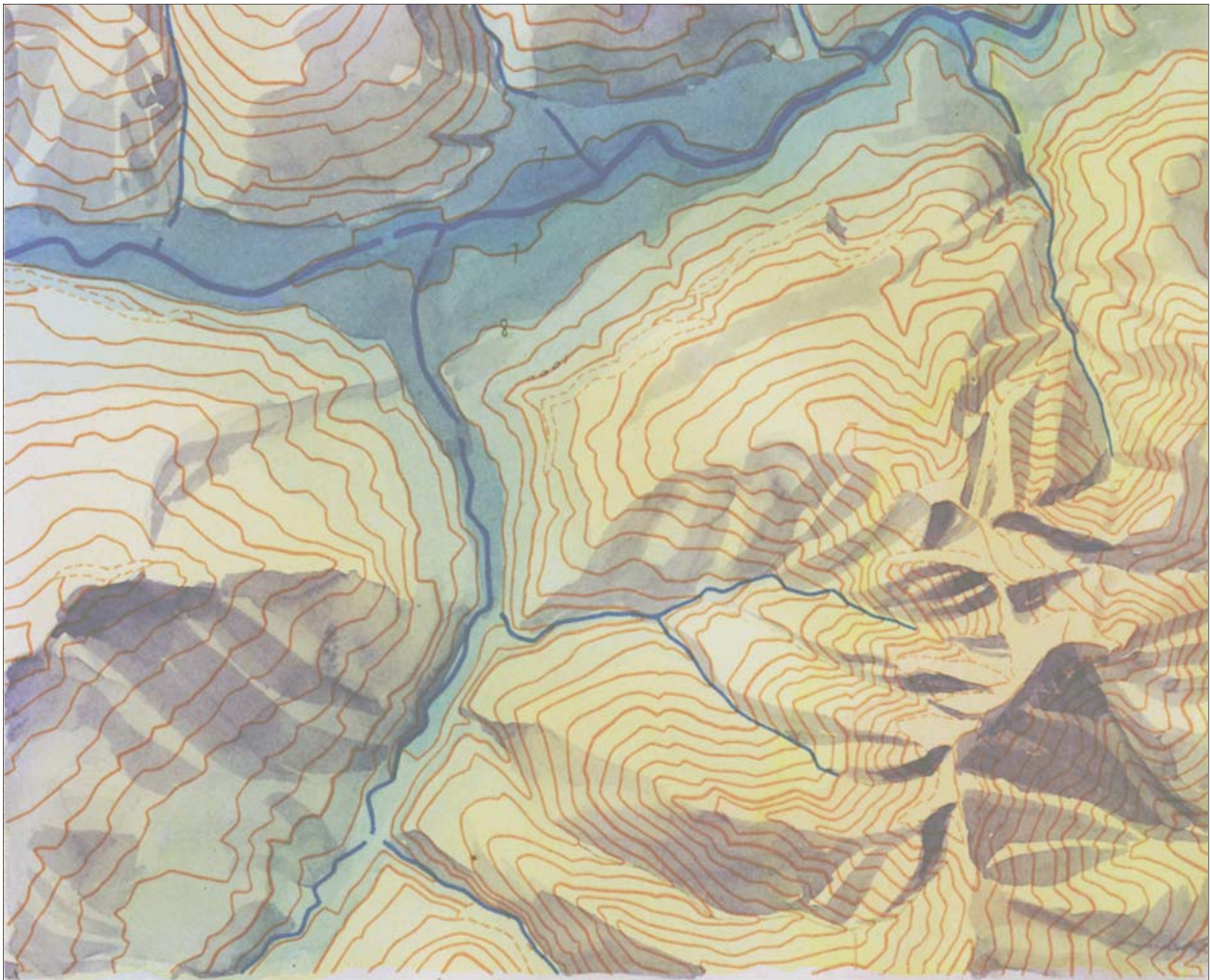
Comparisons of analytical and manually shaded reliefs of mountainous areas show that the numerically processed versions often contain too many details, whereas the manual

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



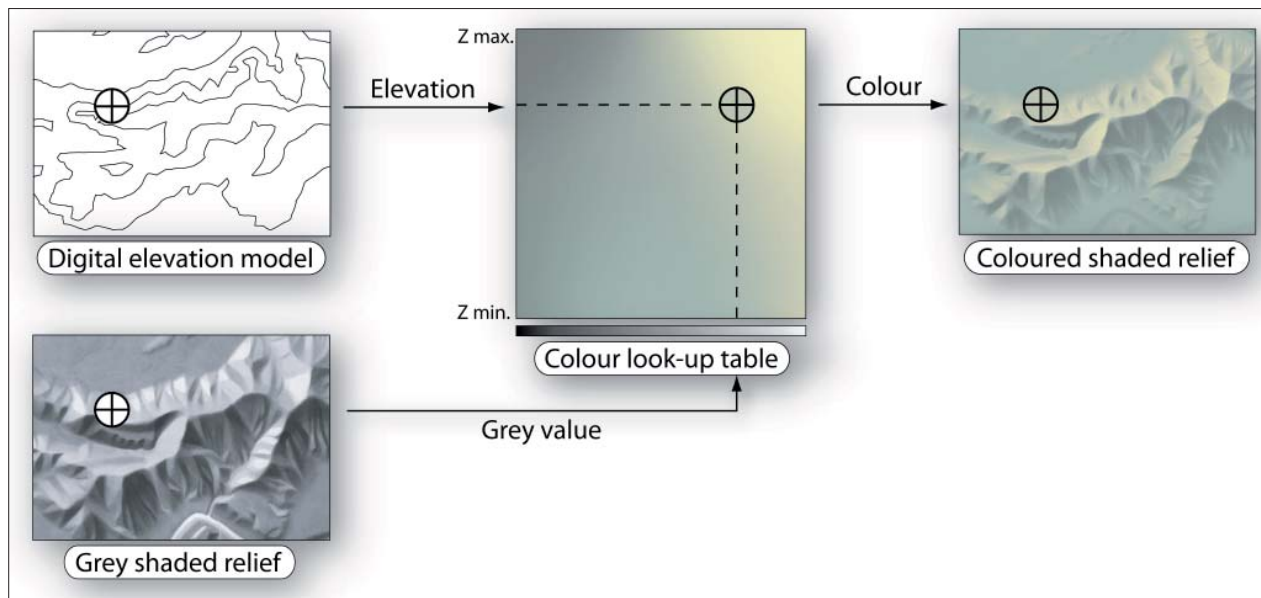


Fig. 5: Generating a coloured shaded relief by choosing the colour from a two-dimensional look-up table built up by elevation and exposition parameters (after Jenny and Hurni, 2006).

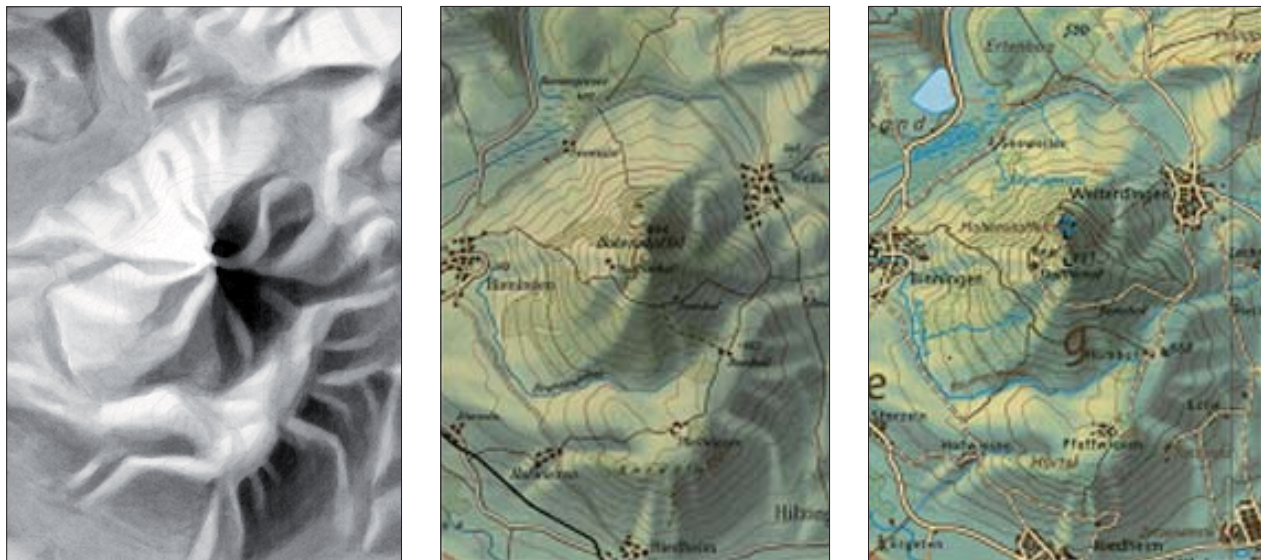


Fig. 6: New school map of Schaffhausen: The coloured shaded relief (right) combines the greyscale value of the relief (left) with the height dependent colour of the specific point. Centre: Old school map of Eduard Imhof from 1954.

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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# Rodnei Mountains Tourist Map

## A Tourist Mapping Project in Romania

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### Abstract

*The paper presents the main results of a tourist mapping research project: Methods, techniques and experimental models for three-dimensional graphic representations of Rodnei Mountains, for tourism. It aims to increase the graphical quality of the published materials, solving two typical big problems for mountain tourist maps. The first objective is to build an orientation tool for the tourist, to transform the classical mountain map, with contours, into an easy to use tool. Secondly, the goal is to give the map the quality of an advertizing material, as the tourism activities are emerging in the area. Based on the newest visualization software and recent information, new types of representations will be obtained. The details will also concern a general view and aspects of unique geological structures and hydrological elements. Activities have been driven on in four main directions: realizing a synthesis on the latest methods and techniques of 3D representations of a mountain area, creating a database of digital information for Rodnei Mountains, experimenting methods and techniques in order to obtain suggestive representations and transforming the obtained models into formats to fit the most important ways of spreading the results of the research.*

### 1. The Tourist Mapping Project

The present project continues a series of tourist mapping projects, dealt with as research work at Babes-Bolyai University in Cluj-Napoca, the Sighetu Marmatiei Extension. The series contains the following topics:

- Methods, techniques and experimental models for three dimensional graphic representations of Rodnei Mountains, for tourism CEEX ET/2006
- Printed and interactive Atlas of the Maramures Land CEEX ET/2006
- Methods, techniques and experimental models for three-dimensional graphic representations of Gutai-Ignis Mountains, for tourism CNCSIS AT/2006
- Conceiving, experimenting and producing tourist maps for children CNCSIS AT/2007
- Tourist resources of Sighetu Marmatiei, in the fream of crossborder relationships, Partnership with the Sighetu Marmatiei Local Counsil/2005

- Tibles Mountains. Toruist prospective research CNCSIS A/2003

Some of the study subjects are: potential of the relief, tourist prospecting, tourist arrangements, tourist cartography, tourist branding, thus being a valuable geodatabase.

The results will be used for different purposes:

- Tourist orientation tool,
- Didactic/educational tasks (for tourism/geography students),
- Branding for tourist purpose (research to identify the potential elements for a consolidation point of the tourist web-portal of Maramures Land),
- Tourist arrangements (local authorities and investors).

The study area is a former mining region. After the mines closed down, people have found three alternatives to earn their living: wood exploitation, temporary or final migration and tourism. The third option explains the need for cartographic materials for the process of tourism improvement. The town Borsa, located in the northern area of Rodnei Mountains, is a resort of regional interest, mostly for winter sports facilities, but also for hiking and for the mineral water sources. Due to the necessity of elaborating competitive investment projects there is also a need for visualizing materials in order to arouse the investors' interest.

According to the field of interest such as the overall configuration of the relief, areas of maximum interest and the presence of certain natural phenomena (glacial relief and lakes, karst, natural mineral waters), the following approaches for several areas of the Rodnei Mountains have been determined:

- Rodnei Mountains – general approach
- Northern Ridge - the most spectacular
- The area of Pietrosu Rodnei - the highest
- The area of Borsa – Complex (the most important from the tourist point of view)

The conclusion of the research will be available both digitally and in printed form, with the following products:



- 3D maps of different areas
- 3D Panorama
- 2.5 D or shaded
- 4D Animations

## 2. The Mountains

Rodnei Mountains are the highest and the most massive in the Eastern Carpathians. Their altitude reaches a maximum at 2303m above sea level. From the geomorphologic point of view they are a tilted horst with the short slope northwards, a higher northern area determining the highest altitudes, and a lower southern area. This leads to a steeper northern ridge with high peaks (over 1600–1800 m) and a milder southern slope. In the horizontal plane they have got a pentagon shape, imposed by the presence of the fracture lines, with the sides oriented towards W, N, NE, SE and S.



Fig. 1: Position of Rodnei Mountains

The northern and north-eastern sides are separated by a range linking Rodnei Mountains to Maramures Mountains, which is in fact the boundary between the basins of Tisa (by its affluent Viseu) and Siret (by its affluent Bistrita). On the northern slope, there are very wide basins in the superior course of the rivers (Dragos Stream, Repedea, Negoiescu) and it is very difficult to obtain a really clear visualization from north. The southern slope has longer hydrographic basins and it is easier to visualize from the perspective point in the south. The main peak looks like a circular bow, with the convex part towards the north, which does not allow a plane horizontal or quasi-horizontal visualization, with one perspective point, because most of the areas corresponding to the northern bassinets are not visible. (Fig. 1)

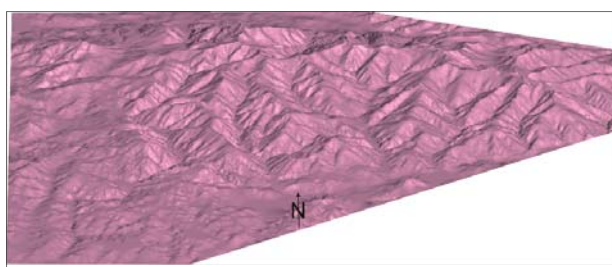


Fig. 2: Rodnei Mountains – rough view from North and South

## 3. Visualization

The 3D cartographic approach, for different reasons, has its advantages and disadvantages. The link between the overall configuration of Rodnei Mountains and the

methods used is obvious. Therefore, several points of perspective have been chosen: visualization from north, west and south. Due to its general shape, the visualization from east has been excluded.

### 3.1. Visualization from North and North-West

From this perspective, it is impossible to visualize the whole topographic area of the mountains, but there is a perfect image of the highest and most spectacular area. By setting the perspective point higher, the visualization area offers an angle to overcome the slope of the southern oriented sides. It is the most suitable representation for Maramures County (Borsa Area) because its corresponding area is in the foreground. Despite the fact that the glacial relief is visible only on the northern side, the overall visualization allows the sight of glacial circles only by using high resolutions and small scales.

### 3.2. Visualization from South

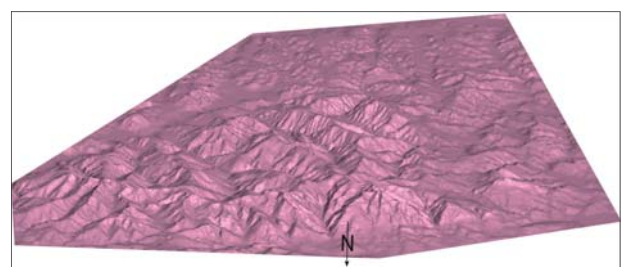
As the shapes of the relief maps are the most present in people's minds and the visualization from the south is the closest to such a result, it is a lot easier to use in orientation, especially for action of tourist branding. However, due to the tipped over horst configuration, the very steep northern frontage is very little represented, even if it is the most representative one. (Fig. 2)

### 3.3. Visualization from the West

Visualization from the west is less spectacular; however we could obtain some 3D images extremely useful from the didactic point of view and also for promoting the mountains as brand of the Maramures region.

In the first situation we can easily notice several aspects important for the didactic process, such as:

- The fracture line Dragos Voda, oriented towards East-West
- The tipped over horst shape
- The contact between the mountain and the Piedmont area.



Aiming at tourist branding, the visualization from the northwest greatly corresponds to the well known image of Rodnei Mounatins, with points of perspective located almost everywhere in the Iza valley, beginning with the Solovan Hill, near the town of Sighetu Marmatiei, (approx. 75 km in straight line).

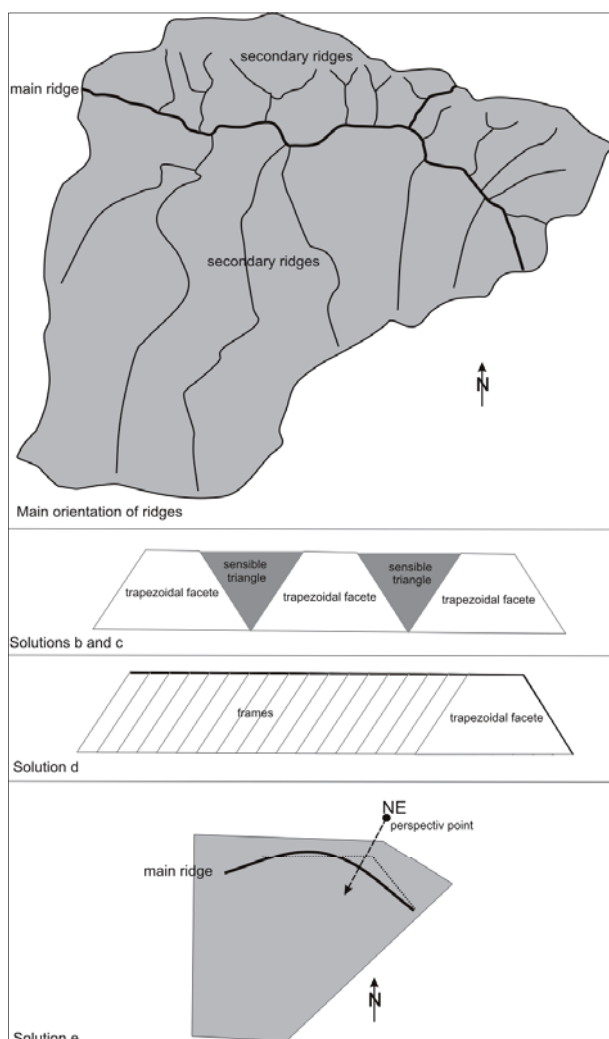
## 4. Results

#### 4.1. The northern face of Rodnei Mountains

The northern mountainsides have a steeper slope than the southern sides, which normally allows a 3D visualization with the perspective point located not very high, especially if these panoramic images do not enhance the image of the opposing mountainsides. However, there is the problem of the south, south-west, and south-east oriented mountainsides inside the hydrographic basins of this frontage.

The following aspects as experimental solutions were used to obtain useful panoramic views:

- Visualization from only one perspective point from the north, up to the point where we have visibility of almost the whole area of hydrographic basins
- Visualization from several perspective points and their



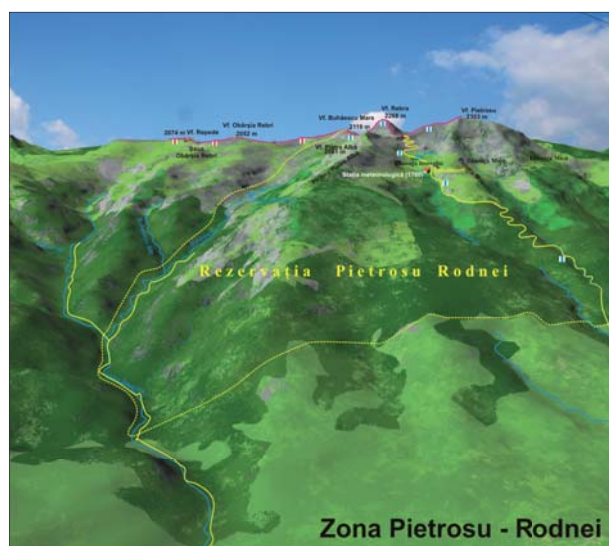
*Fig. 3: Visualization solutions*

- c. Visualization from several perspective points and their linking over the peaks
- d. Visualization from a great number of perspective points, at short distance from each other, in a circular shape, thus obtaining frames, gathered in an automatic program for linking the photo images into panoramic views.
- e. Visualization from only one perspective point in the NE, towards Prislop Pass.

If we consider option a there was a high increase of the perspective point in order to obtain an almost complete visualization of the topographic area in the northern frontage, so that the image didn't have the aspect of panorama anymore. However, by positioning the perspective point at the relief level, the length of the panorama and the convex shape led to a faulty visualization of the areas between the maxima and minima.

By using several perspective points extremely suggestive 3D images were obtained, with good visualization of the trapezoidal and triangular frontages and also of the course of the valleys. The biggest problem is caused by the linking of the sequences, as they have trapezoidal shape, thus allowing wide areas of deformation with triangular aspect. Setting the links on the valleys determines an exaggeration of the bassinets, and their presentation on peaks leads to obtaining plane areas instead of blade shaped areas.

According to point d., using frequent frame type visualizations, the deformation is distributed equally on the whole panorama, and they are imperceptible. The most successful representation was obtained by locating the perspective point in the NE, with the central axis oriented north-east to south-west, approximately corresponding to Prislop Pass. (Fig. 3)



*Fig. 4: The area of Pietrosu Rodnei, 2303m*

#### 4.2. The area of Pietrosu Rodnei

This is the highest area in Rodnei Mountains, corresponding also to a natural reserve, and it is located near the town of Borsa. By its configuration, this area allows a great number of visualizations, even circular flights and animations, as it is flanked by two deep valleys on the eastern and western side and steep mountainsides. The highest area, with many bare cliffs, is easily visible even from downtown Borsa. This area has cirques and glacial lakes almost on all sides. One of the most suggestive visualizations is obtained by setting the perspective point in the north-west, at an altitude of 2000–2200 m, thus offering a better visibility of the northern and eastern mountainsides, and also of the highest peak of Oriental Carpathians (Pietrosu Rodnei 2303 m). In this area, there are many glacial lakes, such as Taurile Buhaescu and Iezer Lake, the later having a very similar shape to that of Romania. From this angle we can visualize the topographic area with an exact demarcation of the cirques and the glacial valleys (Fig. 4).

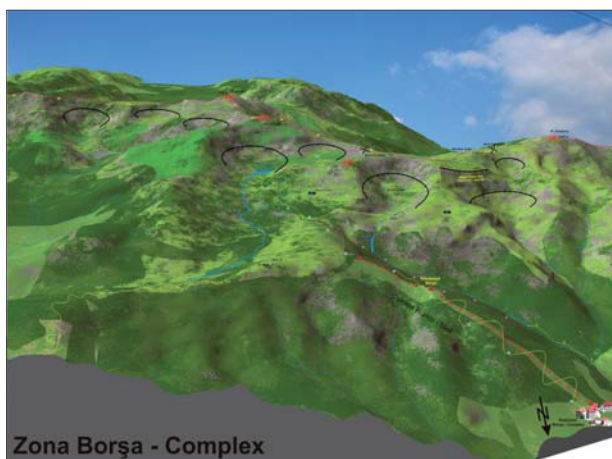


Fig. 5: The Borsa-Complex Area

#### 4.3. The area of Borsa -Complex

This is the most accessible area with the most developed tourist infrastructure in Rodnei Mountains, being a contact area of three counties and near the resort of regional interest Borsa – Complex. The products for this area must cover the 4 fields of action: orientation, improving, branding, and didactic. The most suitable solution for the four fields of action is obtained by the visualization from a point in

the north-east, at an altitude of approx. 2000 m. The topographic surface of interest is almost entirely visible (except for an area in a glacial cirque) thus the elements of interest were represented.

The relief depiction is similar to the real situation with a clear visualization of the effects of the glaciations, resulting in glacial cirques (8 visible) and glacial crests at the foot of the cirques (the ones at Cascada Cailor and Izvorul Bistritei Lake are visible). The entire hydrographic network, comprising the glacial lake Izvorul Bistritei and all the rivers are represented. Areas with forest vegetations (resinous essences), areas with vegetation of Juniper and Cade bushes, alpine grasslands and secondary ones were subject of texture work. Also the steep rocks, cliffs of the natural reserve Piatra Rea were drawn. The infrastructure for skiing, comprising ski-runs, cable transport devices and buildings for services includes the buildings, roads and paths with tourist trails. Mountain peaks with panoramic view over spectacular areas, the saddles on the main crest as points of bifurcation of the tourist itineraries, elements of karsts such as caves and swallow-holes were marked accordingly (Fig. 5).

#### 5. Conclusions

For each of the four fields of action we have obtained a series of products, consisting of:

- orientation materials, maps which are easy to use and very close to the real aspect,
- promotion materials for the whole area of interest, including the base for the future tourist web-based portal of Maramures Land [www.maramures-tourism.ro](http://www.maramures-tourism.ro),
- didactic materials with clear visualization of the relief, with structured representations,
- maps for tourist improvement, very useful in elaborating and on-going of projects, but also in attracting investments,
- Results will be available to be set on information and orientation boards, maps, printed out or in electronic format by different visualization styles.

#### Acknowledgements

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# Automatic Scree Representation for Topographic Maps

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## Abstract

*Scree – a mass of small stones covering a slope on a mountain – is extremely labour-intensive to reproduce on topographic maps when each stone is drawn separately. This is due to the large number of stones – typically several hundreds of stones per square centimetre in a scree field. An automatic procedure to produce scree representations would therefore greatly simplify and accelerate the production of topographic maps of high-mountain areas. This paper will present selected aspects of a project aiming at the development of a new algorithm for the automatic generation of scree representations approaching the quality of hand drawn representations.*

## 1. Swiss scree drawing

The official maps of the Federal Office of Topography swisstopo are famous for their immediate and descriptive representation of the third dimension in alpine areas (Fig. 1). They use contour lines and spot heights that allow the map-reader to extract a numerical altitude for each location on the map — and display the terrain with a three-dimensional effect by the elaborate interplay of the following four elements:

- a shaded relief with an oblique illumination,
- a yellow illumination tone on bright sunlit slopes,

- a rock drawing with an oblique illumination,
- and a scree drawing emphasizing the underlying shaded relief.

The shaded relief is drawn by hand with local adaptations of the direction of illumination to optimally convey the third dimension (Imhof, 1982; Jenny, 2001) and printed in a bright gray tone. To further emphasize the three-dimensional effect of the shading, a subtle yellow illumination tone is added on slopes oriented towards the source of illumination (Jenny and Hurni, 2006). In the area of cliffs and rock faces, sophisticated rock drawings illustrate the local type of rock with various combinations of hachures. This rock hachuring is again modulated with illumination, i.e. rock faces oriented towards the sun are rendered in a much brighter tone than faces oriented away from the sun (Imhof, 1982; Hurni et al., 2001). The scree drawing consists of tiny stones scattered in-between the other map features, and is mainly applied on high-mountain slopes, but also along flat riverbanks to represent gravel and sandbanks.

The stones forming a field of scree vary in shape, density and size. The density and the size of stones on the map do not primarily reflect the density of scree one encounters in situ. They are rather adapted to optimally conveying the impression of an illuminated three-dimensional surface, i.e. when viewed from a distance, the individual stones become

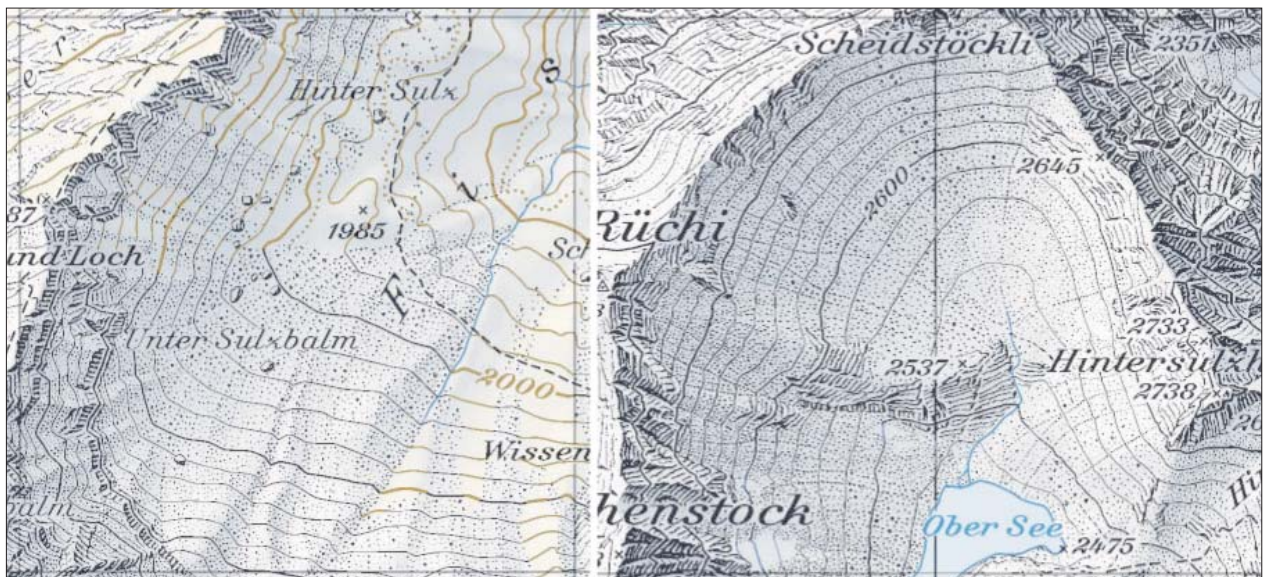


Fig. 1: Enlarged sections of the swisstopo map Tödi (1193) 1:25,000

indistinct and the eye perceives a continuously illuminated surface resulting from the combination of the shaded relief, the shaded scree and the shaded rock drawing.

Another characteristic of scree representation is the arrangement of stones to indicate fall lines, which follow the line of the steepest slope.

## 2. Scree drawing by error diffusion in Photoshop

The density of scree stones can be modulated with a Photoshop function that is applied on a shaded relief. First, a gra-

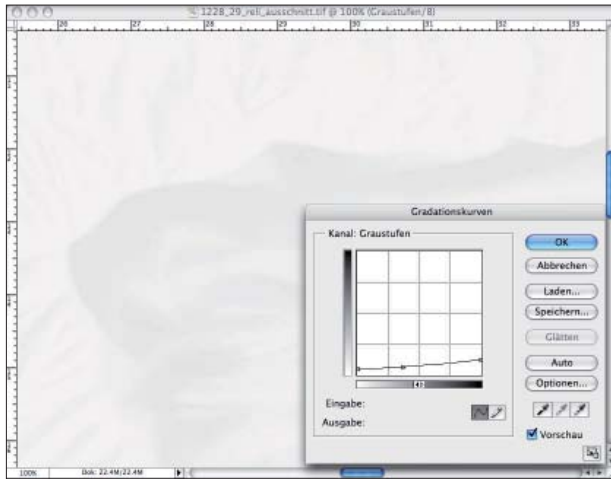


Fig. 2: Adjustment of the brightness of the shaded relief

dation curve is applied on the grayscale shading to increase its brightness (Fig. 2). The shading is barely visible in the resulting image. In a second step, the grayscale image is down-sampled to 254 dpi and then converted to a bitmap image (i.e. a binary image with only black and white colors, but no intermediate gray values). The image is rasterized at 185 dpi with the diffusion-dither option (Fig. 3).

The resulting image shows blocky stones in a pseudo-random arrangement (Fig. 4), where each black pixel represents one scree stone. In a final step, a mask is applied to remove stones outside of scree areas. The Federal Office of Topog-

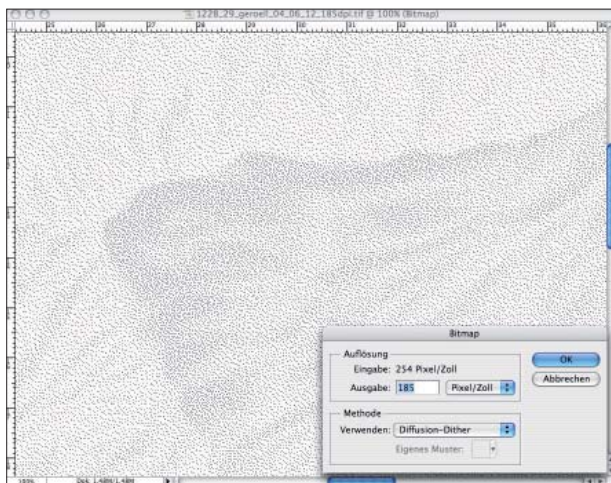


Fig. 3: Diffusion dither converts from a grayscale to a bitmap image

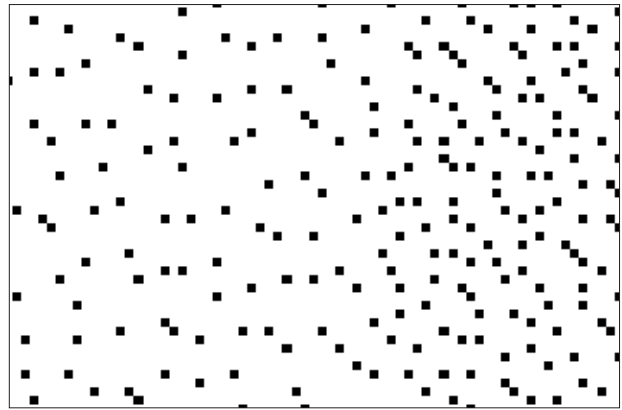


Fig. 4: Each scree stone is represented by one pixel

raphy swisstopo invented this procedure (swisstopo, 2006), which was applied to a test sheet (Fig. 5) to evaluate an updated map design (Feldmann and Kreiter, 2006).

The described technique is applied and does not require non-standard software. Another main advantage is that the density of scree stones can be easily adapted by adjusting the gradient curve. However, it has two major shortcomings:

- The stones are all square-shaped and all of the same size, which results in a very regular and unnatural appearance.
- Stones are not arranged in fall lines, i.e. the lines of steepest slope are not indicated by the stones.

## 3. Pattern filling with an Illustrator plug-in

An alternative approach to the Photoshop technique presented above uses a plug-in for Adobe Illustrator (a vector graphics application). The plug-in was developed at the Institute of Cartography of ETH Zurich and is available for free at [www.ika.ethz.ch/plugins/index.html](http://www.ika.ethz.ch/plugins/index.html) (Werner and Hutzler, 2005 and 2006; Hutzler, 2007). It fills closed polygons with a pseudo-random pattern of user-definable symbols. We applied this plug-in to polygons defining the outlines of scree areas and used the scree symbols in Fig. 6.

The plug-in takes obstacles into account, i.e. areas where no symbol should be placed can be defined by arbitrary lines or polygons. The plug-in then ensures that placed symbols don't overlap these areas or are closer than a user-defined distance. When placing a symbol, the algorithm pseudo-randomly picks one of the stones in Fig. 6. The probability for each stone to be picked can be adjusted by the user. (Note that the shape of the stones in Fig. 6 and applied in Fig. 8 are not generally recommendable for scree representations. Scree stones should have a more compact and convex shape.)

Obstacle lines (blue in Fig. 8) are used to add a flow structure to the placed stones. This imitates the manual placement of scree stones, where stones are arranged along fall lines to indicate the line of steepest slope.

The pattern-filling method with the Illustrator plug-in has the disadvantage that the density of scree stones is not modulated with the brightness of the shaded relief. Hence





Fig. 5: Swisstopo 1:25,000, current map with manually placed scree stones (left) and test sheet with stones placed by diffusion dither (right)

the resulting image does not modulate the apparent scree brightness with the exposition towards a source of illumination. Another potential problem is the very large number of new vector paths that are generated when applying the plug-in to an entire map sheet with many scree polygons to fill. The large number of paths may potentially overburden standard vector graphics applications.



Fig. 6: Stone symbols used to fill scree polygons in Fig. 8

#### 4. Representing fall lines and cullies

The two methods presented above do not automatically arrange scree stones in a flow structure along fall lines as is done in manual scree placement. While the Photoshop method completely ignores fall lines, the Illustrator plug-in can arrange stones in a flow structure. However, the needed obstacle lines must be manually drawn, which considerably complicates the practical application of this method. Yet,

fall lines can be derived from a digital elevation model. The algorithm has to follow the line of steepest slope in downward direction starting at a point on a ridge. Once such a line is identified, it can be symbolized using stone symbols placed along it (Hurni et al., 1999). The algorithm first places regularly spaced stones along the line, then applies random displacements in the direction of the line and vertical to the line, and finally varies the size and the shape of the stones (Fig. 9).

#### 5. Conclusion

Three methods for the placement of scree stones have been presented: (1) a diffusion dither algorithm in Photoshop, (2) a random pattern filling with an Illustrator plug-in, and (3) symbolization of fall lines with scattered stone symbols. The diffusion dither algorithm in Photoshop is fully automatic, but the results are not satisfying, as stones are too regular and the direction of flow is not shown. The random pattern filling created with an Illustrator plug-in requires too much interactive editing and cannot be applied to an entire map sheet. And finally the symbolization of fall lines with scattered stone symbols can only be applied to individual



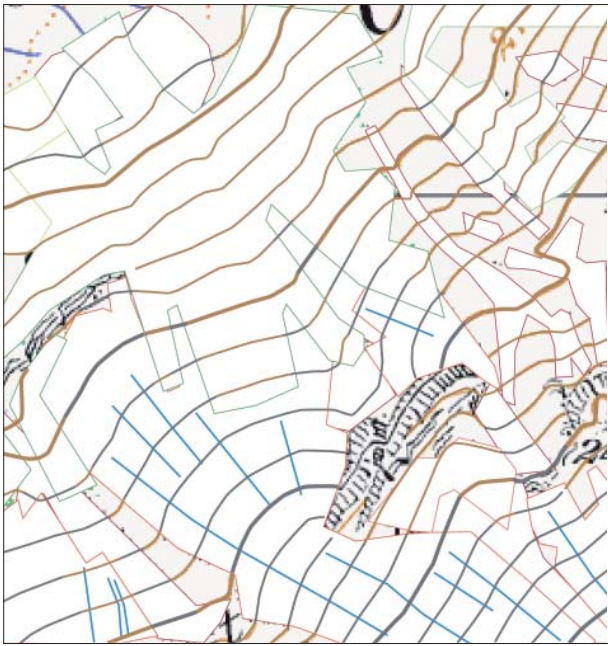


Fig. 7: Red: scree polygons; blue: obstacle lines for scree; green: forest; brown: contour lines; black: rock drawing

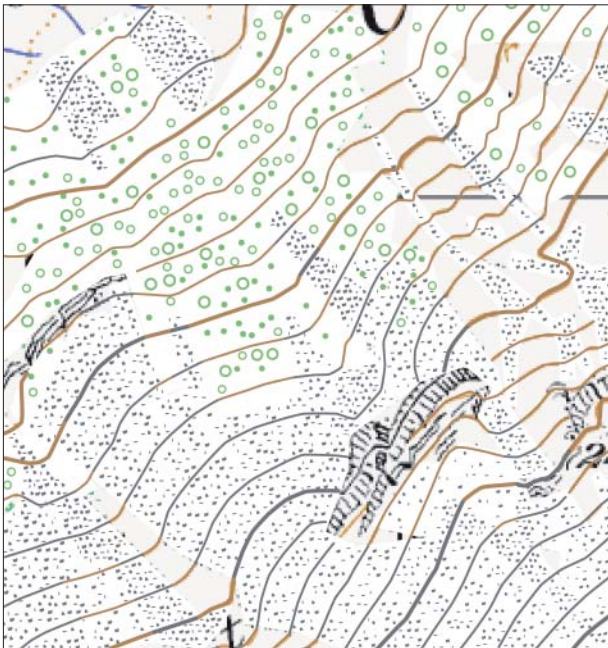


Fig. 8: Random filling of scree polygons with stone symbols and forest polygons with circles

line features, but cannot be used to fill polygons. A method remains to be developed that (1) fills scree polygons, automatically (2) detects and (3) symbolizes fall lines, (4) applies random scattering to scree stones and varies (5) shape, (6) size and (7) stone density according to the brightness of a shaded relief. The Institute of Cartography and the Federal

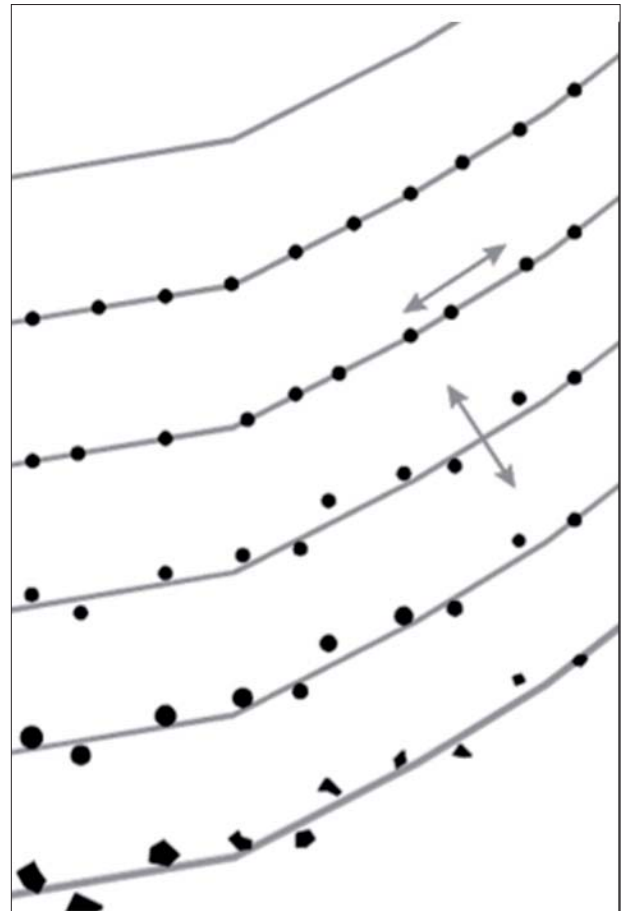


Fig. 9: Scattering of stones along a fall line

Office of Topography swisstopo started a joint research project with the goal to first formalize the hand-drawn representation of scree and then develop a new algorithm that integrates the requirements listed above. It remains to be explored to what degree scree drawing can be automated and what type and level of interaction will be required from cartographers to reach the quality of manually generated scree representations.

## 6. Acknowledgement

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# Photogrammetric Map of the Tatra Mountains (1934) as an Example of Local Adaption of Swiss Style Cartography

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The photogrammetric map of the Tatra, published in 1934, was the first attempt at modern mapping for the area. Earlier, Austro-Hungarian maps were obsolete by the late 1920's. Finally this map covers only the Polish part of the Tatra Mountains in detail.

The Ministry of Infrastructure and later the Military Geographical Institute directed the map work. Work started in 1924 as part of the demarcation of the boundary between the new states of Poland and Czechoslovakia. Terrestrial stereo-pairs formed the foundation of the map work. Future plans included using the map to establish the Tatra National Park.

The map was produced at a detailed scale of 1:20,000. The shaded relief and rock drawings are similar to what is often called the Swiss cartographic style.

Three map versions were published: A - topographic, B - scientific and C - a winter edition for skiers. Here only version C is presented.

Only the Polish side of the Tatra area was fully mapped. The northern part, outside of the Tatra and the Slovakian part were mapped in a simplified way. For the Slovakian side, Czechoslovakian maps were used.

Rocks were sketched on the basis of field measurements. Also, stereopairs of rocky features were used as a helpful aid. As a next step, cartographic instructor Rudolf Schreiner drafted the actual rock drawings. The rock drawings were sketched on previously prepared and drafted contour lines. The illumination for the shading was cast from a northwest direction.



*Fig. 1: High Tatra / right part of the map*





*Fig. 2: West Tatra / left part of the map*



*Fig. 3: Rocky part of High Tatra / Gąsienicowa Valley. Note the rock drawing*



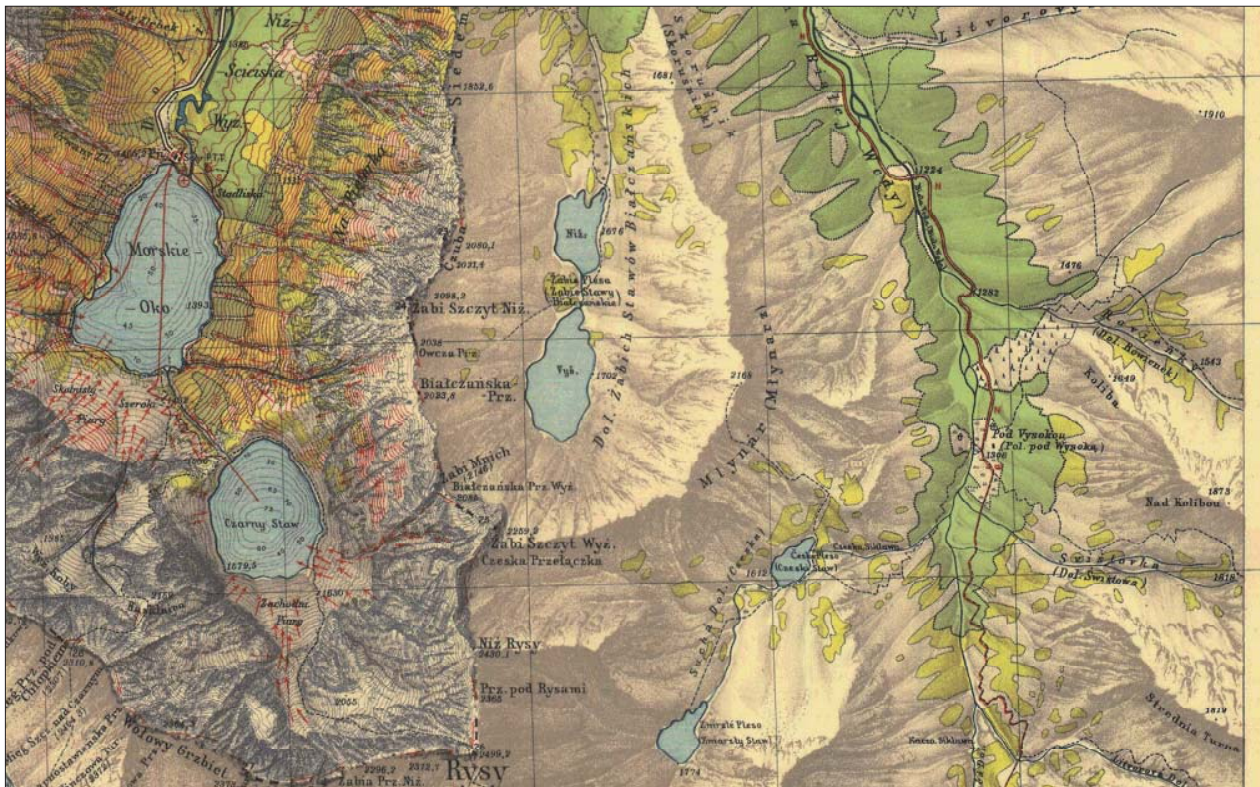


Fig. 4: High Tatra – Rysy peak area. Polish Tatras on the left and Slovak on the right

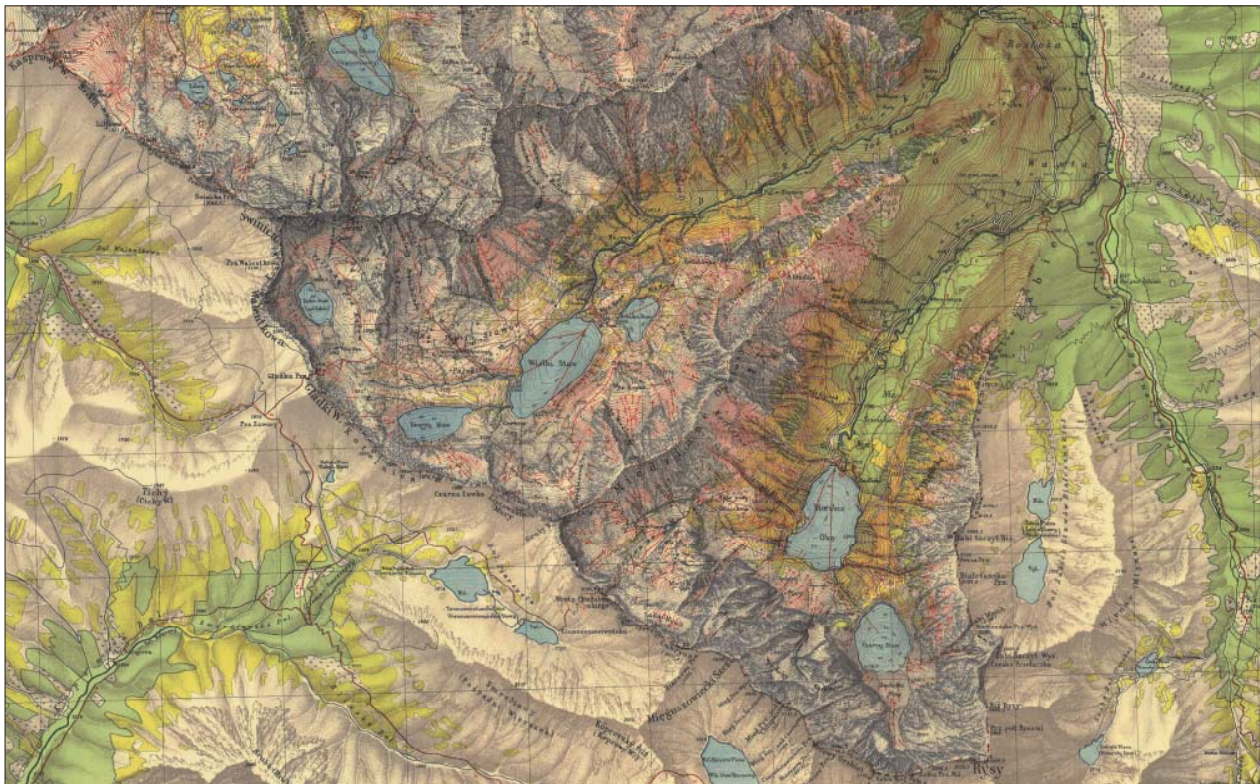


Fig. 5: High Tatra. Note the yellow tint for dwarf pine ground cover

## Reference

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# Designing the DEM of the Base of the Swiss Plateau Quaternary Sediments

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## Abstract

*The bed rock surface, i.e. the base of the Quaternary loose rock is of great practical and scientific interest. Unfortunately, its position is known from punctual and often disperse borehole and pit data only. Since some thirty years, several local and regional attempts have been made to outline the trend of the bedrock by isoline sketches. Starting in 2005, an important attempt was made to collect all available information on the bedrock surface and to integrate them in a Digital Elevation Model (DEM) of the Base of Quaternary of the Swiss Plateau and of northern Switzerland. Beside older studies and isoline maps, data of approximately 13,000 boreholes and all available geological maps have been consulted. These data were compiled in isolines and stream lines designed in a GIS framework by experts. The actual bedrock surface is rather complex as it was carved by a great number of different fluvial and glacial erosion events separated by times of loose rock accumulation and partly filling of the antecedent created depressions. Consequently the interpolation of rock surface data asks for a great knowledge of erosion processes, landscape development and ice age history in connection with spatial sense and decisiveness.*

*The 25 m x 25 m resolution DEM, calculated on the base of the isolines and stream lines, covers loose rock areas as well as areas with no or only few Quaternary sediments. It is consistent in spatial reference and grid size to the land surface model of Switzerland (DHM25). Thus, it can be used for 2D (map) and 3D visualisations, and raster calculations including comparisons between bedrock and actual land surface.*

## 1. Introduction

Precise knowledge about the position of the rock surface and the thickness of its loose rock cover are of primordial interest in many geomorphologic, Quaternary and geotechnical studies. Specifically, geophysical and geothermal prospecting as well as planning of underground constructions can profit from detailed information about loose rock cover thickness. This need for a continuous model of the basis of Quaternary cover was the starting point for the creation of a Digital Elevation Model (DEM) including all possible information about Quaternary sediment thickness. The aim of this work is to propose a consistent model of the bedrock

surface and its loose rock cover of the Swiss Plateau and the adjacent regions including the Alpine Foreland.

The bedrock surface is identical to the land surface at places with no or only a thin loose rock cover („outcrop area“). In the domain of thick loose rock cover, the position of the bedrock surface is known from pit, trench, tunnel, and borehole data only. The scatter of these data is very erratic with clusters in urban areas and along road or tunnel projects, and nearly no information in rural areas.

It is important to note, that the actual bedrock surface does not represent a surface that was, in its whole, the land surface at specific date. It was rather carved, within the last about one million years, by a great number of different fluvial and glacial erosion events each of them reaching and eroding the rock surface at different places. These erosion events have been separated by times of loose rock accumulation and (partly) filling of the antecedent created depressions.

## 2. Material

In a first step, earlier work on rock surface position was compiled (Fig. 1). As a basic principle, these interpretations were taken for authentic, if there was no conflict with more recent data or other interpretations. All available 1:25,000 scale sheets of the Geological Atlas of Switzerland, and regional geological maps in the scale 1:50,000 (Hantke 1967, Schläfli 1999) or 1:100,000 (Müller et al. 1984) were used to delineate the contact outcrop between loose rock and bedrock. Valuable information concerning the bedrock surface can also be found in regional hydrogeological studies (e.g., AfU Thurgau, 2003; AfU Zug, 2007; DÖB Zürich, 1986; all available sheets of the 1:100,000 scale hydrogeological Atlas of Switzerland).

The most important source of raw data was the borehole database of the Swiss National Cooperative for the Disposal of Radioactive Waste / NAGRA, the most comprehensive database of the region. In addition several local to regional published and unpublished databases were consulted (Jordan 2004, Jordan & Schuler 2007, Jordan et al. 2008). Some of them also comprise pit and tunnel information. Boreholes and pit bottoms not reaching the bedrock surface were used as minimum value for the construction of the

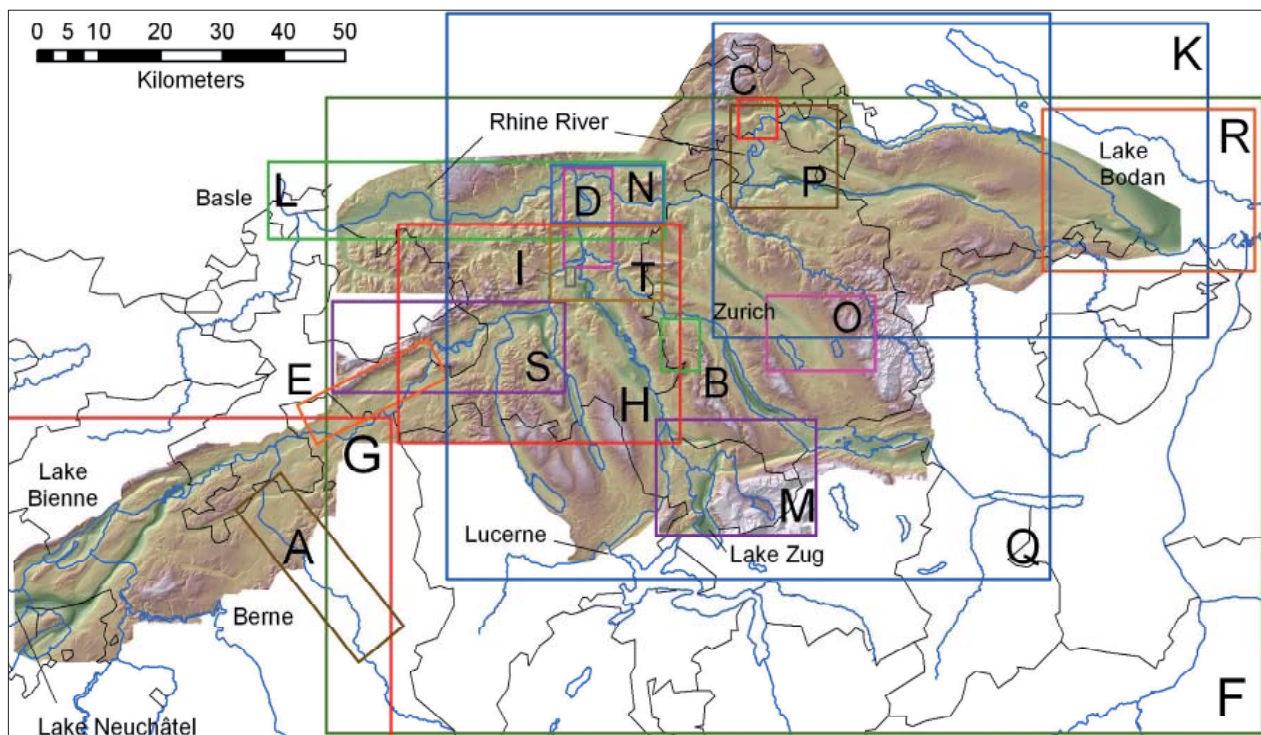


Fig. 1: Actual extent of the DEM and pre-existent isoline maps used for its compilation: A: Werner + Partner AG & Petraqua (1975 and 1976), Werner + Partner AG & Wanner (1981); B: Wyssling (1983); C: Schindler (1982); D: Haldimann et al. (1984); E: Pasquier (1986); F: Wildi (1984); G: Pugin (1986); H: Geol. Inst. Uni Bern (1996); I: Wyssling AG (1996); K: Keller & Krays (1999); L: Wagner et al. (2001); M: AfU Zug (2007); N: Matousek et al. (2000); O: Wyssling (2007); P: Frank (2005); Q: Naef (2004); R: Zaugg & Vogel (2005); Jordan (2004).

DEM. In total, 12,600 point informations were taken in count. The manipulation of this quantity of data pointed out some limitations and some care to take before using the information: The consistency of the database has to be checked in a very early stage in order to recognize and correct input mistakes. Typing mistakes are very common and sometimes difficult to identify in this early stage. Therefore, while digitizing isolines, every data had to be critically considered.

Comprehensive information on hydrological and geomorphological landscape evolution was predominantly available for the Northwest of Switzerland (Hofmann 1977, Keller 1994, Müller et al. 2002, Graf 2003, Hantke et al. 2003). Villinger (1998) gives a general image of the knowledge of the bedrock surface position at an over-regional scale.

### 3. Method

The workflow to reach the bedrock surface DEM comprises four steps:

1. Compilation of data (see Section 2)
2. Interactive design of isolines and valley axes on screen
3. Interpolation of DEM
4. Quality control, going back to step 2 if quality objectives were not achieved.

#### 3.1. Interactive design of isolines and valley axes

The hand design of isolines and valley axes was done by expert on screen using all GIS-facilities but no interpolation code (Fig. 2). All available information has been digitized (if not already done) or scanned and georeferenced. Due to the complexity of the bedrock surface (as a result of its intricate genesis) and the diversity of data type and their respective precision and reliability, it is impossible to expect a statistic surface interpolation algorithm to provide a realistic image of the bedrock surface. The design of rock surface data rather asks for a great knowledge of erosion processes, landscape development and ice age history in connection with spatial sense and decisiveness. In some way, designing bedrock surface has some affinities to forensic plastic surgery, but in a reversed way, i.e., from skin (actual land surface) to skull (bedrock surface). The borehole and outcrop information corresponds to the pin points. And how to interpolate muscles or bedrock, respectively, between these pin points is expert knowledge.

The isolines with an equidistance of 10 or 12.5 m are the backbone of the model. In some regions of higher density of information, and especially in areas with an extremely flat or agitated bedrock surface, equidistance was reduced to 5 m, 2 m or even 1 m (Fig. 2 and 3). The isolines are designed on the following information and priorities:



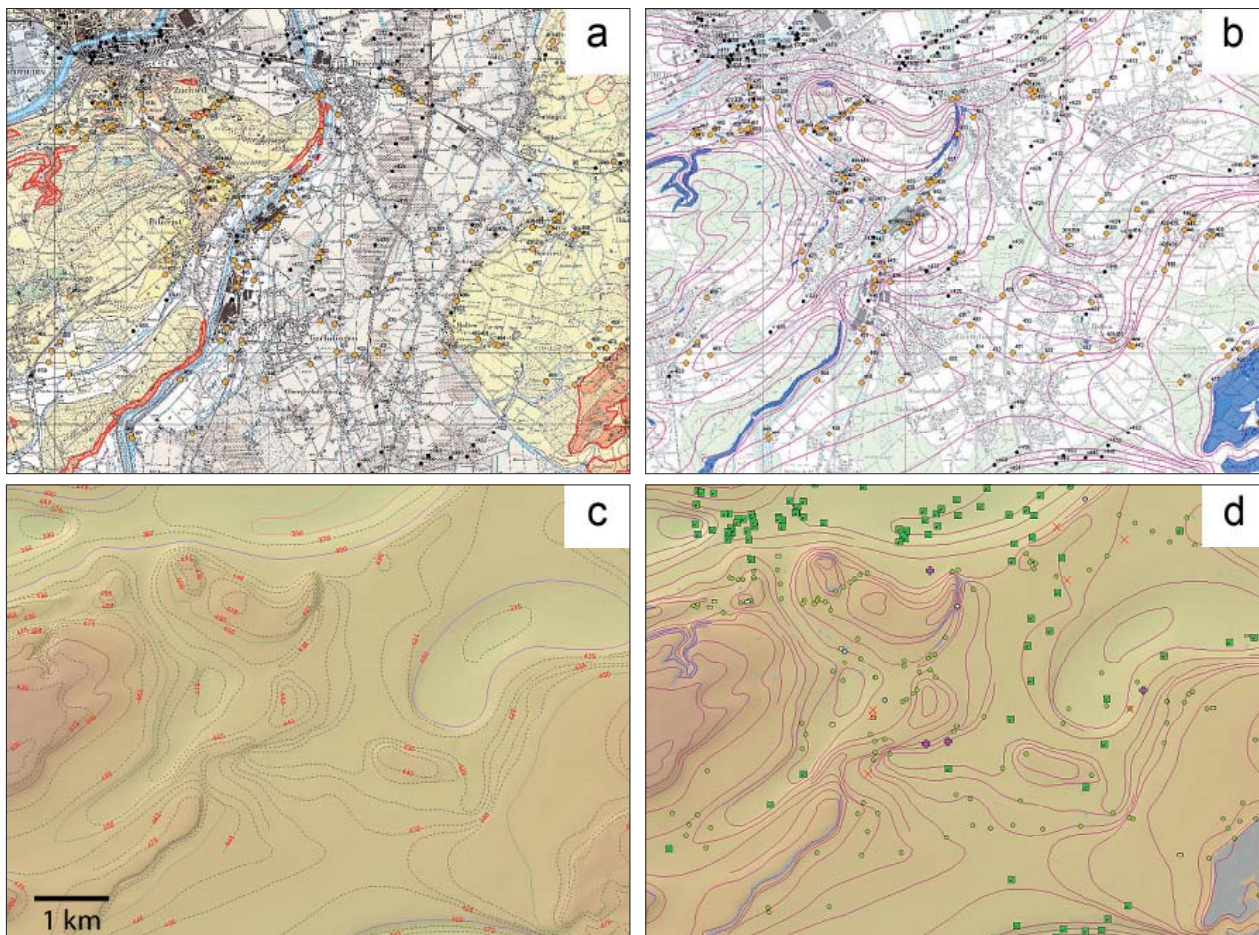


Fig. 2: The four main steps of DEM building: a) compilation of raw data (yellow dots: boreholes; red: outcrop area); b) design of isolines (blue: outcrop area); c) calculation of DEM; d) quality control (green dots and squares: concordance between DEM and borehole data; plus and minus signs: DEM higher or lower than borehole data; crosses bottom of borehole that has not reached bedrock is deeper than DEM; grey: outcrop area calculated by intersection of DEM and DHM25).

1. boreholes and underground construction reports
2. outcrop information about bedrock surface
3. the spatial distribution of outcrops referred to the geological maps
4. the bottom of boreholes that did not reach the bedrock surface
5. regional interpretation of the bedrock surface found in older references
6. bedrock surface in interpreted cross sections
7. migrated seismic profiles or their interpretation when available
8. regional works about landscape evolution (e.g. paleo river networks)
9. general hydrological and glaciological concepts.

Another important element for the modeling of the bedrock surface are the valley axes (Fig. 3). They describe the interpreted paleo flow paths of rivers. They were defined for first and second order rivers as well as important side valleys and gorges. For large glacial valleys, the flow paths were defined in the simplest way. In more complex situations, where valley axes cross, a hierarchy was defined in order to reach a higher detail level.

### 3.2. Raster interpolation

The range of methods for interpolation of punctual data comprises Nearest Neighbour, bilinear interpolation Inverse Distance Weighting (IDW), Kriging, etc. These methods provide contrasting results in modelling topography. Schmidt and Bill (2000) describe the application of different methods to the specificity of DEMs; it appears that very few methods are able to interpolate between the lines without degenerating them in a succession of points. Spline interpolation (Mitasova et al. 1993) is a powerful method when using isolines. For the particular purpose of a dataset including also valley axes there was a need to include the different types of data without losing their specific geometry. The ANUDEM algorithm (Hutchinson 1988, 2000) was chosen for its ability in doing so (Fig. 2 and 3). This method is particularly indicated as it was specifically developed for hydrologically correct DEMs. These algorithms are integrated in the „topo-to-raster“ function of ArcGIS Spatial Analyst (ESRI, 2007). Borehole data were not directly integrated in the calculation but were used for quality control after each interpolation (Fig. 4). Additional isolines were added after each intermediary interpolation step in order to eliminate artificial smoothing of the surface due to high isoline spacing.

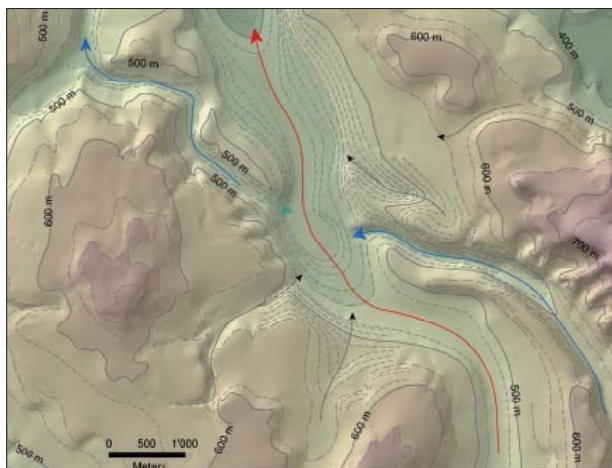


Fig. 3: Valley axes in an area of crossing valleys near Zurich: the older glacial valley (red) was filled by gravel before it was crossed by a younger fluvial valley (blue). At the beginning of the lower section of the fluvial valley with a valley axis higher than the axis of the glacial valley, a reverse axis (turquoise) has to be introduced, to get a good result. Black: secondary valley axes.

### 3.3. Quality control

The quality control was a continuous process of the production of the DEM and was applied all along the workflow. High quality objectives were set before the data compilation phase started. Primarily the best coherence between the borehole database and the outcrop information from geological maps had to be reached. With the later integration of various data which sometimes deviated far from the primary data set, a revision and refining of the tolerance was applied (Fig. 2 and 4):

- for boreholes that reached the bedrock: maximum deviation 5 m, in some complex areas a tolerance of 10 m was allowed.
- for borehole not reaching the bedrock: the modelled surface should be deeper the bottom of the bore-hole (tolerance: 1m).
- outcrop areas have to be within the 5 m tolerance limit:

For example: in areas where the model shows no Quaternary cover, the Quaternary thickness should not exceed 5 m.

- borehole data falling far from the accepted model were excluded and returned to the owner for verification.

## 4. Result and conclusions

The result product is a raster elevation model with a grid size of 25 meters. The present state of the DEM stretches from Lake Neuchâtel in the West to Lake Constance in the East and from the Rhine River in the North to the Lake Zug in the South (Fig. 1). It is expected that the spatial extent will be expanded thank to further fruitful collaborations. Within its actual limits, the dataset is subject to continuous improvement and densification depending on the new raw data findings especially from boreholes.

In a first conclusion, the attempt to bring all informations on bed rock surface within a specific area to a comprehensive DEM was successful. Beyond controversy, the DEM comprises, despite all objectivity in the workflow, many subjective interpretations by the DEM editors or inherited from older interpretations. However, the DEM is a good base for further discussions on plausible alternatives.

The DEM allows direct comparison with datasets of similar resolution, e.g. from the Swiss Federal Office of Topography. Classic DEM derivatives can be calculated out of the Bas\_Quat model, the most interesting being the hill shade in 2D and perspective views and block diagrams in 3D. The DEM allows a detailed examination and the visualization of many significant and interesting structures. The most spectacular comprise abandoned valleys, some of them crossing actual hill ranges, over deepened valleys that follow mostly the actual axes, but being much deeper than the recent valleys, or isolated sheepback shaped hills reaching nearly the surface of valleys now filled by thick loose rock sediments (Fig. 3 and 5). To be honest, it has to be noted, that many of these structures have been already described in the literature. But the present work is not in the first instance a research

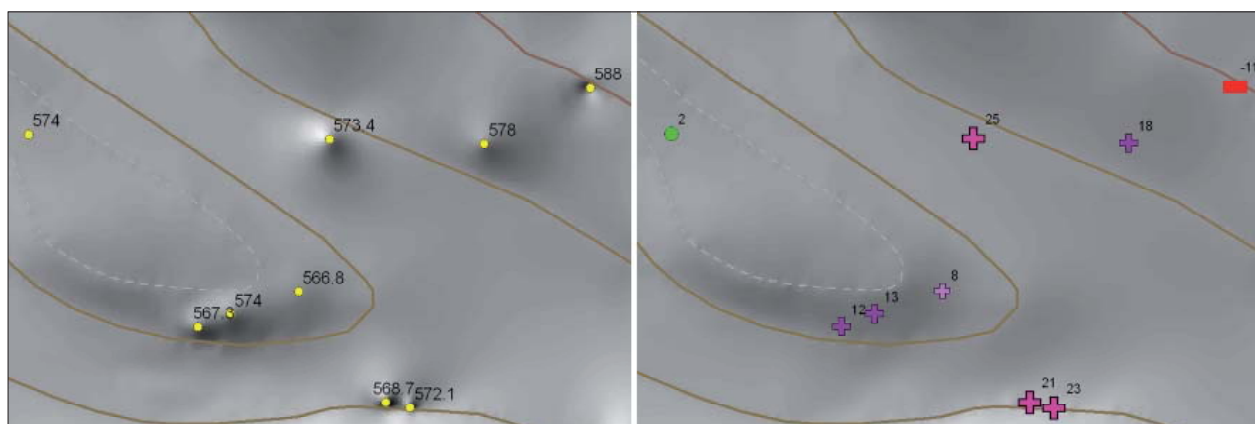


Fig. 4: Considering borehole information. Left: point information is directly integrated in the interpolation along with isolines. It creates spots and funnels on the surface. The value is the altitude (in meter) of the modeled surface corresponding exactly to borehole data. Right: point information is initially used for the drawing of isolines and in a further step as control points. The value is the deviation (in meter) from the model to the borehole data. This helps for corrections of the isoline model.



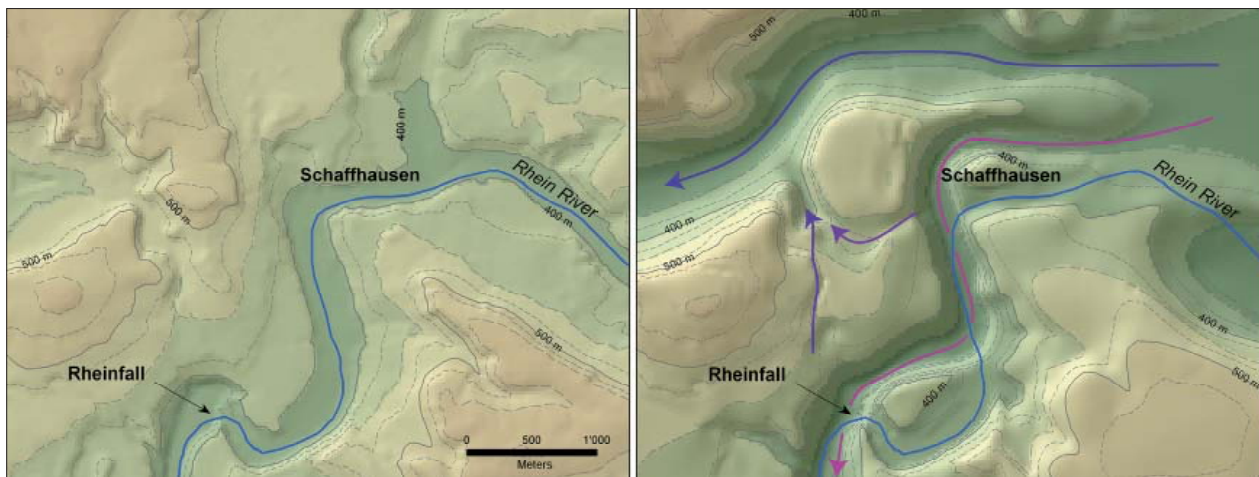


Fig. 5: Recent and former valleys in the vicinity of Schaffhausen: left: actual topography; right bedrock surface showing the traces of older courses of the Rhine river and its tributaries (arrow lines going in age from blue-purple to red-purple). At the Rhine Falls waterfalls, the actual Rhine river drops in one of his antecedent valleys.

work of Swiss Plateau bedrock surface, but an attempt to bring all available information in a coherent DEM.

In a second conclusion, the DEM of the basis of Quaternary cover is an important instrument for the visualization, the control and the further evolution of hydrological, geomorphological and geological concepts. Furthermore, it is a valuable instrument for small to middle scale geotechnical and civil engineering tasks.

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# Documentation of the Retreat of Gössnitzkees and Hornkees Glaciers (Hohe Tauern Range, Austria) for the Time Period 1997-2006 by Means of Aerial Photogrammetry

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## Abstract

*Gössnitzkees and Hornkees are two small cirque glaciers (2006: 58.9 and 30.6 ha, respectively) located in the Schober group of the Hohe Tauern range of the Eastern Alps in Austria. The glacier history of both glaciers has already been documented for the time period 1850-1997 based on field evidence, historical maps and aerial photographs. The temporal change in area, surface height, and volume of both glaciers was presented numerically and graphically. In this paper we intend to extend the observation period to the present. Aerial photographs of 2002 and 2006 covering the area of interest were made available by the Tyrolean regional government and the Austrian Federal Office of Metrology and Surveying, Vienna. A digital photogrammetric workflow was applied to the image data provided. Based on these multi-temporal data we computed the volumetric and areal change of both glaciers along with the respective numerical values at elevational intervals of 50 m. The change in surface height and area of both glaciers is shown in thematic maps. The results include a new orthophoto map at 1:10,000 scale representing the glacial stage of 2006 and an estimation of the equilibrium line altitude.*

## 1. Introduction

Gössnitzkees and Hornkees („kees“ is the local name for glacier) are two neighboring cirque glaciers (46°58' N, 12°46' E) situated quite remotely in the center of the Schober group (Fig. 1). Located south of the main crest of the Hohe Tauern range, the Schober group comprises more than 30 peaks higher than 3000 m a.s.l. – the highest peak being Petzeck at 3283 m –, and 29 relatively small glaciers (mean area 0.18 km<sup>2</sup>, cp. Lieb, 1987: 74). Inner-alpine continental climate prevails. Touristic and scientific interest in this mountain group has always been relatively low compared to the well-known Glockner and Goldberg group to the north, which also includes Austria's largest glacier, Pasterze. The remoteness of the area and the lack of touristically attractive large glaciers are the two main reasons why the Schober group has received little attention to date. Today the main

parts of the Schober group belong to the Hohe Tauern National Park (founded in 1981).

Lieb (1987) and Buchenauer (1990) were among the first scientists to study glacial and periglacial phenomena in this mountain group. Measurements on glacier length change were commenced at Gössnitzkees by Lieb and Kaufmann in 1982, and one year later at Hornkees (for more details see Kaufmann and Lieb, 1985). Since then the terminus positions of the two glaciers have been measured annually. The Institute of Geography and Regional Science, University of Graz, is still in charge of this long-term monitoring program. Glacier reports are submitted annually to the OeAV (Austrian Alpine Club) for documentation and further analysis.

The glacier history of both glaciers was reconstructed for the time period 1850-1997 within a research project carried out by the Institute of Geography and Regional Science, University of Graz, and the former Institute of Geodesy, Graz University of Technology, with financial support of the Hohe Tauern National Park Service. The results of this project were presented and published, for example, in Kaufmann et al. (1999) and Kaufmann and Lieb (2002). The project also included the production of an orthophoto map of the two glaciers at 1:10,000 scale (for the map see Lieb, 2000) and a video film showing the workflow and results such as computer animations of glacier retreat (Kaufmann and Plösch, 2001).

The glaciers in the Schober group have been shrinking significantly due to past and ongoing atmospheric warming (climate change). According to Wakonigg (2007: 103), the mean annual air temperature in Austria has increased by 1.8° C during the observation period 1885-2003. It is expected that the glaciers in the Schober group will have disappeared by the middle of this century if the current climate continues. The small size of the glaciers, their specific topographic situation (with small accumulation areas), and their comparatively low mean altitude are factors which amplify the rate of deglaciation even further. The present

study intends to continue the existing glacier history record to the present time (2006). In this context it should be mentioned that the new Austrian glacier inventory of 1998 – the first one dates from 1969 – has been published recently (Lambrecht and Kuhn, 2007). As far as the Schober group is concerned, detailed information is only available on areal changes in glaciation (1969-1998). Glacier volume loss could not be quantified due to the lack of an area-wide digital elevation model (DEM) of 1969. One of the tasks of the ongoing ALPCHANGE project, which is coordinated by the Institute of Geography and Regional Science, University of Graz, and financed by the Austria Science Fund (FWF), is to reconstruct the glacier history of the Hohe Tauern range, which also includes the Schober group (for more information please see Alpchange, 2007). The latter work is carried out in close cooperation with the Institute of Meteorology and Geophysics, University of Innsbruck (Avian, pers. comm., 2007), and it could benefit from the study presented in this paper.

## 2. Study Area and its Glaciers

The mapping area of the present study covers the same extent as defined in the previously described glacier history project. As will be explained in more detail in the following chapter, aerial photographs of 2002 and 2006 were at our disposal. The area of interest (10.5 km<sup>2</sup>, see Fig. 2) comprises not only Gössnitzkees and Hornkees but also several other smaller glaciers and at least three rock glaciers, including Weissenkar rock glacier. The Austrian glacier inventory of 1969 (as shown in Lang and Lieb, 1993) lists a total of 9 glaciers which are completely or partly located within the study area. Each glacier has a unique code number for identification but not always an official name. All of these glaciers are described in detail in Lieb (1987). Oblique aerial photographs reproduced in Lang and Lieb (1993) show very nicely the areal extent of glaciation in the mid-1980s. In 2006 only 6 glaciers were classified as glaciers by the authors of the present paper.

Glacier MO 15 no longer existed in 2006. This is also true for glacier MO 14, however, a shallow layer of debris-covered ice/firn (1.5 ha) and a small bergschrund was still visible. Kögele glacier (MO 9) was difficult to classify, since it is heavily debris-covered, and visual interpretation of the aerial photographs was hampered by low contrast. According to Kellerer-Pirklbauer and Kaufmann (2007) glacier ice still exists under the debris, preferably on the shady northern slopes.

The size of Gössnitzkees was 58.9 ha in 2006. Gössnitzkees is characterized by its distinct debris cover (over 2/3 of the area) and its seasonal proglacial lake (7095 m<sup>2</sup> in 2006). The cirque glacier is nourished mostly by avalanches coming from the steep cirque headwalls and couloirs, larger accumulation zones are missing. The coverage of Gössnitzkees at the time of 1850 (end of the so-called Little Ice Age) can be nicely traced based on the present-day photographs (see Fig. 2). Glacier area has decreased since then by 62.2%. The local distribution (layer thickness) of the supraglacial debris and the glacier surface topography (longitudinal ridges and furrows) cause differential melt of the glacier ice (cp. the terrestrial laser scanning study of Kellerer-Pirklbauer et al., 2005). Moreover, meltwater channels reshape the glacier surface, producing deeply incised meandering trenches. Since 1996 our Institute has been carrying out annual geodetic measurements in August. Two longitudinal profiles, the glacier terminus position, the areal extent of the proglacial lake, and 10 velocity markers are measured for reasons of comparison (Kienast and Kaufmann, 2004). The glacier flow velocity is rather low and ranges between 0.2 and 0.5 m a<sup>-1</sup>. Glacier surface mapping of a representative section of the glacier is also done on an annual basis applying terrestrial photogrammetry using low-cost digital consumer cameras (Kaufmann and Ladstädter, 2004). It is to be noted that a comparatively large area (2006: 3.3 ha) of the eastern extent of Gössnitzkees (located W of Gr. Hornkopf) became fully disconnected from the main glacier body at the end of the 1990s, causing an additional reduction in area and volume of the glacier.

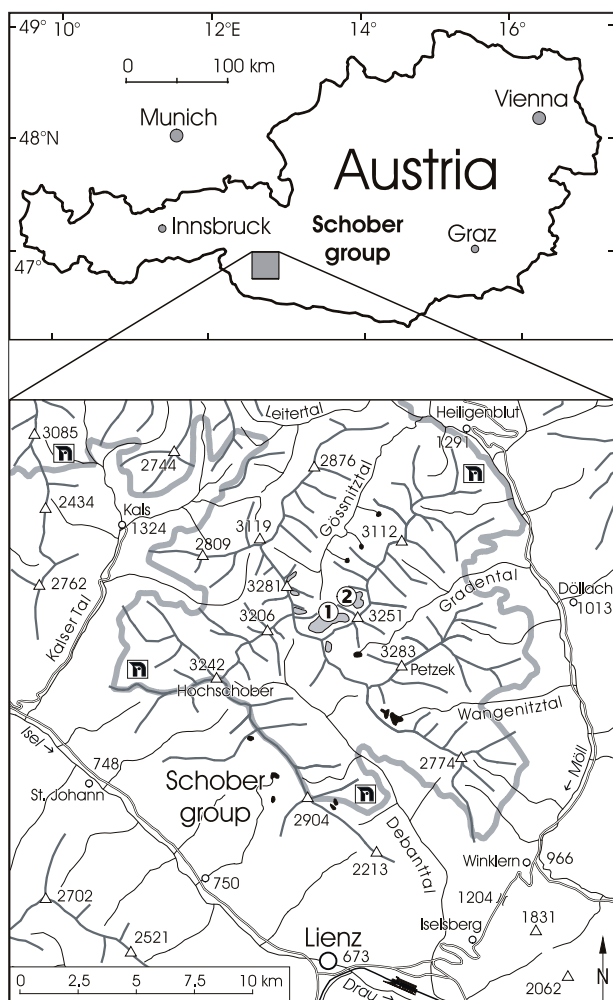



Fig. 1: Location of Gössnitzkees ① and Hornkees ② in the Schober group, Hohe Tauern range, Austria. Large parts of the Schober group are within the Hohe Tauern National Park 

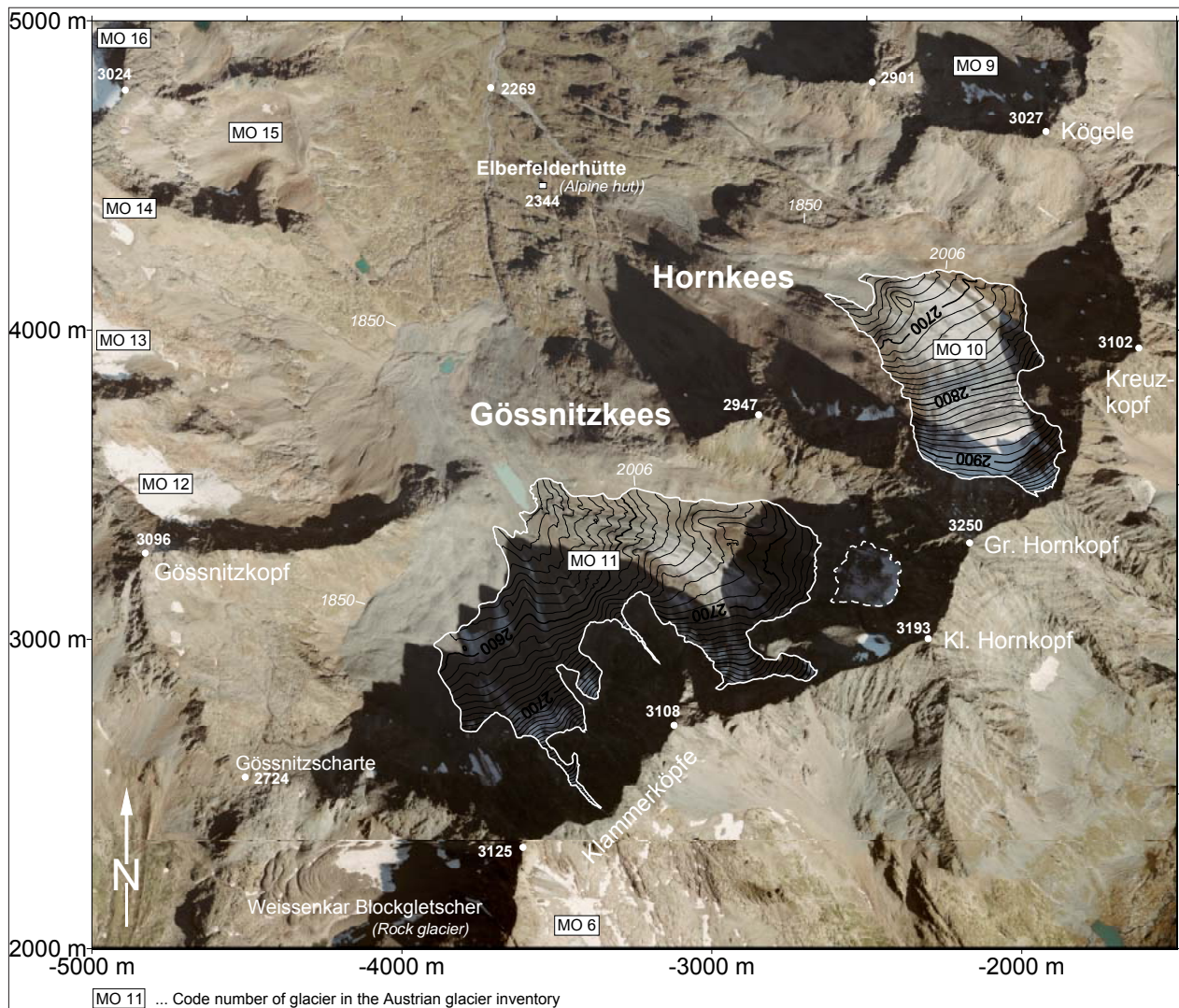


Fig. 2: Orthophoto of the study area. The color photographs forming the orthophoto mosaic were taken on September 1 and July 20, 2006 (area south of Gössnitzscharte and Klammerköpfe), respectively. Photographs © BEV, Vienna. Elberfelderhütte is a mountain hut maintained by the German Alpine Club (DAV). The letters „MO“ of the glacier code numbers refer to the catchment area drained by the river Möll (cp. Fig. 1).

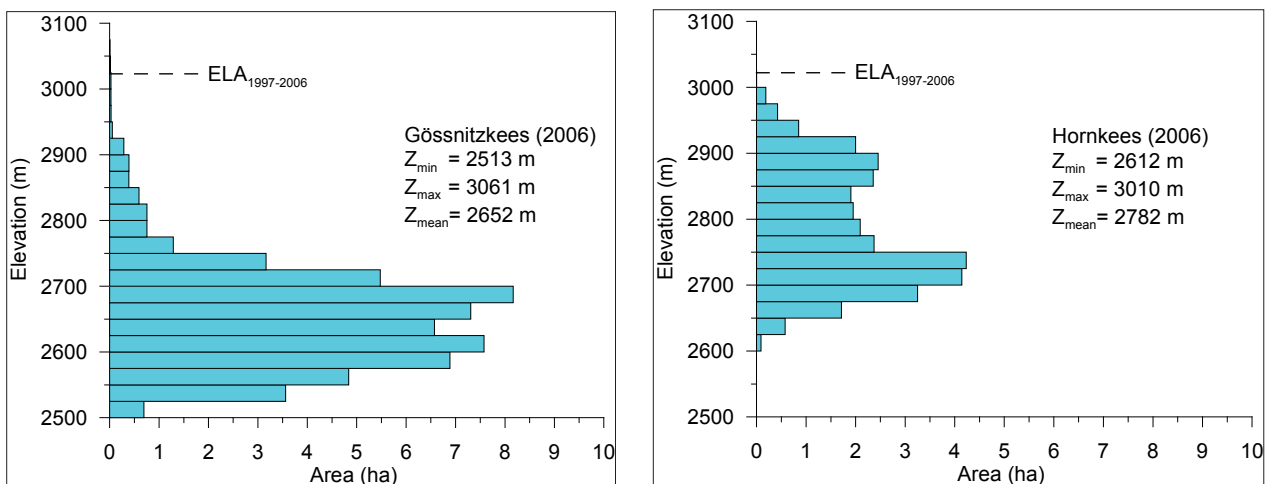


Fig. 3: Area-elevation distribution of Gössnitzkees and Hornkees for 2006. The dashed line shows the mean equilibrium-line altitude (ELA) for the time period 1997-2006.



Date of acquisition	Camera type	Mean image scale	Film type	Pixel size (µm)
September 18, 2002	Zeiss RMK TOP 30	1:14,000	color positive	15
September 21, 2006	Leica RC 30	1:15,900	color positive	15

Fig. 4: Technical parameters of the aerial photographs

Notes: In the 2006 data set, the southern part of the project area (south of Gössnitzkees and Klammerköpfe/MO 6) is covered by photographs taken on July 20, 2006. Therefore, these regions (around Weissenkar rock glacier and Klammerkees) show much more snow in the orthophoto mosaic than the main part in the north.

Hornkees, which is also a good example of a cirque glacier, covered an area of 30.6 ha in 2006. Its area-elevation relationship is more favorable in terms of future glacier survival as compared to Gössnitzkees. See Fig. 3 for comparison. Some of the prominent moraines of the 1850 glacial stage can be easily identified in the orthophoto (cp. Fig. 2). Based on the reconstruction of the maximum glacial extent given in Lieb 2000, the areal reduction in glacier size is about 66.6 % with respect to present glaciation. Debris cover on Hornkees is far less extensive than on Gössnitzkees and is limited to the border areas in the W, N and E of the glacier. Delimitation of the glacier boundary was quite difficult especially in the northern parts of the glacier.

### 3. Aerial Photographs of 2002 and 2006

The basis of the present study are digitized metric aerial photographs provided by the Tyrolean regional government and the Austrian Federal Office of Metrology and Surveying, Vienna. The technical parameters of both data sets are given in Fig. 4. The color photographs were taken more or less at the end of the hydrologic/balance year and are thus ideal for glaciological studies. Moreover, there is no snow cover except for some perennial snow patches. The long cast shadows visible in both data sets are due to the acquisition time late in the year and, most of all, due to early flights in the morning.

## 4. Photogrammetric Mapping

In the preceding (glacier history) project the photogrammetric work, i.e. aerotriangulation and feature extraction, was still done on an analytical plotter based on analog photographs (for technical details see Kaufmann et al. 1999). This time we pursued a digital photogrammetric workflow using a digital photogrammetric workstation from Intergraph.

### 4.1. Photogrammetric orientation

The elements of exterior orientation of all photographs were additionally provided by the owner of the photographs. Since the aerotriangulation of the preceding project was carried out in a local coordinate system (approximate to the Austrian Gauss-Krüger coordinate system), we finally decided to keep this local coordinate system as a reference in order to avoid time-consuming data conversions and recalculations. For the sake of simplicity, a set of evenly distributed stable ground control points, which had already been used for image orientation in the preceding project, were measured in the 2002 and 2006 stereo models. Coordi-

nate offsets of the 1997 system to the other two “georeferenced” systems were determined. No significant planimetric shift was detected between the local system and the given photogrammetric, i.e. Gauss-Krüger, coordinate systems. However, two different systematic offsets in height were detected and appropriately taken into account for height adjustment.

### 4.2. Feature extraction

The primary goal of the photogrammetric mapping workflow was (1) to obtain high-resolution DEMs of Gössnitzkees and Hornkees for the two epochs 2002 and 2006, and (2) to update the DEM of 1997 for orthophoto production. The first step was to update the photogrammetric manuscript of 1997 to generate a new one for 2006. This was accomplished interactively using stereoscopic vision at the digital photogrammetric workstation. 3D superimposition made it possible not only to check the perfect geometric fit of the 1997 data against the 2002 and 2006 terrain situation but also to detect areas where surface height change had occurred, for example, areas which were snow-covered in 1997 and, of course, areas affected by glacier melt. As already mentioned, data capture and editing was done interactively. Continuous contrast enhancement was indispensable in dark areas (shadow areas) and also in bright areas (glacier surfaces). For the convenience of the photogrammetric operator, the mapping area around Gössnitzkees and Hornkees was limited by the glacier boundary of 1997. The digital manuscripts comprise contour lines, ridge lines, drainage lines and spot heights. The glacier boundaries of Gössnitzkees and Hornkees were traced in a second step.

### 4.3. Delimitation of the glacier boundaries

As already indicated previously, the tracing of the boundaries of a debris-covered glacier may be troublesome or sometimes even impossible, not only in nature but also in photographic stereo models. When superimposing the 3D map of 1997 onto the more recent stereo models it was found that the delimitation of the glacier boundary of Gössnitzkees was slightly wrong in two areas. The 1997 glacier boundary could only be drawn approximately because delimitation was made difficult both by a uniform debris mantle and the absence of topographic evidence of underground glaciation. It should be noted that slopes with shallow glaciation or with dead ice, or sliding zones near recently deglaciated areas can also complicate the delimitation of debris-covered glaciers.

Assuming substantial glacier retreat (as observed in recent times), the glacier boundary of a certain glacial stage can be cross-checked or drawn in a supervised manner using the surface height information of a younger stage. If the glacier is growing and surface height is therefore increasing, the surface data of the previous (older) glacial stage can be used to immediately check the glacier boundary of the younger stage. However, the previous (minimum) glacial stage cannot be controlled in this specific case of glacier development.

In general, the intersection of the (modified) glacier surface with the stable terrain defines the (sometimes invisible) glacier boundary. This fact can be utilized interactively using a digital photogrammetric workstation, or, which is more convenient, off-line, by overlaying the contours of both stages derived from the respective DEMs. This procedure has already been successfully applied in the preceding project using transparent analog manuscripts and a light table. Following this general procedure, the glacier boundaries of 1997 could be updated appropriately, and the boundaries of 2002 could be traced with confidence. The glacier boundaries of the 2006 stage can only be cross-checked with upcoming topographic height information of a younger stage, presuming that glaciers continue to retreat. The requested height information can be provided either by another aerial survey or by airborne laser scanning (cp. Würländer et al., 2004). Terrestrial means of 3D surface data acquisition are also possible, such as tacheometry, terrestrial laser scanning, or terrestrial photogrammetry (references have already been given previously).

#### 4.4. Glacier masks and digital elevation models

Glacier masks (binary images) and digital elevation models of both glacial stages, 2002 and 2006, were produced as a basis for analysis of glacier change in area and volume. As for the glacial stage of 1997, the already existing DEM of 1997 was adopted, but a new glacier mask had to be derived

from the corrected glacier boundary polygon discussed in the previous section. DEMs were computed using the program Terrain Analyst of Intergraph. For the ease of further processing, raster-based DEMs with a grid-spacing of 2.5 m were derived from the primary TINs (triangulated irregular networks). Binary masks with a GSD of 2.5 m were derived from vector data (dxf-Autocad) defining the glacier areas.

#### 4.5. Orthophotos

Finally, four aerial photographs of each epoch were needed to completely cover the study area. Orthorectification was

accomplished using the software BaseRectifier of Intergraph. I/RAS C of Bentley/Intergraph was used as a mosaicking tool. Contrast and color balancing of the individual orthorectified photographs to be merged in a single orthophoto mosaic was quite difficult for both epochs, because some of the aerial photographs of 2002 had a red tint, and those of 2006 were taken in two different seasons of the year. The problem was best solved interactively using Photoshop. Orthophotos with a GSD of 0.25, 0.5, 1, and 2 m were provided for further analysis and visualization purposes.

### 5. Quantification of Glacier Change

Data evaluation was performed serving glaciological questions (cp. Fountain et al., 1997; Haeberli et al. 1998; Orlemanns, 2001; Kaser et al., 2003). Glacier change in area and volume was calculated using an in-house developed computer program (for more details see Kaufmann and Plösch, 2000). A similar computer program was used for the new Austrian glacier inventory of 1998 (cp. Lambrecht and Kuhn, 2007; Würländer and Eder, 1998). Volumetric change was quantified for (1) areas which became ice-free, (2) permanently ice-covered areas, and (3) newly ice-covered areas. Information concerning area and surface height change was also provided in elevational bands, e.g.,

Period	Gössnitzkees		Hornkees	
	Change in area (ha)	Change in area (ha a-1)	Change in area (ha)	Change in area (ha a-1)
1850/1873	-9.45	-0.41	-7.21	-0.31
1873/1929	-13.82	-0.25	-13.92	-0.25
1929/1954	-35.01	-1.40	-26.58	-1.06
1954/1969	-4.01	-0.27	-1.70	-0.11
1969/1974	-3.35	-0.67	-0.51	-0.10
1974/1983	+0.24	+0.03	-0.45	-0.05
1983/1992	-11.87	-1.32	.	.
1992/1997	-2.61	-0.52	-5.20 (1983/97)	-0.37 (1983/97)
1997/2002	-12.32	-2.46	-3.10	-0.62
2002/2006	-4.48	-1.12	-2.38	-0.60
1850/2006	-96.68 (-62.2 %)	-0.62	-61.03 (-66.6 %)	-0.39

Fig. 5: Changes in area of Gössnitzkees and Hornkees since 1850.

Notes: The changes in area are given in hectares (ha = 0.01 km<sup>2</sup>); annual values were calculated by simply dividing the area by the number of years; evaluation of the entire Hornkees glacier was not possible for the 1992 stage. Numerical values for the period 1850-1997 are taken from Kaufmann and Lieb, 2002. Note that the values for Gössnitzkees covering the period 1992/1997 have been updated.

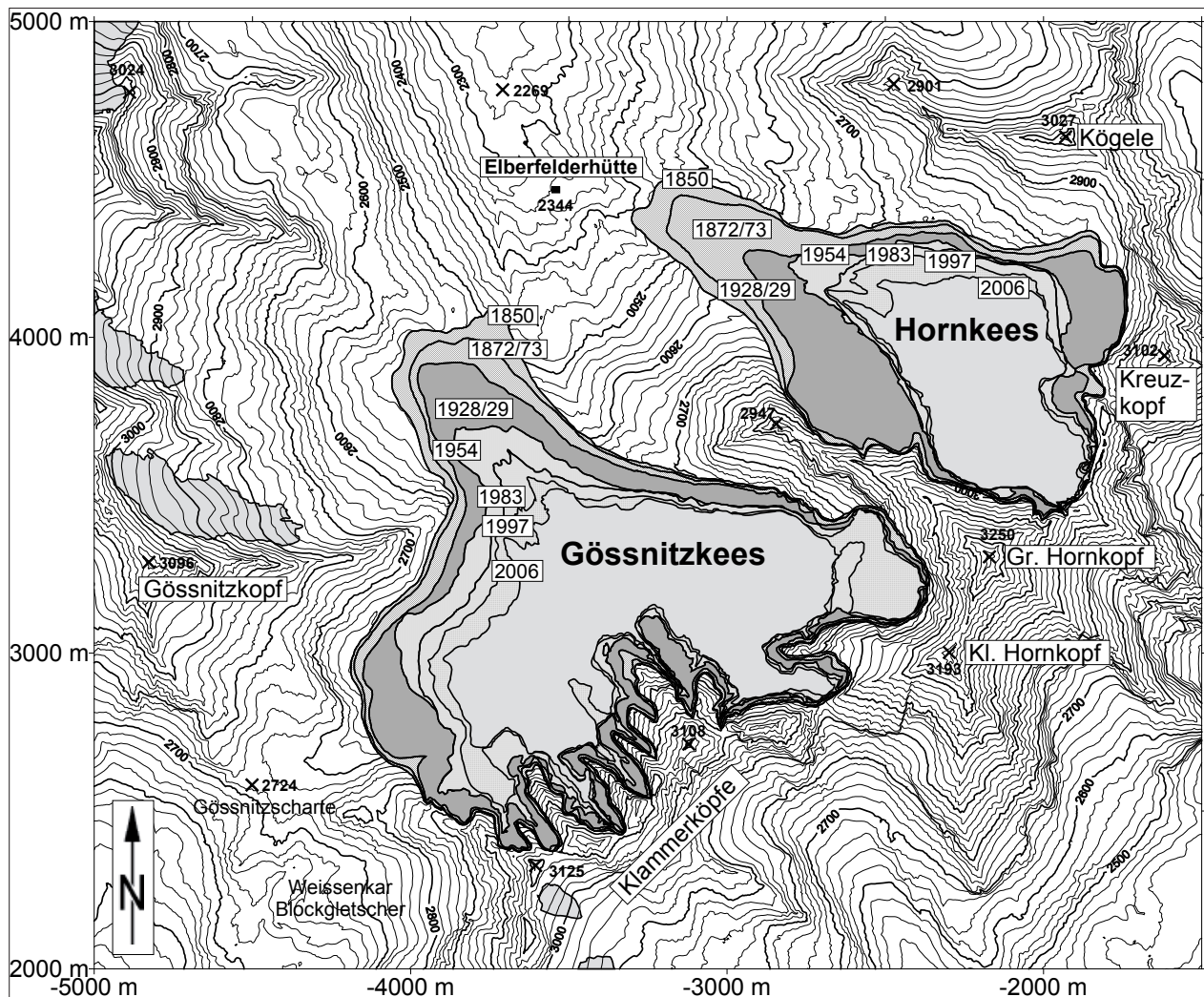


Fig. 6: Thematic map showing the changes in area of Gössnitzkees and Hornkees since 1850.

Period	Gössnitzkees		Hornkees	
	Volumetric change (106 m <sup>3</sup> )	Volumetric change (106 m <sup>3</sup> a <sup>-1</sup> )	Volumetric change (106 m <sup>3</sup> )	Volumetric change (106 m <sup>3</sup> a <sup>-1</sup> )
1850/1873	-11.98	-0.52	-7.80	-0.34
1873/1929	-17.08	-0.31	-12.63	-0.23
1929/1954	-30.65	-1.23	-12.49	-0.50
1954/1969	-3.09	-0.21	-0.40	-0.03
1969/1974	-2.49	-0.50	-0.36	-0.07
1974/1983	+0.55	+0.06	+0.87	+0.10
1983/1992	-8.83	-0.98	.	.
1992/1997	-3.93	-0.79	-5.35 (1983/97)	-0.38 (1983/97)
1997/2002	-3.83	-0.77	-1.87	-0.37
2002/2006	-3.11	-0.78	-1.55	-0.39
1850/2006	-84.52	-0.54	-41.61	-0.27

Fig. 7: Changes in volume of Gössnitzkees and Hornkees since 1850.



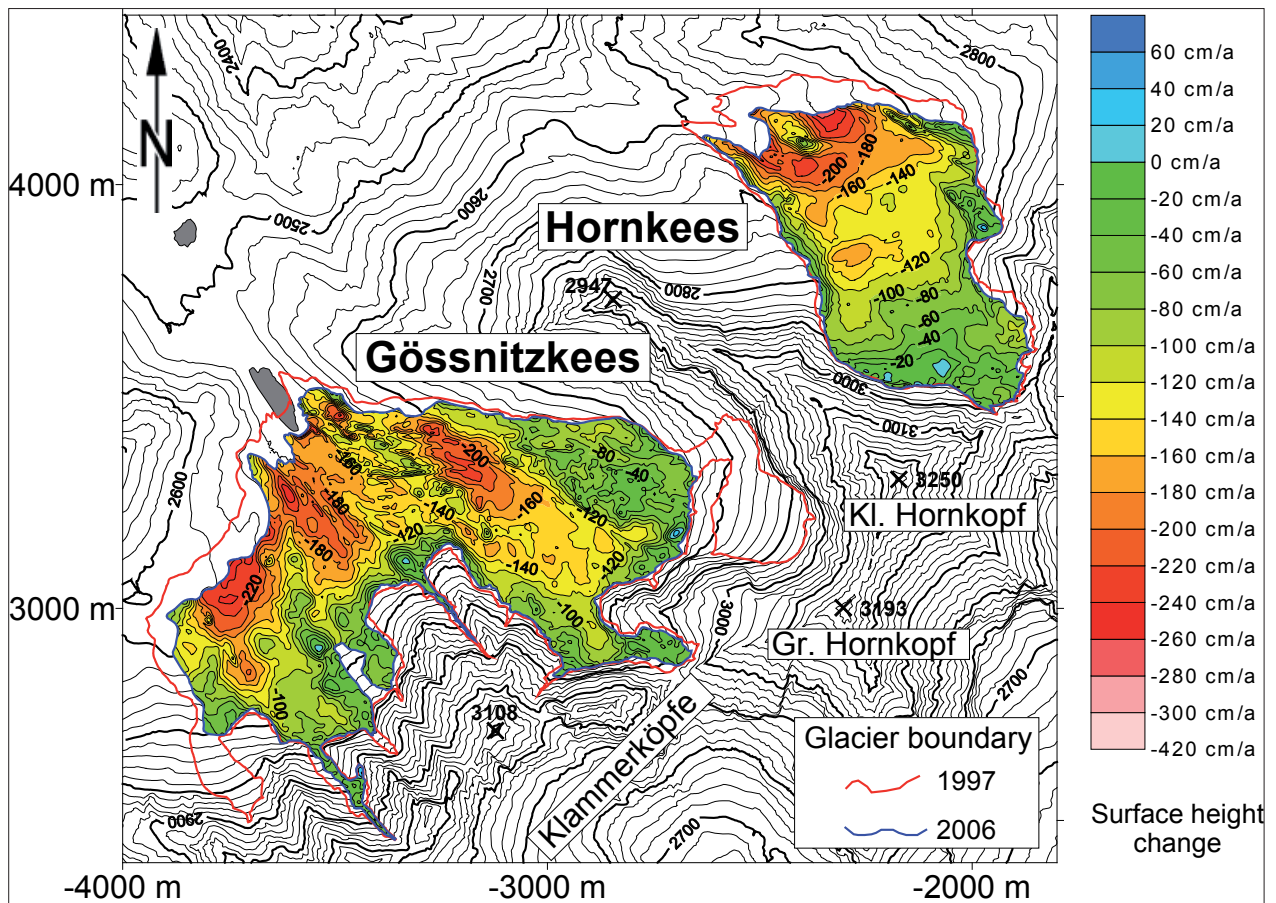


Fig. 8: Thematic map showing the mean annual surface height change of Gössnitzkees and Hornkees for the period 1997-2006.

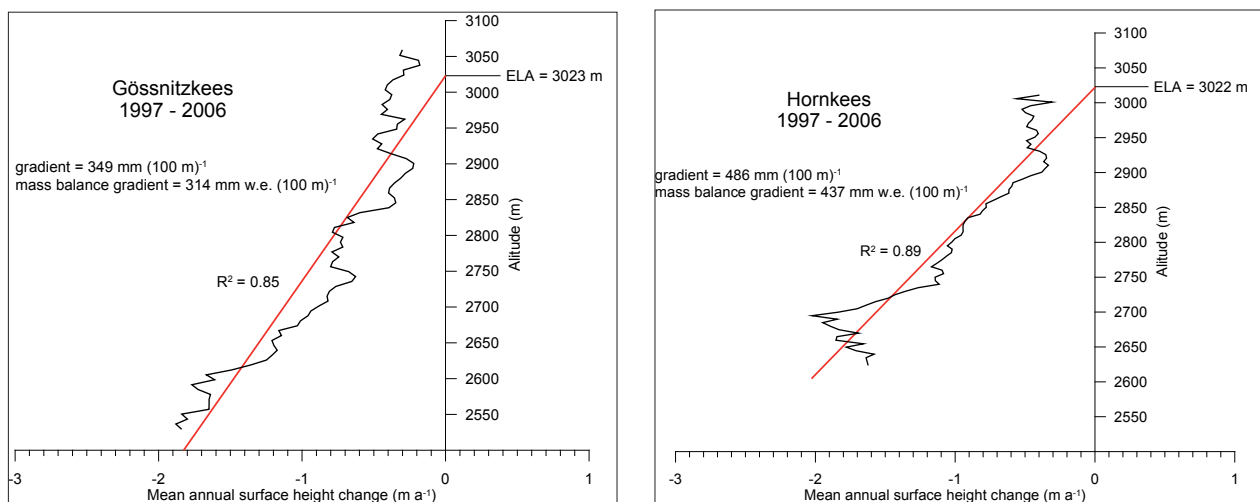


Fig. 9: Estimation of the equilibrium line altitude (ELA) for Gössnitzkees and Hornkees for the time period 1997-2006.

at intervals of 10, 25, 50, and 100 m. Numerical values were also given in relative numbers (%) and in cumulative notation for reasons of comparison. The listings and tables also include the specific net mass balance in water equivalent (w.e.). Finally, the whole glacier history of both glaciers comprising 11 glacial stages between 1850 and 2006 was re-calculated applying one single batch job obtaining all information for selective analysis by the glaciologist.

## 6. Results

In this paper we will present some of the most important results obtained numerically and/or graphically.

### 6.1. Glacier change in area

Gössnitzkees covered an area of 75.7 ha in 1997, 63.3 ha in 2002, and 58.9 ha in 2006; the corresponding values for Hornkees are 36.1 ha, 33.0 ha, and 30.6 ha, respectively. Fig. 5 lists the changes in area of both glaciers since 1850. Both glaciers have already lost almost 2/3 of their areal extent since 1850 (cp. Fig. 6).

### 6.2. Glacier change in volume

From a glaciological point of view, glacier change in volume is of great importance since it directly reflects glacier mass balance. The numbers given in Fig. 7 show the volumetric changes of both glaciers since 1850. The values given can be converted to specific net mass balances. Both glaciers have continuously retreated since the early 1980s. Fig. 8 and 9 confirm that the glaciological situation for both glaciers is quite dramatic. The mean annual vertical surface height change profile (i.e. vertical mass balance profile) was negative for all elevational zones for the period 1997-2006. This means that the accumulation zone has practically disappeared, and the whole glacier area is affected by ablation. The two glaciers are completely out of balance.

Annotations: See Fig. 5.

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### 6.3. Estimation of ELA

The equilibrium line altitude (ELA) for the time period 1997-2006 was estimated at c. 3020 m for both glaciers by linear regression (cp. Fig. 9).

### 6.4. Scenario for the future

Based on the estimated mean ice thickness and the calculated mean annual surface height change (1997-2006) Gössnitzkees will probably be completely melted by 2033 and Hornkees by 2029.

## 7. Conclusions

In the present study the existing glacier history (1850-1997) of Gössnitzkees and Hornkees was updated by two additional glacial stages, 2002 and 2006, thus finally covering a time span of 156 years. 3D feature collection for deriving glacier DEMs and glacier boundaries was performed interactively. Strong cast shadows in the aerial photographs provided were a challenge for the photogrammetric operator. Delimitation of the glacier boundaries in the debris-covered areas would have been more difficult or even impossible without combined analysis of the available data, especially of the multi-temporal DEMs. Numerical values of glacier change in area and volume are presented. Ongoing glacier retreat suggests that both glaciers will vanish around 2030. This implies that all other glaciers of the Schober group will share the same fate, sooner or later.

## Acknowledgments

Aerial photographs of 2002 (© Amt der Tiroler Landesregierung, Innsbruck, 2004) were given free of charge by the Tyrolean regional government with the help of H. Gspan. Aerial photographs 2006 © Austrian Federal Office of Metrology and Surveying, Vienna.

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# Interdisciplinary Research in High Mountain Areas of North-East India

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## Abstract

*The Himalayan Mountains have always been a fascinating area for cartographers, scientists and the general public. With four of the greatest Asian cultures – China, India, Persia and Tibet – converging in the Western Himalayas and the trade and pilgrimage routes that cross them, the vast number of cultural artefacts available has prompted much research.*

*At the University of Vienna, Austria, an interdisciplinary research network, working under the 'umbrella' of the Austrian Science Fund, is undertaking research focussing on the Western Himalayas. The research network includes cartographers, art historians, numismatists, Buddhist philosophers, and Tibetan and Sanskrit philologists. The main objectives are to intensify research on the cultural history of the Western Himalayas as well as to develop a map-based Cultural History Information System (CHIS) for sharing the outcomes with other experts and the interested public.*

*When developing an interdisciplinary (Web-delivered) Cultural History Information System, one of the challenges is to obtain an understanding of the scope of all project partners and their need for geo-located information. This information is the connecting factor for research stakeholders and plays an essential role for communicating within and without the project. For a deeper understanding of the interdisciplinary work of the individual project partners a field trip to Himachal Pradesh (India) in summer 2007 under the participation of art historians and cartographers was undertaken.*

*The paper presents the experiences from this field trip and what influence it had on the overall objectives of the cartographic information system. Furthermore it provides information about the underlying design and architecture of the system. Finally, crucial issues such as designing and delivering a spatial-temporal gazetteer and the design of an appropriate cartographic base map will be addressed.*

## 1. Introduction – The NRN

“The Cultural History of the Western Himalaya from the 8<sup>th</sup> Century” is a National Research Network (NRN) funded for three years (2007-2010) by the Austrian Science Fund. It is dealing with the four great cultures of Asia – China, India, Persia and Tibet – which converge in the Western Himalaya. This region was traversed by historical trade and pilgrimage routes from the Mediterranean to the China Sea and the Indian Ocean. These corridors of communication connected far flung centers and thus over the millennia contributed to common cultural features despite great ethnic and linguistic diversity.

The research within the NRN is concentrated on the western-most part of this region: Northern and Eastern Afghanistan, Northern India (Himachal Pradesh, Jammu and Kashmir), Northern Pakistan, Northwest Nepal, and West and Southwest Tibet, including the neighboring regions in Central Asia. Through the centuries this region was, and continues to be, an area of intense cultural exchange. Our knowledge of the cultural history of this complex region is changing rapidly as a result of the great mass of previously unknown primary documents: e.g., manuscripts, coins, inscriptions, and art objects that are daily discovered in Afghanistan, as well as to a lesser degree in nearby regions. One of the purposes of the NRN is to facilitate the documentation and descriptive analysis of vanishing cultures of the Western Himalaya in order to study, with comparative methods and from different professional perspectives, the manifold facets of those cultures.

One of the project parts, conducted by the University of Vienna, Department of Geography and Regional Research, is aiming at assembling a Cultural History Information System (CHIS) of the Western Himalaya. The basic question to be addressed within the scope of the project is to what extent a Geographic Information System can be built to deliver an integrated cartographic decision-support tool for information-collection and analysis that stores data gathered from multiple resources and provides a communal internet-delivered repository of information and geo-located artifacts? Because of the diverse research fields of the project partners (art history, numismatics, Buddhist phi-

losophy, Tibetan and Sanskrit philology, and ethnography of the Western Himalaya), the goal of the CHIS is a high quality cartographic output, which allows the user to derive a holistic view of the entire data within its regional, cultural, as well as historical context.

In the following the concept and design of the first prototype including the geodata requirements and the structure of the gazetteer for the various geographic locations of individual objects will be described. The fieldtrip to Himachal Pradesh (North East India), conducted in summer 2007, as an example for interdisciplinary field work in very steep mountainous regions, will conclude the paper.

## 2. CHIS

The CHIS itself is a complex system, the main parts of which are different data archives, holding topographic and thematic data, and the user interface for information retrieval and analysis. For the connection of geographic and thematic data a gazetteer, containing geographic locations, their according coordinates and the needed synonyms of the location names, was built. The heart of every spatial information system, the base map, is a combination of various datasets. To implement a first prototype these three points (geodata, gazetteer and system design) have been discussed and will be described below.

### 2.1. Geodata

A main component when building a cartographic information system is the provision of adequate raster and vector geodata for different visualization purposes and scale levels. Datasets needed for the CHIS include administrative boundaries, cities, rivers, lakes, coastlines, roads, railroads, digital elevation models and special datasets showing objects which have significance in cultural historical context like temples or monuments.

For budgetary reasons, the small and middle scale base maps for the main application are created by using free-geodata sources as a basis.

Sources for vector data include

- the Digital Chart of the World (DCW, <http://www.maproom.psu.edu/dcw/>),
- Vmap0 (<http://earth-info.nga.mil/publications/vmap0.html>),
- ESRI Data DVD,
- Hydro 1k (<http://edc.usgs.gov/products/elevation/gtopo30/hydro/index.html>).

The raster datasets used are amongst others

- SRTM (<http://www2.jpl.nasa.gov/srtm/>),
- GTOPO30 (<http://edc.usgs.gov/products/elevation/gtopo30/gtopo30.html>)
- and Tom Patterson's Natural Earth2 (<http://www.shadedrelief.com/>).

Names are derived from various Atlases, as well as printed maps, digital gazetteers, and the global name database GeoNames (<http://www.geonames.org/>).

The datasets are processed for multiple scale levels, so that a high quality output for screen and printing purposes can be assured. Processing involves automatic generalization algorithms and also a lot of manual workforce. The aims are to create refined datasets, which are consistent for the whole area of interest, topologically correct and which ensure a high quality for cartographic visualization.

### 2.2. Gazetteer

To avoid ambiguous place names and geographic coordinates for one and the same location used by different network partners a gazetteer was established. This list of geographic place names contains spatially referenced data as well as a defined hierarchical structure within the geometric objects (country -> state -> district -> city). Besides this data, the different names and spellings of locations are stored.

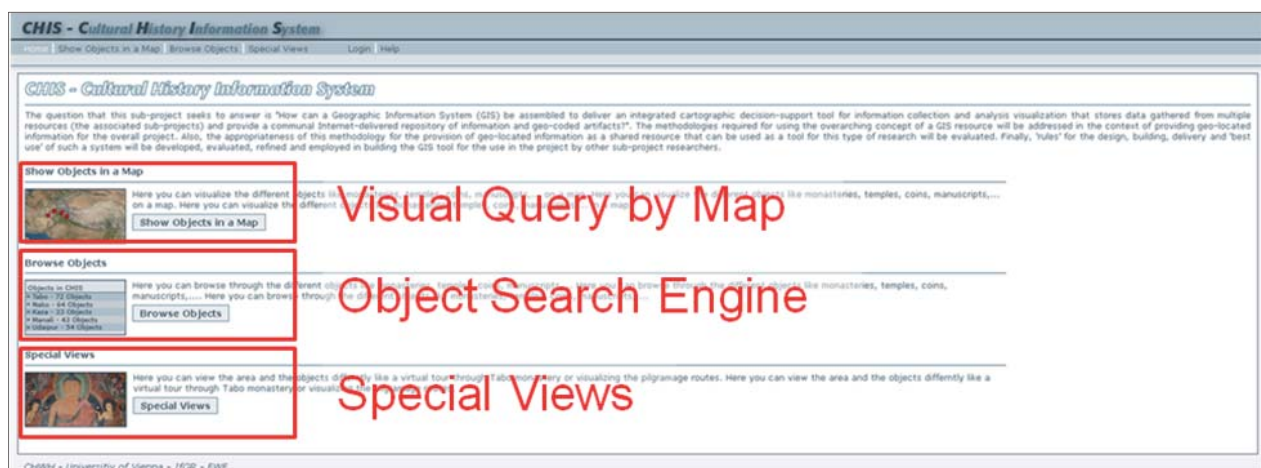


Fig. 1: Main Page



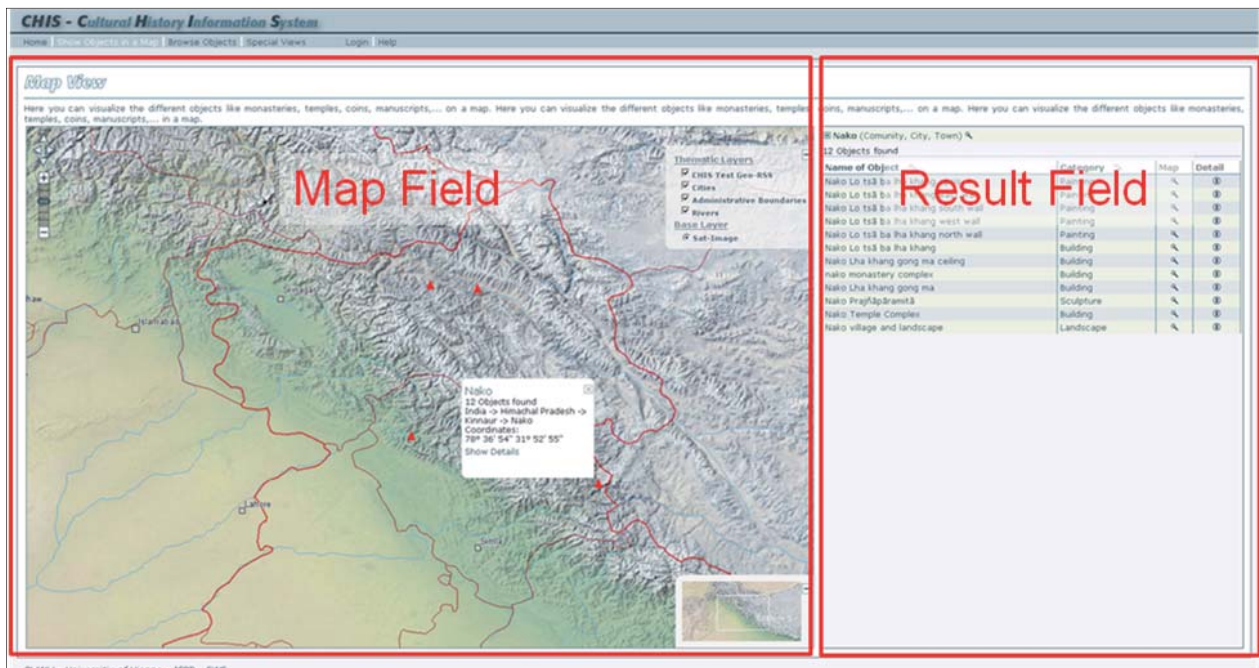


Fig. 2: Map View

### 2.3. System design

The architecture of the information system provides the user with three approaches to get information. It is possible to search for objects in a map (visual query), by a search engine or by opening special views (only for particular locations). The CHIS is an online application and can be accessed by a standard internet browser.

In all parts of the application there are a few fixed elements. The top frame contains the main menu, the logo and the search box. The bottom frame closes the application and contains less important links like imprint or contact. The main content of the application is situated in the “Main Frame”.

The basic design of the application can be divided into the “Browse Objects” view and the “Map View”. In the “Browse Objects” view the result list of the search is more important and therefore the “Result Field” frame is relatively large. In the “Map View” the result view has a less prominent role and the map occupies the largest part of the application.

From the start screen it's possible to jump to the different parts of the application, either over the prominent links in the main frame or using the links in the top frame. Each part of the application is well explained to support the user.

In the Map View the main focus is on the map which occupies the largest area of the page. On the right side the result of the search query is shown. The categories are shown as selected before. The user can change the categories in the layer-list. If a town is selected, all objects within this place are shown as a list. Detailed information to the selected location is also shown (different names, coordinates, geo-gazetteer structure). On the left side of the map a pull-down menu allows to directly select and zoom to the extent of the areas with a main research focus. The zoom slider allows a simple zoom-functionality.

In the browse objects view the user can browse through all objects in the database. Selections can be made by region, categories or time span. Additionally a filter according to keywords relevant for cultural historic research is implemented. On the right side the search result is listed. Detailed information to the selected region is shown on top of the

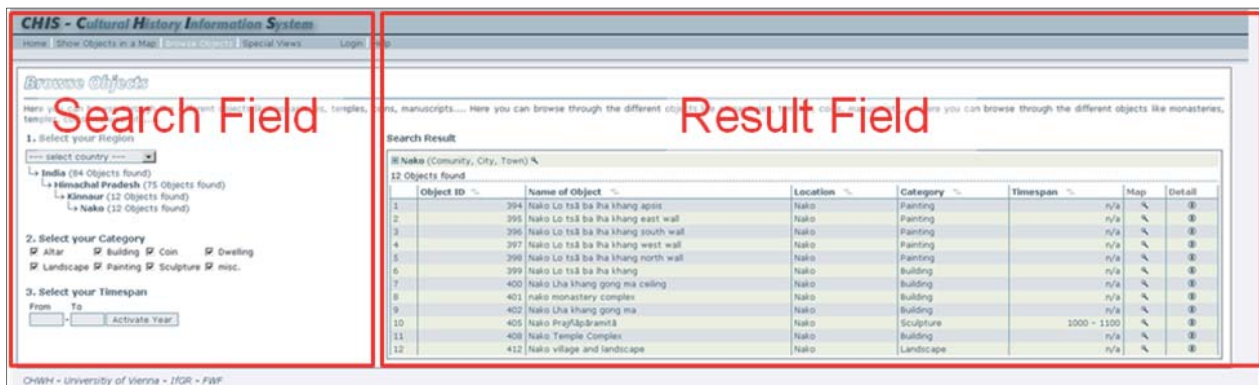


Fig. 3: Browse Objects



Fig. 5: Inside the "Ser Lha Khang" temple (Tabo Monastery)

search frame. A list of the selected information is located below.

### 3. Field trip

In order to collect information in situ and learn about the project partners' research work, a field trip to Himachal Pradesh (India) was undertaken in summer 2007. Four persons, equipped with a laptop, three GPS devices and two digital cameras, have been in the field for 31 days.

The routes and way points collected by GPS extended already available geographic locations and the gazetteer. GPS data and digital photography were combined using special software. As a result geolocated pictures of important cultural historical objects were made available.

In order to present a virtual view of the town Tabo as one of the special side applications in the CHIS, pictures for interactive 360° panoramas were taken in and around the monastery as well as inside the nine temples of Tabo. For the work inside the dark buildings a tripod and/or the use of flash light (which was often not allowed) was needed.

In addition to the Tabo panoramas a lot of other panorama pictures were shot wherever the situation and surrounding was offering the opportunity. These images will also be included in the thematic archives.

### 4. Outlook

At the moment the NRN and the CHIS are in an early stage. The first year of the three year project is over, the project partners got familiar with the other research areas and a first prototype has been implemented.

The available geodata is sufficient for the scale used in the base map, but for large scale maps, accurate geodata is still missing. The production of a user friendly application which is rich in content, is a difficult and time-consuming task. The next two years of cartographic research will show, how the concepts for an online cultural history information system will have to be adapted, so that it can perfectly fulfil its task in spatial communication and allow the greatest benefit for the work of cultural historians.

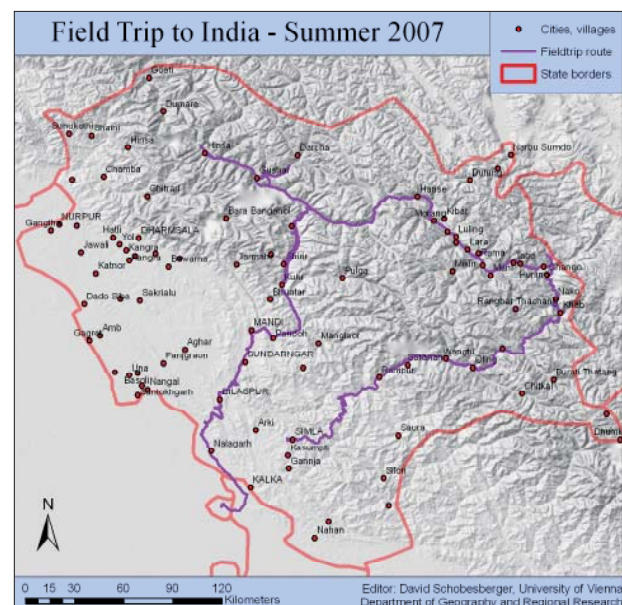


Fig. 4: Route of the field trip 2007

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# Cartographic Design Issues Utilizing Google Earth for Spatial Communication

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## Abstract

*Google Earth is a very powerful tool to visualize global as well as local spatial information in an interactive virtual globe environment. It has the capability not only to quickly transport predefined information that is made available through the program but also to disseminate individually processed geodata to produce distinctive maps for visual communication.*

*However, a map made available or individually produced through such a tool does not per se have to be efficient in a (carto)graphical sense.*

*Three cartographic examples in different scales with diverse thematic (mountainous) backgrounds will be presented to focus on the proposition that cartographic design is essential for visual spatial communication and map production when utilizing such a tool.*

## 1. Introduction

How do we deal and cope with the competence of communicating with graphics? Do we learn to utilize this capability at all efficiently? In everyday life we are constantly confronted with manifold information. This then gets filtered, processed and utilized leading finally to a decision that in many cases can or should trigger an action. Much of this information is stored in graphic forms.

The proverb "A picture is worth a thousand words" refers to the concept that complex information can be transported efficiently in just a single image. This has been and still is the case in cartography. However, it is important to be aware of the fundamentals and their functionality. Not all pictures, graphics or maps communicate efficiently. The following example (see Fig. 1) shows a (maybe) correct geo-information depiction; however a hopelessly overloaded cartographic representation that is insufficient of communicating geo-spatial information efficiently.

The distinguished Swiss Cartographer Eduard Imhof once stated that cartography is like music (Imhof, 1972). You have single notes with specific attributes connected to them. These resemble the fundamentals of cartographic depiction – the graphic variables. Each note is then aligned and com-

bined in such a way that the arrangement can harmonize to produce pleasing music or disharmony.

Graphicacy could be described as the ability to understand and use symbols, graphics, maps, plans, in other words to communicate visually.

## 2. Examples

Cartographic products are manifold and with current technology many different kinds of representations are possible to communicate spatial information. However, all cartographic artifacts do have a similar if not common structure.

Every map has at least one layer that contains information for orientation. This topographic-orientation layer serves as a base for locating the thematic information in a spatial context. It can vary from a very simple depiction all the way to a multi-dimensional complex base map. Superimposed on this layer thematic information is then included. This can be either single or multi-dimensional depending on the information density and depth.

Keeping in mind the cognitive limits the simple rule of thumb not to exceed seven, plus or minus two objects is helpful when evaluating the effectiveness of a map (Miller, 1956). This does not mean that only seven, plus or minus two objects are allowed in a map. Objects can be grouped together to create "chunks" that help structure and organize the overall cartographic representation.



Fig. 1: Google Earth Africa



The following examples show three different types of complexities. They all utilize basic cartographic methods based on the conventional graphic variables. Furthermore, different ways of depiction are used to illustrate the diverse methods of communicating spatial information.

### 2.1. “Global Awareness in School – Understanding the World with Maps”

The goal of this applied project utilizing Google Earth that is being undertaken at the University of Vienna, Department of Geography and Regional Research in close collaboration with interest groups within the educational sector and school cartography is to facilitate scholars to understand the world with maps and to make use of interactive mapping tools. The main educational goals were therefore defined in three domains:

**Affirmative Domain:** to assist topographic navigational knowledge

**Cognitive Domain:** spatial navigational perception, combination of knowledge with content

**Instrumental Domain:** topographic capabilities and skills for independent action

In order to demonstrate the educational purpose of global awareness utilizing maps with Google Earth as well as to focus on the three postulated domains an example of the global vegetation distribution with a tailored base map for orientation was implemented. The first task was to assist the scholar in the acquisition of topographic navigational knowledge. For this reason an individual administrative base map distinguishing the political boundaries, land and sea areas as well as the major circles of longitude and latitude was depicted. The main objective was to visualize a clear and understandable navigational layer for orientation and to link this geospatial layer with the thematic information (Fig. 2). Thereafter the main thematic vegetation information was applied. Comparing and analyzing already existing installations available through Google Earth (Vegetation Programme Animation, 2008; Global Landcover, 2008; Global Vegetation Map, 2008) it was obvious that a cartographic refined product was necessary. The objective of the thematic layer was to communicate the very heterogeneous global vegetation coverage in an efficient and clear manner.



Fig. 2: Global navigational layer for orientation



Fig. 3: Global vegetation

Therefore an adapted generalized version of the complex global vegetation had to be accomplished. Associative coloring as well as area symbolization was used to achieve an understandable cartographic depiction (Fig. 3).

### 2.2. “Decision Support System Tool – Avalanche Information System in Tyrol”

The joint project “Decision Support System Tool – Avalanche Warning Center Tyrol (Innsbruck, Austria) and the University of Vienna, Department of Geography and Regional Research is now ongoing for several years. Its goal has been and still is to develop and maintain a complex and very powerful database driven online decision support system for cartographic visualization and analysis of current avalanche relevant factors in the Tyrolean Alps. In order to understand the avalanche situation, it is important to have real-time spatial coverage of meteorological and snow pack factors as well as information covering the avalanche danger scale. Besides the “classical” map orientated depictions that are being daily produced (Fig. 4) a new 3D map depiction is being evaluated (Fig. 5). This new form of representation is based on the traditional daily produced maps and draped as an overlay on to the current Google Earth terrain. The user has now the possibility to combine both “photo reality” and avalanche relevant geospatial topics utilizing transparency to interpret the thematic information. However, it still has to be clarified to what extent the overlaid thematic information must be adapted in order not to produce mis-

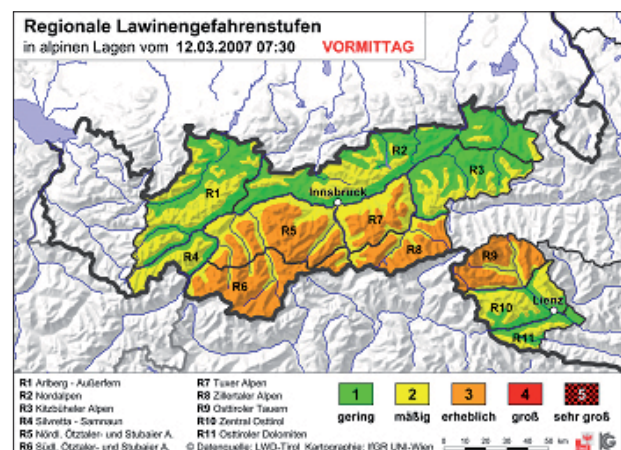


Fig. 4: “Classical” map depiction

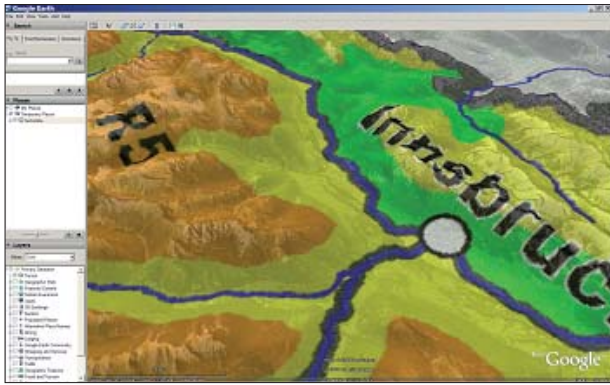


Fig. 5: 3D map depiction

interpretation that can in some cases lead to unforeseen circumstances.

### 2.3. “Optimizing Topographic Maps – Skitour Information System”

The main objective of the project “Optimizing Topographic Maps – Skitour Information System”, a project that is being undertaken at the University of Vienna, Department of Geography and Regional Research to analyze the use and limits of raster maps used as overlays in 3D systems, is to offer the user of the Google Earth driven system a navigational and planning instrument based on an optimized topographic map. The framework for the incorporated maps is the official Austrian cartographic raster model of the base map 1:50,000. This map was adapted to a winter version, eliminating scree, modifying the standard coloring to a bluish “winter look”, emphasizing rock and minimizing the otherwise very dominant contour lines.

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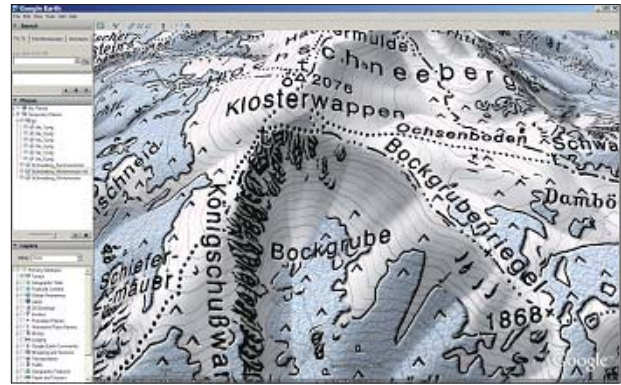


Fig. 6: Google Earth Winter map

## 3. Conclusion

It is apparent that cartography has the potential to promote spatial communication in our society efficiently - if utilized correctly. It depends on the one side how cartography is able to communicate its products based on cartographic knowledge acquisition as well as cognitive design rules. On the other side the user must be capable of understanding and interpreting the symbolized cartographic reality that is being transported. In order for this communication process to function it is essential that graphicacy becomes an integrative part of our societal system. Graphicacy is an important asset that, if applied and understood correctly, can have a strong impact on modern communication within our society.





# Hazard Maps in Switzerland

## State-of-the-Art and Potential Improvements

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### Abstract

*As an alpine country Switzerland has always been threatened by natural hazards. Our ancestors respected nature and used to build their houses in safe places where the risk was naturally low. As the settlements expanded and space got limited people started to inhabit more exposed areas. In order to protect housing and personal belongings protective structures against floods, mass movements and snow avalanches have been built.*

*However, after the experience of massive floods and other extreme weather events during the last decades we know that nature cannot be controlled and this selective approach does not sufficiently protect us and our property. The solution to decrease the damage potential and to satisfy the call for protection of property is the alignment of land-use with the natural conditions.*

*Hazard maps are fundamental for land-use planning and hazard prevention and serve to determine endangered areas and as a base to formulate conditions of building. Although their benefit is not challenged anymore and the Swiss hazard maps are of high quality some improvements might be of value. Especially the visualisation of synoptic hazard maps is a challenge and new digital ways of displaying these complex maps could facilitate their reading.*

*The visualisation of uncertainty is a relevant issue whenever spatial data is concerned. Since the implementation of hazard maps can bear huge consequences for property owners and municipalities the data quality is very important and it would be interesting to know how (if at all) the visualisation of uncertainty alters the process of decision making. However, suitable methods for the assessment and presentation of those uncertainties will have to be found.*

### 1. Introduction

Hazard mapping has a long history in Switzerland. The first attempt to create a hazard map was made after several snow avalanches had been responsible for the loss of life of 54 people and the destruction of 656 buildings during the winter 1951. The publication of federal guidelines helped to standardise the designs and in the meantime hazard maps have been produced for numerous municipalities.

The damage costs of more than 3 billion Swiss Francs caused by the inundations in 2005 were a result of the consistently increasing damage potential and emphasised the importance of hazard maps. The Swiss government reacted and has subsidised the cantons with money and relevant knowledge with the aim to complete hazard maps for every municipality by 2011. After this deadline federal subsidies for protection measures will only be granted for areas with existing hazard maps.

However, hazard maps only serve their purpose if they are properly interpreted. This paper will give an overview on Swiss hazard maps and introduce the challenges of the visualisation of synoptic hazard maps and their uncertainty.

## 2. Hazard Maps in Switzerland

### 2.1. General Overview

The goal of hazard maps is to protect people and buildings by indicating dangerous areas. By aligning land-use with the natural conditions risk as well as damage potential can be decreased. Hazard maps provide a basis for regional and land-use planning, national concepts and plans, the planning and construction of buildings, grants of buildings and concessions, and the granting of subsidies.

In 1965 the first legal foundations for the production of hazard maps were set in the regulation concerning the federal superintendence on the forestry police<sup>1</sup>. In 1979 the federal law on spatial planning<sup>2</sup> laid stress on the importance of considering natural hazards for local and regional planning. The federal laws on water constructions<sup>3</sup> and forestry<sup>4</sup> were revised in 1991 and together with the according regulations they oblige all Swiss cantons to create hazard maps for their municipalities. This legal foundation is very important

<sup>1</sup> Vollziehungsverordnung vom 1. Oktober 1965 zum Bundesgesetz betreffend die eidgenössische Obergericht über die Forstpolizei (FPoIV, SR 921.01)

<sup>2</sup> Bundesgesetz vom 22. Juni 1979 über die Raumplanung (RPG, SR 700)

<sup>3</sup> Bundesgesetz vom 21. Juni 1991 über den Wasserbau (WBG, SR 721.100)

<sup>4</sup> Bundesgesetz vom 4. Oktober 1991 über den Wald (WaG, SR 921.0)

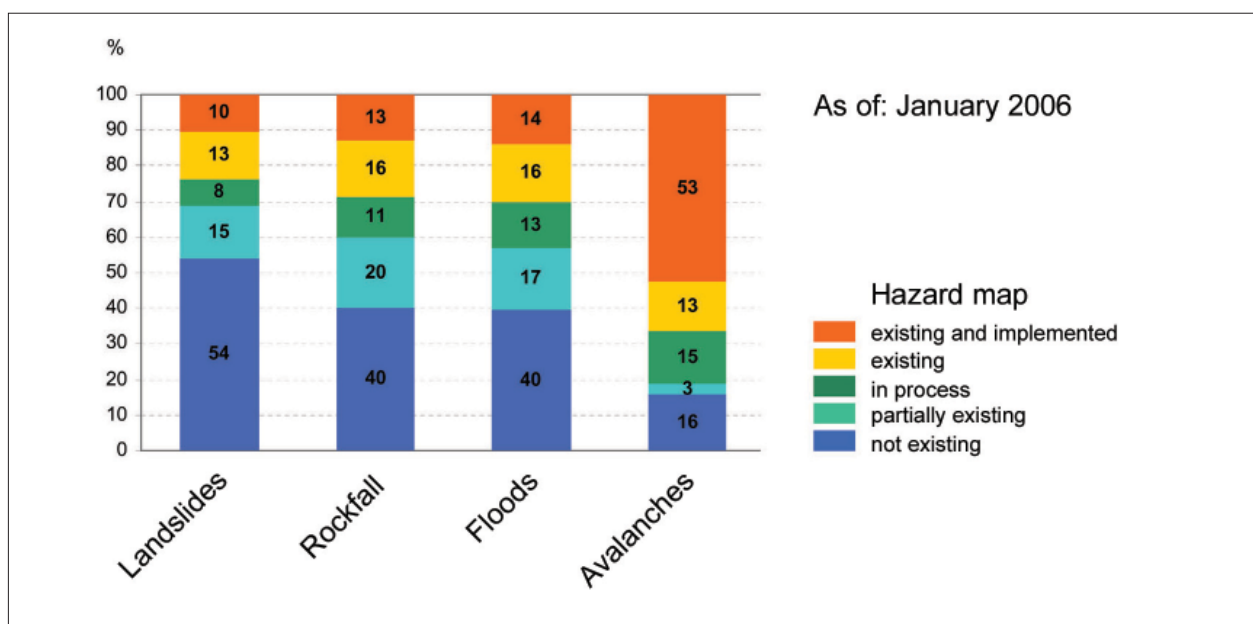


Fig. 1: Percentages of existing hazard maps in Switzerland (BAFU, 2007)

because only after their implementation in regional and land-use planning hazard maps become legally binding.

Due to the federalist structure of Switzerland, the current situation of mapped areas varies from canton to canton; some have already finished most of the mapping, others are still working on their concepts. Fig. 1 shows the percentage of the area which has been mapped until January 2006.

## 2.2. Content of Swiss Hazard Maps

Natural hazards in Switzerland comprise a lot of different processes, including earthquakes and gale-force winds. Since hazard maps are maps of suitability (they indicate areas which are not suitable for a certain land use due to the presence of natural hazards) they aim to relate hazards to specific areas. Therefore, the natural hazards which are considered have to exhibit clearly definable spatial impacts.

For Swiss hazard maps the following processes are taken into account:

- **Floods** (inundations, debris flows, sediment deposition, bank erosion)
- **Mass Movements** (rock-, block-, and ice fall, rock- and block avalanches, spontaneous and continuous landslides, unconfined debris flows, subsidence, sinkholes)
- **Snow Avalanches** (powder and dense flow avalanches, snow slabs)

For each of these processes a separate hazard map is produced which always includes a technical report. The assessed perimeters have to be clearly identified and are usually limited to populated and developed areas as well as transportation routes.

## 2.3. Production and Design

The intensities of possible hazardous events are assessed by the consultation of past events, current conditions, numerical and physical models and expert judgment. These results are transferred into a number of classes (e.g. 10 in Switzerland) according to the intensity and the probability of occurrence of an event. These classes are applied to the study area which is divided into discrete zones. The Swiss system works with four hazard zones coloured as follows:

- **Red** (high hazard)
- **Blue** (moderate hazard)
- **Yellow** (low hazard)
- **White/yellow-hatched** (residual danger, high intensity but very unlikely)

Fig. 2 shows how these colours are linked to the intensity and the probability of an event.

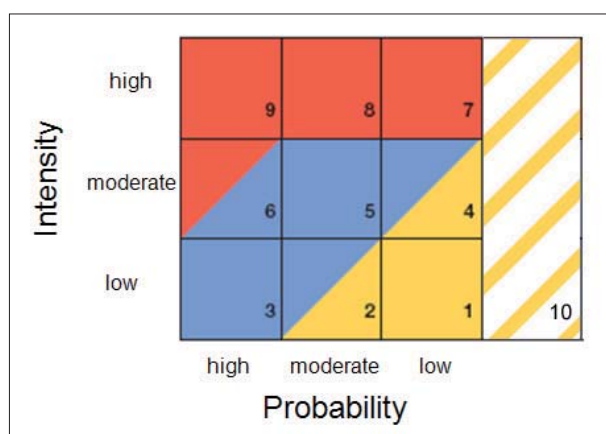


Fig. 2: Magnitude-Frequency Diagram

In the red zone people are at risk both inside and outside of buildings. A rapid destruction of buildings is possible. This zone designates a prohibition domain where development is banned. Existing buildings can be maintained but no enlargements are allowed.

The blue zone indicates an area where people are at risk outside of buildings. It is a regulation domain and damage to the building structure should be expected but no rapid destruction should occur as long as the restrictive regulations have been followed and the construction type has been adapted to the present conditions.

There are no restrictive regulations in the yellow zone and people are only at low risk even outside of buildings. Damage inside of buildings might occur but not at the structure. People living in this alerting domain have to be notified of possible hazards.

If an area is threatened by an event of high intensity but very low probability, this area can be hatched in yellow and white which represents a residual danger. In these zones no public buildings (like hospitals, etc.) should be built.

Zones which are not affected by any natural hazard or the danger is negligible according to present information are kept in white.

The cantons delegate the creation of hazard maps to private engineering companies and working groups. Experts are free in the choice of method as long as it meets the current scientific requirements.

In order to provide for a consistent and equal assessment of the different processes of natural hazards, the magnitude-frequency diagrams as well as the visualisation have been standardised in Switzerland and are presented in federal guidelines. To date each canton might use a slightly different colouring, but the use of red, blue and yellow for the designation of hazardous areas is the rule. The Swiss maps with a scale of 1:2,000 to 1:10,000 allow analyses for each

lot of land and are easy to understand by experts and novices.

### 3. Synoptic Hazard Maps

#### 3.1. The Situation of Synoptic Hazard Maps in Switzerland

After the consultation of the separate hazard maps we know by which processes an area is endangered, however, also the total risk is of interest. This sum is assessed by the overlay of the hazard maps, merging the information of three different maps in one. To date this aggregation only happens on a visual basis, which means that the interactions between the different processes are not taken into account. The national guidelines only state that if an area is threatened by different hazards this has to be displayed in an adequate form and the highest hazard class is authoritative. Therefore different techniques have been applied trying to present this flood of information comprehensibly. Due to the fact that most of the hazard maps are presented as static maps in printed form (although they were mostly made with the aid of a GIS) this task became even more complicated.

Some cantons (e.g. Canton of Berne) label each area with an abbreviation of the underlying hazard and the index of the magnitude-frequency diagram (Fig. 3a).

The Canton of Zug chose a differing way of visualisation and marks the borders of the areas affected by different hazards with coloured lines (Fig. 3b).

#### 3.2. Weaknesses of Synoptic Hazard Maps

Synoptic hazard maps contain an enormous amount of information. The two examples shown below illustrate that the visualisation of such a flood of data is a challenge: too many labels lead to a concealment of the background, the whole picture gets confusing and even experts fail to get a clear picture of the situation. The use of coloured lines

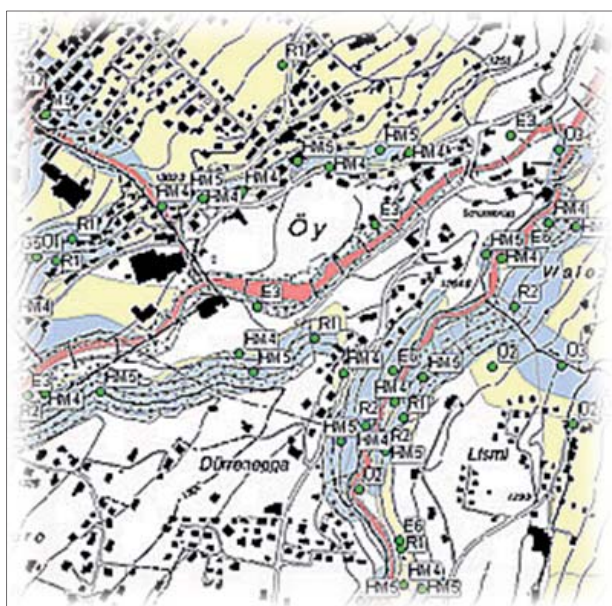


Fig. 3a: Synoptic hazard map, Canton of Berne

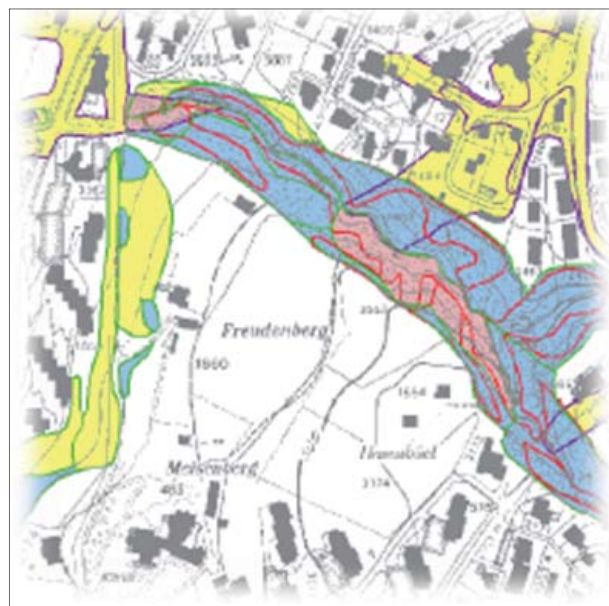


Fig. 3b: Synoptic hazard map, Canton of Zug



might visually be more appealing but the interpretation remains difficult.

Experts having worked with hazard maps for some time are familiar with the content and the appearance of hazard maps. However, novices have to cope with a lot of information. Hence, a decrease of the level of complexity would lead to a better understanding. The disentanglement of intensity and probability organised in a layer structure as it is used in GIS is a plausible idea and will be inquired.

Another point of discussion is the current definition of colours. The choice of blue for the moderate hazard zone has been criticised because there is no logical transition between yellow and red and the blue areas are often misinterpreted as inundations (Zimmermann et al., 2005). However, Swiss experts seem to be used to this colouring and do not consider changing it.

## 4. Possible Improvements

### 4.1. Interactive Visualisation Solutions for Synoptic Hazard Maps

A possible approach to solve the problem of the visual overload of synoptic hazard maps is the use of digital and interactive solutions. The idea is to help the map reader to understand the map by splitting up the complex information and letting him “draw” the map himself. Numerous interactive operations allow the user to choose the displayed layers, to create new layers by blending, to have the processes labelled by mouse-over, to zoom in and out, to choose a specific region, to use animations, etc.

Although interactive tools can lead to a better understanding of maps and can support decision making processes, novice users could perform actions and create maps which do not follow the cartographic standards and lead to misinterpretation, confusion and missing readability. This can be prevented by an appropriate graphic user interface (GUI) which helps to guide and/or to restrict the available interactivity (only predefined actions can be performed).

The aim of the new techniques is not only to facilitate the reading and understanding of the map for decision makers but also to support the communication between experts and lay persons which will lead to a better acceptance of hazard maps.

A digital, interactive visualisation solution could be extended to offer additional value to users outside the field of land-use planning. Fire brigades or insurance companies could be interested in certain information which are contained in the reports accompanying hazard maps but have not yet been visualised. An example would be the fact that synoptic hazard maps only show the highest occurring hazard classes but for insurance companies it makes a difference if a property is “only” situated in a blue zone threatened by snow avalanches or also affected by low intensity floods.

Possible extra features would be the import of extra files containing transportation routes, information of sensitive areas, or other relevant data which could then be compared with the hazard zones.

### 4.2. Visualisation of Uncertainty

*“Once a map is drawn people tend to accept it as reality.”*

Bert Friesen

The issue of spatial data quality in general has attracted attention during the last decade, especially when associated with GIS. A lot of research has been done on classifying uncertainties and also on finding new methods to visualise them but there is little consensus about the best way of visualisation. Furthermore, little effort has been made to assess the use and usability of the different methods (MacEachren et al. 2005).

The production of hazard maps is an interdisciplinary task which depends on a lot of expertise and knowledge. Uncertainties arise from different actions during different stages and are divided into acquisition uncertainties, transformation uncertainties and visualisation uncertainties. Among those categories uncertainty comprises statistical variation, errors and differences, min-max range values, noisy data, or missing data (Pang et al. 1997). Taylor and Kuyatt (1994) added scientific judgment as criterion which is very important in the context of natural hazards. Some of those uncertainties can be assessed quantitatively. However, ordinal or even nominal scales will usually be used.

To date hazard mapping does not yet include the visualisation of uncertainty because it is not clear if and how this can support decision makers. Experts often argue that it would only make concerned people insecure and lead to a discredit of the hazard maps. Another argument is that the approach of applying the magnitude-frequency matrix to the natural hazard analysis output data acts as a classification. It already accounts for the uncertainties as the output is presented in ranges and not in absolute values.

However, data uncertainty is not created by its visualisation. The accuracy of hazard maps has been the topic of many discussions among experts during the last years. Landowners and municipalities are directly affected by the implementation of hazard maps and would be interested to know how reliable the boundaries between the hazard zones are. In the conventional way of representation they suggest a sharp and sudden change in magnitude-frequency although the transition might be rather continuous. Furthermore, areas inside a hazard class are not homogeneous as the colouring might imply (Trau and Hurni 2007).

Decision making in land-use planning is a very complex task and can induce severe consequences for different parties. Poor decisions can be very expensive and even put lives in danger. Therefore, it is very important that the decision making process remains transparent and traceable for everyone. Uncertainties will always be present due to the characteristics of natural hazards and their visualisation could

provide a means to draw attention to them, to support the decision making process or even to reassure people because the uncertainty becomes tangible.

In order to assess all the uncertainties occurring during the production process of hazard maps an analysis of every single step is required. Even if this process varies between the cantons and the different engineering companies it would be interesting to give some examples and to point out the sensitive phases to raise awareness.

Once the uncertainties have been assessed the best way of visualisation has to be found. A lot of different techniques have been presented in numerous research papers and the suggested methods include adding interactive capabilities, additional visual variables, or supplementing maps with added geometry (Deitrick 2007). Interactive capabilities include blinking areas, toggling between data and uncertainty visualisation, animated pictures, etc. The variables used to visualise uncertainty are among others: saturation, crispness, resolution, transparency (fog), colour, and texture. Geometry can be added by arrows, bars, dials or glyphs which are compound point symbols used to summarise a wide array of data aspects simultaneously (Pang 2001).

Those techniques can either be applied on separate maps (maps compared approach; Fig. 4a) or on a single map where data and uncertainty are combined (maps combined approach; Fig. 4b). A third way would be the use of an interactive computer environment where users are able to manipulate the display of the data and the uncertainty (Howard and MacEachren 1996).

Despite all this research analyses showed that there is no global solution and it seems that every specific problem has to be visualised differently in order to get the best results.

The use of digital interactive methods provides a lot of advantages. A prototype offering different approaches could be a way to find the best visualisation.

In the context of land-use planning it is not only interesting to quantify uncertainties and visualise them but also to know how the presence of uncertainty visualisation influences information analysis, decision making, and finally the decision outcome. According to MacEachren et al. (2005) the impact of visual depictions of uncertainty has not yet been sufficiently assessed. They suggest the development of formal and testable models of the role of visual and external display of uncertainty in the decision-making process. The

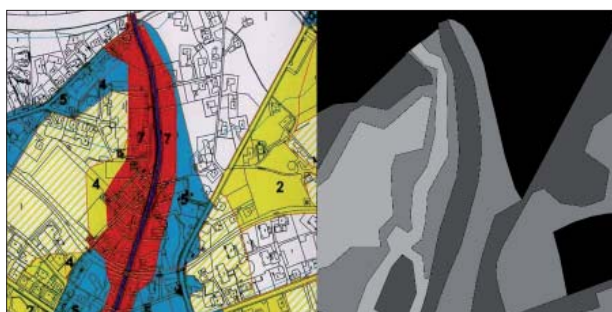


Fig. 4a: Maps compared approach

design and implementation of such models into the survey would help to verify (or to invalidate the claim) that the inclusion of uncertainty visualisation improves the decision making in land-use planning.

## 5. Conclusions and Outlook

Although the first Swiss hazard maps were created over 50 years ago they are still mostly static representations of hazard zones and especially the derived synoptic map is hard to interpret. The use of an interactive computer environment for the visualisation of synoptic hazard maps could help to enhance the understanding of such complex representations and also the communication between decision makers and other parties. The usability and the efficiency of the different visualisation methods will have to be assessed in a survey (possibly internet-based). The implementation of extra features (e.g. import and visualisation of additional data) could provide an added value for specific users such as fire brigades or insurance companies.

Since experts are still debating whether or not the visualisation of uncertainties positively influences decision making processes more research has to be done. The feasibility of the assessment of the uncertainties inherent to hazard maps, their accuracy and finally the methods of their visual presentation will have to be investigated.

Different approaches to visualise the different detected uncertainties will have to be presented and the most effective design for this specific purpose will be identified by a survey collecting the opinions of both experts and lay persons.

Thus the following tasks will have to be completed:

- Investigation of the production process of hazard maps
- Disentanglement of the different levels of information included in a synoptic hazard map
- Creating a new design for synoptic hazard maps
- Implementation of the new design in an interactive computer environment
- Identification of uncertainty sources
- Classification and assessment of uncertainties (if possible quantitatively)



Fig. 4b: Maps combined approach

- Creating of different uncertainty visualisation methods
- Determination and implementation of the best method
- Assessment of user needs (e.g. of fire brigades, insurance companies, etc.)
- Implementation of extra features (e.g. import of additional data)

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# Generating Hypsometric Layers from GTOPO30 for Small-Scale Mapping

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## Abstract

*This paper describes a new method for filtering GTOPO30 grid data for producing hypsometric layers for small-scale mapping. The hypsometric layers should meet the quality standards of manually produced contour lines. They will be used in an updated digital version of an overview map of Europe at a scale of 1:15,000,000 in the Atlas of Switzerland and the Swiss World Atlas. Since hypsometric layers derived from GTOPO30 are too detailed, the paper introduces a new method for generalizing digital elevation models with raster filters. The best results were obtained by combining lower and upper quartile filters. A drainage network, which defines valleys lines, was used for combining the two filters: the lower quartile filter was applied in valley areas, and the upper quartile filter elsewhere. To further simplify the hypsometric layers, the drainage network is generalized with an algorithm that removes the shortest streams from the drainage system. The resulting hypsometric layers are compared to a manually generalized reference data set.*

## 1. The map of Europe of the Swiss World Atlas

The Swiss World Atlas contains an overview map of Europe at a scale of 1:15,000,000 (Fig. 1), which is currently redesigned and updated for the new digital edition of this atlas as well as for the next version of the digital Atlas of Switzerland. The map represents relief with hypsometric tinting combined with shaded relief. For the revised version of the map, improved hypsometric layers will be used that are derived from digital elevation data. Using digital elevation models for hypsometric tinting has the advantage that (1) elevation data is uniform over the whole area, (2) up to date and (3) geometrically accurate. An automatic generation of hypsometric layers considerably accelerates map production when compared to the manual drawing of contour lines, which is a demanding and time consuming task.

GTOPO30, a freely available global elevation model, was chosen as source data (<http://edc.usgs.gov/products/elevation/gtopo30/gtopo30.html>). GTOPO30 was developed in the 1990s by the U.S. Geological Survey, and provides regularly spaced height data at a resolution of 30 arc seconds (approximately 1 kilometre along the equator). We estimate that the medium resolution and the geometric accuracy of

this data set are sufficient for hypsometric tinting at a scale of 1:15,000,000.

The new version of this map should adopt the style of earlier editions and meet their high standards of cartographic representation. In particular, the same colour scheme and the same hypsometric steps are used. The hypsometric tinting follows a geometric progression with steps at 0, 100, 200, 500, 1000, 2000 and 4000 meters above sea level. This progression corresponds with the steps recommended by Imhof (1982). Steps in non-equal intervals are common in small-scale hypsometric mapping: low relief areas can be well differentiated, and the large vertical intervals for higher elevations appropriately differentiate the small patches of high mountain areas.

## 2. Contour lines from digital elevation models

Hypsometric layers generated from the original GTOPO30 elevation data (Fig. 2A) are much too detailed for a map at a scale of 1:15,000,000<sup>1</sup>. They cannot be used at this scale unless their geometry is considerably simplified. We used a set of manually generalized elevation layers for evaluating our automatic algorithm (Fig. 2B). These reference contour lines were manually derived by Ernst Spiess from the GTOPO30 contour lines shown in Fig. 2A. Ernst Spiess is a Professor Emeritus of the Institute of Cartography of ETH Zurich, long-time editor in chief of the Swiss World Atlas, and author of various publications on cartographic generalisation. We are therefore fortunate to have a manually produced reference data set of high quality that is derived from the same elevation model that was used for our automatic attempt. A comparison of Fig. 2A and 2B strikingly illustrates the excessive amount of geometric details of the hypsometric layers obtained from GTOPO30 without generalization.

The development of our automatic method was steered by guidelines for the generalization of small-scale contour lines, which are generally applied in cartography. Horn (1945) and Imhof (1982) formulated the most important guidelines:

<sup>1</sup> Hypsometric layers in all figures are shown at 200% of their original size. Contour lines are depicted at an even larger scale.



Fig. 1: Map of Europe from the Swiss World Atlas (2006), reduced scale.

- Main landforms should be accentuated, while secondary features should be eliminated.
- Contour lines should retain their original position and form as far as possible. They should only be displaced for improving map readability.
- Each landform should be treated as a whole, i.e. all contours forming a landform should be either retained or completely removed.
- Positive forms (i.e. mountain ridges) have priority over negative forms (i.e. valleys); all positive forms should be retained; the smaller ones can be aggregated if they belong to the same bigger form.
- Small negative forms are to be omitted.
- Main valleys (negative forms) can often only be depicted if they are broadened at the expense of smaller forms lying on both sides.

The developed method for the production of generalized hypsometric tints is based on raster filters and requires elevation data in regular grids. A raster filter computes a new value for each cell based on the value of the cell itself and the values of its neighbouring cells. Three different smoothing filters were applied to the original grid model: low-pass fil-

ter, Gaussian filter and non-linear median filter with a filter size of  $5 \times 5$  cells. To obtain the desired level of generalization the filtering was performed several times. The three methods mentioned above provided quite similar results. Fig. 3 shows the results of 10 passes of the median filter with a size of  $5 \times 5$  cells. A visual comparison with Fig. 2B shows that simple median filtering is not satisfactory, as small, but important features tend to disappear, while bigger forms are flattened, i.e. mountain ridges are lowered and valleys are raised. Hence, the area of hypsometric layers at high altitudes is shrunk (some small parts even disappear completely), while valleys are shortened or split into small depressions.

### 3. Combining upper and lower quartile filters

To improve simple median filtering as presented above, we searched for a method that better preserves the original heights of valleys and ridgelines. The proposed method applies different filters for the valleys and ridges. The upper quartile filter was found to be an acceptable solution for filtering ridge areas. This filter assigns the 75 percentile of the neighbouring values to each cell, which preserves important heights and aggregates isolated small hills and mountain peaks (Fig. 4 A, C). Hypsometric layers at high altitudes are expanded, which is consistent with the guidelines for



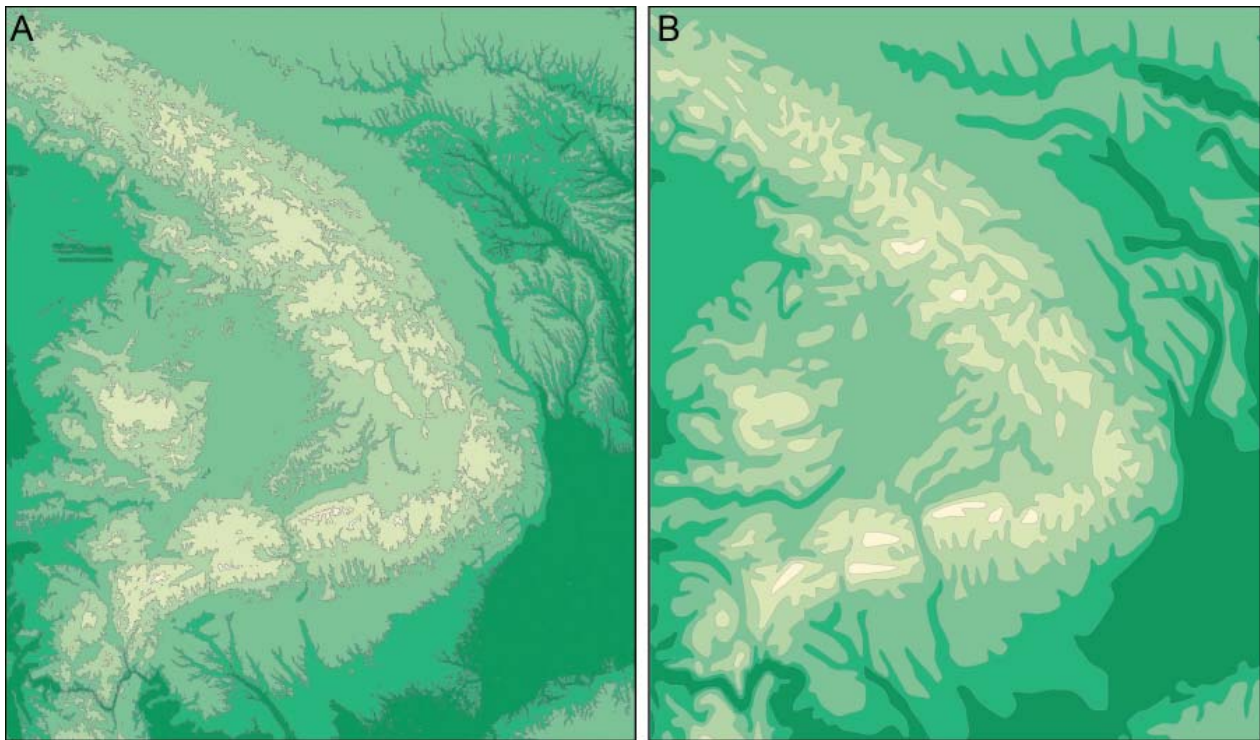


Fig. 2: Hypsometric layers: (A) generated from GTOPO30 data, (B) manually generalized.

manual generalization. For lower areas situated in valleys bottoms, the lower quartile filter is used, which assigns the 25 percentile of the neighbouring values to each cell (Fig. 4 B, D). This filter deepens valleys and eliminates some of the spurious little hills from valley bottoms, which exist in the original elevation data. These small elevations cause problems when deriving contours, since they can split valleys and create unnatural depressions.

We use skeleton lines (valleys and ridgelines) to combine the lower and upper quartile filters. There are several methods for extracting skeleton lines from a digital elevation model. As proposed by Soille and Gratin (1994) the algorithms can be grouped into two classes: either based on morphological features or on a hydrological analysis.

Some of the morphological algorithms can be easily computed using popular GIS software. A common algorithm

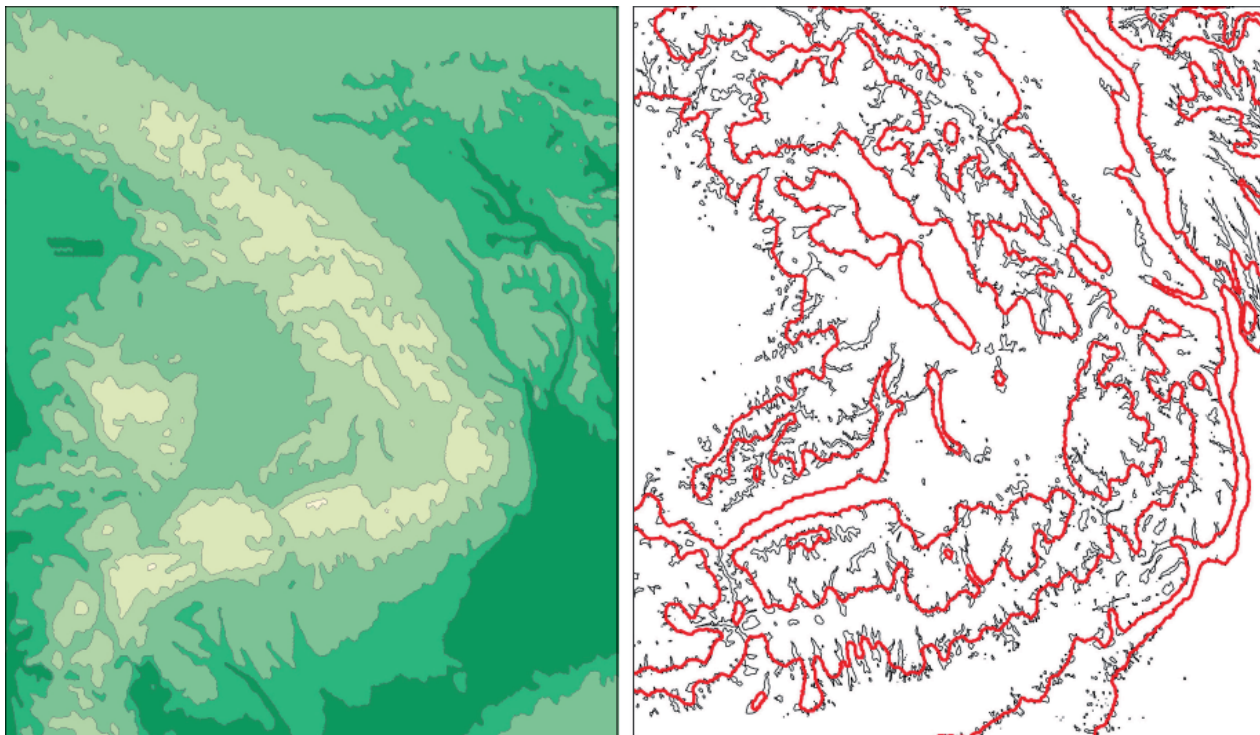


Fig. 3: Median filtering ( $5 \times 5$  cells, 10 passes). Left: hypsometric layers; right: enlarged contour lines (thin black contour lines from unfiltered GTOPO30).



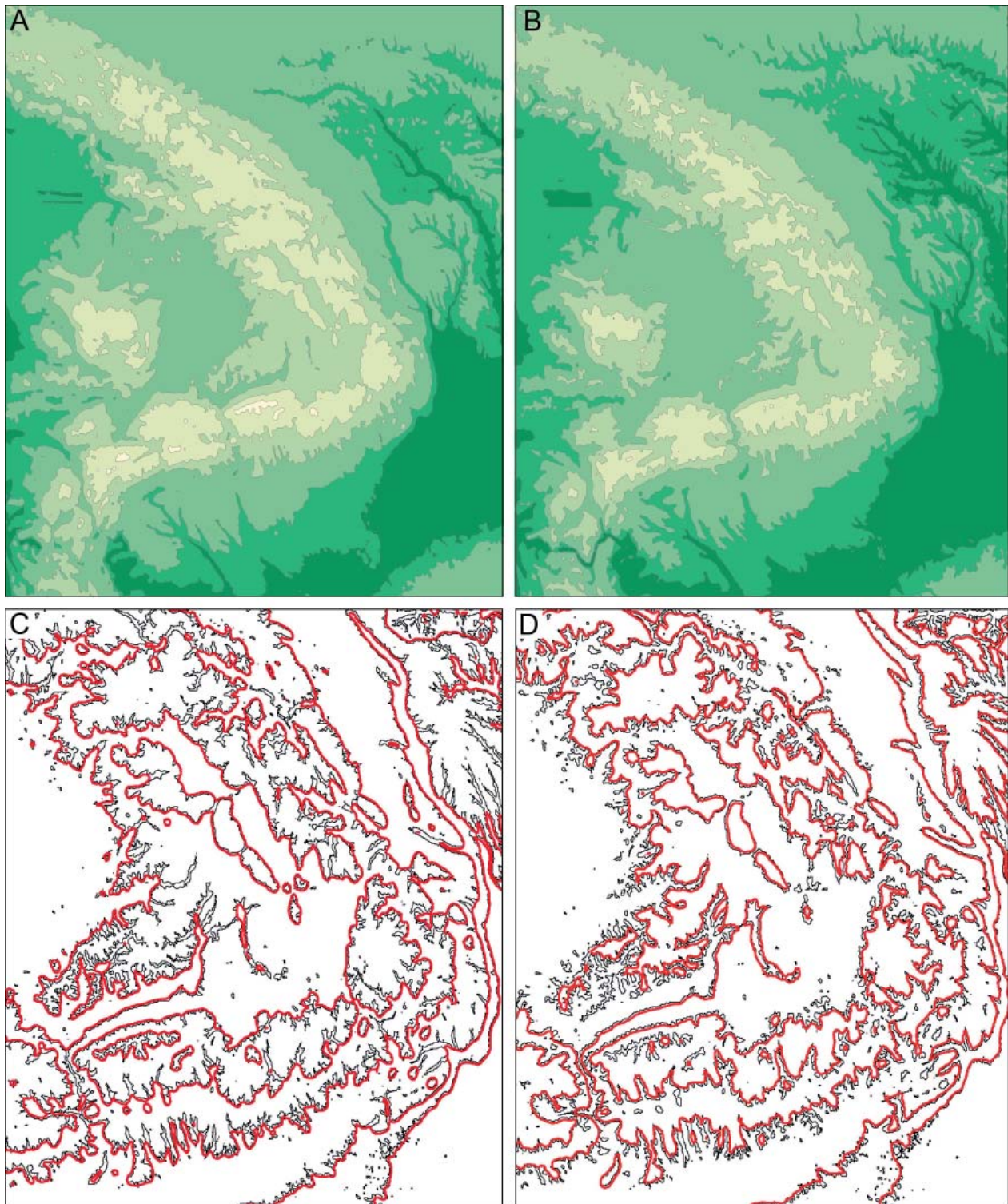


Fig. 4: Results of upper quartile (A, C) and lower quartile filtering (B, D) (thin black contour lines from unfiltered GTOPO30).

calculates the DEM curvature, which allows for differentiating between convex and concave surfaces. Grid cells with extreme curvature values can be classified as valley bottoms or ridgelines. Edge enhancement filters are another class of filters that are easy to compute (e.g. high-pass filters). Böhm (2000) computes changes of aspect and defines skeleton lines by cells with a sudden change. Zakšek and Podobnikar (2005) propose a different method based on an edge detection technique applied to an analytically shaded relief image.

More effective methods for the detection of valleys are based on hydrological analyses, for example the D8 (deterministic eight-node) algorithm, which is a hydrological algorithm for the extraction of drainage networks developed by O'Callaghan and Mark (1984). The D8 algorithm is available in many popular GIS packages. This method computes a drainage network by simulating the flow of water on the DEM. First a flow direction is defined for each cell, which is the direction of the steepest path flowing into one of the eight nearest neighbours. The value of accumulation flow is



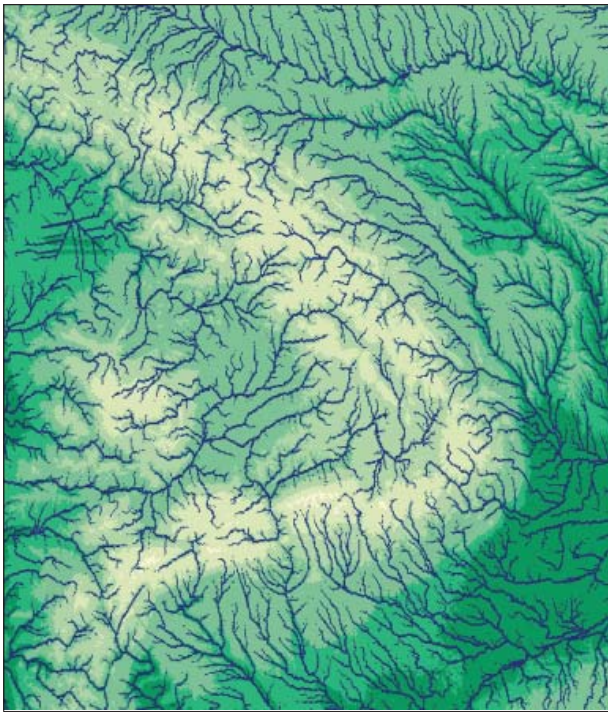


Fig. 5: Drainage network extracted from GTOPO30 data.

then calculated for each cell as a number of cells draining into this cell. Cells with a value that exceeds a given threshold can be qualified to be part of the drainage network. The higher the chosen threshold, the lower the density of the resulting network will be (Wilson and Gallant 2000).

After experimenting with different ways of extracting skeleton lines, the hydrological method (D8 algorithm) was found to give the most satisfactory results. A fundamental advantage of this approach is the continuity of resulting valley networks (i.e. valleys are always connected), which is not

always the case with other methods. Furthermore, with the D8 algorithm the number of small drainage segments can be reduced by selecting a suitable threshold.

The D8 algorithm was applied to the original elevation data, and cells with more than 50 contributing cells were assigned to the network. The network is shown on Fig. 5. In the next step, buffers were built around the cells of the drainage network. In this way the lower quartile filter, which is suitable for valley bottoms, can be applied not only to the thin drainage network, but also to its surroundings. When using buffers, weights for both filters can be assigned and a smooth transition can be generated between areas where the lower and the upper quartile filter is applied. The resulting hypsometric layers and contour lines are shown in Fig. 6. When comparing with the median filter of Fig. 3, the following advantages can be identified: (1) valleys are not shortened or split into parts; (2) some disconnected valleys are joined, and (3) small hills and mountain peaks do not disappear, but are rather aggregated. Despite the filtering, however, the layer contours are still very detailed.

#### 4. Generalisation of the Drainage Network

To further simplify the layer contours, the shortest streams must be removed from the drainage system. Increasing the threshold for assigning cells to the network is not an option, because this not only removes the shortest lines, but also truncates longer streams. To simplify the drainage network we should rather imitate the process of river generalization: the lines that are shorter than a predefined threshold should be removed as a whole – while longer lines should be retained. This was achieved by developing a customized algorithm. The input data for the algorithm is a raster grid storing values of the accumulation flow. For each raster cell

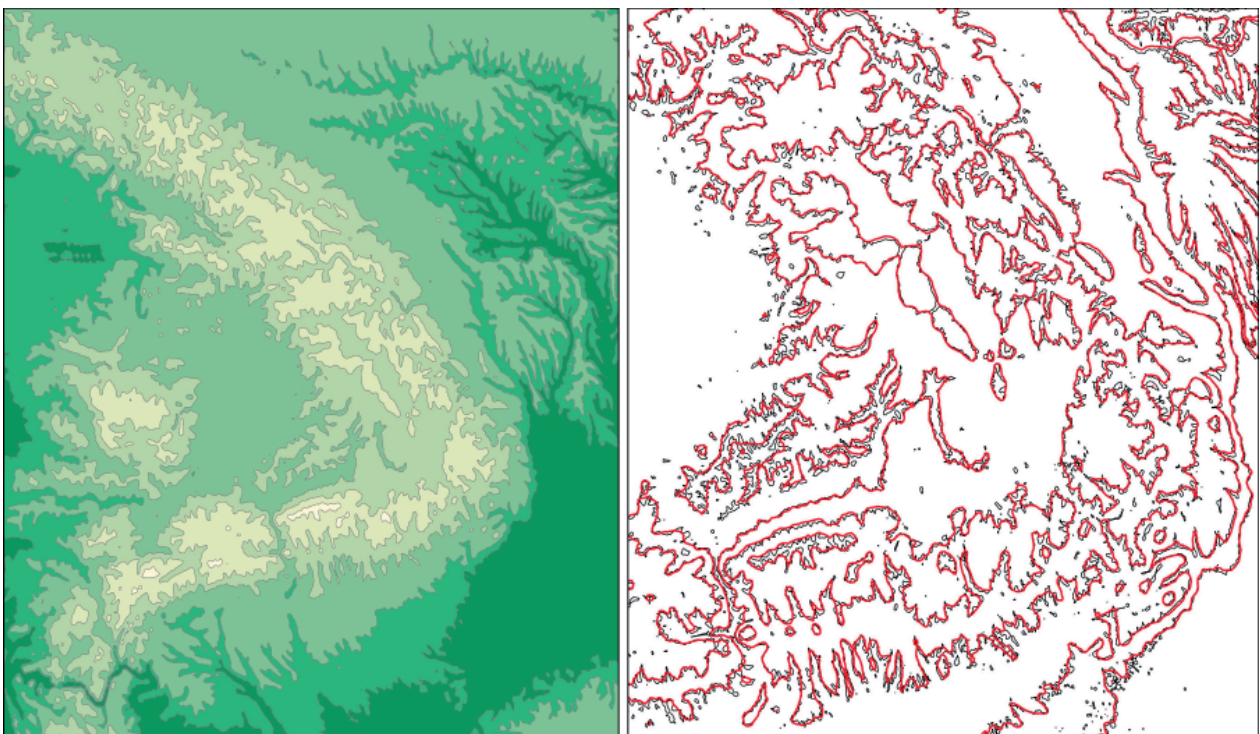


Fig. 6: Results of lower and upper quartile filter combination, (thin black contour lines from unfiltered GTOPO30).

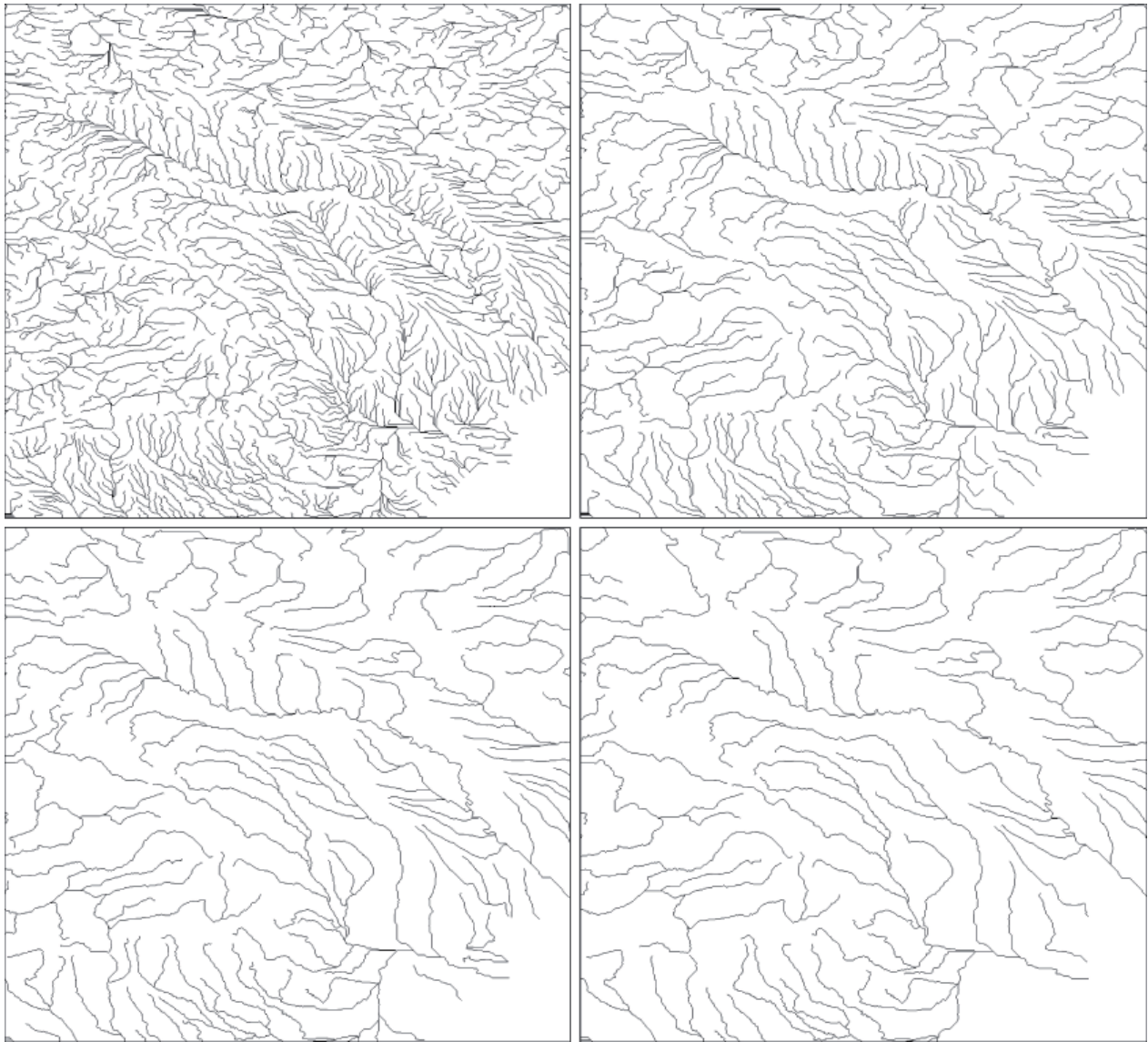


Fig. 7: Drainage network generalization, increasing length threshold value from top-left to bottom-right.

with a value higher than a threshold (we chose 50), the algorithm extracts the downstream path by following the path with the smallest negative difference. If the path is longer than a predefined threshold it is stored in the output raster. The value of this second threshold depends on the desired level of generalization. In this way all paths shorter than the threshold are removed from the drainage network. Examples of different levels of drainage generalization are shown on Fig. 7. In order to define a length threshold appropriate for further DEM processing, different levels of drainage generalization were compared with the manually generalized contours. Finally a threshold of 80 pixels was chosen to create a generalized drainage network for combining the lower and upper quartile filters.

Fig. 8 shows the resulting hypsometric layers (left) and enlarged contour lines (right). A lot of small valleys are removed, while the bigger ones are preserved. Hills and mountain peaks are much more aggregated and the highest elevation layers form more compact areas. The level of detail of Fig. 8 is similar to the manually generalized result of Fig. 2B.

However, a comparison with manually generalized contours shows that valleys are too narrow and therefore not readable enough at the final map scale. In order to further broaden valleys, larger buffers were built around the drainage network. Though results are not perfect (Fig. 9), as some of the mountains peaks disappear.

## 5. Conclusion

Hypsometric layers derived from digital elevation models that are generalized with the presented method are of good quality and can be used for small-scale mapping. This automatic procedure is carried out in a fraction of the time required for a manual generalization. Although the final output can be judged as quite acceptable, there are still several shortcomings that need to be improved. For example, the discontinuities in the upper parts of valleys (small depressions) are a rather disturbing problem. They are caused by errors in GTOPO30. The problem could probably be solved with an algorithm that removes pits from digital elevation models. Such an algorithm could also help extract a more



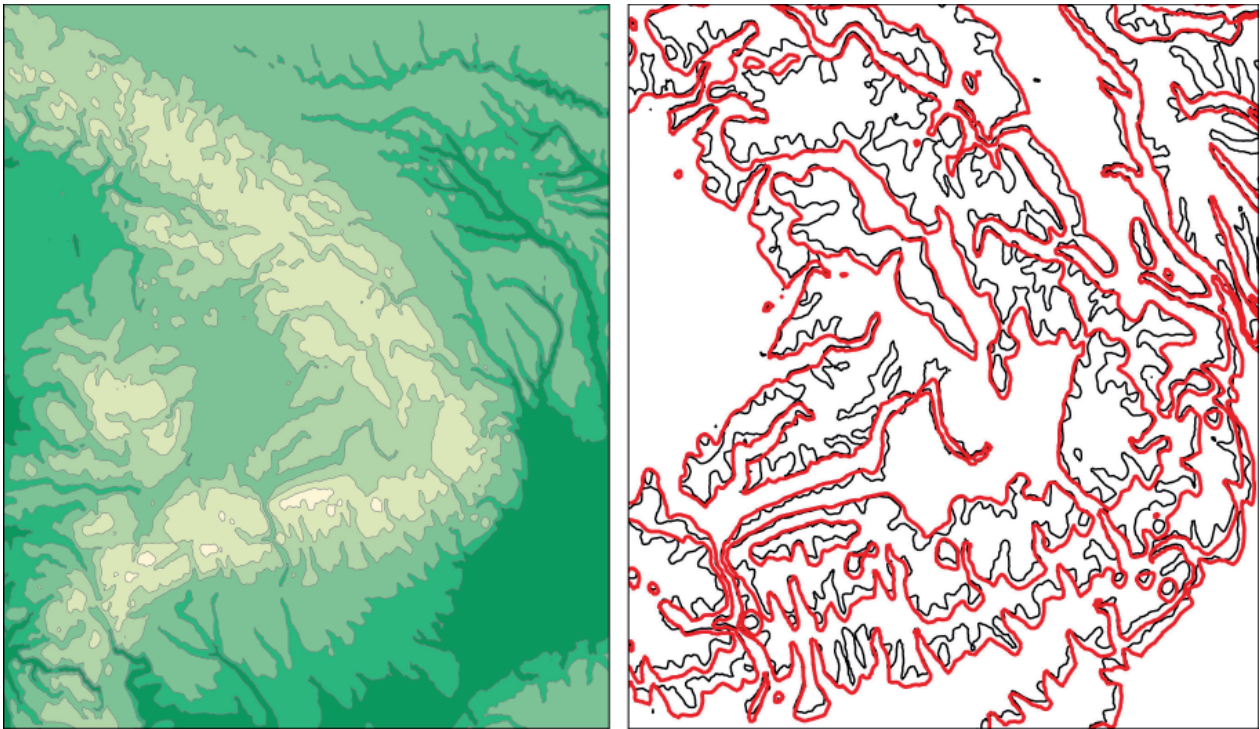


Fig. 8: Results of filter combination after generalizing drainage network (thin black contour lines from Fig. 6).

accurate drainage network, which would improve the selection of valleys to be removed or preserved.

Furthermore, improvements could be achieved with a specialized way of filling valleys. Especially deep valleys are difficult to completely remove from a DEM with the presented method. Also, testing other algorithms for simplifying the drainage network could be worthwhile, e.g. an algorithm calculating the area of watersheds instead of river lengths.

Still other problems arise when simplifying convex terrain forms, since not all mountain peaks and hills are properly processed during filtering. Some of them are excessively lowered and therefore removed from the layer contours. This especially happens with extremely small areas, which are filtered by the upper quartile filter. Also, the shapes of small separated hills may become overly rounded and smoothed. Their original shapes could possibly better be retained when using generalized ridgelines that could also be extracted from the digital elevation model.

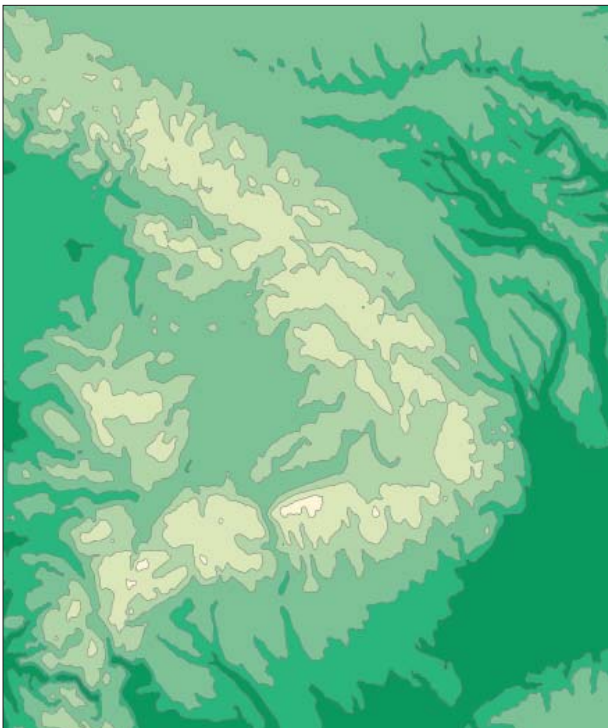


Fig. 9: Results of filter combination: broader valley bottoms.

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# A Real-Time Flow Map of the Swiss 1:200,000 River Network

## Considerations on its Preparation and its Dynamic Integration into a Web-Based Prototype

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### Abstract

*To assist for flood managers and operational hydrologists and to monitor a current situation of the river network, various data visualizations are required in real-time. Flow maps may be one of such helpful visualizations. By representing the quantities of river discharge using the line width of a specific river stretch, quick overviews of the river network are possible. The present paper discusses ideas and concepts of such a flow map for parts of the Swiss 1:200,000 river network. Additionally, remarks are made, and examples are presented, as to the pre-processing, processing and presentation of the data in a web-based flow map.*

### 1. Introduction

The technique of flow maps are appropriate when the movement of goods or ideas between places are to be shown. Particularly, flow maps intend to show interaction between places. More specifically, network flow maps, to which river flow maps are counted, attempt to reveal the interconnectivity of places (DENT 1999). Lines seem to be the most logical network elements (by being the medium of a movement or not, or by being directed or undirected). However, aside from lines, also points or polygons may constitute network elements as RUGGELS and ARMSTRONG (1997) discuss. Points for example must be further differentiated into origin or destination points and polygons such as the basin

area may be a factor that influences the network's extent. Most of the examples of network flow maps found in literature deal with transportation and various forms of traffic as well as with international trade volumes. Only few realizations of hydrographical flow maps exist, predominantly in national atlas systems as shown in Fig. 1 (a and b). In such atlases, however, the short-term or even real-time dynamics are not shown, because the river discharge data is averaged over a considerable long-time span.

In the present paper and in the on-going project "Real-time Cartography in Operational Hydrology" (RETICAH) flow maps are developed for the purpose of monitoring the dynamics of the hydrographical network and to anticipate potential hazards at an early stage. Additionally, the prototype application will also feature visualizations to retrace short-term an ongoing event and in order to compare ongoing events with high-resolution archive data. In this paper, we stick to three layers of the monitoring component. The overall concept is further described in LIENERT et al. (2007).

Aside from point, graph and areal symbolization, the realization of the real-time flow map is an attempt to visualize line symbols dynamically. Moreover, it can also be stated that virtually no application exists so far that deals with dynamic real-time river visualizations. Nonetheless, several cartographic research projects deal with real-time thematic content. The following undertakings – limited to those in

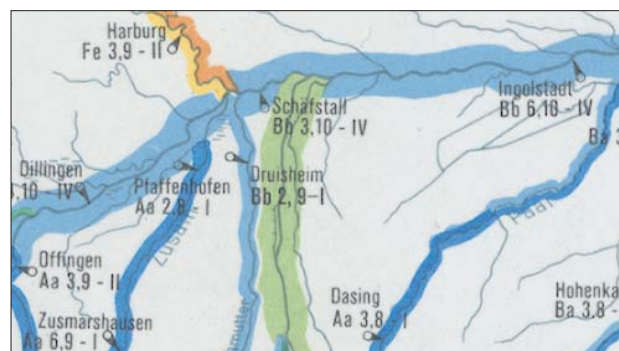
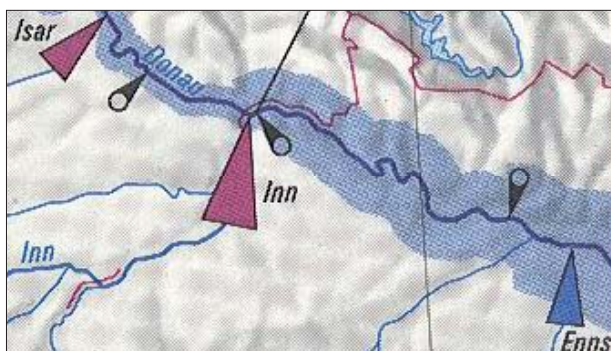


Fig. 1a and 1b: Flow maps of mean annual river discharge (HADES 1992-2007; HAD 2000).



the natural hazard domain – are worth mentioning: In Switzerland, a national information system for avalanches exists which is fed by an automatic network measuring meteorological and snow parameters. This information is stored in a central database and is available to safety services over the internet in form of overview maps with bulletins and measurement graphs (BRÜNDL et al. 2004). A similar system for avalanches has been implemented and tested in Austria (KINBERGER et al. 2007). In hydrology, efforts were made by AL-SABHAN et al. (2003), to interface hydrological models in a GIS combined with real-time rainfall data to users. The authors developed a Java-Applet interface that mostly uses raster visualizations for interpolated parameters (soil-moisture, rainfall) and time-series data. Other projects in the hydrological hazard and risk management focus rather on integration of real-time data into now-casting and forecasting models (e.g., TODINI 2004; FORACI et al. 2005; D-PHASE 2007; ROMANG et al. 2007) than on cartographic visualizations models. Thus, despite the availability of huge amounts of hydro-meteorological measurement and modeled data, the current situation is not fully satisfying as more can be done in order to suitably interface these data with the user in a sound cartographic, interactive and more usable way.

## 2. Goals

Consequently, two major goals are set for this paper: 1) Presenting real-time river discharge data in an interface and 2) find appropriate, quickly legible cartographic visualization for this purpose, with emphasis on a dynamically

generated flow map that represents real-time discharge values of selected parts of the 1:200,000 river networks.

## 3. Methods

Theoretically, natural hazard management nowadays is viewed as a cyclic activity. Four main activities are centered on the hazardous event: After it, regeneration activities takes place which are then replaced by a new risk assessment of the given situation. The following prevention activities comprise taking measures and enhancing the preparedness. The hazardous event takes place and event management must put in place both as the event evolves and as it ceases (KIENHOLZ 2005). Different methods exist and are used to enhance prevention and event management. Focusing on flood events, a few options, its advantages and disadvantages are briefly outlined.

### 3.1. Radar and satellite techniques

Areas indicate the extent of an inundation. Imagery of such areas is created during the flood event and then overlaid by a high-resolution digital elevation model (DEM). Advantage: the areal extent of the inundation can be very well captured this way. Using software such as e-cognition (www.definiens.com), a classification of these images may be carried out and certain areas may be automatically segregated. Disadvantage: The water quantities can merely be estimated and flying over the inundated area several times is a financial and logistic strain. An example of this technique is shown in DLR-ZKI (2006).

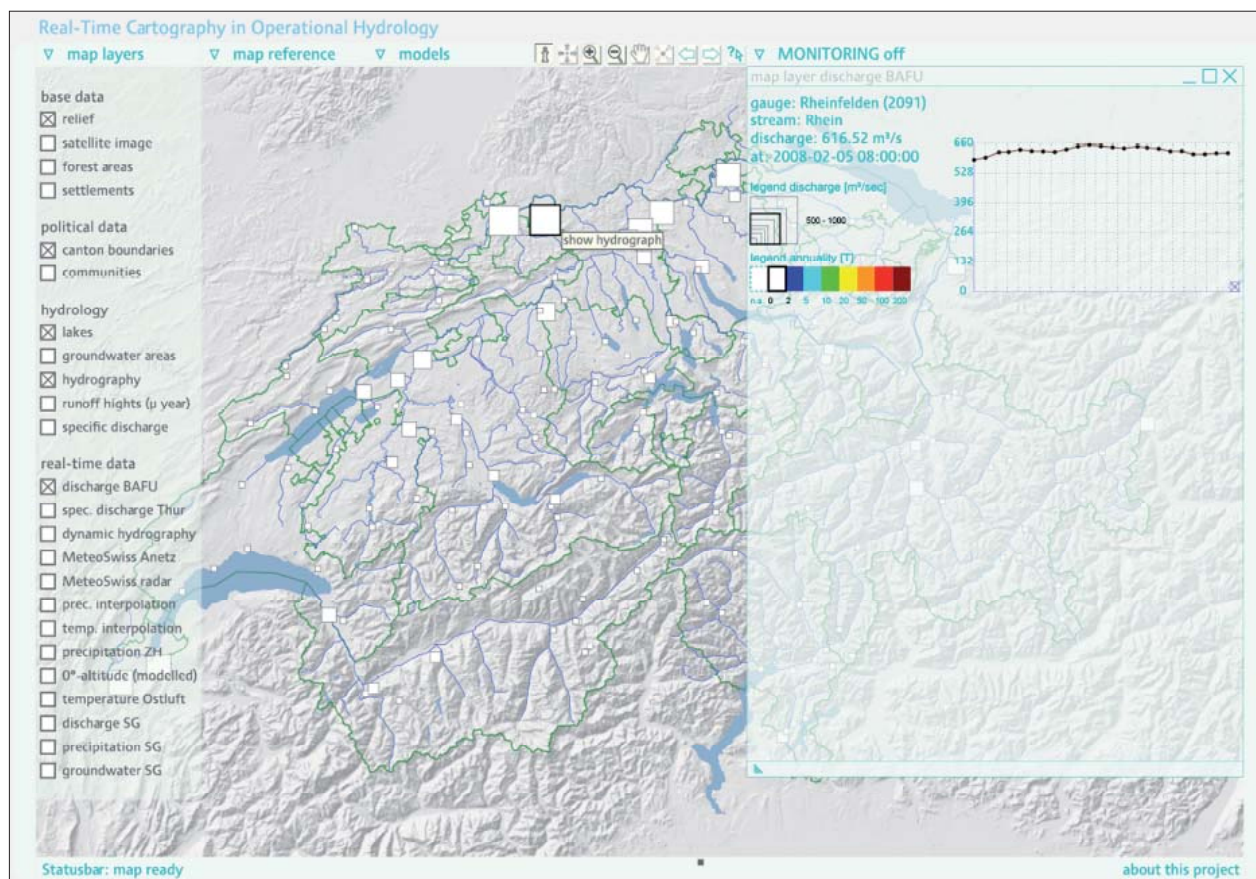


Fig. 2: Point location map representing real-time discharge (own representation).

### 3.2. Measurement networks on the ground (the approach pursued in this paper).

Point location maps: point sizes indicate real-time discharge quantities. Advantage: in general, such maps are easy and quickly readable and comprehensible. Disadvantage: the map may become difficult to read. Also, points may not be appropriate symbolizations of lines structures such as river networks but they might act as a supplementary visualization option.

### 3.3. Flow maps

The line width stands for the real-time discharge quantities between two measurement points. Advantage: sound readability, especially interesting as animated sequence which may allow observing the flood wave moving downstream. Disadvantage: the generation of such real-time maps is quite difficult and data intensive. Those rivers of which no measurements exist must be left with a standard line width on the map.

### 3.4. Choropleth maps of the specific discharges [liter/sec\*km<sup>2</sup>]

The basin area above a river outlet is colored according to a pre-defined classification of the specific discharge. Advantage: such maps can be depicted well and are easy to read. They also integrate those rivers of which no measurement is available. Disadvantage: Having said that, they integrate unmeasured tributaries and geographical in-situ knowledge of the basin might be needed (i.e., about the geology, veg-

etation, settlements) due to the difficulty interpreting such maps.

In Fig. 2 and 3, realizations of a point location and choropleth map representation are shown. In Fig. 2, a classification has first been created. Then the sizes of each of the rectangles are assigned on-the-fly according to the real-time value of the data. This provides a very quick look of where values are high in absolute terms. To know what the data at each respective station means in relative terms, colors are used to classify the real-time value into a pre-defined classification scheme denoting annualities of discharge. In case the actual discharge value is in the range of high annualities (i.e., within rare recurrence intervals), an eye-catching color is used in the map. This information is shown on the map without user interaction. However, if a user moves the mouse over a point location, additional information is shown in the monitoring window such as the name of the location, the exact measurement value and measurement time. If the point location is clicked, a hydrograph is shown, rendered on the fly with the data of the past 24 hours. The hydrograph itself has interactive features. For example, each measurement point on the graph can be queried for its value and each gradient between these points may also be queried. If a user clicks on another point symbol, an additional graph is shown. Up to four graphs may be added to the monitoring window. In this way, users can also instantly compare the situation at different gauging locations.

Fig. 3 shows an example of areal discharge data. The amount of outflow of a certain balance area is related to the area

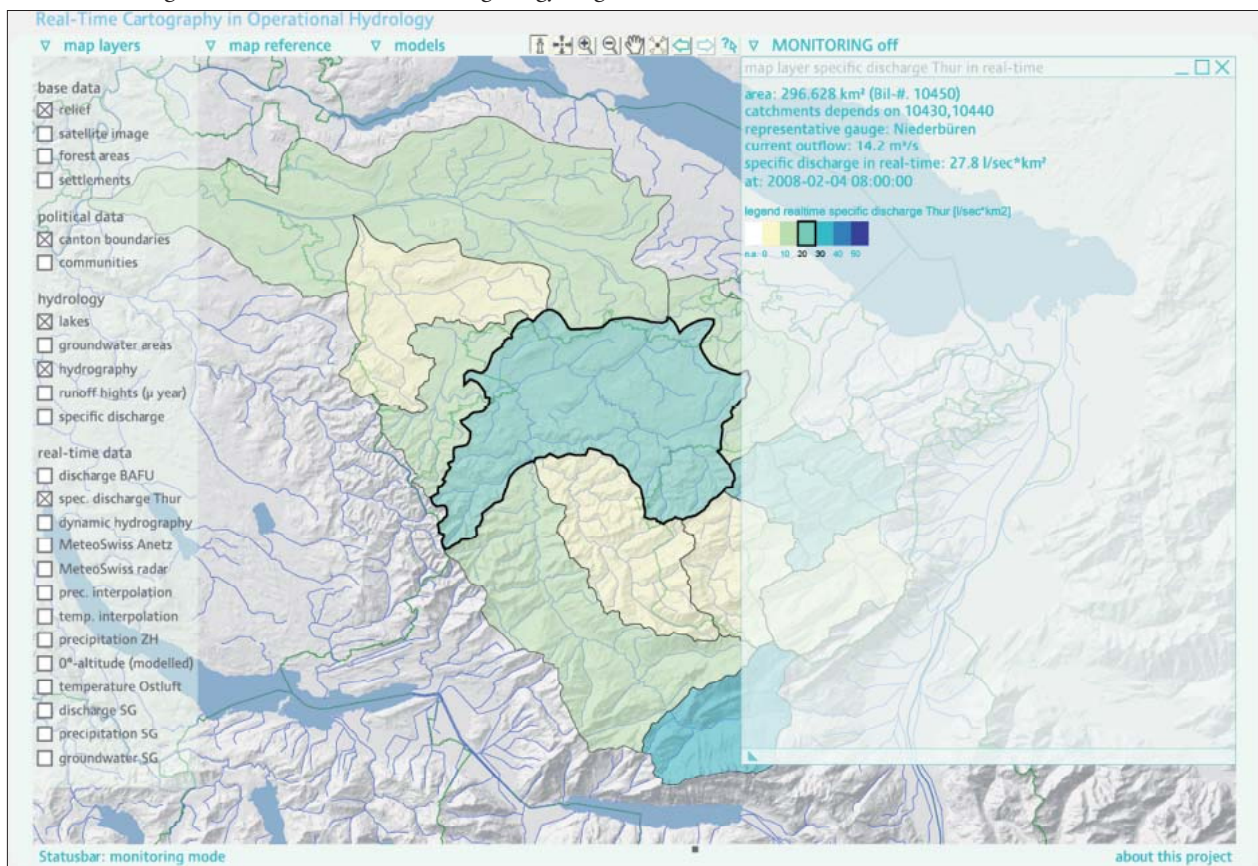


Fig. 3: Choropleth map representing real-time specific discharge (own representation)



itself, preparing the ground for a choropleth map showing the specific discharge [liter/sec\*km<sup>2</sup>]. Creating this map requires real-time data at or reasonably close to the outlet of a balance area. However, creating this map also involves a data model that accounts for the dependency of the different balance areas. The outflow generated from balance area A is a sum of the discharge generated by A itself and the discharge generated from the upstream areas B and C (unless A is headwater). Thus, the data model contains for each balance area not only the foreign key of the representative real-time discharge station but also the foreign key of the real-time discharge stations representing areas B and C. The discharge values for these two upstream areas have to be processed before the specific discharge and the respective color of the area A are determined. The outflow of value of area A must be subtracted from the sum of these two upstream values. Only this way, the correct specific discharge for area A can be calculated and correctly colored. For both maps in Fig. 2 and 3, the legends are created on-the-fly.

The real-time measurement data is stored in, or loaded from, a huge spatial database. Presently, new hydro-meteorological measurement data is acquired hourly from remote servers of various data providers, among them the Swiss Federal Office of the Environment (BAFU). These data are joined together with static spatial data sets, such as the river gauge network or the balance areas in the two examples above. Both the real-time measurement data tables and the static network tables share the same foreign keys in order that the joining can be accomplished. In most cases, station numbers act as foreign keys. These have already been determined by the data provider. Vigorously simplified, the following work steps are passed through when real-time data are visualized:

- Clicking on a map layers checkbox in the *Scalable Vector Graphic* (SVG) map viewer releases a uniform resource locator (URL) string concatenation
- To this URL various GET parameters are passed (such as the specific layer name, the current width and height of the view box, the time stamp of the request, etc.)
- Using the prepared URL string, either a XMLHttpRequest() for standard conform browsers such as *Firefox* and *Opera* browser, or a getURL() for *Internet Explorer* is released.
- The URL string locates to a file that retrieves the desired data out of the database and does the desired preprocessing of the data and the data formatting.
- The requested data is pre-processed using PHP and returned as SVG-readable XML format and then appended to, and rendered in, the SVG application

It should be noted that this workflow only applies to vector data stored in the database. For raster data visualizations, the procedure is entirely different and involves geo-processing tools and services such as *UMN Mapserver*, *GDAL* and *R-spatial*. The raster data processing is not part of this paper.

#### 4. Data and materials

The data for mapping discharge data involves river network data, data about the gauging locations and measured river discharge data. Scripting programs were written that fetch real-time discharge data from remote servers to our own server infrastructure and that read these data automatically into a database. By now, the database contains several thousand data records of hourly discharge for each of the 200 gauges in Switzerland. Each gauge is combined in a database schema. Within this schema, each gauge is represented as a table. Using schemas proved to be very helpful for managing the huge amount of data in the database.

The river network originates from Federal Office of Topography (swisstopo) and is suited for maps of the scale of 1:200,000. The gauging location data has been compiled independently. Although the data is available for whole of Switzerland, the geographical focus will be on the Thur basin in north-eastern Switzerland. It is the largest Swiss basin contributing to the Rhine and does not contain lakes that could retain or attenuate flood waves.

The technical environment is built around the database which is managed by a *PostgreSQL/PostGIS* database management system. It stores all vector and measurement data (either real-time or archived). Incoming data are inserted into the database only, if the data's timestamp is different from the previous timestamp. Technically speaking, the timestamp is chosen as the unique identifier. This way, data can be fetched from remote servers at an arbitrary small interval, but only if new data is available will they be inserted into the database. Archived measurement data and topographic vector data (as the above mentioned river network or gauging locations) are inserted into the database as well. Various PHP scripts act as the interpreter of the system. These scripts run periodically and either pre-process the data themselves (such as the width of the river sections of the flow map; see below) or release additional tools that further process the data. After processing, visualizations are accomplished using the *UMN MapServer* (raster data) or *SVG* technology (vector). Both kinds of visualizations are distributed over the internet and sent to the browser. The data interface itself is developed entirely with *SVG*, making use of additional *PHP* and *JavaScript/AJAX* technology. Further details are given in LIENERT et al. (2007).

#### 5. Approaches, questions and problems

The remainder of this paper deals with realization of the real-time flow map integrated in the web-based project prototype. However, it should be noted, that there is also a variant to produce flow maps offline (e.g., for printed maps), making use of in-house Adobe *Illustrator* plug-ins developed at the Institute of Cartography, *ETH Zurich* (see [www.ika.ethz.ch/plugins/](http://www.ika.ethz.ch/plugins/)).

For the sake of clarity, the following two definitions are made: (1) *river sections* are paths between two data points and are the smallest unit of the 1:200,000 river network. They are not modified when creating the flow map. (2) A



*river leg* is the stretch of a river between two gauges. The rendered width of the river sections between these legs are determined by the upper and the lower gauge.

Stored in the spatial database, the river geometries and certain attributes can be selected using *Structured Query Language* (SQL). Out of over 10,000 river section records, the main SQL statement selects the geometries, the SVG code of the rivers, the river name, and a so-called *code200* attribute. The selection is limited to river name Thur and seven of its tributaries. The resulting data set is sorted in descending order by the *code200*. The sorting is important because this way, objects with low *code200* numbers denote the end section of a river while high *code200* number stands for the river's source section. The sorting also assures that we can fetch the resulting data set – for each river separately – row by row and build an algorithm that adds for each river sections a supplementary rendering width and discharge quantity. For each river leg, a “discharge per section” is calculated using the difference of the real-time value (“rt\_val”) of the downstream gauge and the upstream gauge divided by the number of sections in that leg, like so:

```
disch_per_section = (rt_val_downstream -
rt_val_upstream) / num_of_sections;
```

If the river leg is the first from the source, the real-time value at the upstream gauge is set to zero or any other arbitrary starting value. The discharge values within gauges are interpolated linearly. The starting discharge value is the one measured by the gauge upstream. A newly established counter starting from zero adds the “discharge per section” to each river section. The pseudo code looks like this:

```
rt_val_modeled = rt_val_upstream + (count *
disch_per_section)
```

The starting rendering width value is the width that has been calculated for the upstream gauge. It is the maximum width of all the river sections belonging to the river leg above. The same counter just mentioned adds for the new river section the supplementary width. The width is directly calculated from the “discharge per section” value. Eventually, the width is rendered in accordance with the map scale (i.e., with its inverse value). Expressed in pseudo code, the line may look like this:

```
width_modeled = max_width_upstream + (count
* disch_per_section * mapscale)
```

For the river leg between source and the first downstream gauge, the starting rendering width and discharge values are set to zero (although other values could be set here, see below). In Fig. 4, an implementation of the discussed ideas and of the pseudo-codes is shown. The application is extended so that when the user clicks over a river section the modeled discharge is shown (and so is the discussed “discharge per section” value). Two dynamically created legends are displayed when moving the mouse over these sections. The upper of the two legends shows river width unclassified, related to an arbitrary set upper bound of 400 m<sup>3</sup>/sec. The overall bar represents 400 m<sup>3</sup>/sec while the filled bar is the

absolute discharge value. The legend below relates the colors of the river network to whether data is supported by two gauges (i.e., interpolated) or if the data for the (inexistent) gauge has been estimated. At the moment, such estimations are based on the long-term data provided in HADES (1992-2007). Estimating such missing values in real-time is a problematic challenge (see below). The current solution is to color estimated river legs with a weaker color than those of interpolated river legs.

Undoubtedly, many questions and associating problems remain to be discussed and solved: They can roughly be divided into points such as (1) *cartographic visualization* problems and (2) *hydrological/data-related* problems. In the following, a non-exhaustive list for each point is discussed.

(1.1) The river sections of a main river, just after a confluence of a tributary, is visually not considered. It is logic that these sections should appear wider than the upstream sections. Hard-coding the program using estimated discharge quantities for unmeasured river legs could do this job. Doing this for the complete 1:200,000 river network is both laborious and will inevitably lead to wrong results in real-time mode.

(1.2) Depending on the “discharge per section” value that is being dynamically calculated, the visibility of the rendered width of a starting river might be very poor or not even existing. For rivers that start with considerable quantity of discharge (such as rivers that appear out of karst areas), the starting width and starting discharge quantity can adjusted (though manually if no measurement exist).

(1.3) Given the fact that the rendering width of the network is depending on the scale, the flow map may look very bloated if both the map scale is small and the real-time discharges are high. This means that other map objects are wrongfully overlaid by the flow map and that topographical conflicts occur (even with the same river). This problem may be encountered by multiplying the scale with a certain factor. The better option, however, is to zoom into the map which results in a more clear layout of the flow map.

(1.4) The river network that is not considered for the flow map due to the lack of measurement data is visualized in form of paths with a constant width. This may be confusing for the map reader but can be diminished or even avoided if the separate map layer for the overall river network 1:200,000 is clicked off.

(2.1) The distribution of river gauge stations delivering real-time data are in most of the cases not located at key locations (= location where a river ends or starts or where two rivers join; see also point 1.1). The only option may be to integrate missing data from a hydrological model output. Work is in progress that deals with the integration of now-casting data generated by a semi-distributed hydrological model.

(2.2) In the existing model shown in Figure 4, interpolation of discharge within a river leg is solely depending on the

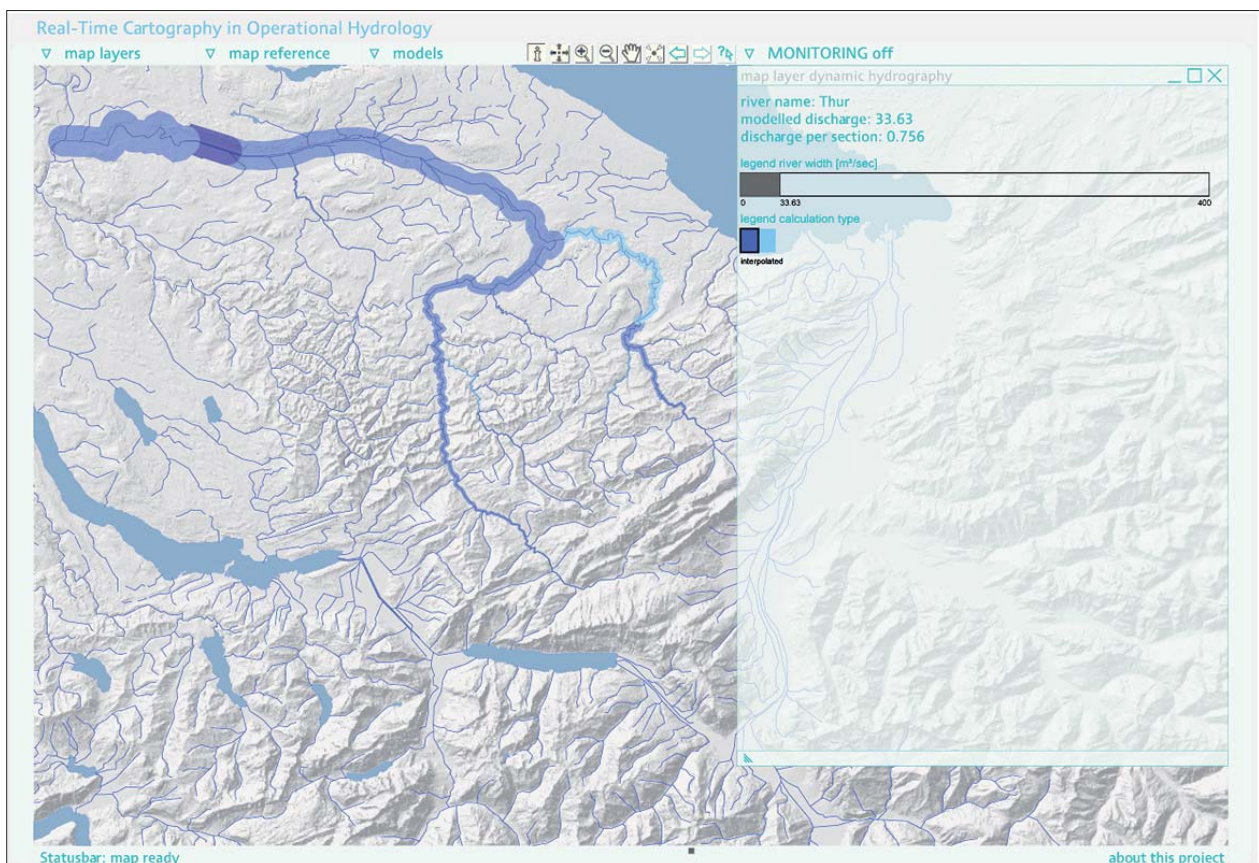


Fig. 4: Flow map representing real-time discharge by line width (own representation).

number of river sections within that leg. The river sections are predefined but often exhibit varying length. This means that interpolated values should not be considered accurate but an approximation to the real, unmeasured value of this river section.

(2.3) The term „Real-time“ in our project means „near real-time“. The gauges providing data for the flow map have a temporal offset between 10 minutes and several hours. This must be considered when viewing the map.

## 6. Conclusion

First attempts show that rendering a real-time flow map with real-time discharge data fetched from a database is feasible. Based on the existing 1:200,000 river network data model, it is demonstrative view of river discharge data for the purpose of monitoring in flood management. The generated flow map, however, is simplified as it does not take into account all rivers. Also, from a cartographic and hydrological point of view it is still objectionable at some points.

Unsurprisingly, the existence and the availability of real-time data, i.e., the density of the measuring network, is decisive for the map quality. Due to the lack of data at key locations of the river network, many parts of the workflow from raw data to the usable map have to be hard-coded. Many aspects, some have been mentioned above, remain to be researched. From a hydrologist' perspective, flow maps certainly hold the potential to support flood risk management for quick overviews. However, they can hardly be the sole means but must be complemented by additional maps such as point location or choropleth maps.

## 7. Acknowledgements

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# Creating a National Geographic-Style Physical Map of the World

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## Abstract

*This paper examines digital techniques for producing a world physical map similar in style to the physical maps published by National Geographic. Discussed techniques include an improved bathymetry dataset of the world, the depiction of world environments with natural colors, and a new method of 3D relief presentation called plan oblique relief. The map also introduces a new pseudocylindrical world map projection. Manual manipulation of digital data was an overarching factor for all phases of map production.*

## 1. Introduction

The physical world maps published by the National Geographic Society during the 1960s and 70s, as the manual era drew to a spectacular close, are some of the best maps of this type ever produced. Painted by artists Heinrich Berann, Tibor Tóth, and John Bonner, innovations included dramatic sea-floor topography and terrestrial environments depicted with natural colors. The resulting maps were attractive,

easy to understand, and revealed the intricate natural world to readers. Attempts by digital cartographers to produce similar physical maps have been less than fully successful, however. Digital map art, although highly accurate, tends to have a mechanical appearance lacking the visual appeal of the best manual art. That National Geographic today still uses manual art for world physical maps indicates the existence of a quality gap. The techniques discussed in this paper attempt to raise the aesthetic level of physical world maps produced digitally.

The pages that follow describe the making of the “Physical Map of the World,” a new map created with digital data and software, with the design inspired by classic National Geographic physical maps (Fig. 1). Creating this new map involved the synthesis of three digital products developed over several years by the author and associates. They include CleanTOPO2 world elevation data; Natural Earth II natural-color environment data; and plan oblique relief. A common element uniting these products was the necessity for significant manual intervention (using digital tools) to

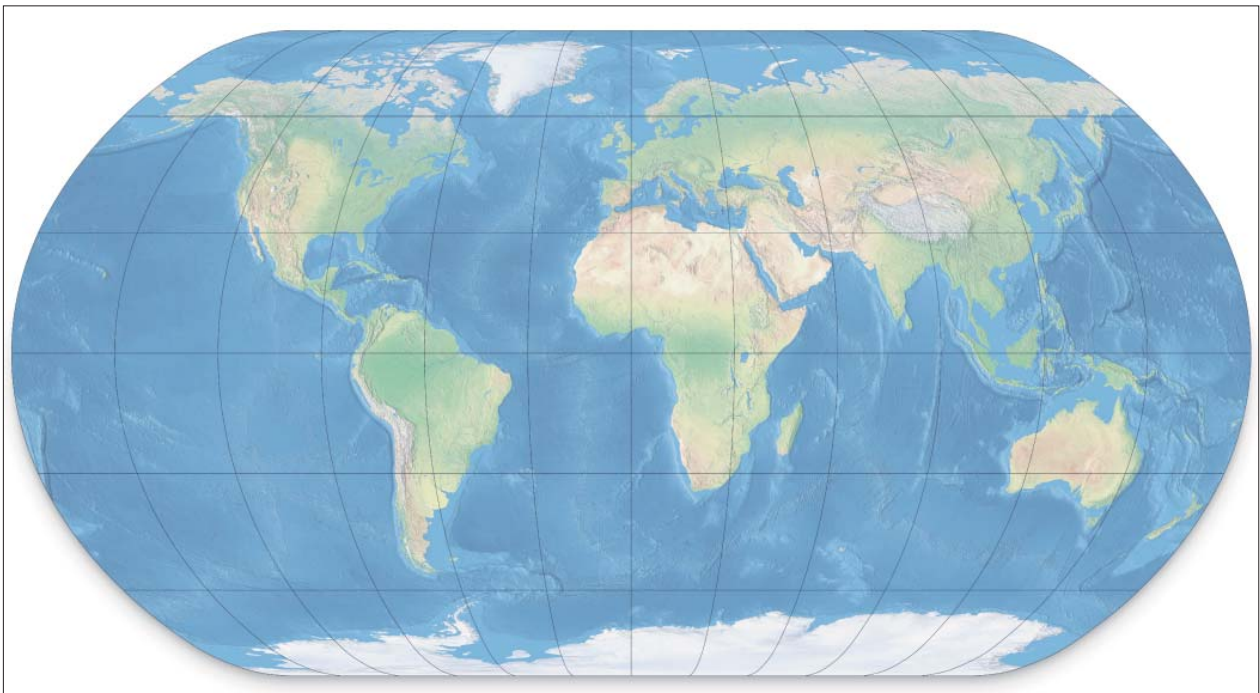


Fig. 1: Physical Map of the World without labels. The final wall map measures 91 x 160 cm and has over 3,100 labels.

create a new digital map with quality on par with older manual maps. The paper notes when and how manual intervention contributed to the mapmaking effort.

Just as the Physical Map of the World is a mix of products, much of the text that follows derives from previous articles published online and in print. The original sources appear at the beginning of each section.

## 2. CleanTOPO2

*The following chapter derives from Patterson, T. (2006).*

### 2.1. Preparing the world elevation dataset CleanTOPO2

To create acceptable sea floor shaded relief for the Physical Map of the World, it was first necessary to first create CleanTOPO2, a world elevation dataset with improved data quality. CleanTOPO2 is a modified and generalized version of SRTM30 Plus (NASA 2008), a public domain dataset that combines sea floor and land elevation data of the entire world. SRTM30 Plus and an earlier related dataset, ETOPO2, feature bathymetry data released by Smith and Sandwell (1997). As remarkable as this dataset is, it nevertheless contains numerous artifacts that mar map presentations. In CleanTOPO2, manual editing to the elevation data itself has removed many of the bathymetry artifacts (Fig. 2). Until the day arrives that the scientific community releases improved bathymetric data, CleanTOPO2 offers a stopgap solution for those creating shaded relief of the sea floor.

Shaded relief generated from SRTM30 Plus and ETOPO2 data invariably impresses readers with its sheer amount of detail and the unusual topographic forms found on the ocean floor. Upon closer inspection of the shaded relief, however, readers see elements that are decidedly unnatural – sharp incisions and rows of small bumps that cut straight through seamounts, abyssal plains, and trenches. These lines are in fact artifacts imbedded in the data that trace the routes taken by oceanographic survey ships. Because the artifacts create graphical noise and can mislead readers about the true character of the sea floor, they were removed wherever possible.

### 2.2. Creating CleanTOPO2

The author smoothed out the offending artifacts in SRTM30 Plus after importing it as a 16-bit grayscale image in Adobe Photoshop. Direct edits to the grayscale elevation data were not possible, however, because the image was dark and all but impossible to interpret. Instead, the author edited a shaded relief rendered from the elevation data that served as a proxy image – clearly seeing topographic detail was essential to success. Drawing edits to the shaded relief on a layer mask allowed their transfer afterwards to a duplicate Photoshop file containing the grayscale elevation data.

The first step was to render a detailed shaded relief from the grayscale elevation data downsampled to 2-arc-minute resolution (10,800 x 5,400-pixels wide). Both the grayscale elevation data and the shaded relief were the same size in pixels. Next, the author opened the shaded relief in Photoshop and duplicated the layer containing it. On the bottom shaded relief layer, applying Gaussian blur (a value 6 was used) smoothed the topography, including the artifacts found on it. The author then added a Layer Mask to the top shaded relief that did not receive Gaussian blur.

Having set up the file, performing edits on the layer mask was accomplished with a pressure sensitive Wacom stylus and tablet. The author painted with a soft brush set at 50 percent opacity until the artifacts disappeared or were diminished. If an artifact was bold, pressing harder with the stylus applied denser tone to the mask until it melted from view; removing faint artifacts required only light pressure. In this manner the author systematically canvassed the entire planet painting out the artifacts while at the same time taking pains not to alter actual bathymetry data. By replacing the original data with a softened version of itself, the potential for doing real harm was slight. When in doubt about whether features were natural or unnatural, they were left unaltered or slightly suppressed. The manual edits took six hours to complete.

To complete the procedure, the author prepared a two-layer Photoshop file similar to the shaded relief file described above, but using the grayscale elevation data instead. As before, the bottom layer received Gaussian blur and the top layer a layer mask. Copying and pasting the

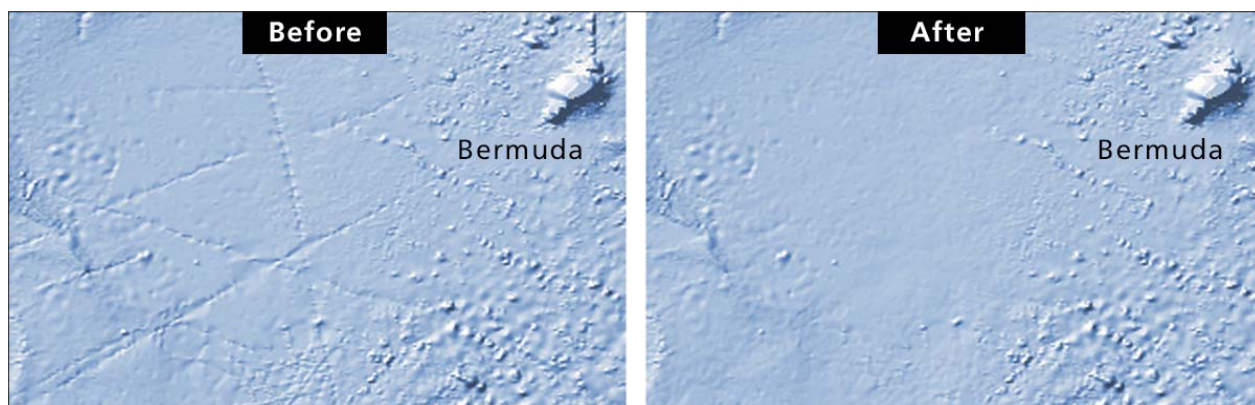


Fig. 2: Shaded relief rendered from ETOPO2 reveals linear artifacts on the Hatteras Abyssal Plain southwest of Bermuda (left). Artifacts are less visible in the shaded relief rendered from CleanTOPO2 (right).



layer mask contents from the shaded relief file to the grayscale elevation data file transferred the edits. The final step involved flattening and saving the elevation data as 16-bit grayscale TIF image, thus creating CleanTOPO2.

### 2.3. Deciding what to edit

The above procedure did not remove all of the bathymetry artifacts that permeated the original SRTM30 Plus data. Editing efforts concentrated on deep ocean basins where the artifacts were most noticeable because of the flat bottom, making the edits easier to accomplish. By contrast, the fractured topography of mid ocean ridges received minimal editing. Here the artifacts largely become lost amidst the topography and editing is prone to degrading the data.

Some oceans required more editing than others (Fig. 3). Problem areas included the North Pacific south of the Aleutians, a region marred by parallel north-south artifacts; the Atlantic off the US east coast; and, radiating linear artifacts found near Cape Town, Honolulu, and Tokyo. At 72 degrees North and South latitude the Smith and Sandwell bathymetry merges abruptly with polar datasets derived from other sources. The author erased the seam lines.

The Indian Ocean and central Pacific required little editing, perhaps because of the relative absence of data collected by survey ships in these areas. Not that these areas were completely clean. Much of the Smith and Sandwell bathymetry (2007) derives from satellite altimetry (NOAA 2008), a collection process that gives the ocean floor a slightly dimpled texture, which appears on CleanTOPO2. Besides

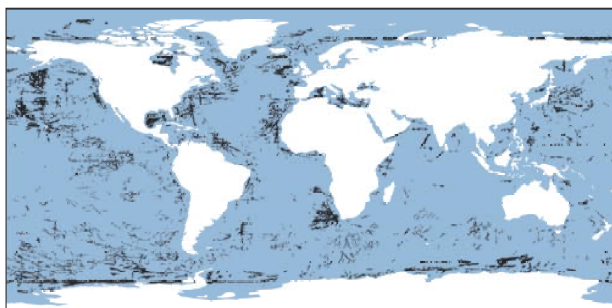


Fig. 3: The black marks show the extent of CleanTOPO2 bathymetry edits.

the linear artifacts, the author removed or diminished other suspicious data, including included isolated pits and bumps on the continental shelves that appeared suspiciously deep or high, suggesting erroneous depth values.

## 3. Natural Earth II

*The following chapter derives from Patterson, T. (2007).*

### 3.1. The land cover data set Natural Earth II

Natural Earth II derives from Natural Earth land cover data introduced in 2005. It improves on the older version by transforming fragmented land cover into smoothly blended environmental zones shown with natural colors. Natural

Earth II attempts to do with environmental data what hypsometric tint maps do with elevation data – provide an informative, attractive, and unobtrusive base for small-scale maps, such as the Physical Map of the World (CIA 2007).

### 3.2. Potential natural vegetation

The way that Natural Earth II depicts the world is familiar to anyone who has seen a physical map in a National Geographic Society atlas (Fig. 4). Developed by Tibor Tóth in 1971 and expanding on the pioneering work of Hal Shelton (Patterson and Kelso, 2004), colors on the National Geographic maps show the natural vegetation (and non-vege-

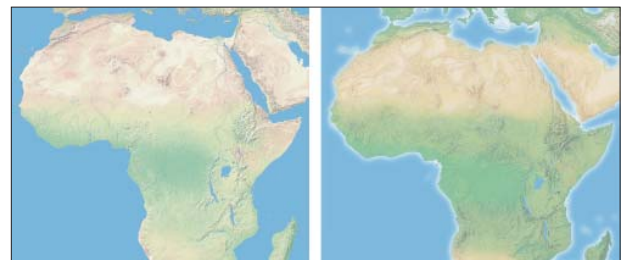


Fig. 4: Natural Earth II (left). A National Geographic physical map painted by Tibor Tóth in 1971 (right).

tated environments) that potentially would exist without human influences on the land. Tóth used potential-vegetation maps compiled by A.W. Küchler, a prominent biogeographer who held positions at several U.S. universities in the 1950s and 60s, as a guide for his expressive hand-painted work.

Compared to land cover that shows what exists on the land at a specific time, potential natural vegetation is a theoretical concept. Potential-vegetation maps assume that modern human-altered environments are a superficial and temporary phenomenon when viewed through the long lens of time. For example, representing Las Vegas with warm desert beige ignores today's urban landscape veneer. New York City in the humid East would appear as forest green. Tóth's palette for portraying potential vegetation uses colors that readers – even city dwellers with little day-to-day contact with the natural world – intuitively associate with the natural environment.

### 3.3. Making Natural Earth II

Creating Natural Earth II, a digital product, involved manual techniques similar to those developed by Tóth more than three decades ago. The starting point for production was the original Natural Earth land cover dataset, which is available on-line (Patterson, 2007). Modifications to the data in Adobe Photoshop included painting with the Brush tool, cloning, applying color adjustments, and masking. Polar, desert, and highland environments in Natural Earth II are mostly the same as those in the original Natural Earth. These environments tend to have little human population and are still relatively intact, or affected in ways not discernable on a small-scale map. Modifications to arid environments involved replacing light yellow-green

irrigated croplands with desert beige. By contrast, humid forest environments in the mid-latitudes and tropics – places most favored for human habitation – received major modifications. In these areas, forest cover was restored to its estimated original extent before the significant growth of human population and activity in the last two or three thousand years.

### 3.4. Forest restoration

Restoring forest cover to its original extent was an inexact exercise involving multiple sources of information and visual interpretation. The best indicators that forest once existed in an area are remnant patches of forest that exist on contemporary land cover data. For example, the original Natural Earth dataset shows scattered patches of forest throughout northwestern Europe on a landscape otherwise dominated by urban and agricultural land. This information, plus the prevailing moist climate and common knowledge that forests once covered the entire region, made the decision easy. A continuous green tone fills northwestern Europe on Natural Earth II.

Determining original forest extent was more difficult for drier areas where remnant forest cover is scarce today, such as central India and northeastern Brazil. Classic physical geography references helped with this task, including Küchler potential-vegetation maps, Köppen climate maps, and precipitation maps, all obtained from *Goodes World Atlas*, 1978. Helpful online resources (see References for URLs) included the Global Distribution of Original and Remaining Forests, a map published by the United Nations Environment Programme UNEP-WCMC (UNEP 2008). The Degree Confluence Project is a website where GPS users post photographs of the 11,076 places on Earth where lines of latitude and longitude intersect on land (Degree Confluence Project 2008). Photographic evidence of forest at a coordinate intersection today is strong evidence that natural forest existed there in pre-modern times.

In drier forested regions, denser green tones occupy river valley bottoms and upland areas that are presumably moister. In some areas where small but significant forest stands exist, such as the Rocky Mountains of the western United States, appear with slightly more green. Conversely, in large regions with uniform forest cover, areas with relatively fewer trees received emphasis. The Black Belt prairie that traces a crescent through Mississippi, Alabama, and Georgia in the southeastern United States is one such example. These subtle modifications present a more complete picture of the natural environment and produce a more visually interesting map.

### 3.5. A moving target

In mapping restored natural vegetation difficult questions arise about how far back or ahead in time one should go. Even without human influence, the natural environment is in constant flux. Southwestern Alaska, for example, is now covered with tundra vegetation even though the climate there is just warm enough to support forest cover –

it is hypothesized that not enough time has elapsed since the end of the last ice age for trees to colonize this remote area far from other forests and seed sources. In other regions, vegetation change can be rapid. The semi-arid Sahel bounding the southern edge of the Sahara is greener today than it was a few decades ago because of increased rainfall. The idea that plant succession will eventually lead to a climax community that will remain in stable equilibrium for a long time is refuted by scientists today because natural disturbances are not as rare as once thought.

When human influences are factored in, mapping potential -natural vegetation becomes even more complicated. That industrial societies have altered natural landscapes significantly is not debatable – the manicured suburbs where many of us live are evidence of this. However, should the more benign activities of indigenous peoples in former times, such as intentionally lighted fires to clear forests or drive game, be a valid consideration for mapping potential-natural vegetation? For example, fires set by the pre-Columbian inhabitants of North America expanded the extent of the Great Plains grasslands into adjacent forestlands.

Alan Weisman in *The World Without Us* (2007) deconstructs how contemporary cities would revert to a natural state relatively quickly if the human species were to disappear suddenly from Earth (a scenario that is both troubling and fascinating). According to Weisman, in a matter of days weeds would start to grow in the cracked pavement of Manhattan, establishing a beachhead for other plants and the eventual return of forest. Mid-latitude forest environments, such as New York City, are resilient to change. More fragile environments elsewhere might never fully recover to what they once were because of human influences. Consider the drier parts of the Hawaiian Islands where introduced kiawe (mesquite) trees thrive on land that once was native grassland, a vegetation type unlikely to return ever again. The small map scale, vegetation boundaries with fuzzy edges, and generalized classification of Natural Earth II partially circumvents these problems.

### 3.6. Classification

Using a generalized classification brought other benefits to Natural Earth II (Fig. 5). Because it is a base for mapmaking, a generalized classification with fewer environmental colors improved legibility. A base map that is too colorful and varied can distract from thematic information overlaid on it. A practical concern was the need to limit the shades of green representing forest types to a number that a reader could easily differentiate, a task made more difficult

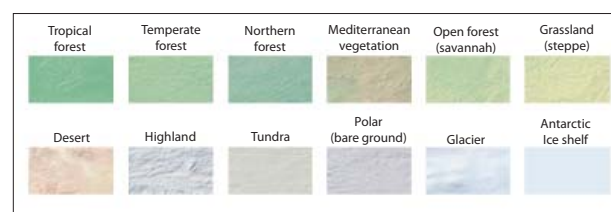


Fig. 5: Terrestrial environment classification for Natural Earth II.

by colors that merge together on the map just as forest types do in nature.

The Natural Earth II classification contains three forest types (tropical, temperate, and northern) and two types of partial forest (Mediterranean vegetation and open forest/savannah). Coloring these forests involved visually comparing Köppen climate maps and the restored forest extent on Natural Earth II and applying an assigned color in Photoshop where they coincided. For example, brownish green Mediterranean vegetation found in scattered pockets around the globe correlates with Mediterranean (Cs) climates in Köppen's system. Following this approach, northern forest correlates to Köppen's Db, Dc and Dd climates, tropical forest to Af and Am climates, and temperate forest to several intermediate climates in his system.

A generalized environment classification also must come with omissions. Natural Earth II does not classify shrub land or wetlands as distinct environments. Shrub land – a vegetation type that garners little respect – is subsumed by Mediterranean vegetation, open forest, grassland, and desert in the Natural Earth II classification. Wetlands are also part of other classifications. The Everglades of Florida appear as grassland and the bogs of the Western Siberian Lowlands, the largest wetlands on earth, appear as lightly tinted northern forest. Delineating the boundary between grassland (steppe) and forest environments was difficult. Natural Earth II reclassifies herbaceous land cover (a category that includes croplands and pasture) in the original Natural Earth dataset as grassland. Factoring in the absence of intentional burning by humans, forest cover encroaches on and blends softly into the Hungarian Alföld, Great Plains of North America, Llanos of Venezuela, and other grasslands of the world.

#### 4. Plan Oblique Relief

*The following chapter derives from Jenny, B., and Patterson, T. (2007).*

Plan oblique relief is a digital technique for rendering three-dimensional terrain on otherwise planimetric maps. When created from CleanTOPO2 elevation data, the technique produces a depiction of undersea topography that is similar to Heinrich Berann's ocean floor maps painted for National Geographic (Lawrence 1999). Following Berann's successful example, the Physical Map of the World uses plan oblique relief.

Plan oblique relief contains the characteristics of both conventional shaded relief and 3D perspective views, such as panoramas. As the "plan" in its name suggests, plan oblique relief uses a planimetric base for its initial construction as do most shaded relief maps. The "oblique" in its name refers to the shallow angle used for rendering the terrain – but in a manner that eliminates the occurrence of perspective. On conventional shaded relief maps, terrain rendering occurs from a theoretical position directly overhead and infinitely distant. Plan oblique relief uses a lower position, somewhere between directly overhead (90 degrees) and the horizon (0

degrees). This results in 3D terrain that projects upwards perpendicular to the bottom of the map and parallel to the reader's view.

The effect of plan oblique relief is not unlike axonometric city maps, such as the famous Bollmann map of Manhattan (Hodgkiss 1973), but with three-dimensionality applied not to buildings but to terrain. Because plan oblique relief portrays the landscape in a way that people see it in their everyday lives – from a horizontal perspective – the author contends that novice readers (and even experts) have an easier time understanding it at a glance compared to understanding conventional shaded relief. High solitary mountains, such as Mt. Fuji and Mt. Kilimanjaro, which appear as indistinct dots on a small-scale shaded relief map viewed from above, reveal their recognizable forms and appear as the major mountains that they are when rendered as plan oblique relief. Compared to 3D perspective views, which look most natural of all, plan oblique relief better preserves geographic shapes without any front-to-back foreshortening and convergence toward a distant vanishing point. 3D perspective views mimic the view from an airplane window; plan oblique relief is suited to map making and reading.

The author used an alpha version of Natural Scene Designer 5.0 (Natural Graphics 2008) to create plan oblique relief for the Physical Map of the World. Although rendering plan oblique relief from CleanTOPO2 data was simple – placing the light source in the southwest, determining the right amount of vertical exaggeration, and clicking the render button – it required considerable Photoshop manipulation afterward. Much as in making a 3D panorama, map elements, such as drainages, were rasterized, draped on the plan oblique terrain, and rendered as separate elements. The author had to fix misalignments between the map elements and plan oblique relief manually.

Because plan oblique relief contains vertical offset (terrestrial topography projects upwards and bathymetry downwards), the Physical Map of the World is planimetric only at sea level. The graticule does not shift vertically for differences in elevation. Although this is not a major problem because of the small map scale, it nevertheless is evident where high mountains and the graticule lines coincide. For example, the summit of Mount Kenya lies 17 kilometers south of the equator but it appears slightly north of the equator because of the vertical offset.

A more serious issue with plan oblique relief on the Physical Map of the World is poor rendering quality. Imperfect elevation data is the underlying problem. Despite efforts to remove artifacts from CleanTOPO2, poor quality bathymetry data is still widespread, especially in the oceans of the southern hemisphere. Plan oblique relief, because it is truly three-dimensional, is more revealing of data imperfections than conventional shaded relief. Consequently, the author had to change plans and publish two versions of the Physical Map of the World, one a large wall map and the other a small wall map. The large wall map uses conventional shaded relief generated from CleanTOPO2 at full resolution. The small map uses plan oblique relief generated from



downsampled CleanTOPO2 data that better hides the data artifacts.

## 5. Conclusions

The final Physical Map of the World is in the public domain and available for free on-line at: [www.shadedrelief.com/world](http://www.shadedrelief.com/world). Visitors to the website will find versions of the map with plan oblique relief and conventional shaded relief, with and without labels. A separate Adobe Illustrator file containing over 3,100 map labels is also available.

Although National Geographic physical maps inspired the design of the Physical Map of the World, it differs significantly. From color to typography to map projection, all facets of the design received scrutiny and modifications according to the preferences of the author. For example, the Physical Map of the World has a cleaner, more open appearance compared to a typical National Geographic physical map. Because fewer lines make for a less busy map, the Physical Map of the World dispenses with shoreline casings and instead relies on figure-ground contrast and shoreline embossment applied in Photoshop to distinguish land areas from water.

A unique feature of the Physical Map of the World is its projection. Rather than using a traditional projection, such as the Miller or Robinson, or the Winkel Tripel now favored by National Geographic, it uses an entirely new projection created with an alpha version of Flex Projector, the first-ever software for designing custom map projections (Jenny and Patterson 2008). The new projection, called the Natural Earth projection, is a pseudocylindrical projection designed specifically for presenting Natural Earth II environmental data. The Natural Earth projection combines characteristics of the Robinson and Kavraiskiy VII projections and com-

pares well to them in regard to map distortion. A unique feature of the Natural Earth projection is its rounded corners (where the pole lines and lateral meridians meet), which imply that the world is spherical instead of rectangular in shape.

Labels on the Physical Map of the World originated from numerous cross-referenced sources, including published atlases and web sites, most notably Wikipedia. Most city and water body labels derive from the Physical Map of the World, and available online as a PDF (CIA 2007). The GeoNet Names Server database maintained by the U.S. National Geospatial Agency (NGA) was the main reference for place name spellings of smaller physical features (NGA 2008). Because the map will cater to an international audience, endonyms (Appennino) were favored over exonyms (Apennines) for place names based on Romance and Germanic languages, which are often cognates of familiar English names and easy to identify. For other languages, transliterated names of major features (mountain ranges, plateaus, deserts, etc.) received English place name descriptors. For example, Verkhoyansk Khrebet in Russia is labeled on the map as Verkhoyansk Range. Smaller physical features, such as mountains within ranges, have entirely local names.

Before releasing the final Physical Map of the World, the author placed a draft with preliminary labels online and invited the public to comment. Many people responded to the invitation, catching spelling errors and offering greatly appreciated advice about map content, most of which was used. It is appropriate that this paper end by acknowledging Bernhard Jenny, Stefan Räber, Michael Borop, Will Pringle, and Félix Pharand for their valuable contributions to the Physical Map of the World.

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# The Terrain Models of Joachim Eugen Müller (1752-1833) and the Production of the "Atlas Suisse par Meyer et Weiss"

## An Analytical Study Using Non-Contact 3D Digitizing Techniques

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### Abstract

*Whilst Swiss cartographers are rightly regarded as pioneers of mountain cartography and their innovative methods of depicting relief have been emulated throughout the world, this paper evaluates the significance of one Swiss model maker to the development of mountain cartography.*

*Joachim Eugen Müller (1752-1833) was born in Engelberg and worked as a carpenter. After acting as a mountain guide for Johann Rudolf Meyer (1739-1813) and Johann Heinrich Weiss (1758-1826), he was commissioned by Meyer to construct a terrain model of a significant section of Switzerland, which he finished in 1797 at a scale of 1:60,000. This model formed the basis for the "Atlas Suisse par Meyer et Weiss" at a scale of approximately 1:120,000 and would continue to be the most accurate map of Switzerland until the production of the Dufour map some 50 years later.*

*Using non-contact 3D digitizing techniques to create digital replicas of the models, this paper evaluates the significance of Müller's work by assessing the accuracy of his models in relation to modern digital elevation data. The results provide objective testimony to the skill and endeavour of Joachim Eugen Müller. He provided Weiss with data of hitherto unparalleled accuracy using primitive techniques by modern standards. The results also demonstrate that non-contact 3D digitizing techniques not only provide a suitable data capture method for analytical work but also provide a potential means of preserving digital facsimiles of precious artefacts of the development of mountain cartography.*

### 1. Historical Context

#### 1.1. Joachim Eugen Müller and the cartographic situation of his period

The eighteenth century witnessed significant progress in methods and techniques of surveying and mapping in Europe. Relatively modern principles of surveying based on triangulation had already commenced in France and Great Britain towards the end of the century. Though admirable

attempts had been made to depict the high mountains of the Swiss Alps, most notably by Franz Ludwig Pfyster (1716-1802) (Bürgi 2007), a sufficiently accurate map of Switzerland, based on rigorous survey methods, did not yet exist. Only local networks of triangulation had been established and a modern topographical survey of the whole of the country was a distant prospect.

This deficiency was recognised by a wealthy industrialist, Johan Rudolf Meyer (1739-1813). Meyer was an enlightened individual and, inspired by the impact of Pfyster's model, invested part of his fortune in funding the first systematic survey of Switzerland. Experienced at mountaineering, Meyer was fully aware of the challenge that lay ahead and set about enlisting expertise to fulfil his dream. He engaged the services of the Alsatian geometrist Johann Henry Weiss (1758-1826) and together they set about planning their venture by ascending Titlis in the summer of 1787. A carpenter of Engelberg, Joachim Eugen Müller, then aged 35, acted as a guide. Imhof (1981) suggests that Meyer discovered in Müller, not only a skilful mountaineer, but also an intelligent observer, particularly from the topographic point of view.

By the following winter, Müller had constructed a relief model of the Engelberg area and subsequently began work for Meyer in the spring of 1788. Müller and Weiss then worked with the mathematician and physicist, Johann George Tralles (1763-1822) of the University of Bern during the summers of 1788 and 1789. Professor Tralles was a pioneer of modern land surveying techniques and had begun base-line surveys in different parts of Switzerland. No doubt Müller learned a significant amount about surveying principles and particularly triangulation.

#### 1.2. Survey method

The precise method of survey employed by Weiss and Müller remains unclear. The survey however, began on 10<sup>th</sup> June 1788 whereupon Weiss, Müller and Tralles climbed several peaks including Hohgant, Morgenberghorn, Stockhorn, and Niesen (Wolf, 1879, cited in Klöti, 1997). This early

collaboration between Meyer, Weiss, Müller and Tralles which employed new and meticulous survey techniques did not last, Weiss and Meyer preferring a simpler and less time-consuming triangulation technique (Klöti, 1997).

Meyer funded the construction of a simple but effective surveying instrument built by David Breitinger (1763-1834) of Zürich. Neither the instrument nor detailed descriptions of it have survived but a useful description of a contemporary instrument is provided by Imhof (1981). Imhof suggests that the instrument consisted of an alidade or dioptré mounted centrally on a circular disc of wood upon which angular measurements could be plotted on a circular sheet of paper. Levelling the instrument would have been carried out using a spirit level. No angular measurements were read, a ruler attached to the alidade would be used to simply draw a line in the direction that the alidade was pointing. The vertical measurement was taken by rotating the sighting device in the vertical axis, negative or positive movement of which could be read from a scale attached to the alidade in the form of a calibrated arc. The alidade did not have a sighting telescope, simply two pins at opposite ends of the alidade.

The method employed by Müller was a form of graphic triangulation, similar in some respects to plane tabling. However, the plane table is rectangular and distinctly larger than Müller's small disc, the map's extent being a function of the dimensions of the plane table and the scale of survey. In this way, the surveyor not only records the azimuths of the positions of points, he can also record their position through intersection in the field on the same piece of paper. Müller, on the other hand, would have used a new circular sheet of paper at each new survey station and would have determined the points of intersection either at his base camp or back at his workshop.

Imhof admits that certain things remain obscure. He suggests that it was necessary for him to have a coordinate reference system to plot his points and scale as well as the orientation. A base-line measurement was also necessary to establish the coordinate system. There was no triangulated reference system at the time and so we do not know from where Müller obtained his reference points. Imhof suggests that perhaps they were based on the preliminary work he did with Weiss and/or those of Professor Tralles.

Though it is impossible to be certain of the precise technique employed by Müller, it would appear that he used a form of triangulation that required the graphical transformation of his points onto a base of a pre-defined scale. Imhof does not elaborate further on the method of plotting the intersecting points onto a base. Here, we can postulate theories based on the surviving paper discs. Perhaps plan errors could be adjusted by minor movements in the paper discs, hence the presence of slots cut along lines of measurement (Fig. 1). However, this would normally require the central hole to be the same width as the slots and allow similar movement at the centre. Alternatively, the slots could have been cut to simply view the intersection of lines where two or more

opaque paper discs overlap. Having established the location of the point, it would have been straightforward to mark the base underneath the discs through the coincident holes of the overlying paper discs. Indeed, this technique would have been necessary given the scale of the terrain models being made. A 15 cm diameter disc would create lines 7.5 cm long – or 4.5 km at a scale of 1:60,000 or 9 km at a scale of 1:120,000. The slots in the disc are indeed at varying distances from the centre and not all the lines have slots within them. Note also that they are marked in ink, perhaps prior to cutting, suggesting that Müller may have been able to judge the rough distance of the target from his survey station. Given this evidence, there would appear to be little need for a sophisticated coordinate system given the strongly graphical nature of the technique employed.

Müller would have calculated the difference in height between points by using the recorded vertical angle taken from the instrument together with the horizontal distance presumably taken from the plan plotted during the graphical triangulation process. It is unlikely that Müller could have achieved high levels of accuracy given the low precision instrument and technique he was using. We have no information that relates to the vertical datum that he used and indeed, we have no indication that the curvature of the Earth was taken into account. Furthermore, whilst we know that some 264 discs have survived (ETH Zurich, Hs 1060:469-478) we don't know the total number of stations from which Müller surveyed or indeed the number of intersecting points that he measured.

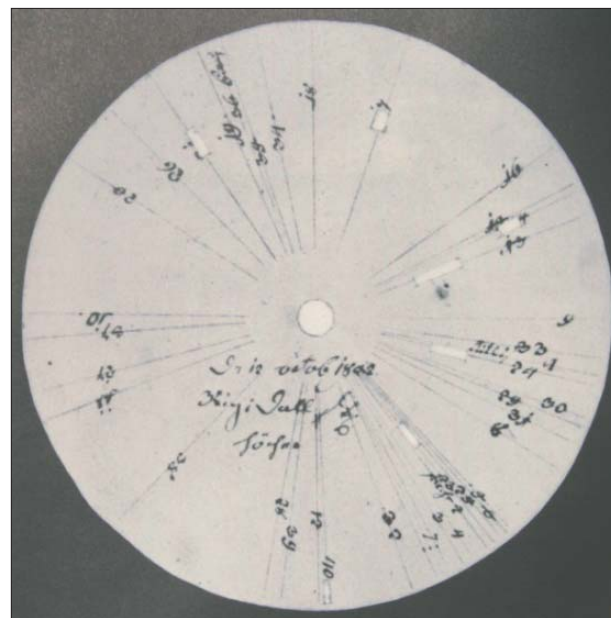


Fig. 1: Paper disc reproduced in Imhof (1981).

Imhof uses various assumptions to estimate a density of one station per 200 km<sup>2</sup> which he admits is a little excessive perhaps, as this density corresponds to that of the current Swiss third order triangulation. He suggests that the number of the points obtained by intersection must be some ten times larger than that of the survey stations. Müller probably had five hundred to a thousand points for the geometrical con-

struction of his model, assuming a surface of 20,000 km<sup>2</sup>, gives a density of one point for 40 or 20 km<sup>2</sup> respectively.

Müller mapped the ground located between the points obtained on the basis of field observation and had a portable compass which enabled him to determine the orientation of valleys and mountain peaks. His panoramas demonstrate great attention to detail and would have been an essential source for modelling the terrain.

### 1.3. Terrain modelling method

Müller carried with him the tools required for modelling – including the plaster. At his base camp, Müller would construct small relief models of the region that he had just explored. He would then transport the models to Meyer at Aarau. While Müller conducted his own surveys and modelling, Weiss was engaged in the graphical triangulation of large expanses of Switzerland. He managed to measure altitudes of a significant amount of the country. When all this work was sufficiently advanced, Weiss and Müller (Müller practically alone, according to the opinion of Professor Rudolf Wolf [1879]) undertook the construction of a great relief during the winter months spent at Aarau. They constructed a model at a scale of 1:60,000 of the Swiss Alps and Pre-Alps regions. Weiss concentrated on the East of the country while Müller completed the rest. Towards the end of this work, Weiss developed the contents and the drawing of the map. The alpine areas were then drawn, essentially, according to this great relief. As Imhof points out, we have the very rare and interesting case of a chart established according to a terrain model, not the other way around.

Unfortunately, the relief model at a scale of 1:60,000 and a size of 1.5 by 4.5 metres does not exist anymore. Meyer had the model on display in his house in Aarau where visitors could admire its hitherto unknown representation of a major part of Switzerland. It did not take long for the French Ingénieurs Géographes in Napoleon's service to recognise the significance of the model (Bürgi, 2007) and the Dépôt de la Guerre practically confiscated the model when it was on display in Paris. Meyer's recompense was a fourth of the costs of the survey and construction of the model. The model was of high military importance as it showed a topographically intricate part of central Europe that had hitherto been unmapped with such accuracy. The French army therefore wanted to prevent the model falling into enemy hands. The relief model was supposedly destroyed in 1922 (Bürgi 2007).

Fortunately, Joachim Eugen Müller was a prolific builder of relief models. At least 16 different models at different scales still exist at various locations throughout Switzerland (Mair and Grieder 2006). Among them is a model of the Bernese and Wallis Alps which is not north-oriented, at a scale of approximately 1:120,000 and a size of approximately 50 by 70 centimetres. Various copies of this model have survived. It is of particular interest as it is one of the very first models made by Müller and was presented to the Bernese government in 1789 together with another model at a scale of 1:40,000 (which unfortunately does not exist

anymore [Wolf, 1879]). Meyer presented these two models when applying for the permission to extend the area near lake Thun that Weiss, Tralles and Müller had previously surveyed. Meyer also applied for the permission to publish the surveyed area as part of his Atlas Suisse (Klöti 1997). Meyer was granted permission and in 1796 a first test sheet of the Atlas Suisse was published. This map named "Carte d'une partie très intéressante de la Suisse" was at the scale of the latter Atlas Suisse of 1:120,000 and had the exactly same extension and orientation as the model of the Bernese and Wallis Alps described above. For further analyses, we are therefore fortunate to have a relief model (Swiss Alpine Museum Model 420.00029) and a map that were both produced by Meyer's team at about the same period of time and show the same geographical area.

## 2. Scanning the Models

### 2.1. Non-contact 3D Digitizers

Non-contact 3D digitizers are used in a wide variety of application areas including medical science for prosthesis fitting and cosmetic surgery, in manufacturing for reverse engineering and rapid prototyping and in cultural heritage for the restoration and conservation of art objects. In theory, one of the major advantages of non-contact 3D digitizers is that they operate without touching the object being digitized and therefore present minimal risk to that object. Non-contact 3D digitizers are an interesting alternative to close-range photogrammetric reconstruction (Niederöst 2003), as they are quick, easy to operate, and allow for verifying the digital model on the spot using a connected laptop computer.

The scanner used was a Minolta VI-900 laser scanner which is a high resolution, high accuracy 3D scanner that uses laser triangulation to measure distances to points. More precisely, the scanner projects a near-infrared laser stripe over objects in the scene. A camera mounted in the scanner records distortions in the shape of this stripe which is offset by a known distance from the source of the laser stripe. Minolta firmware analyses the distortions in the stripe and through triangulation converts the distortion to distance measurements (Piper *et al*, 2002). A digital image or texture of the scanned scene at 640 x 480 pixel resolution is also taken by scanning the CCD through a RGB filter while the stripe light is not emitted.

The accuracy of the scan is moderated by adjusting the focal distance. The accuracy of the scanner using the 8 mm wide angle lens is given as x: ± 1.4 mm, y: ± 1.04 mm and z: ± 0.64 mm.

### 2.2. Set up and capture

The set up of the models and the scanner is dictated by the size of the object and the physical location of and handling restrictions on the object – in our case a solid terrain model. The scanner itself is mounted on a heavy duty tripod, which allows for the scanner to be tilted sufficiently allowing scan-



ning of a model without overhanging it, avoiding potential catastrophic damage to both the scanner and the model (Fig. 2). The model is therefore scanned at an oblique angle and due to the nature of relief models this results in dead ground in the shadow of elevated features thus necessitating a number of scans from different angles.



Fig. 2: Scanning in operation.

A wide angle lens with a focal length of 8 mm was used to allow for an object distance range of 2 m. Due to the size of the models, in most cases exceeding the field of view, the models were scanned in segments. Model 420.00029 (74 x 48 cm) in the Alpine Museum, Bern was of a dimension that allowed for the model to be placed on a table. The table was then moved to allow for the scanning of multiple angles and segments of the model.

The maximum recommended ambient light for the scans is 500 lx. This light level is fairly low for the subsequent capture of the colour image, resulting in images that appear dark and reproducing colour poorly. Appropriate light conditions had to be achieved by moderating blinds and lighting, thus balancing the light conditions required for the image and the laser scan.

## 2.3. Post-Processing

Post-processing of the scans was done using RapidForm 2002<sup>®</sup>. For each model the individual scans were imported and checked. RapidForm allows the model to be viewed with the texture or as a shaded relief (Fig. 3).

The first step in assembling a complete model is to register the scans or 'shells' to each other. The initial registration is performed by defining common points between two shells and the system then matches the overlapping areas. RapidForm takes into account the fact that pairs of corresponding points are not accurate enough while performing the command, because they are selected by the user. A secondary 'fine' registration automatically matches the overlapping areas and registers the shells to each other. In order to gain a measure of the success of the image registration a shell/shell deviation measurement is calculated, which provides a colour map of the deviation and a maximum error. If the error is found to be acceptable, the two matched scans are then merged and the resulting shell used to register the next shell. The process also merges the textures of the individual shells.

The alignment of the shells in space is defined from the location of the scanner in millimetres. As the scanner is situated at an angle to the model the model space is tilted and not horizontal. A manual transformation of the finished shell was performed and the model moved into a horizontal model space by aligning the frame of the scanned model to a horizontal plane. The resulting shell was then exported as a xyz text file. Unfortunately, the merged texture, however, could not be exported satisfactorily, but can still be viewed in RapidForm.

## 2.4. Resolution and Accuracy

The VI-900 produces a point cloud with an average resolution of 0.44 mm. On a flat surface the scanner produces a regular grid of points. The point density, however, is affected by the irregularity of a surface, producing increased densities on slopes that face the scanner's laser source and having the opposite effect on slopes angled away from the scanner. Here the distances between points increase slightly

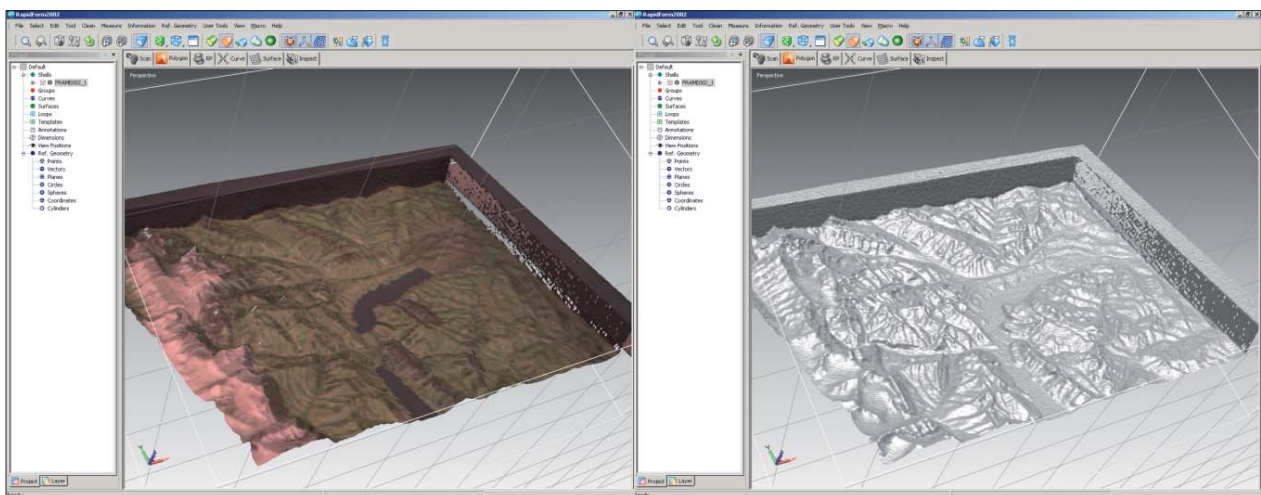


Fig. 3: Post-processing of the scans using RapidForm 2002<sup>®</sup>.

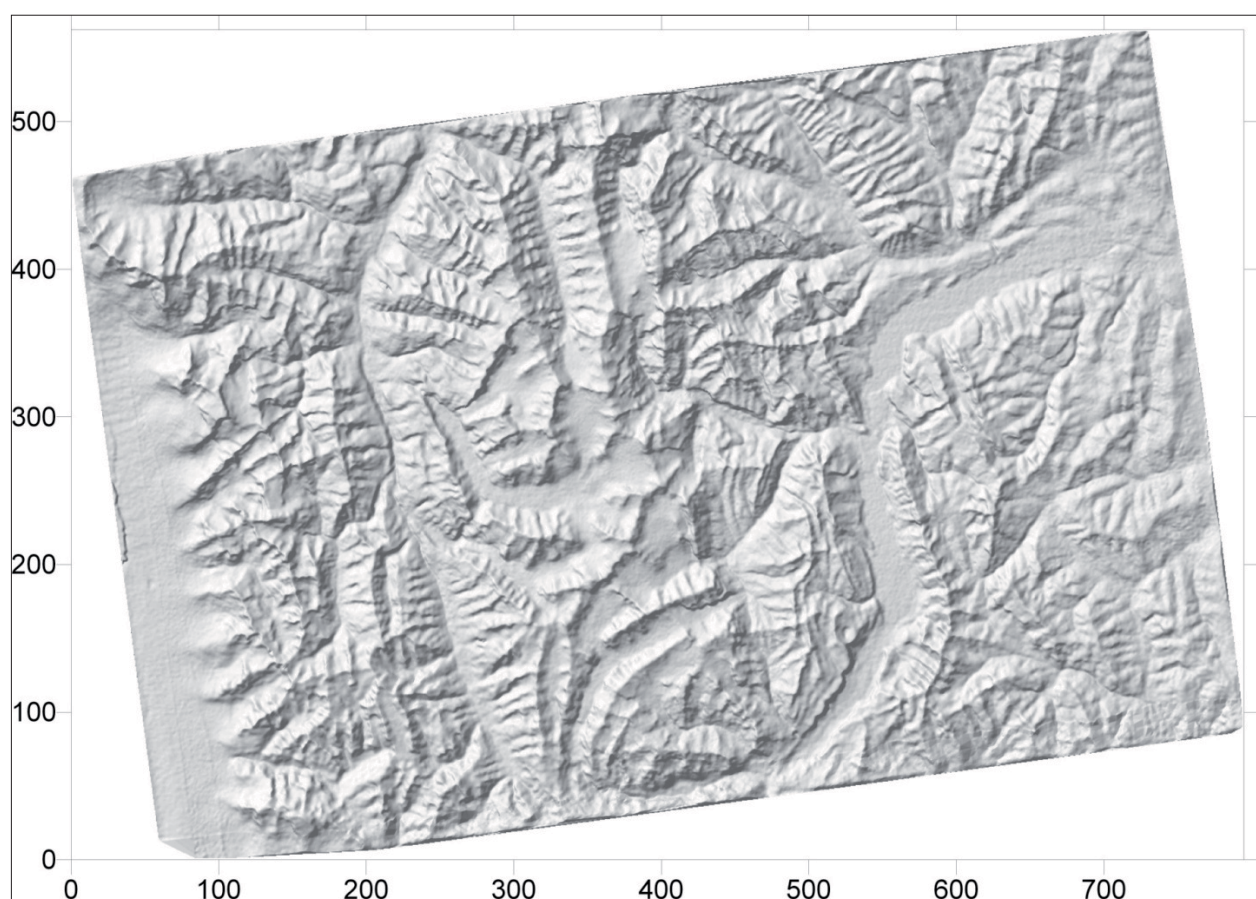


Fig. 4: Digital replica of Müller's model.

to between 1 mm and 1.5 mm. The resulting point data set is therefore quite irregular, depending on the orientation of the terrain. The point density is still considered high enough for the purposes of this study, but will have an impact on the choice of surfacing techniques for the data.

The scanner can introduce noise at distances greater than about 1.5m. The transition is quite subtle and as the problem was not apparent whilst scanning itself a more detailed investigation into the effects of distance on the scan results is planned for the future. In the final assembly of the model, priority was therefore given to shells that displayed little noise, with additional shells only used to fill in dead ground from the high quality shells. The scans of model 420.00029 did not exhibit this problem, but other, larger, models were affected. The shell/shell deviation measurements provided by RapidForm show that the maximum error in registering the shells of model 420.00029 to each other was 1.159 mm with standard deviations between  $\pm 0.279$  mm and  $\pm 0.316$  mm for different shell combinations. These errors fall within the stated accuracy levels of the scanner hardware. The scanner provided a data set of considerable size and density. Some 797,132 data points represent the 750mm x 480 mm of the model area. On average the resolution was 0.44 mm which, at a scale of 1:120,000, is equivalent to about 52 m ground distance. The final digital replica of Müller's original model is shown in Fig. 4.

## 2.5. Georectifying the Model Data

In order to compare the altitudes of the Müller model with modern surveyed data, the Müller data was geo-corrected in order to make the coordinate system compatible with the modern Swiss topographic survey. The supposition here is that if we eliminate plan error as much as possible, we can then compare altitudinal differences without the extra complications of horizontal scale error, which can be looked at separately.

Georectification of the Müller model was undertaken using ERDAS Imagine®. Swisstopo Digital elevation data DHM25 re-sampled to an interval of 50 m for the same geographical area as the Müller model was available as a reference for the geo-rectification process. Control points were selected and linked for points covering the model area. Points were selected that were as unambiguous as possible, such as prominent peaks. Control point residual values were examined for error, with any point errors exceeding one pixel or greater contribution to the error being eliminated. Fifty six points remained after this process having a mean RMSE of 2.23 pixels (111.5 m). An affine transformation was employed for the geo-rectification process and the final image was converted to an X, Y, and Z ASCII format file in readiness for import into Golden Software's Surfer® software package.



## 2.6. Digital Terrain Modelling

Surfer® provides sufficient modelling capabilities to provide some indication of the accuracy of Müller's model. In order to gauge the level of similarity between the model and what we take as reality, re-scaling of the height values collected by the 3D Digitizer would have to be undertaken. Clearly, this could be carried out by a similar process to that carried out for plan. However, it was decided to simply re-scale the Z-values of the Müller data to the scale that was theoretically assumed to be the case after many measurements had failed to identify a consistent vertical scale. The initial vertical scale was therefore changed to 1:120,000 and Thunersee was used as a datum having an altitude of 558 metres according to the Swisstopo data.

Given the high density of data points, triangulation with linear interpolation was selected as the preferred interpolator. This method is an exact interpolator with each triangle defining a plane over the grid nodes lying within the triangle. The tilt and elevation of the triangle are determined by the three original data points defining the triangle. Because the original data are used to define the triangles, the data are honoured very closely.

One of the useful capabilities of the Surfer program is its capacity to measure the difference between X,Y,Z data points (.dat file) and a gridded surface (.grd file) for each point stored as X,Y,Z values. Surfer computes the vertical difference between the Z value of the data file (e.g. Müller) and the interpolated Z value on a gridded surface (e.g. Swisstopo elevation model) using the simple formula  $Z_{res} = Z_{dat} - Z_{grd}$ . Thus it provides a quantitative measure of how well the grid file agrees with the original data. The residual value is therefore the difference between the Z value of a point in the data file and the interpolated Z value at the same XY location on the gridded surface with residual values being reported as either positive (Swisstopo data lower) or negative values (Swisstopo data higher).

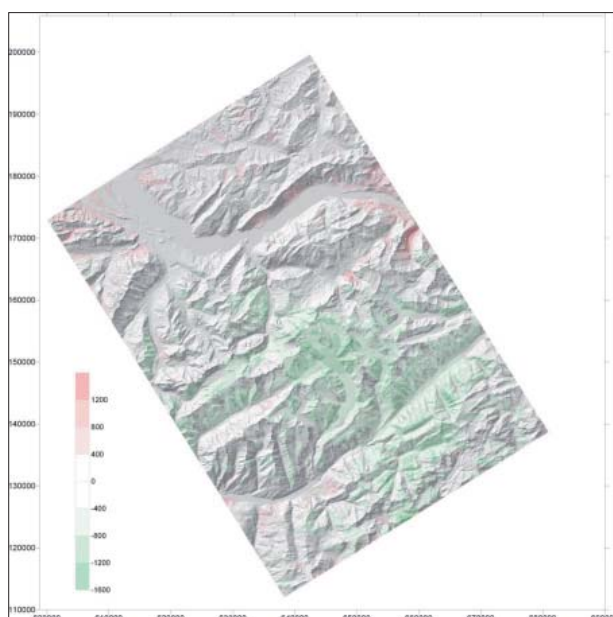


Fig. 5: Positive and negative residuals.

## 3. Results

At this stage in our research we are mainly interested in identifying any broad trends in the differences between Müller's model and modern surveyed points. This might throw some light on the techniques employed for the survey and indeed for the model-making process.

Much can be learnt from the analysis of the residuals. The pattern and amount of error (Fig. 5) demonstrate a high degree of spatial autocorrelation throughout the model. The highest errors appear to be located on the central portion of the model, the Bernese Oberland. When we consider both positive and negative residuals we can see that the distribution of error is not random, with overestimations of height being evident in the north-west and south of the model. The central Bernese Oberland appears to be significantly underestimated. In order to examine the general trends in the error, trend surface analysis was applied to the residual values. A first order polynomial interpolation of the residuals suggests a systematic error that follows the broad trend described above. Apart from isolated peaks in the south, the broad trend is overestimation towards the north of the model and a dip towards the south. Using the polynomial surface, we can adjust the Müller data accordingly. The overall impression from these adjusted errors is that the central Bernese Oberland at the centre of the model has been underestimated. A quadratic polynomial trend surface was then applied to the adjusted surface's residuals and an adjustment made once again. The pattern of the residuals demonstrates a much lower level of spatial autocorrelation with high residual values concentrated on valley slopes rather than mountain peaks and valleys.



Fig. 6: Rank order of principle peaks - Swisstopo, Müller and Meyer-Weiss.

Another interesting angle to take is to compare the relative altitudes of the principal mountains with the model area (Fig. 6). This is very revealing. Even over very short distances, Müller's estimation of altitude appears to be at odds with reality. This is also not limited to the Bernese Oberland. Interestingly, when we compare the rank order of mountain altitudes as depicted on the Meyer-Weiss Atlas de Suisse map of 1797 we find that the rank order here is in harmony with today's data.



As with all analysis of this nature, any explanation for the distribution of error between Müller's model and the modern surveyed data supplied by Swisstopo will be largely educated guesswork. There are many factors that could contribute to the results as outlined so far; some of them not associated with Müller's survey and model construction techniques. These factors include the errors introduced by the 3D digitizer and the deformation of the terrain model over time. We must also be mindful that the model may not have been mounted in its frame in its original horizontal position. Furthermore, as there is no datum identifiable on the model, an arbitrary datum had to be applied to the scanned data. When we consider that the maximum range of height within the model is a mere 4 cm or so, these factors may well have had a significant impact on the results.

Nevertheless, even at this exploratory stage, we can establish some working hypotheses with which we can move forward in our research. Firstly, the models appear to have been constructed by establishing principle peaks in positions that compare closely to today's data. Intervening surfaces were perhaps modelled by 'interpolation' as one would expect, to a lower level of accuracy in both height and plan. These principle peaks do not appear to have been modelled to the same level of accuracy in Z as they have in X and Y, the emphasis being focussed towards plan accuracy rather than height. The lower accuracy in the vertical axis of the model is not likely to have been due to inaccuracies in surveyed height data as contemporary values, available to Müller (as seen on the Atlas Suisse), were closer to reality.

#### 4. Conclusions

This paper has attempted to apply scientific and objective measures in assessing the models of Joachim Eugen Müller and of necessity has had to forgo any appreciation of the exceptional levels of landscape modelling that were achieved. Throughout the paper, the term 'error' has been used frequently in its statistical sense but still might give the impression that the analysis has been focussed on weaknesses rather than strengths. However, it is abundantly clear that the models are a remarkable testimony to the dedica-

tion, skill and artistry of Joachim Eugen Müller. Given the lack of sophisticated surveying equipment and established triangulated survey network, his achievements are all the more remarkable. Indeed, looking at the models, it is difficult to believe that they are some 200 years old. The high standard of his work helped to establish a new benchmark in Swiss cartography and indeed was the progenitor of a Swiss 'school' of modelling (see the excellent book by Mair and Grieder, 2006).

3D non-contact digitizing has proved itself to be highly suited to this type of research. It is fast, flexible and accurate. However, we are now in a position to suggest improvements in the way that it is operated in future. During the initial scanning it was not easy to gauge the success of each scan using the scanner's built-in viewer, and issues with the scans only became apparent during post-processing. The texture capture proved to be especially difficult, as the necessary lighting condition for the laser scan did not lend itself for the capture of the image information. This, combined with the relatively low resolution of 640 x 480, meant that the images were low resolution and poorly exposed. A secondary image capture using better lighting and a better image sensor, such as a calibrated digital SLR, and subsequent image registration to the finished 3D model would be our preferred method in future.

The results of our analysis suggest that the terrain models were made to establish the three dimensional structure of the landscape with the emphasis on providing a depiction of the landscape as a continuously changing surface. Absolute altitudes and relative heights were perhaps of secondary importance to the more important problem of filling the gaps between known measured points. With Müller's talent for landscape recording, he ensured that the first 'modern' maps of Switzerland depicted its landscape as closely as possible and ahead of the systematic triangulated surveys that commenced later in the nineteenth century.

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# Web Application for Topographic Maps Changes Acquisition

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## Abstract

*Paper presents a server-client based web application that allows map users to collect changes in maps by themselves and deliver them to data provider. The application was initially prepared to help update the content of the 1: 25,000 National topographic map of Republic of Slovenia, which became quite out of date due to lack of funds and other priorities at the National map agency in last years. The noticeable advantage of the application over similar ones is that client, not only can mark the area of the change, but also select the type of object that he would like to add, change, or remove from the map. The selection is available through an entire catalogue of objects and phenomena, presented on a map.*

## 1. Introduction

Regular updating of topographic maps and topographic databases, especially in the mountain areas, has become a great problem in many countries, including Slovenia. At least in the Alps and other parts of central and southern Europe, the Switzerland is probably the only state, where the terrain acquisition for updating national topographic maps and databases is still being done (Gurtner, 2006). In spite of different new technologies and possibilities (LIDAR, etc.), the terrain capturing and interpretation remain the most reliable methods. They are not very distinctive for orientation and navigation purposes, but for capturing of landmarks and other important objects, like single tracks in forests, passages in steep and rocky slopes, springs, small graveyards, memorial signs etc.

The decisions of many National mapping agencies are quite understandable. Since the establishment and updating of topographic data is mostly financed from the budget, they try to reduce production costs. Terrain capturing method is long lasting compared to all the others and therefore very expensive. On the other side these objects (tracks, etc.) have lost the relevance for most of official use, including the military one and their capturing can no longer justify high costs. But there are still a lot of individual users, using paper maps as a guide in different outdoor activities. There are also more and more "modern" users, using raster map images as back-

grounds on their GPS based devices (Fig. 1). They all are looking forward to have high-quality and regularly updated topographic maps.

The problem of updating large scale topographic data in Slovenia has started soon after 1991, when Slovenia became an independent country (Petrovic, 2006). The Slovenian State Topographic Map at the scale of 1: 25, 000 (DTK 25) is the largest scale map of Slovenia, presenting the entire territory on map sheets at the unique scale. The 198 map sheets were published from 1994 to 1998, as a remake of former Yugoslav's military topographic map, last updated in 1985 and 1986. Unfortunately the design modifications had the priority over the updating of content. Only the highways and major roads, water accumulations, large buildings or larger new build-up areas were added to the source map sheets.

Later on, the National Mapping Authority, due to lack of funds, decided not to update DTK 25 any more and moved to 1:50,000 as the largest official topographic map scale of Slovenia. Even though the rest of the content of that map is regularly updated, the tracks have not been updated since 1980's. There is also a large scale topographic database which covers about 60% of the Slovenian territory at the moment, but these are mostly populated flat or hilly areas and it could be happened that mountain regions will not be captured at all. However, there is still the DTK 25. Although it has not been updated since mid 90's and the majority of content is even older. It is still the only available topographic data source for outdoor users.

## 2. Updating the official topographic data by users

The individual users show the most interest in getting detailed and high-quality topographic data of mountain regions and since using the available data, they are also representing the best data usability and quality control. The users are often skilled enough that they can provide reliable information about the real situation on the terrain and they are even prepared and willing to share their corrections with other users. There are quite a lot of different web services and pages, where different mountaineers, bicycle riders or mountain skiers share their tracks (usually GPS



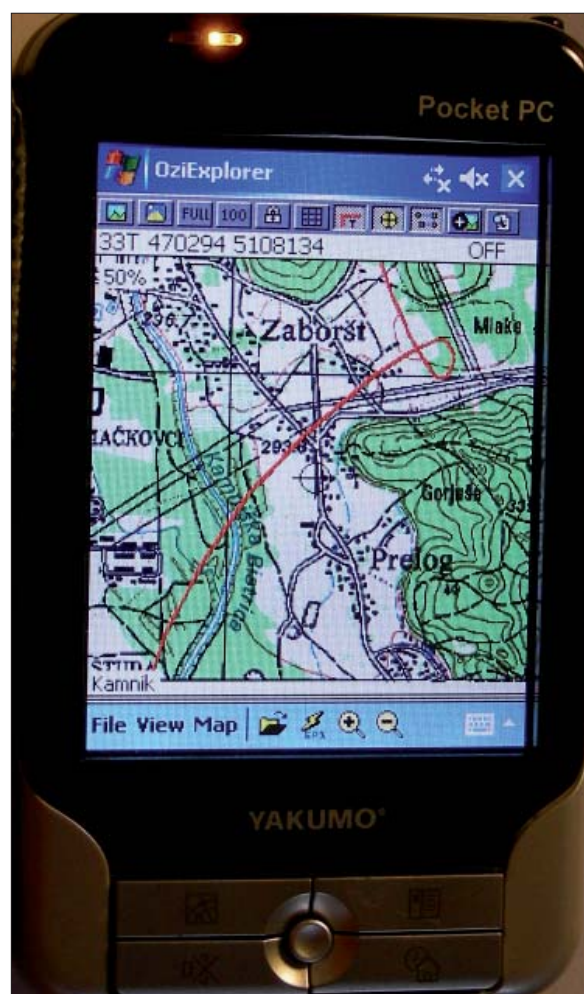
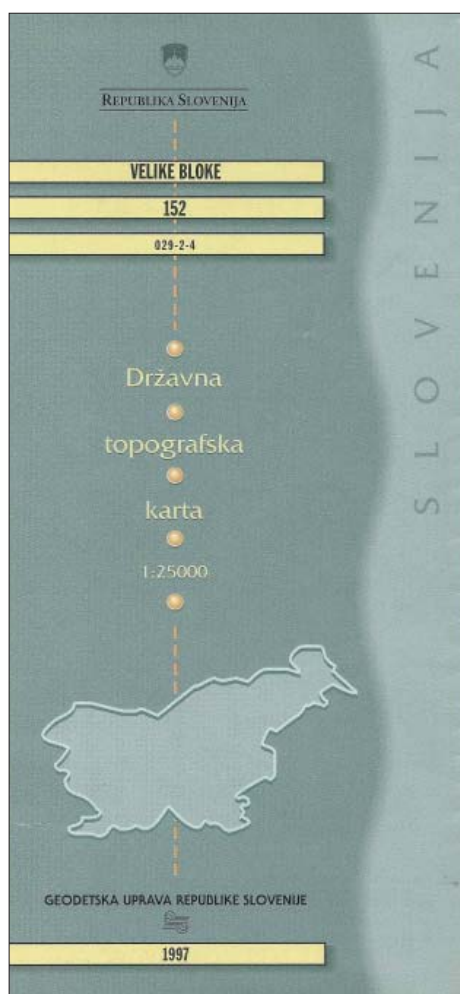


Fig. 1: Large scale topographic map (DTK 25) in paper form (left) and in raster digital form as a background on GPS included PDA device (right).

recorded) or even build different databases, freely available to all the costumer.

A step forward was made by some commercial data providers and also some national mapping agencies, who asked their users to help them find mistakes in their databases. In many cases (like Teatlas Map Insight™ (Teatlas 2008) or Navteq Map Reporter™ (Navteq 2008) users can only mark the point and argue the type of mistake, while the exact position of the changed object has to be captured by

the data provider itself. We personally assume that the providers can evaluate only the minor part of all corrections reported by users, since every report causes quite a lot of further activities.

Therefore, we tried to find a better solution which would enable a non-expensive but still efficient method for updating DTK 25, keeping it in a condition which enables different users to use it in future. After analysing some Slovenian web forums and other personal web sites, we realised that

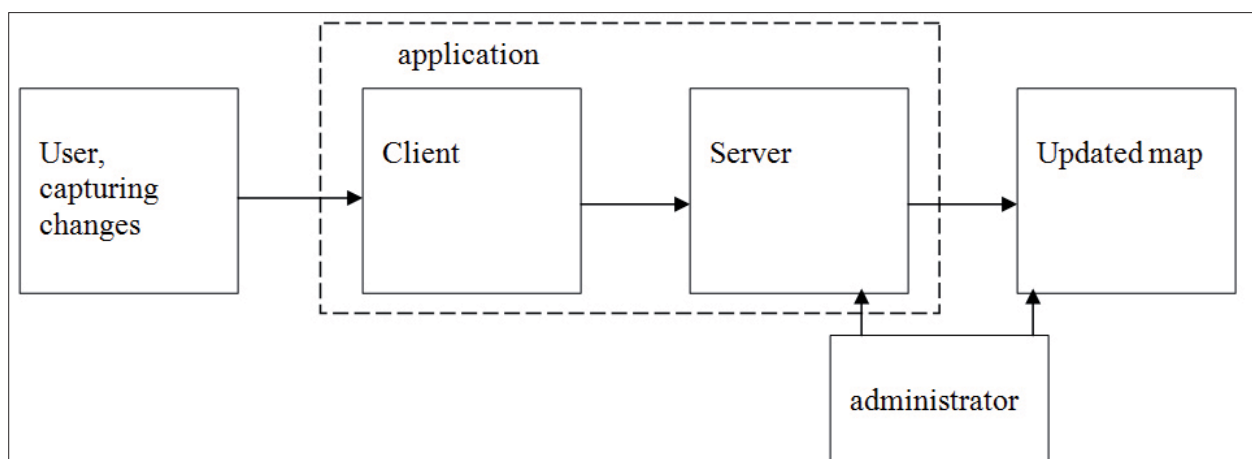


Fig. 2: Idea of updating DTK 25 by users.

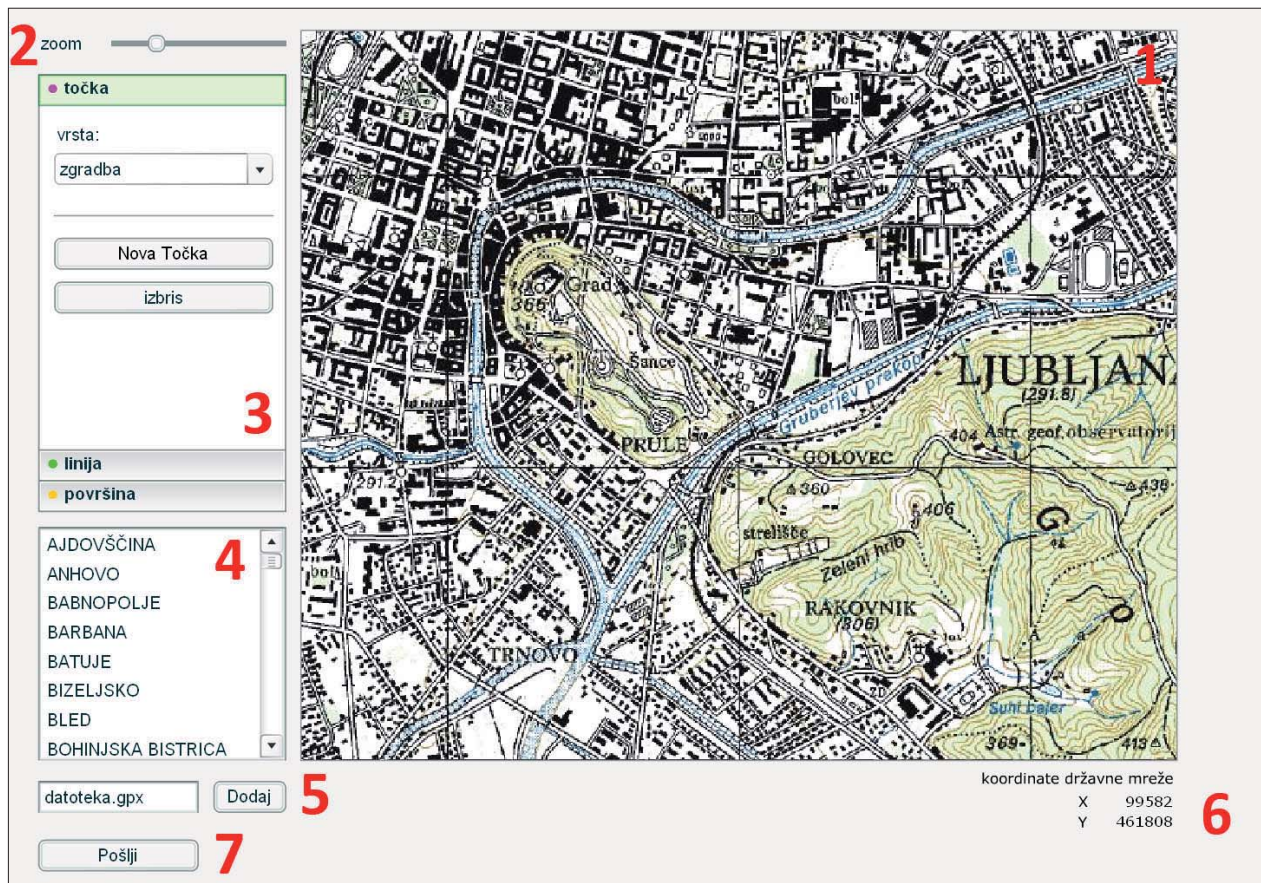


Fig. 3: User interface of client application

- 1 – Main window with zoomable and panable map
- 2 – Scroll bar for zoom ratio
- 3 – Field for selecting type of object
- 4 – Selection of map sheet
- 5 – GPX files import
- 6 – Pointer coordinates (in national coordinate system)
- 7 – Command button to send all the data to the server

the users of DTK 25 should be interested enough in keeping the map up-to-date. We decided to make a concept and establish a server-client based web application, where users can mark all the changes and corrections found on the terrain in such a way, that the changes can be almost directly involved into the map or database. To detail the notification of the object changes at the approximate place, we would also allow users to determine the exact position and the type of the new or changed object, as it was captured on the terrain.

Some doubts about such deep involvement of users into the official topographic map content are justified, of course. The main problem is the quality. How to assure that the position accuracy of user corrections would not be worse than the map's current accuracy? We tried to enable one procedure with direct insertion of captured GPS tracks into the application. Accuracy of selected records would be later analysed. The other problem is how to motivate users to cooperate. It is indeed not possible to give a new version of map for free to every contributor, so this remains as a challenge for us.

### 3. A server-client based web application

An application named Reambulator v1.0 was developed in ActionScript 3.0, which is a part of Adobe Flash CS3™ environment, initially designed for composition of web pages. Environment has a lot of pre-prepared graphical solutions which makes programmer's work easier. Server part of application, the database was made using PostgreSQL™ with PostGIS module, while PHP code supports the communication between user interface and server. Figure 3 shows the user interface of client application.

The application enables users to add any point, linear, or area features that exist on the displayed map. They can add new items, replace the attributes (type of object), or mark non-existent objects (Fig. 4). The position of new objects can be inserted manually on the map background, while GPS captured data in GPX format can be also uploaded into the application. When the user confirms the record, the data is sent to the server, where all users' records are stored. The administrator evaluates all the acquired records and decides, which data can be inserted onto the map directly,



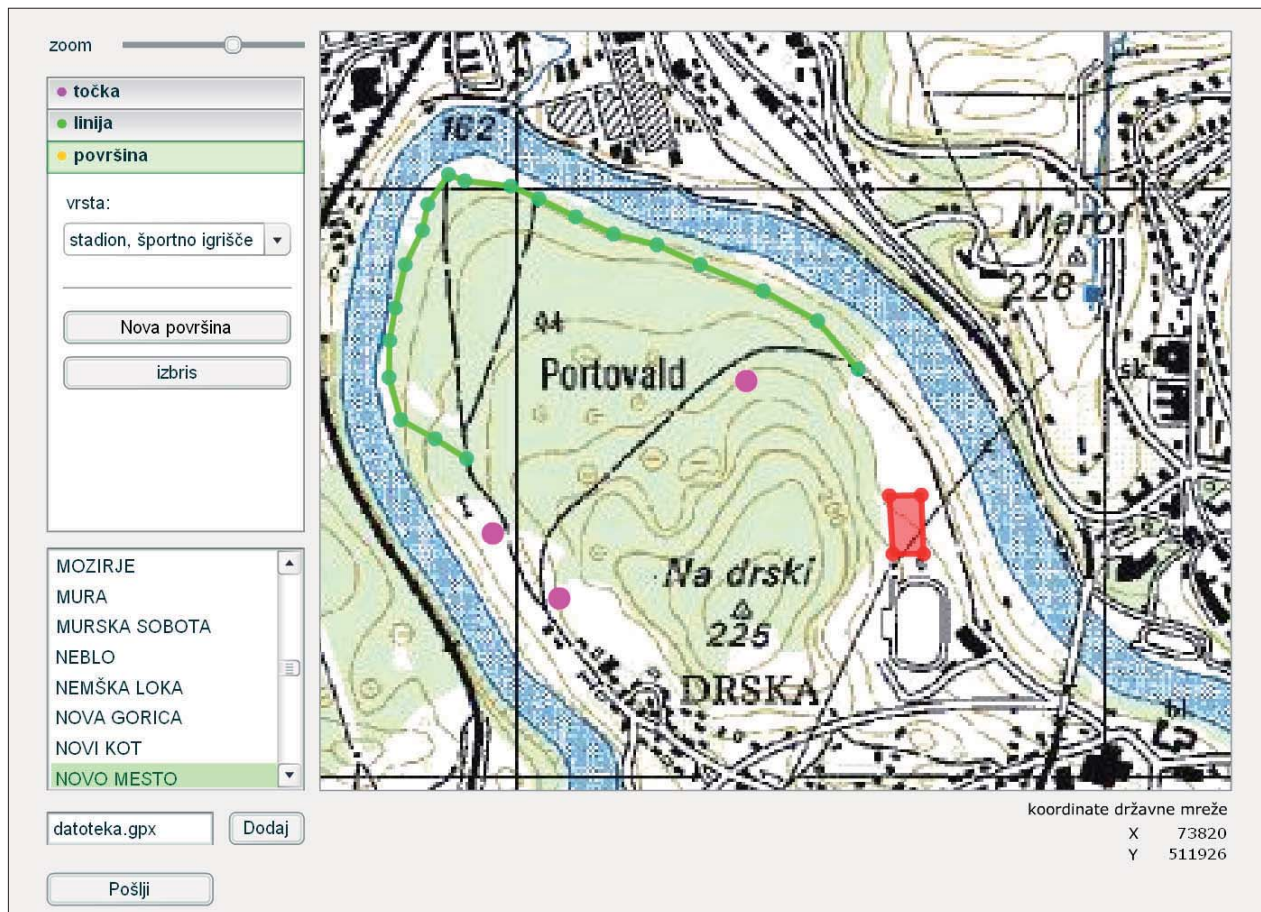


Fig. 4: Example of inserted point, linear and area features.

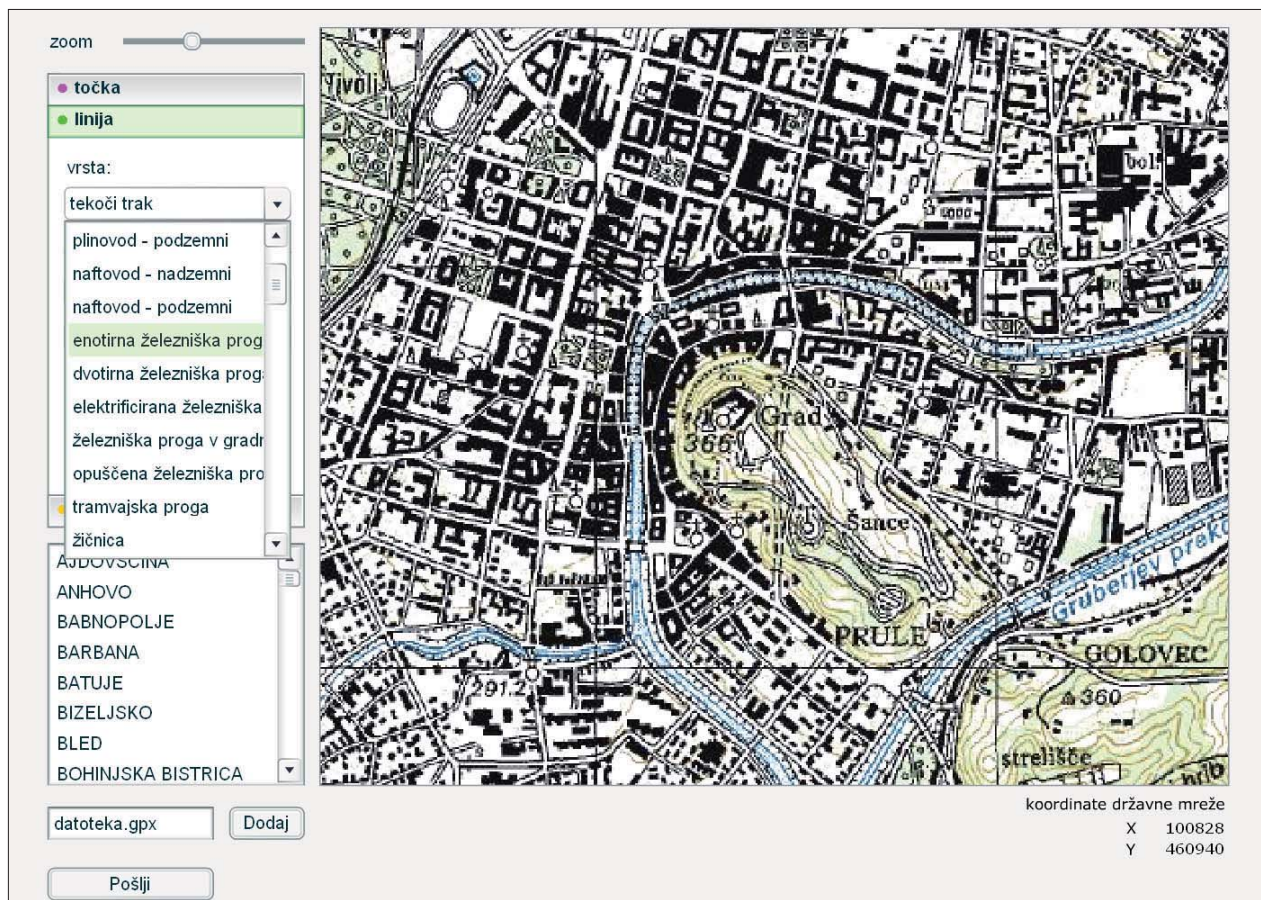


Fig. 5: Selection of object type.



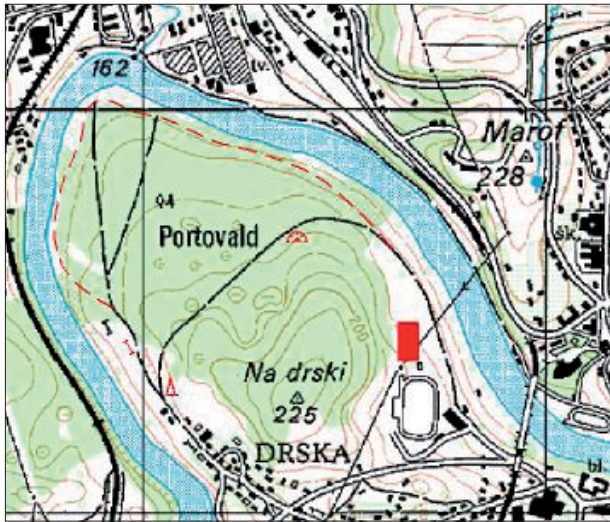


Fig. 6: Symbolised new objects in the original map content.

which data has to be checked with aerial or satellite images, and – in some cases – where terrain checking has to be performed.

The advantage over other similar applications is that – after importing GPS data or manual determination of object positions – the user selects the object type from the list of all available object types which are included in the map (Fig. 5).

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The graphic data is linked to the attribute information by the object type. If we have a pre-prepared and server-side symbol table in the application, every inserted new record can be automatically presented on a map as a new object with correct symbolisation. In our case we used OCAD 9™ for symbolisation and the administrator can graphically check logical relations between the previous map content and the appropriate corrections (Fig. 6).

## 4. Conslusions

The presented application Reambulator v1.0 is only available in “lab” environment. We made some tests with the data that we captured ourselves, which of course is far from the later real-life use of the application. We are planning to put the application on the internet and submit it to real-life use in near future; however, there is still a lot to be done regarding the user interface. Furthermore, if experience would satisfy our expectations we are looking forward to launch the application in cooperation with the Slovenian Mapping Authorities.



# New Requirements for the Relief in the Topographic Databases of the Institut Cartogràfic de Catalunya

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## Abstract

*Since 1983 the Institut Cartogràfic de Catalunya (ICC) has been collecting information for the generation and for the updating of topographic products, including databases, digital terrain models, orthoimages and maps. At large scales, until 1:25,000, the topographic and elevation data is digitized using photogrammetric systems. Since 2002 another source of elevation data is provided by the LIDAR systems acquired by ICC.*

*In this context, new requirements have been added to the topographic datamodels in order to improve the Digital Terrain Model (DTM) and the Digital Surface Model (DSM) and allow a better exploitation of the enormous amount of digital elevation data. Some examples of new applications are the derivation of topographic products at smaller scales applying automatic generalization, the improvement of the DSM to optimize the orthophoto workflows, the integration of LIDAR data to refine the existing models, or the enrichment of the cartography at 1:1,000 scale to derive an appropriated DSM for high resolution orthophoto (10 cm of pixel) or for city model generation.*

## 1. Introduction

The Institut Cartogràfic de Catalunya (ICC) is a public law entity of the Generalitat de Catalunya, the Autonomous Government of Catalonia. From its creation in late 1982, the ICC has focused its efforts in the cartographic production in Catalonia either in promoting the studies to improve the production workflows.

Since 1983 the ICC has been collecting information for the generation and for the updating of topographic products, including databases, digital terrain models, orthoimages and maps. At scales up to 1:25,000, data is mainly collected using photogrammetric systems, and stored as 2.5D data models. Since the acquisition of the digital camera in 2004, the complete workflow is digital.

In the year 2002, the ICC acquired an airborne LIDAR system, which represents another source of elevation data. At the moment, its main use is for estimating the risk of floodings. Another area of application is the improvement of elevation data in zones where photogrammetry doesn't

reach the desired accuracy because poor or no visibility of the ground as it is often the case in zones such as forests covered by dense vegetation in mountainous areas.

Finally, there are a whole set of new requirements that the traditional topographic data models and the derived Digital Terrain Model (DTM) and the Digital Surface Model (DSM) need to fulfill for a wider exploitation of the enormous amount of existing elevation data. Some examples are the derivation of topographic products at smaller scales by automatic generalization, the improvement of the DSM to optimize orthophoto production workflows, the integration of LIDAR data to refine the existing models, or the enhancement of the cartography at 1:1,000 for deriving appropriated DSMs for high resolution orthophoto (10 cm pixel) or for city models.

## 2. The relief in the ICC topographic databases at large scales

The two ICC topographic databases of interest for terrain modeling are the Topographic Database at 1:5,000 (BT-5M) and the cartography at 1:1,000 scale. The ICC also produces the Topographic Database at 1:25,000 scale, but the detail is too generalized to achieve the 1.5 m RMS accuracy required for ICC's master DTM.

### 2.1. The topographic database at 1:5,000 scale

The Topographic Database at 1:5,000 scale is the most detailed database that covers Catalonia. The data is compiled using photogrammetric systems according to a 2.5D data model. The accuracy is 1 m RMS for X and Y and 1.5 m RMS for Z. The updating cycle is 5 years over all the country and more frequently over the most dynamic areas. During the stereoplottting process all the features required to generate a DTM and a DSM are compiled together with the topographic objects.

Both the DTM and DSM are in triangle or grid format, depending on the capabilities of the application software used and the final product to be obtained.

The features collected on purpose for the DTM generation are scan lines, break lines, spot heights, contour lines used



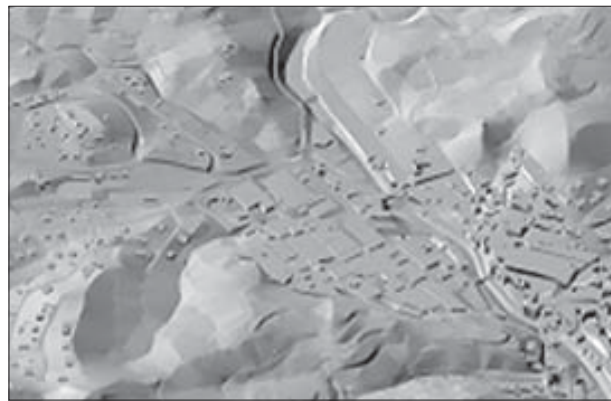
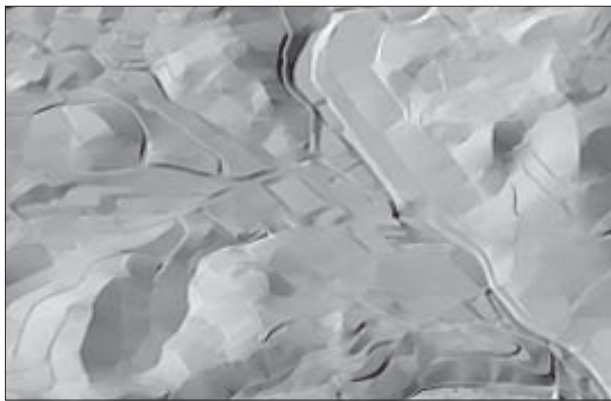


Fig. 1: The images show the differences between DTM (left) and DSM (right).

to infer break lines, and flat areas. Moreover all the planimetric features captured on the ground are used as break lines. The main use of DTM is to derive the contour lines and the shaded relief at smaller scales.

For orthophoto rectification at large scales, the DSM is used instead of the DTM because of the problems when there are differences between the terrain and the actual elevation. This is the case, for example, of buildings or bridges (Fig. 1). The features for the DSM include all the features collected for DTM excluding the areas covered by buildings or bridges, where their elevation substitutes the terrain. Some processes are required to generate special data to avoid vertical triangles, which are not supported by most of the software available.

The altimetric data is checked during data capture by running quality control processes that apply different techniques to detect and correct mistakes. The digital photogrammetric systems allow the superimposition of stereo images and vector data, and this is a powerful tool to detect severe mistakes. Checking the height of the intersection of crossing break lines or contour lines allow to queue and correct the elevations at the erroneous intersection points. Also, the generation of contour lines allows analyzing the result of the interpolation of these elements. Finally, the shaded relief provides an idea of the quality of the model and helps to detect small errors. All these verification processes can be repeated until the data becomes acceptable.

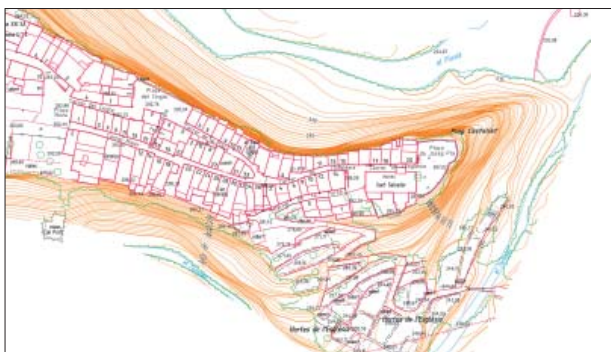


Fig. 2: The image shows a detail of Cartography at 1:1,000 scale.

## 2.2. The cartography at 1:1,000 scale

The Cartography at 1:1,000 scale covers the urban areas and the areas planned for urbanization. The data is compiled photogrammetrically and it is completed by data surveyed on the field. The accuracy is 20 cm RMS for X and Y and 25 cm RMS for Z. The updating cycle is approximately 5 years. Although the data model is 2.5D, it is not designed to generate neither a DTM nor a DSM. The relief is represented by contour lines and spot heights as in the traditional cartography at this scale.

## 3. The relief derived from the ICC LIDAR data

In 2001, the ICC acquired an Optech ALTM 3025E airborne laser scanner (LIDAR), which started production in February 2002. The current state of the art of this technique allows for measuring the distance traveled by the laser beam to the centimeter level precision, although the GPS and INS errors reduce this precision to 15 cm in normal operating conditions.



Fig. 3: Shaded relief derived from LIDAR data.

Very recently, the ICC has acquired an ALS 50-II LIDAR from LEICA GeoSystems that is about to enter production.

Some examples of applications are flood risk analysis, mapping of power lines, management of forest areas, analysis of the changes in the shore line, change detection in urban areas and as primary segmentation criteria for multispectral classification.

## 4. New ICC applications based on elevation data

### 4.1. Spot heights generalization

Since 1997 the ICC has been applying automatic generalization techniques in the production workflows of the vector topographic databases and maps, but these techniques never have been used on the objects that characterize the relief. The main reason is that the available commercial software has not offered, until now, any tool specifically designed for relief generalization.

From 2002 the Research Group of Geoenvironmental Cartography and Remote Sensing of the Department of Cartographic Engineering, Geodesy and Photogrammetry of the Universitat Politècnica de València (UPV) has developed the GENCOTES application for generalizing spot heights. The main principle behind this software is the analysis of the morphology of the terrain (Palomar and Pardo, Vall de Núria, 2004) while taking into account cartographic aspects such as the significant points or the map names.

In 2006, the ICC and the UPV signed a collaboration agreement for adapting GENCOTES to the cartographic production environment of the ICC. As a side effect of the geomorphologic analysis of the terrain, the original data would be enriched with the classification of the spot heights.

The ICC decided to apply this tool to the generalization workflow that produces the Topographic Database of Catalonia at 1:25,000 scale from the master database, the Topographic Database of Catalonia, at 1:5,000. Until before,

the generalization operations applied on contour lines have been automatic selection and point filtering, followed by manual revision and editing of the conflicts, and in the case of the spot heights, the generalization has been done totally by manual processes. The main reason for start using GENCOTES on the 1:25,000 generalization workflow was the significant number of spot heights that must be present on a map at this scale requiring a costly manual generalization.

GENCOTES automatically generalizes the spot heights in two steps: a hierarchical classification of the spot heights for giving a specific value to each one based on parametric criteria, and a selection taking into account the hierarchical classification and a balanced distribution of these points on the final data. In terms of hierarchy, three kinds of spot heights are considered:

- a) Special interest points. Defined by the specifications as significant, must remain in the generalized data (for example, on the roads, related with map names, etc.).
- b) Geomorphologic interesting points. They identify characteristic terrain points, such as peaks, passes or depressions.
- c) Remainder points. All the other spot heights that have not been considered in the previous categories.

Although the results with ICC data were really promising, some modifications were introduced for taking into account the complete set of the ICC rules and to obtain results more similar to the manual generalization.

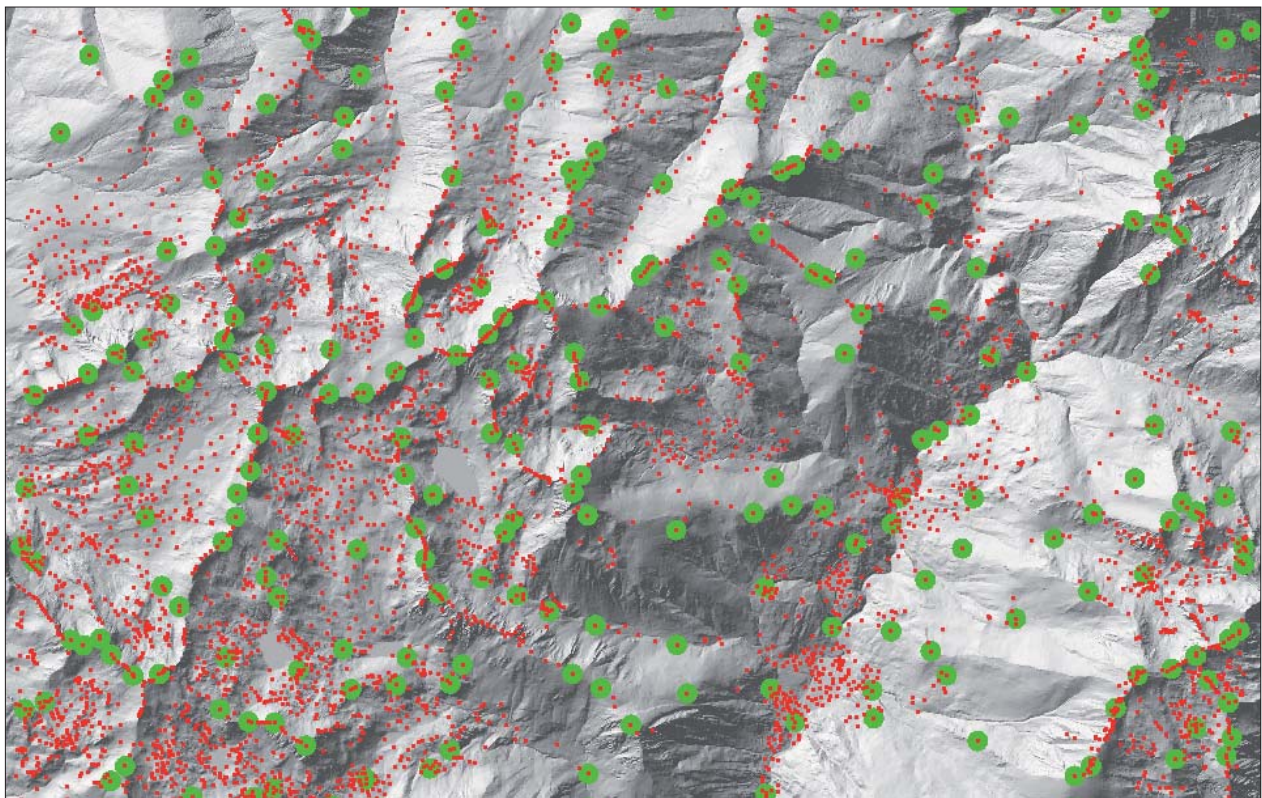


Fig. 4: The result of automatic generalization on the complete map sheet, corresponding to a high mountain area in the centre of Pyrenees: original spot heights in red and the result of the automatic generalization in green.



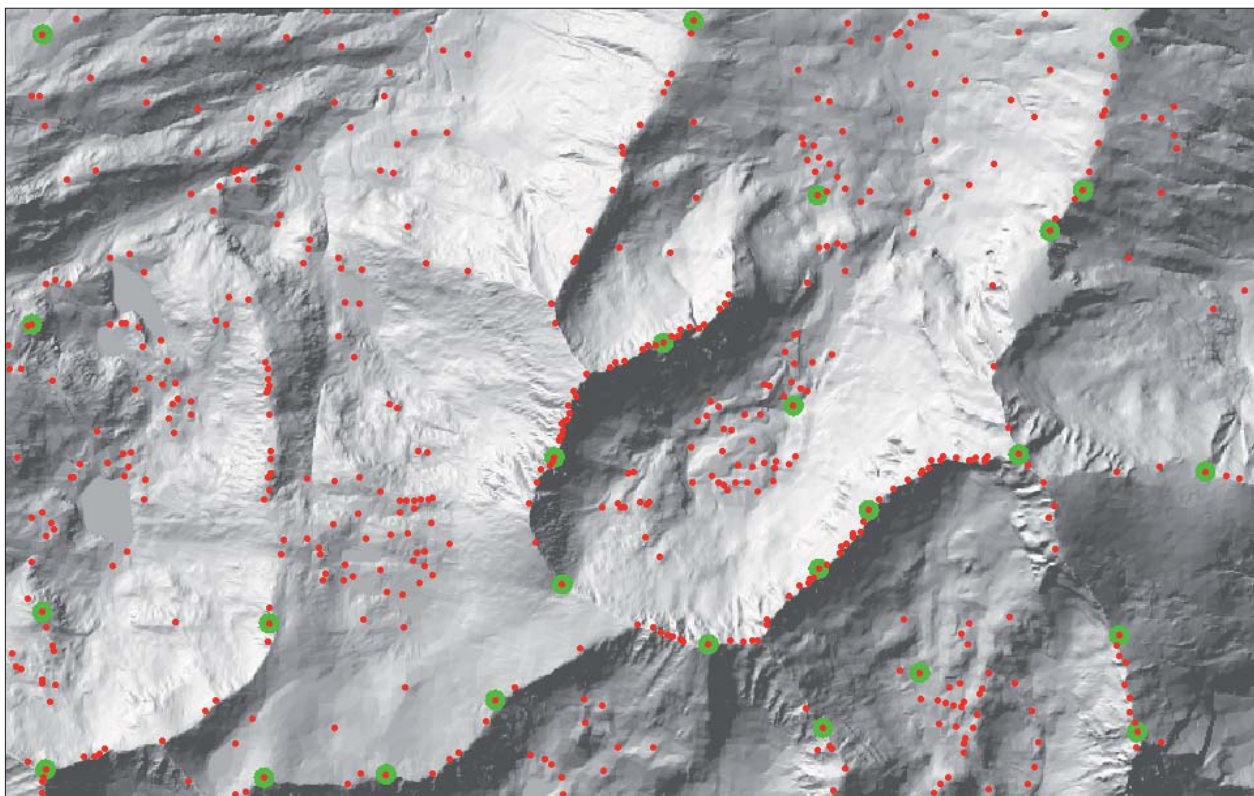


Fig. 5: An enlarged view of the results (10 km<sup>2</sup>).

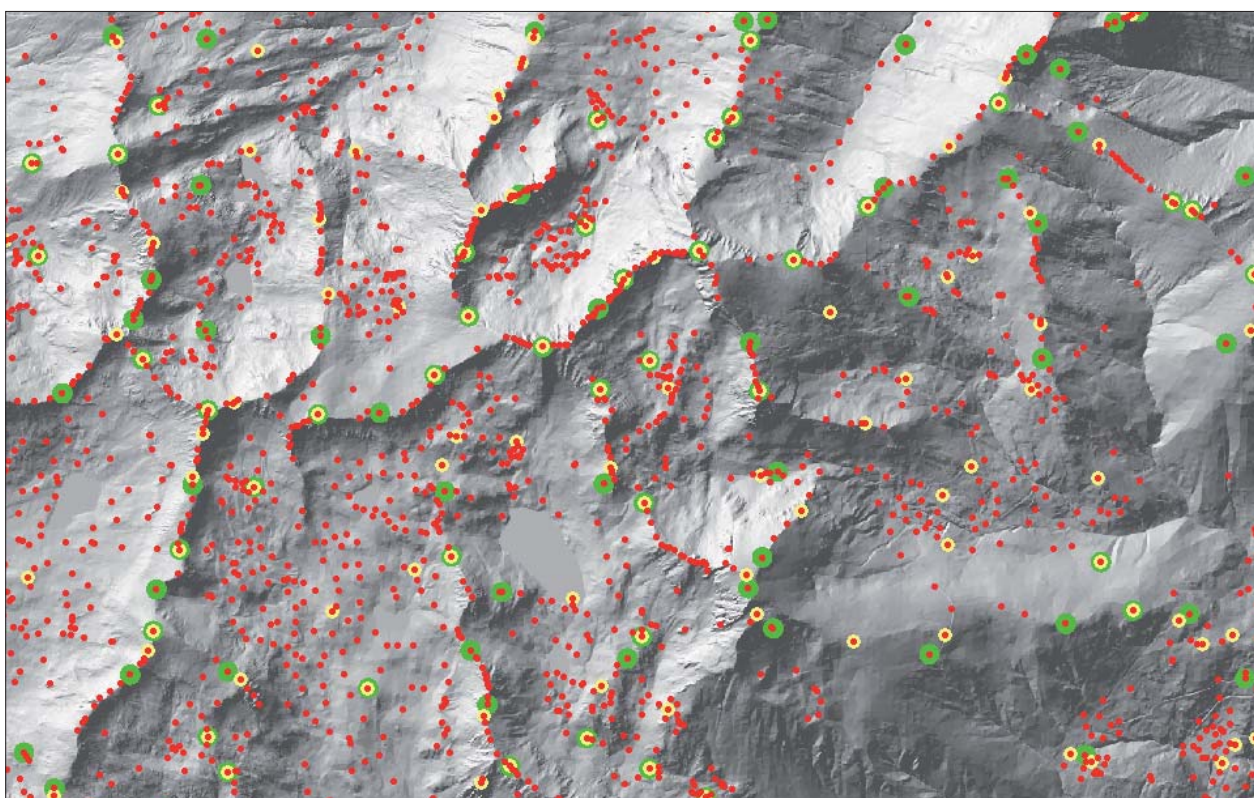


Fig. 6: The original spot heights in red, the manual generalization in yellow, and the automatic generalization in green (40 km<sup>2</sup>).

The altimetric point generalization obtained using GENCOTES is in some aspects lightly different from the manual generalization. The differences come from the difficulty of describing and specifying all the contextual and aesthetical rules that the cartographers apply during manual generalization. Nevertheless,

the results were good enough to implement the tool into a real cartographic production environment. Results show an improvement in terms of global homogeneity and an effective time saving without a loss of quality. Moreover, the geomorphologic classification of the original spot heights will be used to enrich the original database and it will be



exploited in further applications of terrain generalization or terrain analysis.

#### 4.2. The new data model for cartography at scale 1:1,000 and DTM/DSM generation

From its creation, the ICC has been covering Catalonia with orthophoto images at 1:5,000 scale, with pixel of 50 cm, using internally developed software that is constantly improved. The updating cycle has been reduced to 2 years and an annual coverage is to start in 2008. In the most populated areas, the ICC is also producing orthoimages with pixel of 20 cm.

Increasingly, a larger number of users are asking for higher resolution (10 cm) and accurate orthophotos in urban areas. As it is known, the main problem for high resolution orthophotos is the availability of a good and accurate DSM.

A DSM can be obtained by stereoplotting of contour lines, scan lines, break lines and spot heights, by applying photogrammetric automatic image matching (correlation) or by using the direct measurements of a LIDAR system. Correlation and LIDAR data require manual quality checking and editing to add break lines and control points to the model, specially in built up areas, bridges, walls, embankments, cliffs and plain water and also in areas of poor texture in

the case of correlation or too dense vegetation in case of LIDAR.

As the ICC has mapped almost the full coverage of the urban areas of Catalonia at 1:1,000 scale, the generation of urban DSM from stereoplotting is the most feasible option from both a technical and economical point of views. However, and as mentioned before, although the 1:1,000 maps are 2.5D, the elevation data were not designed to generate neither a DTM nor a DSM (Fig. 8, top).

Therefore, the old model has been improved by adding the elements required for the computing of an adequate elevation model for large scale orthophotos. The changes include the classification of the elevated sections of some linear elements (roads and railways over bridges), the selection of the elements collected on the ground that must be considered as break lines, the generation of polygons for buildings and constructions (Fig. 8, bottom) and the compilation of auxiliary element to properly model bridges and tunnels.

#### 5. ICC challenges related with elevation data

The ICC has complete and updated elevation coverage of Catalonia. Further applications of these data require to additional enhancements such as a more detailed classification of the break lines, or the use of LIDAR data to refine the accuracy of the master elevation database.



Fig. 7: The upper image shows a detail of an orthophoto rectified using a DSM obtained from LIDAR data. The lower image shows the result using a DSM obtained by stereoplotting.

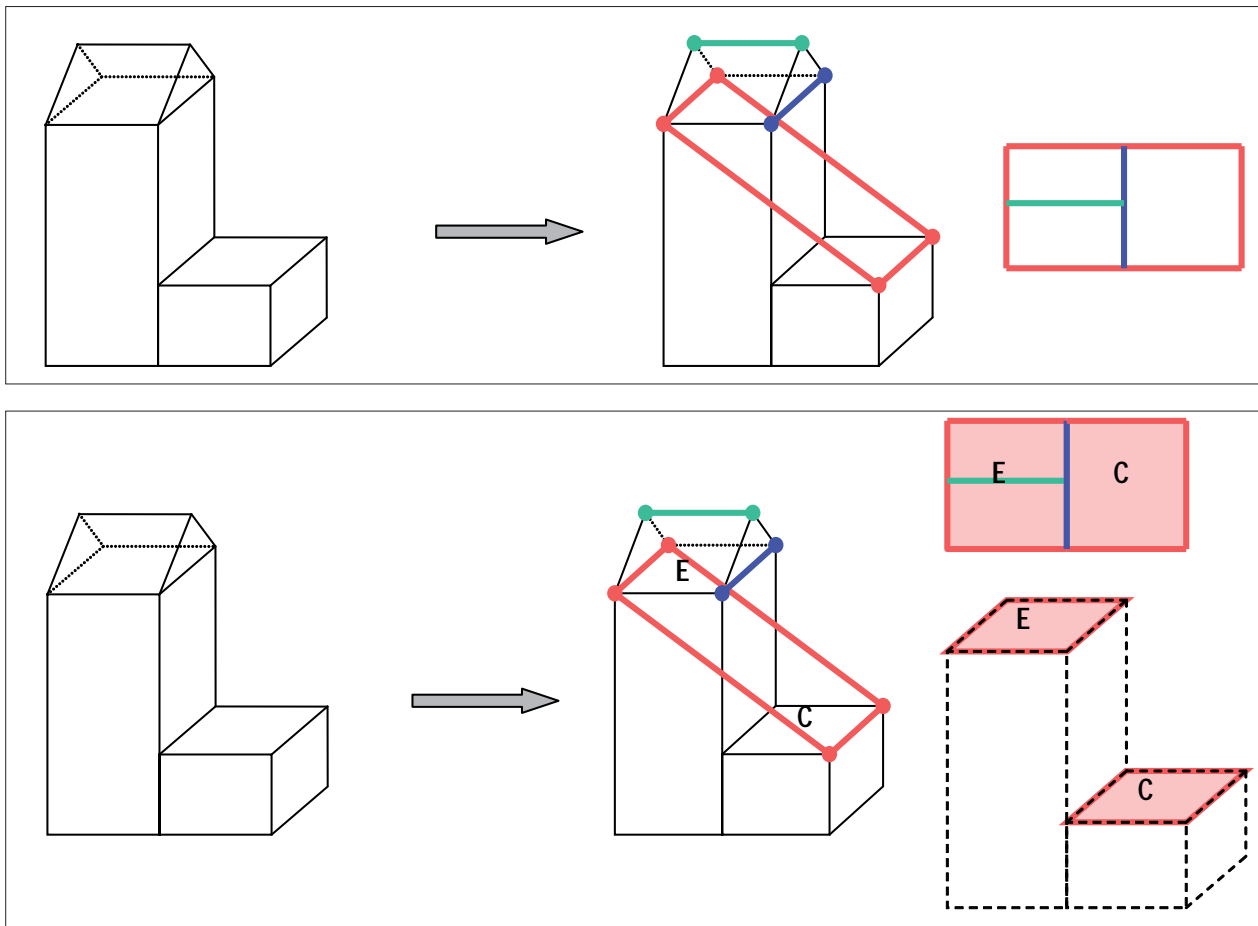


Fig. 8: The upper picture shows how the data is compiled in the old model at 1:1,000 scale. Red lines represent the roof edges, blue line represents the ridge top line and green line represents the top of roof cornice. The lower picture shows the improved model by adding the generation of flat polygons for the buildings at the cornice height.

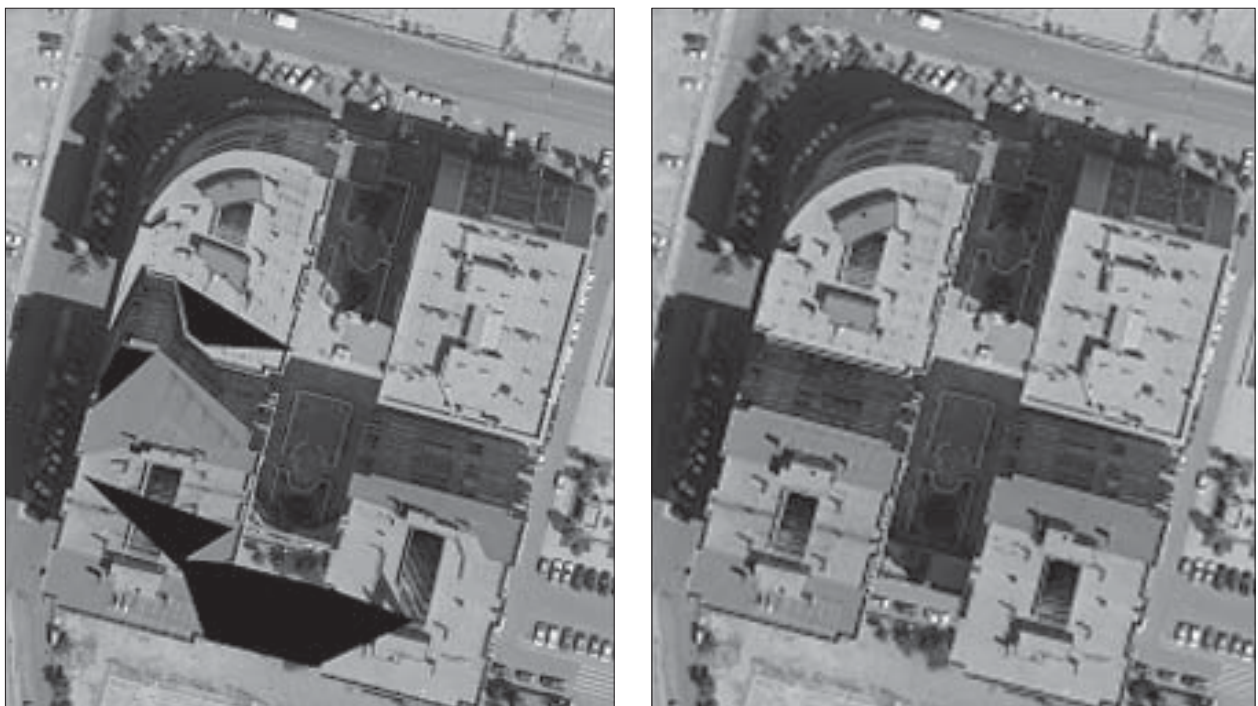


Fig. 9: The improved model allows for a correct orthophoto rectification. The left image shows the result using the old model. The right image shows the result after the improved model.



### 5.1. Classification of the break lines

As mentioned before, while stereoplotting of the Topographic Database at 1:5,000 all the objects needed for generating the DTM and the DSM are compiled at the same time as the topographic objects. The features collected on purpose for the DTM are scan lines, break lines, spot heights, contour lines used to infer break lines and flat areas. Moreover all the planimetric features captured on the ground are used as break lines. The break lines which are not coincident with planimetric elements are not classified, for example, the break line collected on the bottom part of an embankment has the same classification that a break line collected to represent a ridge.

The poor classification of these break lines is not a problem for the master elevation model generation, but it limits further exploitations, such as generalization for smaller scales (1:25,000 or 1:50,000) or the selection of specific break lines to enrich the LIDAR data.

The results of GENCOTES have encouraged the ICC and the UPV to continue their collaboration to apply a similar methodology for automating the classification of break lines. So far, there are some preliminary results on a test area, and during this year, a prototype will be developed.

### 5.2. The use of LIDAR data to refine the existing elevation data

Comparisons of the LIDAR DTMs with the photogrammetric BT-5M DTMs have been done several times by analyzing the differences of 1 m grids derived from both datasets. The results show that the BT-5M achieves the nominal accuracy in elevation, except in the dense forested areas.

The following example shows the comparison on 2 areas, one in a very flat terrain in a delta river (Delta de l'Ebre) (Fig. 10) and another one in a mountainous area covered by a dense mountainous forest area (Garrotxa) (Fig. 11).

In the delta area there are no occlusions. The differences higher than 1 m are sparse and usually due to the different flight mission date or due to some problems in a LIDAR data filtering. For example, because of small hummocks or rough terrain smoothed or eliminated because it has been confused with vegetation. It can be considered that the elevation data obtained from the BT-5M has the expected accuracy in this very flat area.

Quite often, in forested mountainous area, the stereoplotting operator can not see the ground and therefore it is not possible to achieve the expected elevation accuracy. The result is that the differences between the LIDAR and the BT-5M elevations are larger than 1.5 m in the forested areas.

After analyzing the previous results, it has been decided to use the LIDAR data to correct the master DTM in the dense forest areas. Consequently, we are now covering all Catalonia with LIDAR data and preparing a workflow for integrating both datasets.

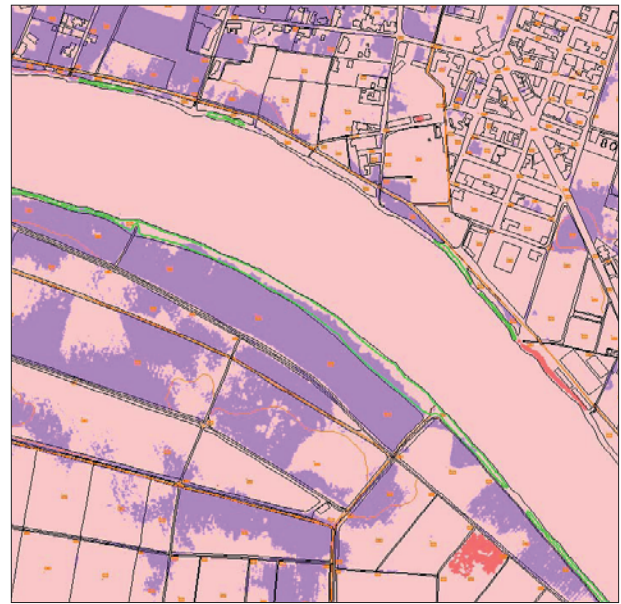


Fig. 10: Differences between elevation data in the Delta de l'Ebre area. The violet colour indicates that the BT-5M data is above the LIDAR data by between 0 and 1.5 m. The rose colour indicates that the BT-5M data is under the LIDAR data by between 0 and 1.5 m. The red colour indicates that the BT-5M data is under the LIDAR data between 1.5 and 3 m.

Delta de l'Ebre	dz
Points	1.038.361
RMS	0.376
Maximum error	1.300
Minimum error	-2.883
90% points	0.519



Fig. 11: Differences between elevation data in mountainous forest areas. The violet colours indicate that the BT-5M data is above the LIDAR data in intervals of 1.5 m. The rose and red colours indicate that the BT-5M data is under the LIDAR data in intervals of 1.5 m

Garrotxa	dz
Points	1.693.111
RMS	1.378
Maximum error	10.184
Minimum error	-7.253
90% points	1.960



## References

- Palomar, J., Pardo, J. (2004): Generalization of height points in trail maps. Proceedings of 4<sup>th</sup> ICA Mountain Cartography Workshop, 30 September - 2 October 2004, Vall de Núria, Spain.
- Baella, B., Palomar, J., Pardo, J., Pla M. (2007): Deriving the relief of the Topographic Database of Catalonia at 1:25,000: spot heights generalization from the master database. 7<sup>th</sup> ICA Workshop on Progress in Automated Map Generalization, 2-3 August 2007, Moscow

# An Ambitious Relief Model Project

## A Combination of a Handmade, a Computer-Generated and a Profiled Relief Model

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### Abstract

*The main topic of this paper is to explain the construction of a five metre long and seventy centimetres wide relief model, scale 1:50,000, displaying a section of the Alps running from north to south. The final relief model surface will be coloured according to the tectonic structure of the landscape, while on the sidewall a geologically coloured profile will be visible. The production of the relief model combines workmanship with computer techniques. An intermediate piece of the model will consist of a preserved handmade relief model by Jakob Oberholzer from 1911. The rest of the area will be carved in four different parts by a milling machine. The geological painting will be accomplished manually by the geographer Toni Mair, who has extensive experience in painting relief models. The complete model will be on display in a tower, where selected topics from the earth sciences will be explained via geological relief models. It is a part of the so-called future "FocusTerra" exhibition at ETH Zurich.*

### 1. Introduction

The number of natural disasters has increased dramatically in recent years. The general public calls for information about the reasons leading to those catastrophes, and is concerned about future developments. Are natural hazards predictable, and will the population be alerted in good time? Experts in the field of natural hazards are currently planning an exhibition at ETH Zurich called "FocusTerra", which among others topics aims at demonstrating the detailed geological processes involved in natural disasters.

### 2. FocusTerra

FocusTerra is a new earth science research and information centre of the ETH Zurich, which will be opened on 2<sup>nd</sup> April 2009. FocusTerra intends to present to a wide audience the most important, the most beautiful and the most recently discovered features of our planet earth. It does so by preparing and exhibiting visually appealing models, current experiments and spectacular objects.



Fig. 1: FocusTerra site – patio with exhibition tower.

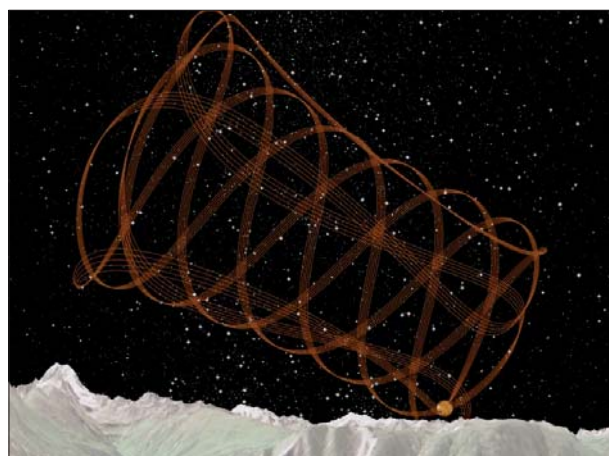


Fig. 2: Screenshots of the Atlas of Switzerland. Left: Stars and constellations visualised and labelled over the Bernese Oberland. Date, time, degree of cloudiness as well as the sector and the requested line of vision can be chosen. Additional information is available for every displayed astronomical object. Right: The Venus orbit during the last 40 years over the Bernese Alps. On each day one single point has been drawn.

FocusTerra is co-funded by the Federal Authorities of the Swiss Confederation. Additionally, the ETH Zurich foundation offers interested patrons and sponsors different ways in actively supporting the dialogue between humankind and earth. Located as centrally as possible, FocusTerra will be hosted in the historical main building of ETH Zurich. With FocusTerra a permanent exhibition is under construction, which covers, along with temporary exhibitions or events, three floors, including a patio, where a fashionable tower marks the core of the exhibition (Fig. 1). FocusTerra is one of the sustaining elements within the “Kultur- und Bildungsmeile” (cultural and educational passage) between the Museum of Fine Arts, and the area where ETH and University of Zurich are located.

FocusTerra, situated at the crossroads of research, education and publicity, allows insights into scientific topics such as vulcanology, history of climate, tectonics, natural hazards and a whole range of other issues. As a small part of the exhibition the multimedia station “Atlas of Switzerland”<sup>1</sup> will be show-cased. The atlas presents virtual panoramic views and block diagrams combined with information and visualisations about the natural environment. The latest version of the atlas, which is scheduled to be exhibited at FocusTerra, conquers also the universe by stretching out to the dimension of planets and stars (Fig. 2).

FocusTerra presents relief models to ease the understanding of mountain building processes. Visitors will see an impressive selection both of precious historical relief models and more recent products.

### 3. Relief Models

Why relief models? Relief models are scaled down, three-dimensional, sculptural landscape sections. Hence – quite different from the use of a two-dimensional map – the user is enabled to perceive ground and land cover close to the way they actually look in nature. In order to get this satisfying result, the relief must not be vertically exaggerated. Traditionally, relief models were constructed for touristic,

military and scientific purposes in the first place, but also for didactic reasons at schools and universities. E.g. Geologists and their students used such models to investigate and examine the morphology of a specific landscape. Today’s relief construction is restricted mainly to orders by museums, exhibitions, visitor centres, and enthusiasts.

The construction of handmade relief models has a long tradition in Switzerland. In the middle of the 19<sup>th</sup> century, after Switzerland was surveyed and mapped by the Swiss National Survey, relief modelling was booming. Creators of such splendid alpine relief models are, among others, Xaver Imfeld, Carl Meili, Simon Simon, and Eduard Imhof. Published in 2006, a recently compiled catalogue contains and describes more than 1100 reliefs of Switzerland (Mair and Grieder, 2006). The majority is in the possession of private owners, some belong to parishes, schools, libraries, museums, while others have disappeared. The Swiss Alpine Museum in Berne owns the world’s largest collection of alpine mountain reliefs.

The experts responsible for the content of FocusTerra were challenged to choose both beautiful and well-preserved reliefs with lifelike and geologically coloured layers for the exhibition. Especially models showing the geological strata can easily explain geological processes to the visitors. Where might these relief models be found? 150 relief models are estates of the ETH Zurich, most of them identified as cultural assets, stored in shelters of ETH Zurich. Of those, 106 are part of the geological-mineralogical collection, 44 are treasured by the Institute of Cartography. Finally 24 especially well-preserved and finely carved, handmade relief models have been selected for FocusTerra. Among them are also fictitious relief models showing typical features of alpine landscapes such as torrents, rockslides, and glaciers. Additionally, Toni Mair, the only remaining professional Swiss relief-maker, provided a cast of his Dent Blanche relief (Fig. 3). Below is the list of the selected reliefs of the Alps including names of the creators, the scale, the year of construction, and the dimension of the object:



<i>Object</i>	<i>Scale</i>	<i>Author</i>	<i>Year</i>	<i>Dim. [cm]</i>
Switzerland	100,000	Perron C.E.	1896 – 1900	350 x 240
Dents du Midi	16,666	Graff J., Hausamann A., Vaucher J.	1896	75 x 75
Matterhorn (Fig. 3)	5,000	Imfeld X.	1896	74 x 68
Dent Blanche (Fig. 3)	5,000	Mair T.	2005	90 x 70
Titlis / Sustenhorn	25,000	Imfeld X.	1889 – 1890	139 x 62
Urnersee	25,000	Imfeld X.; col.: Heim A.	1877 – 1890	105 x 96
Pilatus	10,000	Imfeld X., Heim A., Meili C., Hürlimann H.	1908 – 1913	125.5 x 84
Rigi	25,000	Imfeld X.; col.: Heim A., Buxtorf A., Baumberger E.	1908	80 x 55
Mythen	5,000	Reichlin J., Heim A.; col.: Imhof E.	1932	37 x 63
Fluhberg	5,000	Oberholzer E.	1952 – 1953	96 x 58
Mürtschenstock (Fig. 3)	10,000	Imhof E.	1920 – 1922	45 x 30
Lenzerheide	25,000	Meili C.; col.: Geiser M.		51 x 87
Luganersee	25,000	Becker F.; col.: Heim A.	1896	70 x 100
Säntis (profile series)	25,000	Escher A., Heim A.		
Säntis	25,000	Meili C.	1904	97 x 51
Säntis	5,000	Meili C.; instructions: Heim A.	1899 – 1903	
Peak Säntis (Fig. 3)	2,500	Meili C.; col.: Heim A.	1899	85 x 55

*"Historic and thematic reliefs"*

Jura (Canton of Basel)	60,000	Gressly A.	1860	62 x 46
Rockslide of Elm	4,000	Heim A.	1900	46 x 71
Glacier	18,000	Heim A.		
Torrent	18,000	Heim A.		
Alpi Apuane	50,000	Sacco F.		
Volcano island	10,000	Heim A.		
Workflow series of relief models	20,000	Mair T.	2007	
Glarus' Alps	50,000	Oberholzer J.; col.: Geiser M.	1911	70.5 x 95

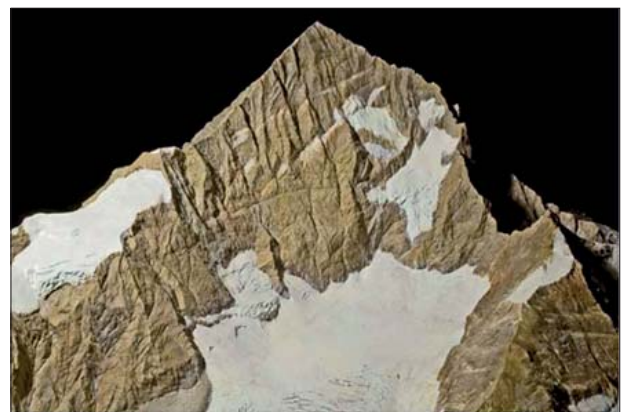


Fig. 3: (From upper left to bottom right): Models of Matterhorn – south face; Säntis – peak region; Mürtschenstock – seen from the North; Dent Blanche – peak region seen from the Southeast.

#### 4. New Relief Model of the Alps

As an additional attraction FocusTerra intends to construct a new, large-area relief. Because of the initial financial outlay, the limited time for preparation and a lack of professional relief model artists, new techniques were claimed. The result will be a combination of a hand-crafted, a computer-generated and a profiled relief model. So far, this modern approach has hardly ever been tested to automatically carve relief models of this size.

The goal of this project is to give the visitors an up-to-date topographical and geological overview about the Alps, their structure and tectonic developments. To fulfil this aim, the most suitable and most interesting section within the north south alpine profile has been chosen. The final dimension of the construction results in a five meter long and seventy centimetres wide relief model, scale 1:50,000, showing parts of the Alps from Lake Constance in the North to the Po Valley in the South. The model needs to be arranged according to the complex, ankle-dominated interior (Fig. 8). The final relief model will be coloured according to the tectonic features of the original landscape, while the sidewall will reveal a geologically coloured profile.

This fascinating landscape contains a unique, impressively shaped mountain environment, the so-called “Glarus overthrust”.

#### 5. The Glarus Overthrust

The Glarus overthrust is located along the borders of three cantons – Glarus, Grisons, and St.Gallen. It is a remarkably spectacular area of more than 300 square kilometres, covering the territory of 19 communities. This geological phenomenon starts rising in the valley of the Vorderrhein until it reaches a height of more than 3000 metres. After this peak, the rocky formation sinks towards sea level before it again gains altitude just at the northern fringe of the Alps. 250-300 million years old rock material drifts over younger sedimentary rock which is approx. 50 million years old. [The currently prevailing view is that the Helvetic nappes at

the Glarus overthrust were evidently displaced northwards by at least 35 km. The process largely occurred in the overthrust zone – only 1-2 m thick at many points – where the so-called Lochsiten limestone can be observed. This light-grey limestone, weathering to yellow, often has a marble-like appearance] ([www.impergeologie.ch/pdf/unesco.pdf](http://www.impergeologie.ch/pdf/unesco.pdf)). The structure is apparent even to non-geologists, as the overthrust line is highlighted by contrasting colours. As a part of this process the Martinsloch appears, a hole displaying a diameter of 15 m within the rock face of the Tschingelhörner, located 2600 m a.s.l. (Fig. 4). In spring and fall, the sun shines through the hole onto the church of the mountain village Elm. Each year this sun phenomenon is visible for two minutes only; evidently the basic condition is a fine, clear sky without any signs of cloudiness.

The Glarus overthrust is listed as a candidate region for the UNESCO Natural Heritage. The Glarus overthrust is a clearly visible example of the mountain building processes and contributed to a better understanding of plate tectonics. The nomination is based on arguments presented under three main headings: geological structure, history of geology and aesthetics: the nominated property is declared not only as a geologically overthrust feature, but as well as a unique witness for the evolution of mountain building. The nomination of the “Glarus overthrust” to the list of UNESCO World Natural Heritage operates under the name “Swiss Tectonic Arena Sardona”, alluding to the mountain Piz Sardona (3055 m a.s.l.), which defines the geographical centre of the proposed World Natural Heritage Site. The decision of entry will probably take place in July 2008.

#### 6. Jakob Oberholzer

Jakob Oberholzer (1862 – 1939) was an art master who described and mapped the Canton Glarus very precisely. In 1917 Jakob Oberholzer became a honorary doctor of the University Zurich for his contributions to geological research. A collection of his beautiful drawings coloured according to geological features was published in “Glarner Alpen” 1933. In the village of Ennenda, Glarus, a plaque reminds his lifelong work.



Fig. 4: Left: Water-colour drawing by Hans Conrad Escher, 22 July 1812, shows Martinsloch as well as the borderline of the overthrust zone very clearly. Right: Martinsloch with the sun shining through.



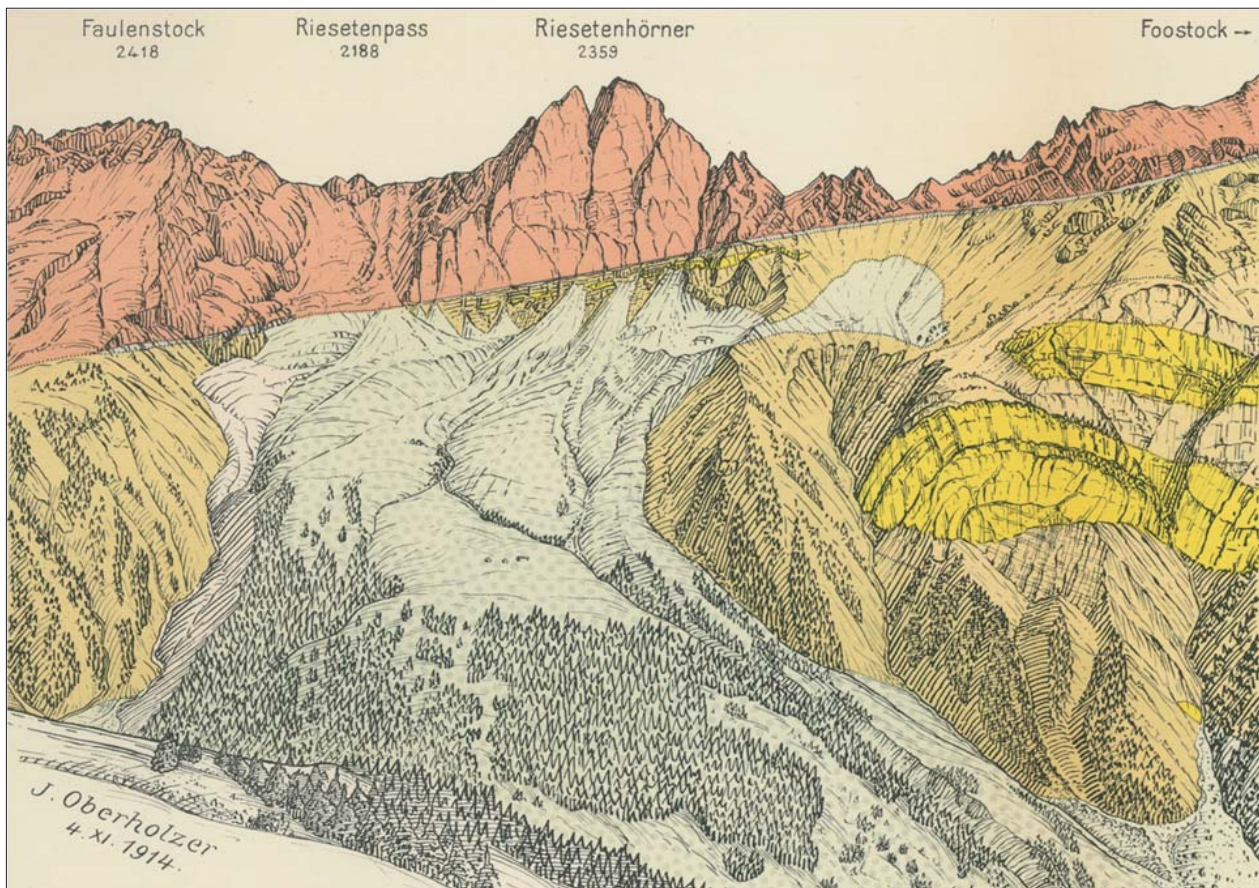


Fig. 5: The upper red layer is sliding over younger material. The drawing shows the Glarus overthrust nicely, and also – in the middle – the old landslide shaded in grey by Jakob Oberholzer, 1914.

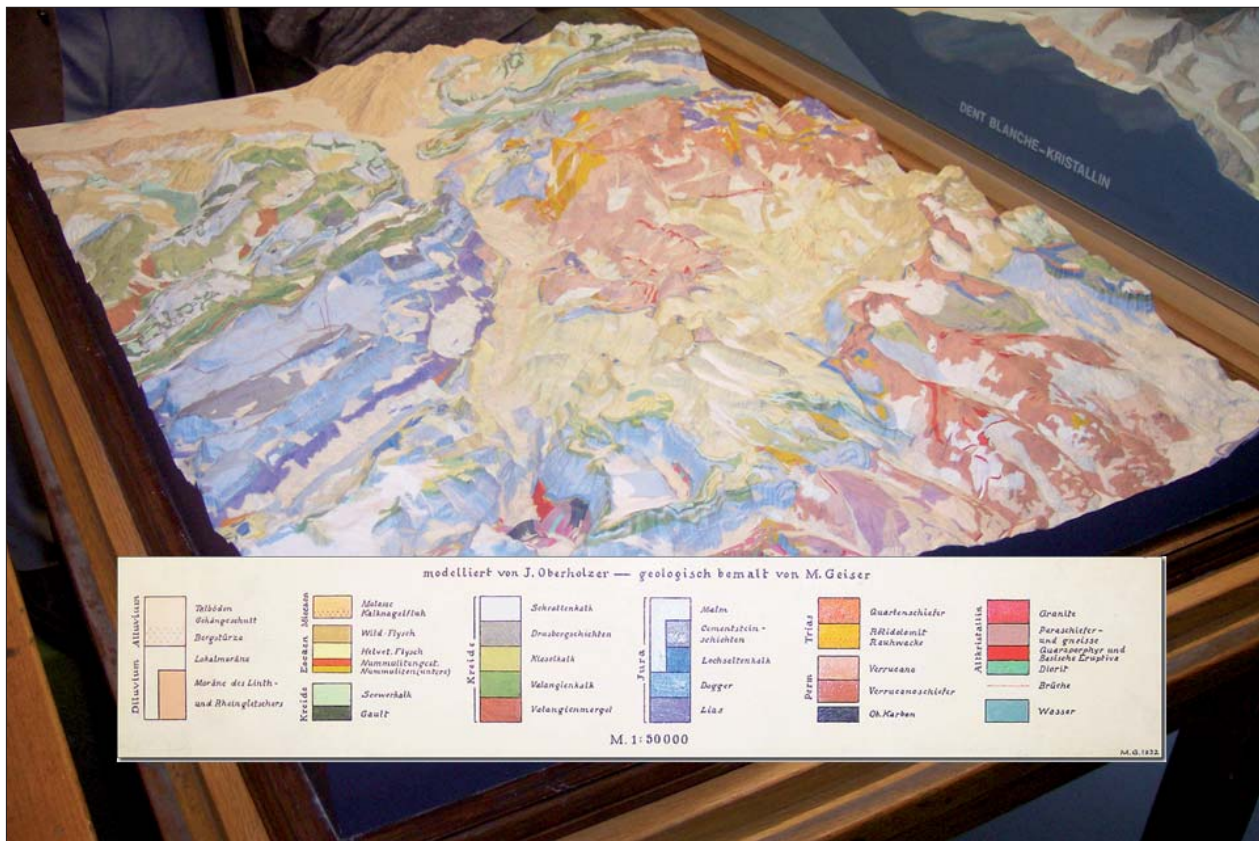


Fig. 6: Relief model made by Jakob Oberholzer, 1911, geologically coloured by Max R. Geiser and the legend. (Photo composition Stefan Räder).



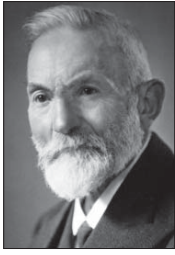


Fig. 7: Jakob Oberholzer (1862–1939).

His graphic skills and his ability of detailed observation play a crucial role not only in designing geological maps, but also in creating various reliefs. 1911 Jakob Oberholzer built a relief model in the scale 1:50,000 of the mountainous Canton Glarus, which includes the Glarus overthrust (Fig. 6). Like most professional handmade models, the Oberholzer model is made of plaster. The model has been geologically coloured by Max R. Geiser, Zurich. The object measures 112 by 88 cm. The Glarus relief is a lifelike reproduction in pristine condition. It is for this reason that the handmade Oberholzer model will be used as an intermediate piece for the above described relief of FocusTerra. But who is going to create the other part of the relief model? And how?

## 7. CNC Milling Machine

A CNC (Computer numerical control) milling machine is producing the final part of the sculptural work. Why a CNC milling machine? The milling process is quite simple and does not require any manual skills which are normally essential for the production of landscape models. The result

is a relief which provides sufficient quality for the project in question. On top of this, production period and production costs stay within a reasonable range.

Raplab<sup>2</sup>, ETH Zurich provides a three-axis CNC milling machine with a work space of 2.4 by 1.5 m. This machine can create 3D surfaces with a vertical difference of up to 25 cm, which is a satisfactory value for the purposes of the project. The machine uses a subtractive process to carve three-dimensional objects out of non-metallic and non-ceramic material.

In tests, different types of wooden material and soft packing material like styrofoam, foam-plastic, medium-density fiberboard, or synthetics have been evaluated. Crucial for the choice of the best material was the degree of hardness. As for the relief of the Alps the choice fell on the material “Ureol” – a quite compact material with an adverse time management: milling takes much more time than with softer materials.

The basic requirements for a accurately milled relief are the input data. Those are to be collected via digital elevation models (DEMs) of the highest possible precision. The Alp relief displaying Swiss terrain including parts of the Italian border area is based on the DHM25, produced by swiss-topo<sup>3</sup>. This DEM was derived from the Swiss National Map 1:25,000 and reflects its accuracy. Since some of the southern parts lie outside the area covered by DHM25, an additional DEM is necessary.

Milling tests based on the DHM25 in combination with to different elevation models lead to the conclusion that the

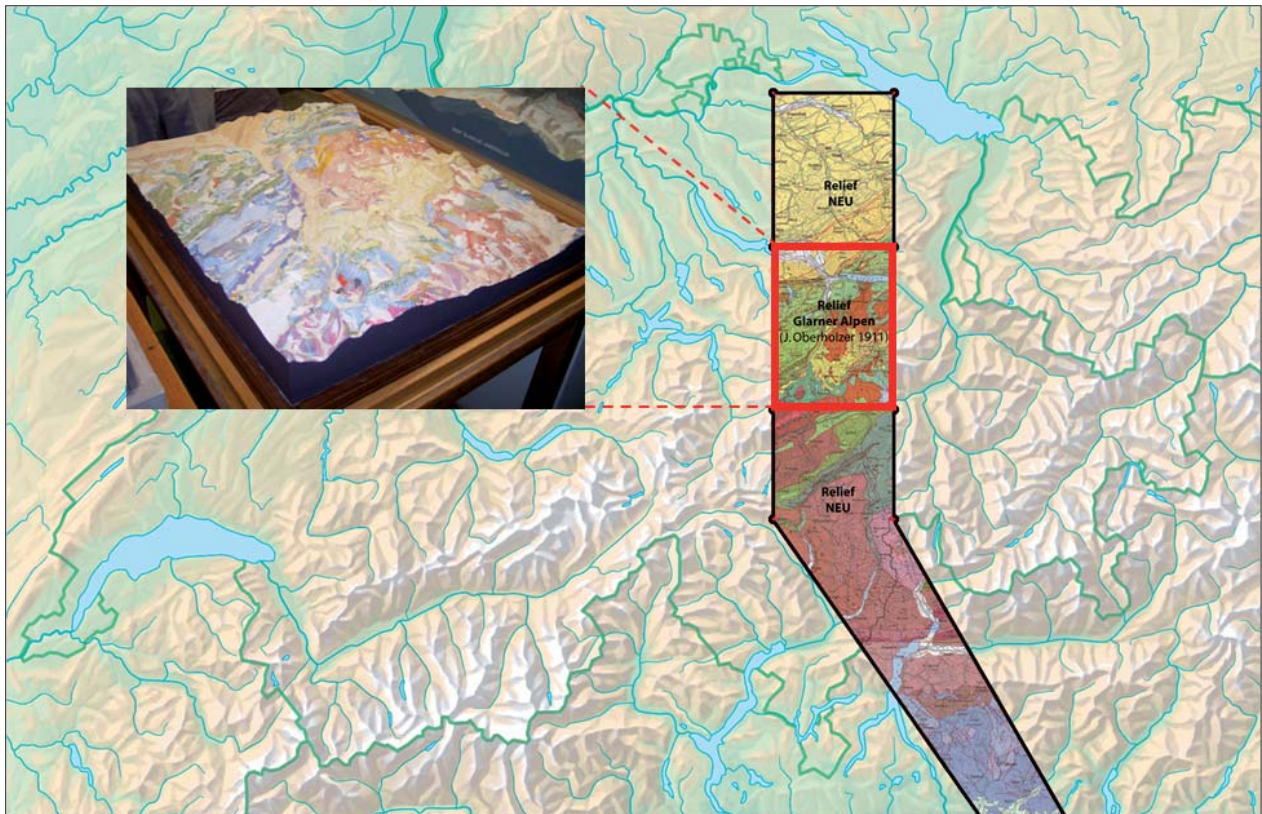


Fig. 8: Extension of the relief model: in red the Oberholzer relief, in black the automatically carved section.

open source elevation data of Jonathan de Ferranti allow for the best visual results. For his DEM, which he reworks manually, Jonathan de Ferranti uses besides the SRTM data also other freely accessible data. Those data are offered by de Ferranti in the SRTM-format. They might not be as reliable as a authorised or commercial DEM, but they are available across national borders. Ferranti's DEM needs to be projected onto the Swiss national grid in order to be compatible with the data of the DHM25.

Where the two DEMs collide unsightly artifacts emerge. A manual adjustment eliminates the most substantial errors. Additional enhancement of DEM-quality can be achieved by masking the lakes in the DEM. In doing so, the water surfaces appear even. For this purpose the VECTOR25 data set of swisstopo served as a source. Other lacks of quality which can be hardly omitted become visible especially in steep terrain.

Due to the large dimensions and the angulated footprint of the relief (Fig. 8), the model is going to be milled in four separate blocks.

Besides the input data the milling process itself defines the quality of the relief. The actual milling is subdivided into three stages:

1. Horizontal Roughing: Removing of the Ureol in terrace-like levels with a milling bit equipped with a ball nose diameter of 12 mm.
2. Semi-finishing: Smoothing the terraces, again using the milling bit as described in stage 1.
3. Finishing: Two milling direction each adjusted to a 45 / -45 degree angle, by using a milling bit with a ball nose diameter of only 3 mm.

The milling phases described above take several hours for each block of the model. A supervising person is present during the complete milling process. The manual painting with gouache colours will be accomplished by relief artist Toni Mair (Fig. 10), who has extensive experience in painting relief models. Finally, the newly carved and painted pieces will be assembled and fitted to the nearly 100 years older Oberholzer relief model.

Once completed, the relief will be positioned onto a pedestal of 120 cm in height and embedded into a wall. Painted on the pedestal is the interior of the earth with its tectonic layers (down to a depth of approx. 60 km). The back wall will also get painted with the vertical prolongation of the excavated rocky material. Illumination comes from one direction which the relief obtains a natural shading. The entire installation might be admired without an interfering showcase or glass wall between relief and visitor.

## 8. Conclusion

The quality of computer-generated reliefs depends on one hand on the material, on the other hand on the quality of the input data. The end result may as well be influenced by the choice of milling bits and the direction and speed of milling. CNC milling machines would be capable of generating overhanging portions of rock faces, thanks to their adjustable milling bits. But currently this is not very useful, since today's DEMs do not contain such information. Moreover, milled precipices appear as too schematic (Fig. 11).

The initiators are quite satisfied by the result, which might not entirely convince a trained relief maker in all its parts. Nevertheless the quality of the relief can be called satisfying regarding the purposes described above. The fact, that analogue and digital methods might be compared for the first time ever in one model, deserves to be underlined: This is a true novelty!

## 9. Outlook

It is the author's firm belief that in the future relief constructors might produce high quality reliefs with the support of CNC milling machines. Those products will not have to fear competition with the manually built, artful pieces of relief artists such as Imfeld or Imhof. In his view, the relief making process ideally starts with an automatically carved negative form of the future relief model. For this step affordable DEMs of high quality need to be available. A plaster mold allows to work according to traditional carving methods by using potter tools. Hence the time and cost consuming phases of building a step model made of wood could be skipped, i.e. the transformation of contour lines to wallboard plates, the sawing of the plates by following the contour lines, and the assembling of the plates to a stack to obtain a rough negative terrain model. In order to cover up shortcomings of the milling, especially in the case of such complex landscapes as alpine regions with rock, it is still indispensable to make adjustments manually. Only then it will be possible to create lifelike portrays of landscape surfaces. This means that the skills of a professional relief artist are still needed to bring the relief model to perfection.

<sup>1</sup> The "Atlas of Switzerland" is a joint project of the ETH Zurich's Institute of Cartography, the ETH Board, the Swiss Federal Statistical Office (SFSO) and the Swiss Federal Office of Topography (swisstopo). [www.atlasofswitzerland.ch](http://www.atlasofswitzerland.ch)

<sup>2</sup> "Raplab" stands for Rapid Architectural Prototyping Laboratory, a model laboratory of ETH Zurich. [www.raplab.arch.ethz.ch](http://www.raplab.arch.ethz.ch)

<sup>3</sup> "swisstopo" is the competence centre of the Swiss Confederation responsible for geographical reference data and all products derived from them. The Federal Office of Topography (swisstopo) is located in Wabern near Berne. [www.swisstopo.admin.ch](http://www.swisstopo.admin.ch)



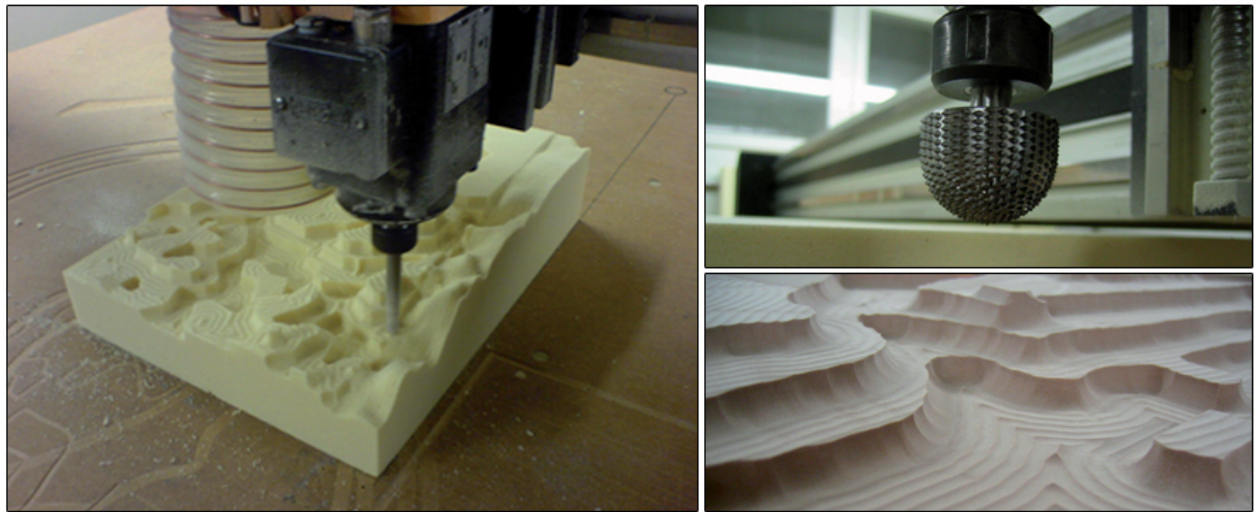


Fig. 9: Left: Test by a CNC milling machine, Raplab ETH Zurich. Upper right: Selected milling bit with ball nose. Bottom right: milled surface after horizontal roughing.



Fig. 10: Toni Mair, relief artist, with a CNC milled prototype (left, see circle) short before adjustment on coloured handmade Oberholzer relief (right) (photos Stefan Räber, 2008).

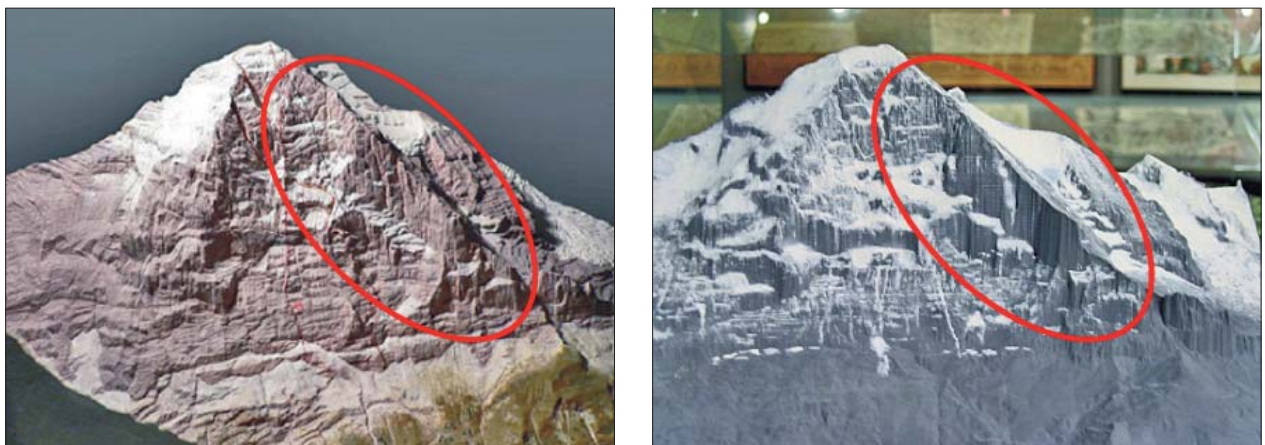


Fig. 11: Handmade, more vivid model (left) vs. automatic, more schematic model (right). Both photos show the Eiger north face.



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# Panoramic Maps Over the Years

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## Abstract

*The aim of this paper is to present how the spirit of the time and the development of Alpine tourism affects the artistic depiction and the content of panoramic maps. It starts with an appreciation of H. Berann's work and describes the use of panoramas until today by including them on new media platforms like the Internet.*

## 1. 1939: The rise of H.C. Berann's career

Heinrich Berann's cartographic career started in 1934. Some of his early works contain no cartographic information. On Fig. 1, only the beauty of the countryside is communicated, including the hint that the landscape can be accessed by tourists by a chair lift.

The panoramic map of Gstaad (Fig. 2) already shows lifts and ski runs. The "lifestyle" element is present in the form of the ski-tracks and snowcapped fir trees in the foreground.

From 1973–1988, Berann painted 3 further panoramic maps of the Adelboden–Lenk area (Fig. 3). The reason was a new trend in the Tourism business. Tariff associations and mergers required new panoramic images. Berann changed his painting style and adapted the new requirements. The artistic elaborations on the panoramic maps have disappeared. The topographic and cartographic information prevails.

## 2. 1989: A new era begins

Lenk is probably the first health resort in Switzerland that used a panoramic map based on a computer model (Fig. 4). However, the colour scheme, structures, and precision of the depiction of the terrain are not yet very convincing. Contrary to hand-painted panoramic maps, the advantage of being able to view the model from various perspectives has never been utilized. Only this one print has remained until now.

In 2000, the first version of the "Atlas of Switzerland" was published. In 2004 an improved Version with navigation, visualisation and analysis functions followed. In the 3D section, panoramic views and block diagrams can be combined with satellite maps, lakes, forests, human settlements and glaciers (Fig. 5). In addition, fog, hard shadow, hypsometric

gradations, gradient of slope, aspect, visibility and terrain profiles can be calculated and displayed.

## 3. New technologies have come, old ones remain.

In tourist areas like Adelboden–Lenk, conventional panoramic maps are displayed on presentation boards equipped with LED lamps showing the status of open or closed lifts and display the avalanche danger level (Fig. 6).

Google Earth is an ingenious information tool (Fig. 7). Every user with access to the Internet can add its own information, images or videos and thereby to the enormous growth of this tool. However, this also presents its weakness. It is impossible to check and review all information and therefore Google Earth is also filled with erroneous and useless information.

Tourism is depending on controllable Internet presences which are individually tailored to the customer's needs. In this medium, art does not play a major role any more.

The handcraft mainly consists in layouting in a way that there is as much room as possible for lifts, slopes, and symbols by leaving enough space for the base map elements.

Even in summer panoramic maps, one can observe an increase of information density, allowing the placement of new, more customer specific elements and attractions on the map, like e.g. hiking trails, bixe trails, trotti trails, wheelchair and stroller roads, high rope, etc. Today, every season, tourist resorts come up with new ideas and offers.





Fig. 1: H.C. Berann: Beatenberg, Berner Alpen (Source: [www.berann.com](http://www.berann.com), provided by Matthias Troyer).

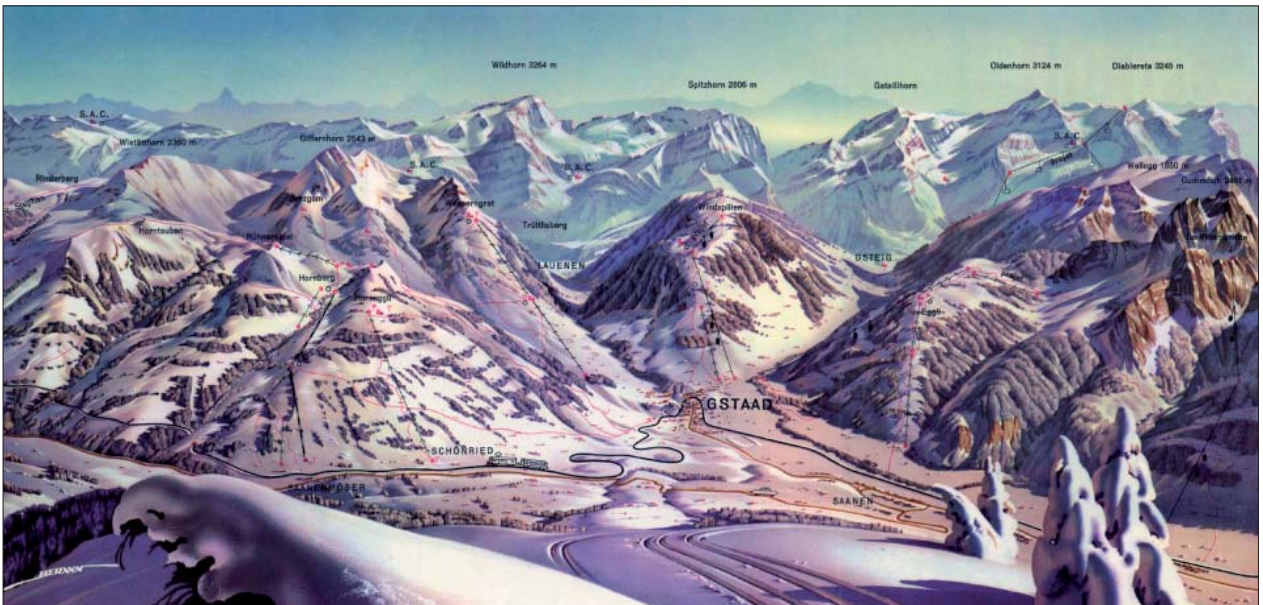


Fig. 2: H.C. Berann: Gstaad (Source: [www.berann.com](http://www.berann.com), provided by Matthias Troyer).



Fig. 3: H.C. Berann: Adelboden-Lenk (Source: [www.berann.com](http://www.berann.com), provided by Matthias Troyer).



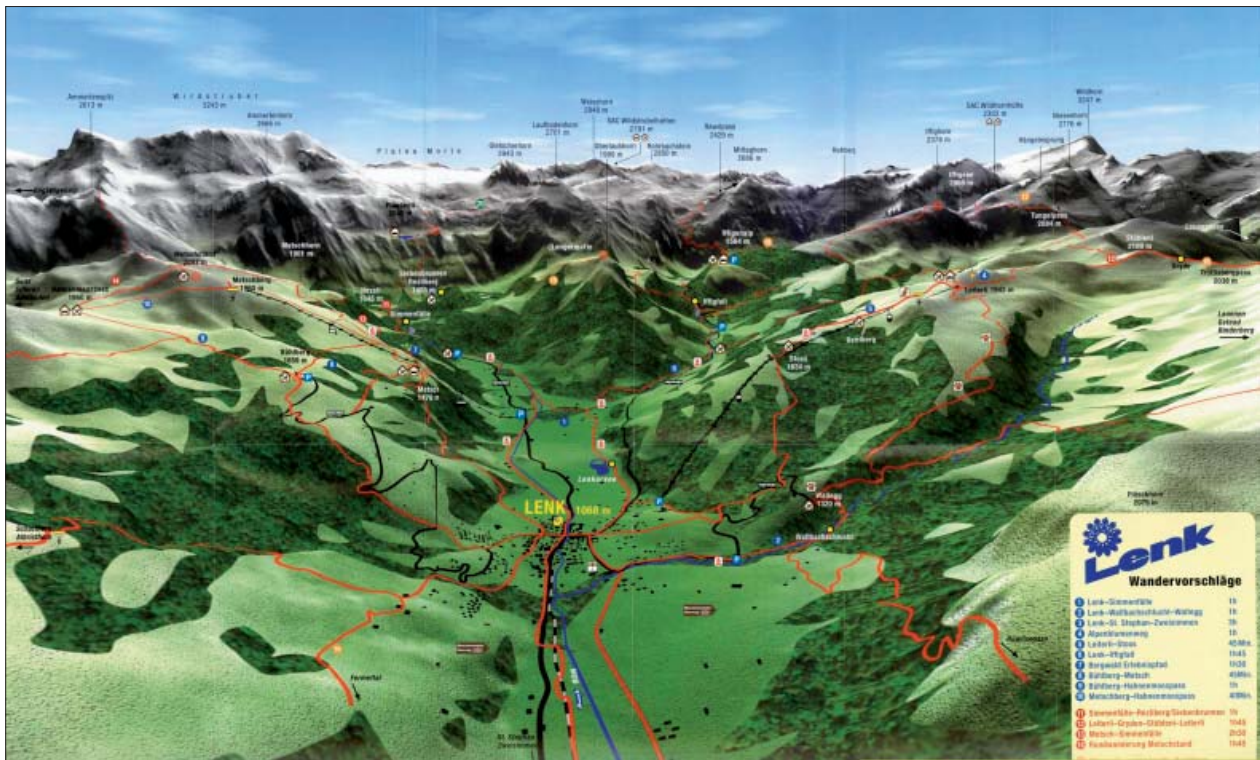


Fig. 4: Lenk, CAD production by Kümmerly+Frey, CAD, ca. 1989



*Fig. 5: Atlas of Switzerland 2.0 (© IKA-ETHZ and swisstopo).*





Fig. 6: Panorama map on display presentation boards at Adelboden-Lenk produced by Visiorama/Rohweder, 2005.



Fig. 7: Lenk in Google Earth, 2007.





Fig. 8: Adelboden-Lenk, Visiorama/Intermaps/Rohweder

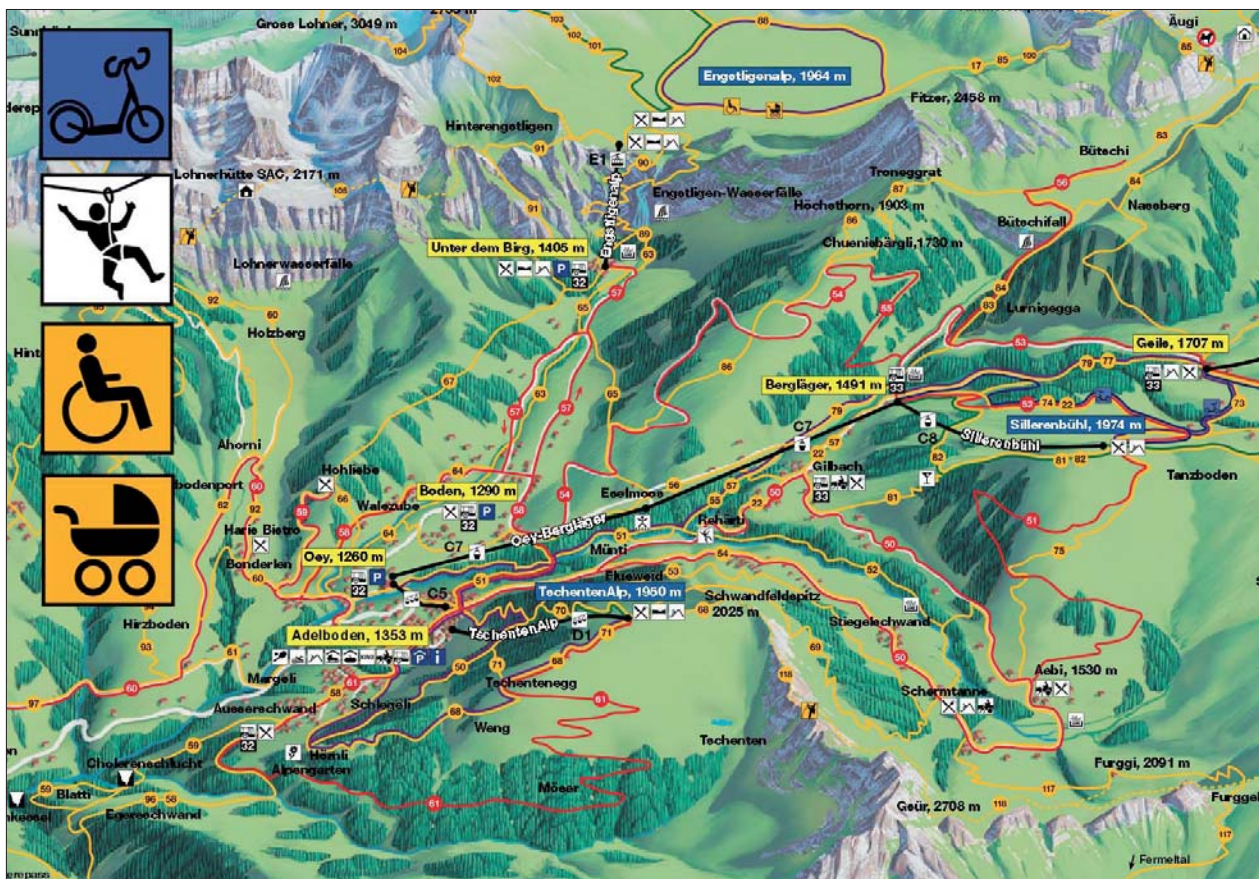


Fig. 9: 2006 Adelboden-Lenk, Visiorama/Rohweder



# Evaluating the Effectiveness of 2D vs. 3D Trailhead Maps

## A Map User Study Conducted at Zion National Park, United States

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### Abstract

*This paper discusses the findings of a comparative user study conducted in Zion National Park, Utah, in September 2006, which tested conventional (2D) and perspective (3D) trail maps in an outdoor setting. The study aimed to answer questions about the effectiveness of both map types for communicating cartographic information, whether hikers are attracted to one map type over the other, and the map preferences of hikers at Zion National Park. The findings revealed that 2D and 3D maps have different strengths and weaknesses for communicating trail information to park visitors. The decision about which map type to use should be made on a case-by-case basis, depending on the steepness of the terrain through which the trail passes, and the hiking experience and demographic characteristics of typical users of the trail.*

### 1. Introduction

Many inexperienced map users have trouble reading 2D topographic maps that typically depict landscape features with contour lines, shaded relief, and height points. To help these users, which comprise a large segment of the general population, cartographers have increasingly turned to 3D perspective maps, which allow users to more easily visualize three-dimensional landscapes. Applications such as Google Earth and the Atlas of Switzerland indicate the growing popularity of 3D maps in recent years. However, as useful as 3D maps are, they are not without problems: compared to 2D maps, they are more time-consuming and expensive to produce; scale diminishes from the front to the back of the map, making distances difficult to judge; and high mountains can obscure adjacent lowland areas and slopes facing away from the reader, depriving the reader of critical information.

Little research presently exists on the effectiveness of 3D maps in general, and less information is available about their effectiveness for hiking, the focus of this study. Most research on the topic relies on surveys of expert users (Häberling, 2003; Petrovič and Mašera, 2006) or students. Small sample sizes and testing conducted in controlled indoor settings are the norm. The research presented here, in contrast,

evaluates 2D and 3D maps by gathering data from a large sample of actual hikers at Zion National Park, Utah. The study investigated the trailhead maps that hikers see before setting off on a hike.

The idea for the study originated at International Cartographic Association (ICA), Commission on Mountain Cartography (CMC) workshop at Vall de Núria, Spain in 2004. At that meeting, US National Park Service (NPS) cartographer, Tom Patterson, questioned whether the 3D maps increasingly used by the NPS for trailhead exhibits were worth the extra time and expense to produce—about twice the cost of 2D maps. Patterson presented an outline for a proposed study to investigate the effectiveness of 3D trailhead maps compared to 2D maps. David Schobesberger, then a graduate student at the Institute of Geography and Regional Research, University of Vienna, teamed up with Patterson and expanded and refined the study for his M.A. degree research. Schobesberger was the principal investigator for the study, which took place in September 2006 at Zion National Park.

### 2. Definition of 2D maps and 3D maps

This article uses the terms 2D maps or conventional maps for maps that depict the surface of Earth from a theoretical vantage point of directly overhead, in an orthogonal projection. Two-dimensional maps have relatively equal scale in the x and y dimensions. From topographic sheets to atlas plates to road maps, the vast majority of maps available today are of the 2D variety.

By comparison, 3D or perspective maps, often called birds-eye views or panoramas, depict the terrain with faux three-dimensionality and contain perspective that diminishes the scale of distant (background) areas. Häberling (2005) defines a 3D map as a “computer-generated perspective view of a three-dimensional geo-data model with cartographic content.” German-language cartographic literature usually refers to 3D maps not as maps, but rather as map-related representations (Hake, 2002). Three-dimensional maps are suitable for display on printed brochures, computer monitors, outdoor exhibit panels, and a variety of other two-



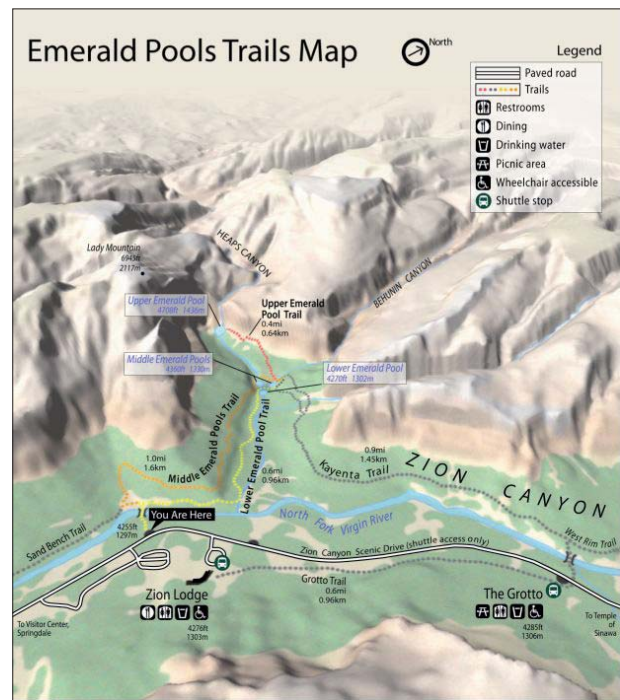
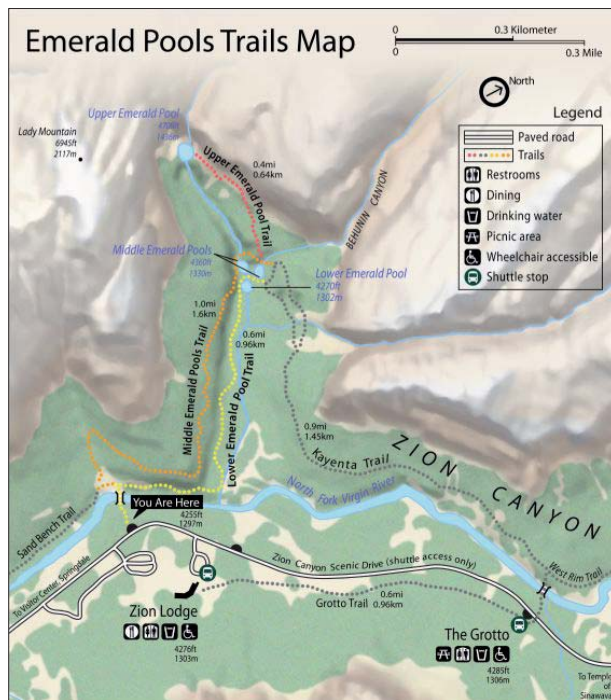


Fig. 1: The 2D map (left) and 3D map (right) of the Emerald Pools trails used for comparative testing.

dimensional media surfaces. Fig. 1 shows the 2D and 3D maps used for comparative evaluation for one of two trails studied at Zion National Park.

The following summarizes the assumed advantages and disadvantages of 3D maps.

Advantages of 3D maps:

- They appeal to readers, especially in informal situations such as when on holiday. For example, the eye-catching 3D maps often used in ski resort advertisements.
- The virtual camera position and viewing direction are customizable.
- Readers can easily visualize and understand elevation differences and topographic features.
- Overlaying thematic or photo-realistic information is possible.

Disadvantages of 3D maps:

- Scale varies from front to back within a scene.
- High topographic features can obscure information in the background.
- Printing of vector lines on 3D terrain is difficult.
- 3D map production requires more time than for 2D maps.
- 3D maps are more expensive to make than 2D maps.
- Successful production depends on a high-quality digital elevation model, which is not always available.
- Specialized software is needed for production.

- Standardized techniques for 3D map production are not familiar to many cartographers.

### 3. Research goals and study design

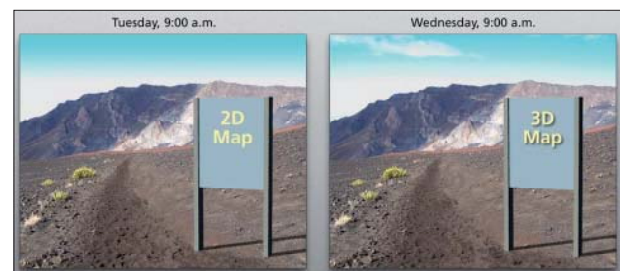


Fig. 2: 2D and 3D trailhead maps with equivalent content and design were displayed for testing on alternating days and under similar conditions. Source: Patterson, 2004.

The goals of the study were to find out the differences in communication efficiency between 2D and 3D maps, which type of map attracted the attention of more people and motivated them to go hiking, and the type of map preferred by park visitors.

The study used two methods for collecting data. Trailhead monitoring: involved mounting either 2D or 3D maps at the trailhead exhibits on alternating days, and monitoring the exhibits from far enough away so as not influence the park visitors' behavior and interaction with the map. The principal investigator noted hiker characteristics and the time that they spent interacting with the maps.

Questionnaires: the principal investigator conducted hiker interviews at midway point along the studied trails, noting the respondents' answers on standardized forms. The questionnaire had four parts:

1) Background information – Collected data included age, gender, whether hiking with a group or solo, hiking experience, native language, and whether they are left or right handed. The respondents were also asked if they had hiked the trail before or were carrying maps or any devices for orientation, to control for bias.

2) Trailhead map interaction – Respondents estimated their time spent reading the trailhead map, rated the map for graphic design and legibility, and rated how well the map on display matched the actual landscape seen from the trail.

3) Cartographic communication – Relying on mental maps formed at the trailhead, respondents were asked to recall basic geographic information presented on the maps.

4) Orientation and direct preferences – Respondents indicated as best they could their present position on a copy of the map that they saw at the trailhead exhibit. The principal investigator afterwards measured the difference between their estimated position and their actual position. For the last task a copy of both map types was handed to the respondents and they were asked to compare both and tell their preferences.

Fig. 2 demonstrates the testing methodology of using alternating 2D and 3D trailhead maps. A more detailed description of study methodology including the full questionnaires is available in the final report submitted to the NPS (Schobesberger, 2007).

#### 4. Zion National Park study site

The research took place from September 4 to 21, 2006, at Zion National Park, Utah. With more than 390 parks in the NPS system to choose from, selecting the appropriate park and trails to study was a difficult decision. Zion National Park offered many advantages as an ideal study venue.

Topography was a top consideration. At Zion the dramatic landscape was conducive to making 3D maps with unambiguous three-dimensionality, a necessity for comparative testing with flat 2D maps. Zion is a park renowned for its hiking trails, and it offered two suitable trails for testing, one easy and the other moderately strenuous. Both trails attracted ample numbers of hikers needed for the study, but they were not overcrowded. In addition, the trailhead exhibits at these trails were well situated for unobtrusive monitoring of hikers as they read the maps. The park with its shuttle bus system, very supportive park staff and the consistent good weather in September was also ideal concerning logistical issues.

#### 5. Characteristics of study population

A total of 208 people were asked to participate in the questionnaire. Twenty people refused to take the survey resulting in a final response rate of about 90%. By comparison, a wilderness experience study conducted in the remote backcountry of Zion National Park in 2002 had a response rate of 80%.

Of the 185 valid questionnaires, 100 were collected on the easy trail popular with less experienced hikers, and 85 on the strenuous trail that attracted more experienced hikers. Male respondents outnumbered females on both trails 61% to 39%. The study excluded children under the age of 15. Because the study occurred in mid September when school was in session, it includes relatively few young people (15-25 years). Most questionnaire respondents were between the ages of 26 and 60.

During the trailhead monitoring sessions that took place at the easier of the two trails, a total of 827 people walked within close range of the trailhead exhibit. Of these, 46% were females, 43% were males, and 11% were children (gender not noted). Most of the hikers traveled in pairs (49%), followed by an assortment of groups (27%) and families (17%).

### 6. Study findings

The principal investigator analyzed the gathered data with SPSS statistics software. The large sample sizes collected during the study yielded many correlations significant at the 1% level of certainty, determined with the chi-square test. The following is a brief description of the main findings.

#### 6.1. Map preference

Questionnaire respondents looked at a 2D and 3D map of the trail they were on and indicated which they preferred. Counting all respondents on both trails, a clear preference did not emerge: 48% declared that the 3D map was their favorite and 47% favored the 2D map.

However, the questionnaire revealed significant correlations based on gender, age, handedness, English as native language, and whether a respondent had looked at the trailhead map before going on the hike. Three-dimensional maps were clearly preferred by the 26-40 age group. The other age groups had more balanced preferences, leaning slightly toward the 2D maps.

Females preferred 3D maps (52%) over 2D maps (44%). With males the preference was the opposite: 50% preferred 2D maps, whereas 46% preferred 3D maps. Considering the preponderance of male respondents (113) to females (72), the overall preference with equal gender rates should tend stronger for 3D maps. Respondents who were not native English speakers preferred 3D maps (52%) over 2D maps (42%).

A small but significant correlation exists between handedness (left-handed vs. right-handed people) and map preference. For the left-handed respondents, 45% prefer 3D maps, 40% prefer 2D maps and 15% were undecided.

An unexpected correlation exists between map type preference and whether respondents looked at the trailhead map before setting off on their hike (Fig. 3). Respondents, who passed the trailhead without looking at the map, preferred 2D maps (55%) over 3D maps (41%). Those who looked

at the map preferred 3D maps (53%) over 2D maps (43%). The reasons for this correlation are not known. The fact that visitors who actually read trailhead maps prefer the 3D versions, suggests the need for more 3D maps.

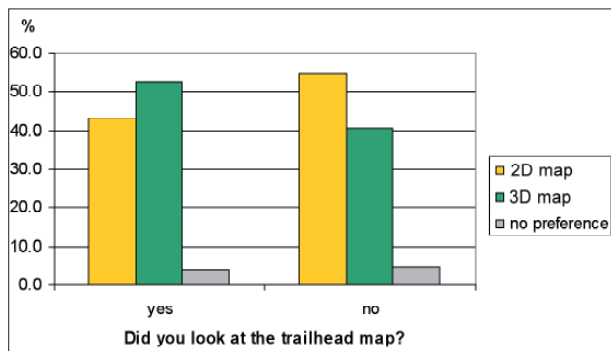


Fig. 3: Map type preference based on whether a respondent looked at the trailhead map.

## 6.2. Cartographic communication

The questionnaire investigated whether 2D maps or 3D maps better communicate relevant trail information to hikers, based on the mental maps they formed at the trailhead. To statistically analyze these data, the principal investigator converted the answers given by respondents to a point system. Of 20.75 possible points that a respondent could tally, the average was 6.14 points for 3D maps and 5.79 points for 2D maps. However, the correlation was not significant at the 5 percent level.

Looking at the distribution of points for different communication tasks reveals only small variations. 3D maps are slightly better for communicating distances, a general overview of topography, and environment, whereas 2D maps are slightly better for communicating names.

Conclusion: Both map types are equally well suited for communicating spatial information. The decision on which map type to place at a trailhead, is not a matter of communication efficiency, but of other criteria such as user preferences, age, or the gender of prospective readers.

## 6.3. Positioning accuracy

The questionnaire ended by asking respondents to mark their present location on the trail on a paper print of the

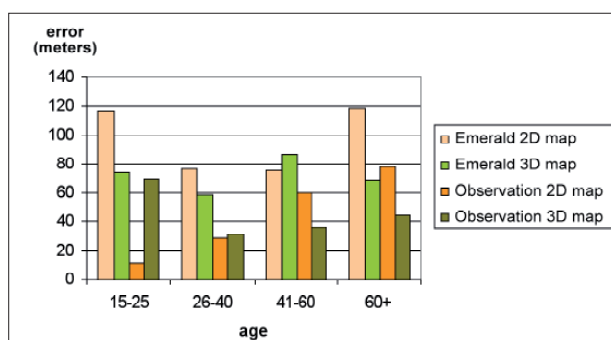


Fig. 4: Average position error normalized by trail length by age groups.

same map type that they observed at the trailhead. There were significant differences in positioning accuracy between the 2D and 3D maps.

In general, hikers identified their positions more accurately with the 3D maps than with the 2D maps. Fig. 4 shows the average position error by trail, map type, and age group. Nearly all groups show a smaller positioning error with the 3D maps. This is especially true for older people (over the age of 60) and females. Paradoxically, despite this advantage, when asked which map type they prefer, respondents over the age of 60 strongly indicated 2D maps.

## 6.4. Map attraction

This part of the user study investigated which map type was more successful at attracting and holding the attention of hikers as they passed within viewing distance of a trailhead exhibit.

Monitoring at the trailhead revealed that when the 3D map was on display, 50 percent of hikers viewed the map and 50 percent passed by without looking at it. When the 2D map was on display, 45% looked at the trailhead exhibit and 55% did not. Although the 3D map was more successful at attracting the attention of hikers, the fact that 50 percent of hikers did not look at it is not an encouraging statistic.

## 6.5. Summary of key findings

- 3D maps enable hikers to more accurately identify their position on the landscape compared to 2D maps, especially for older people (over 60 years of age) and women.
- Hikers who looked at the trailhead exhibits prefer 3D maps (53%) over 2D maps (43%). Those who did not look at the trailhead exhibit prefer 2D maps.
- Older respondents, men, and native English speakers generally prefer 2D maps.
- Younger respondents, women, and non-native English speakers generally prefer 3D maps. Left-handed individuals prefer 3D maps.
- Less experienced hikers on the Emerald Pools trails rated the 2D map easier to read. More experienced hikers on the Observation Point Trail rated the 3D map easier to read.
- 3D maps were rated as more accurate by experienced hikers on the Observation Point Trail than by inexperienced hikers on the Emerald Pools Trail.
- Respondents on both trails generally agreed that 3D maps depict reality better.
- The two map types revealed slightly differing strengths for cartographic communication. Readers of 3D maps had a better understanding of distances, topography, and environment. Readers of 2D maps could better recall place names.



- 3D maps attract more trailhead readers than do 2D maps.
- At the trailhead, 3D maps are on average viewed for a few seconds longer than 2D maps.

For more information please refer to the final report for the NPS ([www.nps.gov/hfc/cart/zion\\_map\\_study.pdf](http://www.nps.gov/hfc/cart/zion_map_study.pdf)).

## 7. Outlook

Although the study revealed interesting correlations about map users and the effectiveness of 2D and 3D trailhead maps at a national park in the US, the findings are not necessarily valid internationally. The existence of large differences in map preferences between native English speakers and those who are not, suggest that a similar user study conducted elsewhere in the world would yield different results. A need exists for comparative evaluation of 2D and 3D trail maps in other countries, along with testing for different communication goals and map content besides trail information.

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# Developing a 3D Dynamic Map of New Zealand's Backcountry

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## **Abstract**

*This paper traces the development and ongoing refinement of a dynamic, interactive 3D topographic map of New Zealand. The initiative is a joint effort by two small private companies working in parallel. One has focused on the development of a high performance virtual reality software platform and 3D viewer. The other has been responsible for map data and the visual representation of topography and landforms. The development of backcountry map textures in particular posed a number of challenges, as a key objective was to create seamless, accurate and intuitive scenes, without the quilted mosaics and variation in shadow angles seen in Google Earth and many other 3D mapping applications.*

## **1. Introduction**

Geographx is a small New Zealand (Wellington) based private company that undertakes a range of mapping work for both print and electronic publication. Our niche areas are large format feature wall maps and dynamic 3D visualization.

For some years now, Geographx has worked with Data Interface Technology Ltd, another New Zealand company that has been developing and refining a 3D virtual mod-

eling environment. The software application is branded as K2Vi (Key to Virtual Insight). Our role at Geographx has been to develop a 3D topographic dataset that could be used as a base map for K2Vi. Initially we worked to cover the New Zealand landmass (an area a bit bigger than the UK, but smaller than Italy). However we always intended to eventually build datasets for other countries, and we still plan to do this.

When we started, virtual 3D mapping was more a dream than a reality. Software and hardware constraints meant we invariably worked with small areas, fun to look at but of little practical use. "Eye candy" we called it. Now, however, we have a genuinely useful application. Development is ongoing and additional functionality is being added every month.

A major driver for this progress has clearly been the technological advance in hardware – we now have more powerful computers, more memory, and improved video graphics cards. Equally impressive has been ongoing development of the K2Vi software platform. I'm not really qualified to talk about the technical side of this, save to say that there are essentially two main products undergoing coordinated development.



Fig. 1: Virtual 3D model of Paradise, NZ, rendered using K2Vi Professional software.



One, K2Vi Professional, is an interactive virtual modeling environment, a construction set for simulating a real world situation. Typically such a model will focus on a specific site or area, and may include existing or planned future infrastructure – examples include tourist developments, proposed new roading / tunneling or bridging projects, hydro-electric dams, and wind farms). A range of high resolution input data may be used to construct these, including terrain models, land textures, 3D object models, and GIS point, line and polygon data (Fig. 1).

The second product is K2Vi V3, a dynamic 3D viewer, a globe similar in concept to Google Earth. This is the product we have tailored our Geographx base map for. The result is an interactive, dynamic tool for exploring and querying topography. It is also the real world environment into which we can drop and visualize the more detailed site models created with K2Vi Professional (above).

## 2. Development of the New Zealand 3D Dataset

The objective was to develop a 3D map:

- To a level of detail equivalent to 1:50,000 map scale
- Focusing on landforms and physical geography
- Using textures created from raw GIS map data

Now New Zealand is an interesting place to map. We are lucky to have a great variety of landforms tucked into a relatively small area. We are a geologically young country however, located on a tectonic plate boundary. Earthquakes, land slips and volcanic activity can and do change the face of the land.

Another cartographic challenge stems from our biculturalism and the lengthy nature of some Maori place names. Try working this name (Fig. 2) into your map and you will probably find you need a bigger piece of paper.

The raw data for the 3D map was drawn from the Land Information NZ National 1:50,000 topographic vector dataset.

The underlying 20 m cell resolution digital elevation model (DEM) that gives shape to the map was created by Geographx from contours and other height data contained in the LINZ data. The completed elevation model contains over one billion cells.



Fig. 2: Example of a lengthy Maori place name. It translates as “The summit where Tamatea, the man with the big knees, the climber of mountains, the land-swallower who travelled about, played his nose flute to his loved one”.

The overlying map textures were created from point, line and polygon features sourced from the same LINZ dataset.

Place names were sourced from the NZ Geographic Place Names database.

From the outset we sought to differentiate our 3D map product from Google Earth.

The key differences are:

1. We created our map textures from the ground up using raw map data, rather than using satellite imagery.

The major reason for this was to avoid the “quilted bedspread” look you get in Google Earth. This results because satellite imagery from different dates, seasons, and time of day is mosaiced into a confusion of different vegetative textures, shadow angles and shadow depth. Satellite imagery also is prone to cloud cover and invariably contains too much clutter and unwanted information.

By creating our map textures from raw GIS map data, we could better control the information to be visualized, and present it in hierarchal fashion, the aim here being to visually represent the terrain as intuitively as possible. We only sort to include visual data clues to the features that could be readily identified from the air.

We have tried to enhance the “intuitiveness” through graphical techniques – examples lie in the bump mapping of forested areas and the reflectivity added to the larger rivers. You will notice that lakes, whilst recognizable as such, are not all the same colour (nor are they in nature), and that the hypsometric tinting of terrain is intentionally muted by emphasis on the overlying landcover.

Finally, and most importantly, the created map textures are seamless with no abrupt changes in colour, and constant shadow angles over the entire area of interest.

2. We have paid little attention to urban metropolitan areas. This is a high maintenance area and we simply do not have the resources to go there. Besides which, we are more interested in mountains and landforms - if you want to check out your own house, I recommend you stick to Google Earth.

## 3. Features and uses of K2Vi Viewer

As explained, the functionality of the K2Vi V3 Viewer and the 3D map continues to evolve. The following is not a complete list of features but is indicative of the development path being followed.

- Continuous readout of viewer position, altitude, heading
- Instant readout for any point of position, altitude, distance from viewer
- Scale and distance measurement tools
- Query place names and any associated geographical information



Fig. 3: Virtual Environment Modeling in real world context using K2Vi V3 Viewer.

- Style and scenario switching (eg: toggle between summer/winter textures)
  - Overlay vector point, line, polygon data
  - Billboards – featuring attribute data, text, images, hyper-links etc
  - Import detailed 3D site projects including 3D object models and animations
  - Real time shadow analysis
  - View corridor analysis
- As commercially-driven operations, both companies are acutely aware of the need to find practical uses for any new products. We have identified the following end uses for the 3D Map in K2Vi V3. There will, we hope, be others.
- We have a Virtual Camera in that we can snap an aerial view of any place from any height or position without leaving the office – this also provides us with a source for 3D panoramic base maps.
  - Interactives can be customized for visitor centres and education programmes – typically these utilize touch screens, “dumbed down” functionality, allow some form of free flight, and include themed “break-out” hta applications featuring additional media such as video, slide shows and sound bites.
  - As real world context for Virtual Environment Modeling (site infrastructure modeling as earlier described and pictured on Fig. 3).
  - Free Flight, particularly terrain familiarization for defence and emergency management (fire fighting, search and rescue).
  - UAVs (unmanned aerial vehicle) and real time tracking
  - Multimedia retail product for the recreation market (on DVD)
  - The 3D map textures are currently also being used in conventional plan view vehicle tracking applications utilizing satellite telemetry and cellular networks, and also in 3D Television Weather Mapping applications.





# Historical Mapping for Landscape Reconstruction

## Examples from the Canton of Valais (Switzerland)

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### Abstract

*Alpine landscapes have evolved rapidly over the last two centuries. River embankments and urbanization have affected most of the large alluvial plains, agriculture has radically changed and its relative landscapes also. Forests are gaining space in most of the Alpine countries and tourism has modified landscapes in several areas, both in alpine forelands and high valleys. In Switzerland, the availability of accurate topographic maps since the middle of the 19<sup>th</sup> century has allowed us to reconstruct historical landscape change. Former landscapes were reconstructed using historical maps in a Geographic Information System (GIS) in two different contexts in the Canton of Valais (Switzerland). The evolution of the Rhone river alluvial plain and the history of vineyard landscapes were analysed. This paper presents the methodological aspects relating to the study of old maps.*

### 1. Introduction

Over the last two centuries, landscapes have changed very fast and in this context landscape planning is becoming more and more important. It is now agreed that today's landscapes are part of the legacy from the past and analysing historical landscape changes is essential to predict the development of future landscapes (Grangirard, 1997; Marcucci, 2000; Bender et al., 2005). Long-term change may be explained by describing past landscapes and by understanding the driving forces of landscape change (Marcucci, 2000; Bürgi et al., 2004; Bürgi et al., 2007). Maps as a historical source provide important information about landscape change especially when they are used in a Geographic Information System (GIS) (Kienast, 1993; Gurnell et al., 1994; Simpson et al., 1994; Marston et al., 1995; Gurnell, 1997; Vuorela et al., 2000; Winterbottom, 2000; Petit & Lambin, 2002; Gurnell et al., 2003; Paulmier, 2004; Bender et al., 2005; Poirier, 2006; Domaas, 2007). The Canton of Valais is an alpine region formed by two mountain ranges – the Bernese and Pennic Alps – separated by the Rhone river alluvial plain. Today's landscape of the Rhone river valley is the result of important changes since the first Rhone river corrections, which occurred from 1864 to 1893. The hydraulic works completely modified the geomorphological behaviour of the river, which allowed the development of intensive agriculture and more recently the spatial diffusion

of commercial and urban zones in the formerly flooded areas (Stäuble & Reynard, 2005; Stäuble & Reynard, 2007). The canton of Valais is the principal wine producer in Switzerland with more than 5,000 ha vineyards. The vineyard surfaces evolved differently from one site to the other: in some places, agriculture was replaced by other activities, whereas in others, viticulture became the main agricultural activity (Martin & Reynard, 2007; Reynard et al., 2008).

This paper presents how former landscapes were reconstructed by analysing historical maps within a GIS. It describes the methodological aspects relating to digitalisation, spatial treatment and analysis of landscape features from historical maps. Problems relating to changes in map characteristics and to the accuracy of former maps as well as several examples of landscape evolution are presented.

### 2. Study area

Both studies are located in the canton of Valais in Switzerland (Fig. 1). Transformations of the Rhone river landscape were studied in two specific sections of the Rhone river in order to analyse the changes on a large scale. One site is located downstream to Sion in the so-called plain of Conthey on the right bank of the Rhone river and the other one is located downstream to Sierre on the left bank of the river (Chalais – Grône – Granges). The study of historical changes of vineyard landscape focuses on six sites, which show typical features of evolution trend.

### 3. Maps

Landscape reconstruction was undertaken using historical maps as a main source. Thus, the quality of the research depends on the accuracy of the historical maps and their potential to be integrated in a GIS. Indeed, the oldest map that could be used is the "Napoleon map". It is the only one used in this study that was not drawn by the Swiss topographical Bureau (today's Federal Office of Topography Swisstopo). We used also the topographic surveys for the Dufour map, the Dufour map, the Siegfried atlas and the National maps. The maps are briefly described here and the characteristics of each kind of map are summarized in Fig. 2. An example of each map is illustrated in Fig. 3.

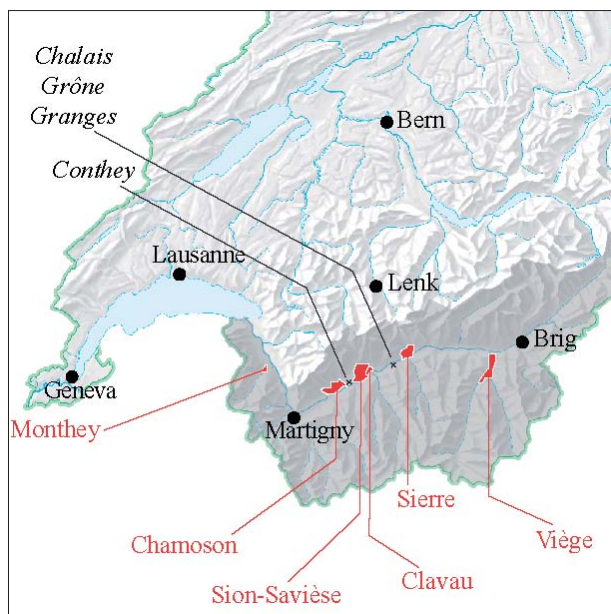


Fig. 1: Study sites. In red: vineyards. In black and italics: Rhone river alluvial plain. Reproduced by permission of swisstopo (B081074).

The “Napoleon map” was ordered by the French government under Napoleon in 1802 to provide a basis for the improvements of the road that leads to Italy over the Simplon pass (Lechevalier, 2005). Four cartographers mapped the entire Rhone river valley from Lake Geneva to Brigue on 65 different sheets.

The first topographic surveys for the Dufour map were drawn in the 1830's. In the Alps the maps were drawn at a 1:50,000 scale. For the Rhone river study we used three maps dated between 1839 and 1841.

The Dufour map is based on the topographic surveys but it was published at a smaller scale (1:100,000). The sheet we used for the Rhone river study was published in 1845. The topographic surveys and the Dufour map were not used for the study on vineyards, because vineyards are not indicated.

The Siegfried atlas is the first publication of surveys at a 1:50,000 scale (in the Alps) and 1:25,000 (in the rest of Switzerland). The first edition of the maps was published between 1870 and 1926 and each map was then revised several times until 1949. Several editions of the Siegfried maps were used for both studies.

From the beginning of the 20<sup>th</sup> century, as new geodesic measurements were being performed, the accuracy of mapping increased and new maps could be drawn. The National maps were first published at a 1:50,000 scale between 1938 and 1964 and then, between 1952 and 1979 at a 1:25,000 scale. Both of them are completely revised every six years. National maps are still in use nowadays. From the 1940's to the 1950's we used the 1:50,000 scale National map and from the 1960's until today we used several editions of the 1:25,000 scale maps.

#### 4. Method

Each map was scanned and integrated in the GIS using a minimum of four ground control points with ArcMap (9.1)<sup>1</sup>. Two different methods were used to integrate the maps into the GIS: the coordinates were integrated manually using a printed map, or they were integrated using a reference map already present in the GIS with a coordinate system. Territorial features such as churches or farms that already existed on the oldest maps were used as ground con-

Map name	First edition	Revision	Scale	Point of origin for height measurements	Method of ground representation	Ellipsoid	Projection
Napoleon map	1802	-	1:5,000	No height indication	-	-	-
Topographic survey for the Dufour map	1839-1841	-	1:50,000	Repère Pierre du Niton (R.P.N.): 376.2 m	Contour lines: 30 m	Schmidt 1828	Equivalent conical projection
Dufour map	1845-1865	Until 1939	1:100,000	R.P.N.: 376.2 m	Obliquely luminated hachures	Schmidt 1828	Equivalent conical projection
Siegfried map	1870-1926	Until 1949	1:50,000	R.P.N.: 376.86 m (“old horizon”)	Contour lines: 30 m	Schmidt 1828	Equivalent conical projection
Siegfried map	1870-1922	1949	1:25,000	R.P.N.: 376.86 m (“old horizon”)	Contour lines: 10 m	Schmidt 1828	Equivalent conical projection
Swiss National map	1938-1964	Every six years	1:50,000	R.P.N.: 373.6 m (“new horizon”)	Contour lines: 20 m	Bessel 1841	Conformal oblique cylinder projection
Swiss National map	1952-1979	Every six years	1:25,000	R.P.N.: 373.6 m (“new horizon”)	Contour lines: 10 m; Alps: 20 m	Bessel 1841	Conformal oblique cylinder projection

Fig. 2: Characteristics of the maps used in this study (after Grosjean, 1996; Gurtner, 1997 and [www.swisstopo.ch](http://www.swisstopo.ch), modified).

<sup>1</sup> The Napoleon map was photographed by Michel Lechevalier and the team of the Third Rhone river corrections integrated it in the GIS. The Siegfried maps were scanned by ourselves or by Swisstopo, who edited some maps on a CD-ROM. The topographic surveys for the Dufour map were scanned by Swisstopo. Scanning of the National maps was done by ourselves. We georeferenced all the maps except the Napoleon map.



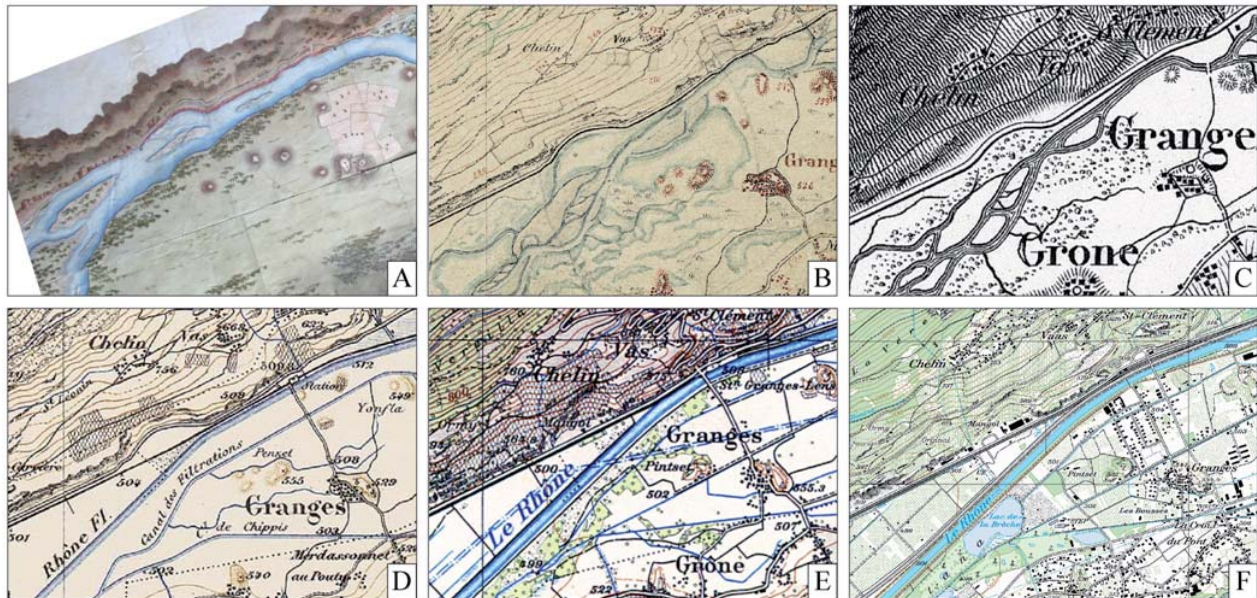


Fig. 3: Examples of maps used in the Rhone river study. A: Napoleon map (1802). B: Topographic survey for the Dufour map (399 Saint-Léonard, 1839). C: Dufour map (XVII, 1845). D: Siegfried map (481 Saint-Léonard, 1880). E: National map 1:50,000 (273 Montana, 1943). F: National map 1:25,000 (1286 Saint-Léonard, 2001). Reproduced by permission of swisstopo (B081074).

trol points. For the more recent maps the squaring of the coordinates could be used.

Territorial features, such as rivers, isles, wetlands, roads, houses, vineyards, orchards, etc. were digitized on each map on which they appeared. Digitalisation gives a representation of the historical landscape and allows quantification (for example: wetland surfaces in 1880, 1906, 1933 and its disappearance trend and velocity; see Fig. 5). On the other hand the overlaying of two different layers allows us to analyse the spreading and shrinking of some particular features (for example: appearance and disappearance of forest). The GIS integration also allows 3D representations of the landscape (see below).

## 5. Limitations

Using historical maps for the analysis of landscape change cannot be undertaken without an awareness of the problems relating both to the survey and to the integration in the GIS. Indeed, the accuracy of maps increased through time as is discussed below. Moreover, one has to keep in mind that maps are not reality but a representation of it (Kienast, 1993). Furthermore, as maps are static, they do not take into account the landscape dynamics with precision. This is especially the case of alluvial landscapes that may have changed several times between the images given by two successive maps. The period in which the field survey was carried out is also important as high and low water levels influence the extension of some features such as wetlands, forest cover or gravel bars.

The integration of old maps in a GIS enables 3D representations of historical landscapes that may be considered as closer to the natural landscape – as seen by an observer – than maps. Consequently, they could be an appropriate way

to communicate with the public. Nevertheless, 3D views lead to a loss of information: surface deformation, absence of localisation, reduced vision of the area (depending on the chosen view point). 3D views should, therefore, be reserved for cases where the object of study is closely connected with the physical landscape or used to complement information given by maps.

In addition to these general limitations, each kind of map may present some problems. The Napoleon map was drawn for the improvement of a road. Even if the accuracy is good enough to be integrated in the GIS, the precision of the cartography is unequal depending on the distance to the road. Indeed, if the road is on the right bank of the Rhone river, the section of the left bank will have very poor information about land cover and land use. The map gives, therefore, indications for qualitative analysis of the landscape at the beginning of the 19<sup>th</sup> century, but it cannot be used for quantitative analysis (Stäubli & Reynard, 2007). Furthermore, we have no information about the projection used to draw the map. As the French cartographers usually used the Flamsteed modified projection at the beginning of the 19<sup>th</sup> century, we may suppose that it was also the case for the Napoleon map, but no further investigation has been carried out until now (Bureau topographique fédéral, 1898).

On the topographic surveys for the Dufour map the ground is represented with contour lines with an equidistance of 30 meters. Nevertheless, to draw the maps, the cartographers used only 400 to 500 spot elevations and drew the contour lines on sight, which means that the relief may not be completely exact (Grosjean, 1996). On the Dufour map, the relief is represented with obliquely luminated hachures, which does not give much information about the elevation. Anyway, we consider that the accuracy of the topographic surveys for the Dufour map is good enough to perform



quantitative analyses and that they are the oldest maps that can be used for the quantification of landscape change.

To be able to overlay the maps, all of them were integrated in the CH1903 reference system. As the Dufour and the Siegfried maps were surveyed with a different projection system (Fig. 2), distortion and inaccuracies may be important in the GIS. The number of ground control points was therefore increased in order to reduce distortions, but an important shift still exists between the Siegfried maps and the National maps. Moreover, one has to bear in mind that the techniques of mapping improved over time, especially with the progress in geodesy and photogrammetry. Even if the accuracy of old maps is high, it is therefore not equal to the more recent ones. Finally, the point of origin for height measurement of the Dufour and Siegfried maps is approximately three meters above today's point of origin (Fig. 2) (Grosjean, 1996; Gurtner, 1997). For all these reasons, the layers had to be manually or automatically rectified and lined up sometimes.

Fig. 4 illustrates the problems that can occur by georeferencing old maps. The western map (St-Léonard 1880) and the eastern map (Sierre 1886) do not fit completely: the width of the Rhone river is not the same and a forest is represented on the Sierre map but not on the St-Léonard one. It does not seem possible that the forest developed in only six years. This is an example of cartographic imprecision and of the shifting that can occur with georeferencing, even if it is done as precisely as possible (using many control points). It is, therefore, important to use other sources of information, such as historical records, to understand historical landscape change.

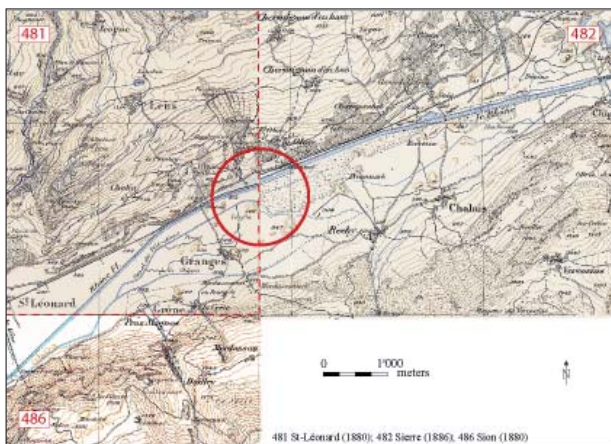


Fig. 4: Problems with fitting two Siegfried maps (Stäuble & Reynard, 2007 modified). Reproduced by permission of swisstopo (B081074).

## 6. Examples

The analysis of historical maps in the Rhone river valley highlighted four stages in the landscape evolution. Until the middle of the 19<sup>th</sup> century the Rhone river and the valley may be considered as close to a natural state. Since the 1860's, the landscape of the valley changed rapidly: the First

Rhone river corrections allowed the development of intensive agriculture and more recently urbanization (Fig. 7). The study of six vineyard areas showed different evolution trends. We present here only a few examples taken from the two studies (for more details, see Stäuble & Reynard (2005, 2007), Martin & Reynard (2007) and Reynard et al. (2008)).

The draining of wetlands in the plain of Conthey was mapped and analysed. The First Rhone river corrections were performed between 1864 and 1893. The aim of the hydraulic work was not only to reduce flood risk, but also to increase agricultural surfaces by building canals, which would drain the wetlands. Fig. 5 illustrates the retreat of wetlands in the plain of Conthey. Its quantification helps to analyse the reasons for the disappearance of wetlands in this area. Even if the canals were in use since 1877 (Pasche, 2004), only half of the area was drained before the 1930's. Indeed, during the 1930's, the so-called "Wahlen Plan" aimed at increasing the agricultural surfaces in order to improve food availability in Switzerland. The analysis of maps and the quantification of changes permit us to understand the importance of the "Wahlen Plan" in the drainage process in the area. Moreover, the development of roads

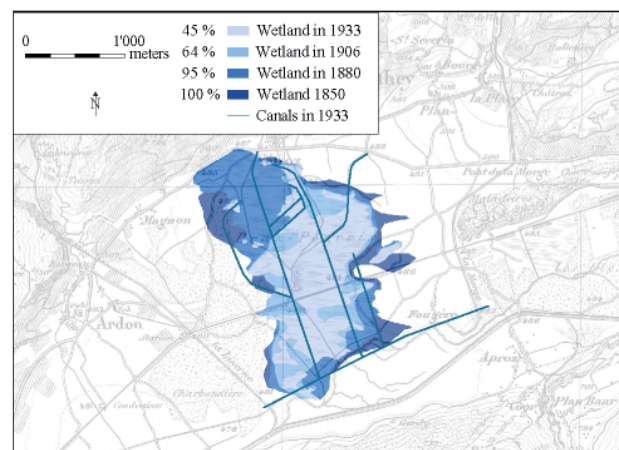


Fig. 5: Retreat of wetland in the plain of Conthey. On the map of 1943, all the land is drained (Stäuble & Reynard 2005 modified). Reproduced by permission of swisstopo (B081074)

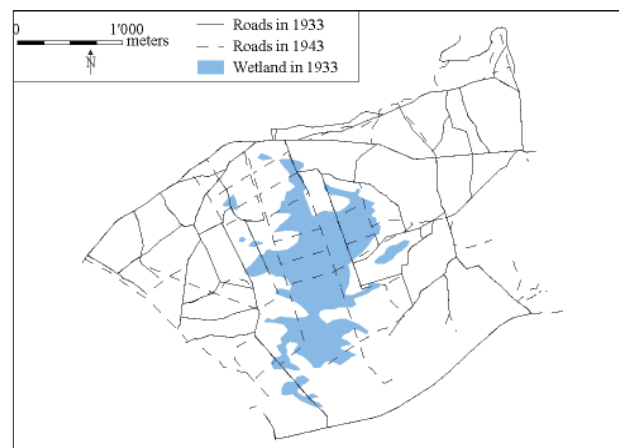


Fig. 6: Retreat of wetland in the plain of Conthey and development of roads for agriculture (Stäuble & Reynard, 2005 modified).

(Fig. 6) shows that as soon as the land was drained off, the land was used for agriculture. Before the first national maps at a 1:25,000 scale, orchards were not drawn on maps; the analysis of the road development helps understanding the transition between wetland and agriculture.

Mapping historical landscapes allows us to highlight the increase in vulnerability of the Rhone river alluvial plain, which is currently very high: in case of a hundred year return flood, almost 7,000 ha of the valley could be flooded. The potential damage is estimated at 2.8 billion Swiss francs for the current state of the valley (Canton du Valais, 2000).

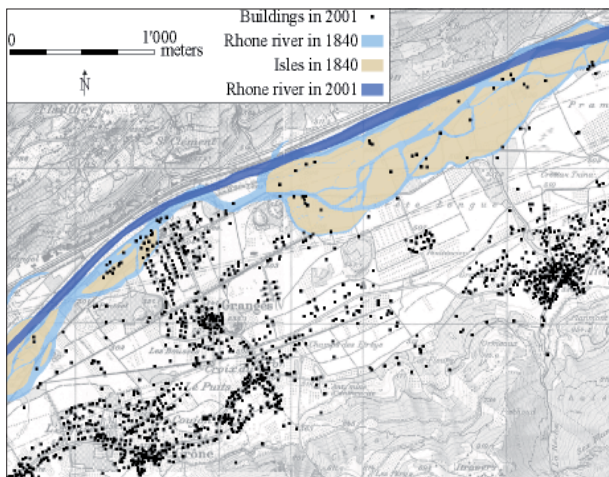


Fig. 7: Today's buildings in relation to the Rhone river before the first river corrections. Houses have been built on the old braids of the Rhone river (Stäubli & Reynard, 2007 modified). Reproduced by permission of swisstopo (B081074).

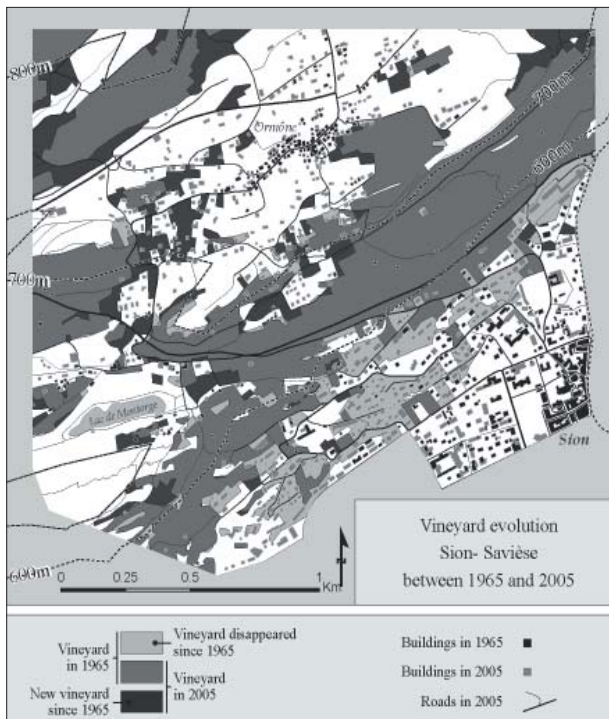


Fig. 8: Vineyard landscape change between 1965 and 2005 in relation to urbanisation in the surroundings of the town of Sion (Martin & Reynard, 2007, modified). Reproduced by permission of swisstopo (B081074).

Since 2000, the Canton of Valais has undertaken the Third Rhone river corrections, which aims at increasing the security of the valley and its ecological and socioeconomic state. Figure 7 shows the recent development of buildings in sectors where the Rhone used to flow before the First Rhone river corrections.

Fig. 8 shows how historical maps were used to analyse the relationship between vineyard landscape change and urbanization. The growth of Sion (capital of the Valais canton) during the last decades caused the disappearance of most vineyards at the foot of the hillside and on the plain, which were replaced by buildings. Between 600 m and 700 m, no important change is observable. Above 700 m, unlike around Sion, the vineyard has stretched everywhere, sometimes higher than 800 m. At the same time, numerous new houses were built all around the village of Ormône, but mostly at the detriment of meadows and not of vineyards. This evolution has now almost stopped the possible development of vineyards.

## 7. Conclusions

GIS allows dealing with heterogeneous spatial information such as historical maps whose accuracy and scale vary over time (Joliveau, 1996). We have pointed out some important methodological problems, such as changes in mapping characteristics (scale, projection system, reference point for elevation calculation, etc.), precision during the field survey, and accuracy of some important natural elements – forests, wetlands – in relation to the season that the survey was carried out. Moreover, some landscape elements, such as agricultural surfaces like orchards, meadows and cereal fields, that may change from one year to the next, are not represented on maps, even on the more recent ones. The reconstruction of historical landscapes is, therefore, always partial. Nevertheless, the integration of maps in a GIS environment allowed us to reconstruct some aspects of past landscapes and helped us to understand the driving forces of landscape change by crossing territorial features such as urbanization, building of infrastructures and changes of some natural elements like forests or wetlands. Maps represent, therefore, a first step in understanding landscape change by allowing us to formulate hypotheses on landscape driving forces. Further investigations – such as interviews of actors, consultation of archives – have yet to be carried out to confirm the hypotheses.

## Acknowledgements

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# Mountain Ski Maps of North America

## A Preliminary Survey and Analysis of Style

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### **Abstract**

*This paper examines mountain ski resort trail maps in North America. It starts with a survey of the complete set of maps in use today. For each map, the survey catalogs the point of view, creation method, style and artist where known. The main types of view used are: panoramas, profiles, and planimetric maps. Creation methods include: paintings, illustrating, and computer modeling/rendering. A brief history of the artists involved in creating North American ski maps follows along with discussion of samples of work by several key artists and a brief analysis of map style.*

### **1. Mapping Ski Mountains in North America**

Trails maps for ski areas are iconic images of the nature of the sport and its relation to the terrain on which resorts are built. Canada and the United States have well over 400 ski areas that are large enough to merit a trail map. The development of the maps has paralleled the development of the sport of lift-served skiing. As skiing in North America has grown and more money has flowed to building bigger resorts and marketing the resorts to skiers, more attention has been paid to marketing materials (Frye 2007). The combination of bigger areas to map and an increase in money in the sport led to a shift from simpler wayfinding maps to more elaborate mountain portrayals.

This study looks at the total number of ski maps in use and categorizes them by angle of view, method of creation, size, and artist if known. An evaluation of these factors is provided in the context of how they affect the style of the ski map. In addition, an examination of the artists involved in the maps' creation yields information about the history of mapping ski resorts.

### **2. Survey of Ski Maps in Current Use**

A mountain ski map as defined for this paper is a map of the trails and ski facilities of a lift-served ski area. Maps are included for any ski area that has a vertical drop (top to bottom elevation change) of at least 200 feet (60 meters). In addition, due to the limit on time and expenses for gathering materials, the study includes only ski areas and resorts

with established websites, indicating that they are both currently operating and that they are marketing to the public to entice skiers.

The resulting survey of ski maps does not include private ski areas, very small areas or many of the non-commercial (community) ski areas. These areas may have trail maps but are outside the main ski area focus of the industry and this paper. In addition, many resorts have maps in their marketing materials and on their websites that display Nordic or cross-country skiing trails, base lodge areas, resort towns, and lodging. These maps are not included in this study.

The survey of ski maps was conducted during January 2008 by a thorough internet search for ski resorts and then for ski maps used by each resort. Compiled lists of resorts data were accessed at [www.skitown.com](http://www.skitown.com) and [www.skireport.com](http://www.skireport.com). Each ski map was obtained directly from the individual ski resort website. The visit to the individual websites confirmed that each resort was currently operating and allowed viewing of the trail maps provided by the resort. Where there were multiple trail maps, for example different maps for print and web use, the map designated for print and on-slope use was used. An electronic file was available for 428 out of 429 resorts researched (the only exception was Apple Mountain in Michigan, not included as part of the survey).

For each trail map the following information was catalogued: view type, creation method, artist, existence and type of interactive web map, and size of resort (vertical drop, number of lifts, number of slopes). In addition, subjective style notes were made to assist in categorizing maps and assigning authorship. View type describes the general nature of the view of the mountain: the camera or optical view used. Creation method describes the general technique used to construct the final image.

In order to isolate some of the more important trends in the creation of ski maps, a distinction was made between major resorts and minor resorts. The major resorts are the top 100 ski areas as defined by an index calculated by multiplying the vertical drop (top to bottom elevation difference) by the number of lifts and by the number of trails. The use of the vertical drop in the index aided in putting the larger mountains (in terms of terrain covered) toward the top of



	All Resorts	%	Major Resorts	%
<b>View type</b>				
panoramic	368	86%	100	100%
profile	36	8%	0	0%
planimetric	24	6%	0	0%
<b>Creation method</b>				
painted	307	72%	89	89%
illustrated	85	20%	7	7%
annotated photo	24	6%	1	1%
computer rendered	12	3%	3	3%
<b>Total</b>	428	100%	100	100%

Fig. 1: Survey of North American mountain ski maps, counts and percentages by view type and creation method.

the list. Most smaller mountains did not make it into the top 100 resorts.

The initial results of the survey are summarized in Fig. 1. Some immediate patterns emerge such as the preponderance of ski maps using the panoramic view, indeed for the major resorts it is the only type of view used. Also, the painted technique, originally using traditional tools and now often using the computer, is the dominant method used to create the trail maps. Painted panoramic views have a strong tradition in ski mapping and much of this dominance in the current survey can be attributed to just a few artists.

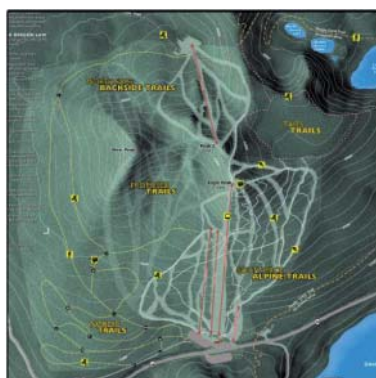
### 3. Types of Views

Three general view types exist in the set of maps evaluated in the survey (see Fig. 2). Planimetric views are mostly or entirely map like, viewed from directly above over all portions of the image. Panoramic views are oblique perspective views of any angle – there are a great variety of angles used, from very low to very high. A third category is profile views. These are generally very simple elevational views of the mountain from a very low oblique angle or ground level that have little or no three dimensional character and look into the mountain with little or no perspective. Assignment of low oblique views to either panorama or profile groups was a difficult task. Views with little or no attempt at shading or perspective were labeled as profile.

Panoramic views dominate ski trail maps, they comprise 86% of all maps and 100% of maps for the top 100 resorts. There are several probable reasons for this. As Patterson (2000) notes in discussing the panoramic work of Heinrich Berann, one of the earliest panoramic mountain ski map painters, that with a panorama, “Something truly magical happens. Readers feel drawn into the panorama as if they were flying high above the land.” The panoramic ski map may be particularly evocative of the mountain terrain for skiers and potential skiers for whom the feel of the image may replicate the feel of flying down the mountain on skis.

Planimetric views are relatively rare in the survey of current ski trail maps, only 6% of the total. In a brief view of cross-country (Nordic) ski trail maps associated with ski resorts, the planimetric map is much more prevalent. Given the exceptional accuracy of trail and feature placement it may at first seem surprising that true maps are not used more. They are better wayfinding instruments for experienced map users. Wayfinding, however, is only one reason for creating the map and can be minor compared to the need for the map to market the ski area and entice new skiers to visit.

The marketing of ski areas is a consistent factor in creating informational materials, including maps, for resorts. The demands of the marketing department can be at odds with an accurate portrayal of the mountain (Phillips 2007, Powers 2008). Ski areas often ask for the mountain to “look



Planimetric view



Panorama



Profile

Fig. 2: General types of views utilized in mountain ski maps (left to right: Willamette Pass, Oregon; Crested Butte, Colorado; Spirit Mountain, Minnesota).



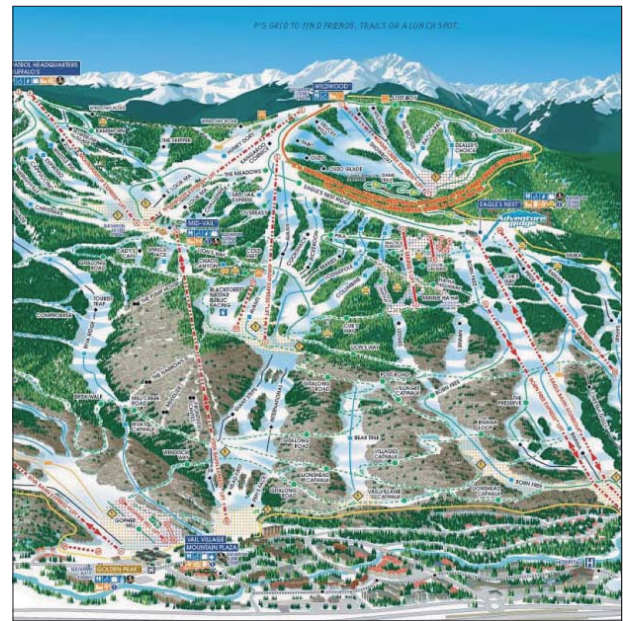


Fig. 3: Left: Peter Powers (Terragraphics) painted view of Mt. Bachelor ski resort in Oregon. Right: Gary Milliken illustrated view (portion) of Vail ski resort in Colorado.

bigger” and for the trails to appear more clearly delineated and map-like. Two requests that are often at odds with each other.

Profile maps constitute about 8% of the total ski maps in this survey. While in some ways a subset of panoramic maps they generally lack some of the key features of panoramas such as depiction of a true depth of field. The profile maps are more in use for smaller mountains, and can make them look larger than they would in an oblique view. The flatter profiles provide an image more amenable to schematic illustration of trails.

#### 4. Methods of Creation and Graphic Styles

The basic methods of creation used by artists creating ski trail maps are painting, illustration, and computer rendering. An initial distinction was made for both painting and illustrating between use of the computer and traditional techniques but the end result is often similar and in many cases difficult to distinguish.

Painted maps are by far the largest group of maps in the survey, 72% of all maps and 89% of maps for the top 100 ski areas. For examples of maps created with traditional painting techniques, see below images of Whistler Blackcomb by James Niehues, Arizona Snowbowl ski resort by Bill Brown,

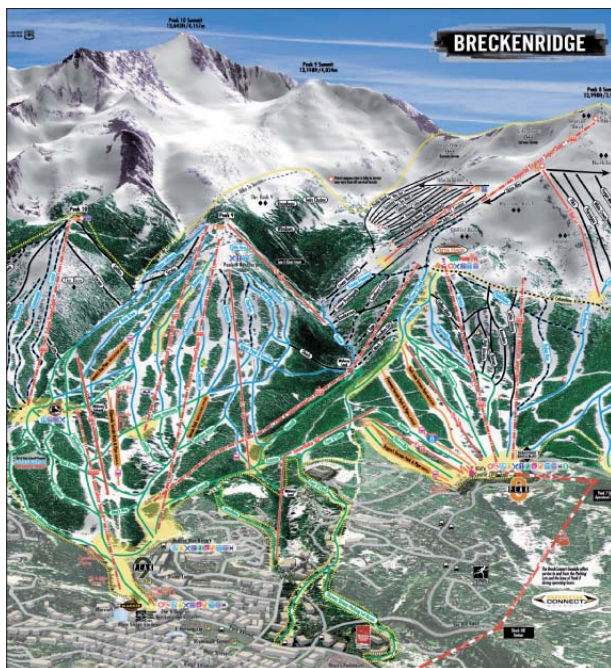


Fig. 4: Left: computer rendered view of Breckenridge resort, Colorado. Right: the author's computer rendered view of Northstar-at-Tahoe, California.



and Mammoth Mountain ski resort by Hal Shelton. For an example painted on the computer see Mount Bachelor by Peter Powers and Terragraphics (see Fig. 3, left side). Painted maps allow the greatest flexibility in terrain depiction and control of all aspects of the image but also require the greatest artistic skill. Despite the fine work by artists such as Hal Shelton and James Niehues, examples abound of unconvincing painted maps.

Illustrated maps are more prevalent in use for smaller ski areas (20% of all areas) than for larger areas (7% of top 100 areas). They are characterized by hard lines and sharp edges. The illustrated maps of Gary Milliken (VistaMaps) are the most prevalent in the major ski areas and the largest and most extensive vector art images (see Fig. 3, right side, showing Vail, Colorado ski resort). These maps usually rely on vector software programs – though some are illustrated with traditional tools – and have a mechanical, less natural feel than the other techniques.

In the survey of ski trail maps, a surprisingly small number of computer rendered images was found, only 3% of all resorts and 3% of top 100 resorts. The author has created two such views for major ski areas, see the example below (Fig. 4) for Northstar-at-Tahoe. This view uses procedural textures and modeled trees to mimic the patterns of slope and forest on the mountain. Breckenridge is another resort that recently converted from painted trail map to computer rendered map (Niehues 2008). The Breckenridge map is a standard satellite photograph draped over a digital elevation model. It includes rendered three-dimensional buildings for the town of Breckenridge.

Annotated aerial photographs are used in 6% of all resorts but only one of the top 100 resorts. They are the simplest of trail maps to create and can be effective for more compact areas but often suffer from the inability to control

generalization, selection and emphasis of features, all advantages of maps and rendered views. For an nice example, see the website for Whitewater resort, British Columbia: [www.skiwhitewater.com](http://www.skiwhitewater.com).

## 5. Individual Artists and Ski Trail Maps

The array of ski maps in use today reflects the history of artists involved in the business. Maps by Hal Shelton, Bill Brown, and Don Moss, are still in use though some were created 30-40 years ago. Hal Shelton was the first prominent ski trail map artist and he came to the work from both landscape painting and cartographic backgrounds. Shelton had a distinguished career as an innovative map designer with the U.S. Geological Survey and with the Jeppeson Map Company (Patterson and Kelso 2004). Painting ski maps was a bridge for him between his work as a cartographer and his later work as a fine artist painting landscapes (Masia 2005).

Shelton was most active in the 1960s and 1970s. Later in the 1970s and into the 1980s the bulk of the work passed to Bill Brown and then in the 1980s to James Niehues, forming a progression of Colorado based artists (Phillips 2007). Niehues (2008) describes this passing of the baton and notes that the business of ski trail mapping is a niche market that has been dominated by a single artist at most times. Other important artists include Don Moss working out of the northeastern United States in the 1960s and 1970s (Masia, 2005) and Murray Hay working out of Alberta, Canada.

Recent entrants into the business have included Peter Powers and his company Terragraphics, Gary Milliken and this author. These new artists all create ski trail maps with digital tools but not in a single style or creation method. Their variety of styles and creation methods include vector graphics, digital painting and 3d modeling/rendering.



Fig. 5: Hal Shelton painted view of Mammoth Mountain ski resort in California.



The total count by artists with at least two views is as follows. James Niehues tops the list with by far the highest number of trail maps, 112 total maps and 57 out of the top 100. Peter Powers' company Terragraphics counts 25 total, Gary Milliken 8, Don Moss 4, Murray Hay 3, Bill Brown 2, K.M. Mastin 2, Hal Shelton 2, and the author 2. Note that only about one-third of maps had clear attributions, additional research will be needed to identify more artists and obtain a more accurate count.

### 5.1. Hal Shelton

Hal Shelton's painted view of Mammoth Mountain ski area in the Sierra Nevada Mountains of California is truly a masterpiece (Fig. 5). Its natural coloring, panoramic view, trees textures and depth of field combine to produce a pleasing and easy to read trail map for skiers. A second painting of the mountain in summer appears to also have been painted by Shelton and uses a different view (higher oblique) but is no less effective. Shelton was the first major ski trail map artist and he set the bar very high for all those who have followed.

Of particular note in this view is the effective depth of field. Shelton used a slightly blurred effect for the background ranges, a light haze intensifying toward the horizon and careful placement of the mountain in relation to the background and sky. Though the summit does not break into the sky, it is the focus of the view and gives the impression of a big mountain, always high on the list for any ski resort.

### 5.2. Bill Brown

Bill Brown's views of Ski Santa Fe in New Mexico and the Arizona Snowbowl (see Fig. 8, below) show a continuation of the classic panoramic trail map style initiated by Hal Shelton. The individually painted trees, the use of haze to bring depth of field and the overall naturalistic look are key elements to this style. Brown's positioning of the subject mountains against the sky without multiple background ranges brings an intimacy to the view and also makes the mountain taller in the mind's eye.

### 5.3. James Niehues

The distinctive signature of James Niehues appears on more ski trail maps in North America than any other. Indeed, he has painted mountain ski maps around the world, over 120 by his count, and he sits firmly in the classic school of painted panoramas. Niehues credits Hal Shelton and Bill Brown as his mentors but also the panoramic views from Europe, such as those created by Heinrich Berann (Niehues 2008).

Perhaps the most distinctive element of Niehues' work is the rendering of trees. His painstaking painting of each tree, its form, its highlight and its shadow give his work a forested texture unlike most others. The difference between evergreen and deciduous trees in areas such as Vermont is a tribute to the care he takes in preparing each map view. Other distinguishing characteristics are his buildings and cars parked at ski area bases. See Niehues' view of Whistler Blackcomb (Fig. 7).

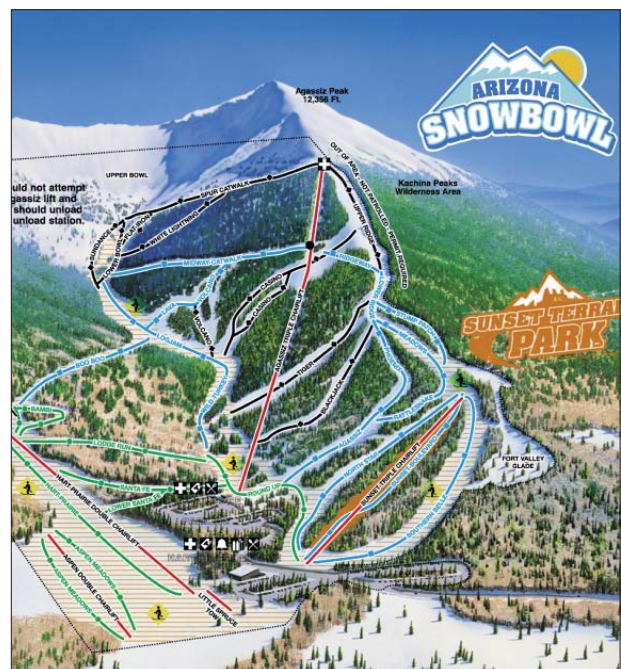


Fig. 6: Bill Brown painted views of Ski Santa Fe, New Mexico and Arizona Snowbowl.





Fig. 7: James Niehues painted view of Whistler Blackcomb in British Columbia.

Niehues does not use computer elevation models for visualizing. He uses topographic maps and reference air photos, often taking the photos himself. He then prepares rough sketches for approval and completes the work with traditional brushes and paints (Phillips 2007). Because of the variety in Niehues work it is hard to describe a single technique for positioning and distortion of terrain and camera for his panoramas. His view of Whistler Blackcomb uses the classic technique of a progressive projection (as described by Jenny 2004) that renders the foreground with a steeper angle than the background.

## 6. Conclusions and Future Research

This survey of mountain ski trail maps shows that the painted panorama style is preeminent. It shows that several artists have been key in the development of a classic style of North American ski maps and also that new and different techniques by a new set of artists has brought changes around the edges of the old school style. Much work remains to provide a complete picture of the history and stylistic character of ski maps.

One area of research will need to look at the relationship of maps to marketing and how the needs of the resort for advertising the mountain affect the look of the map. Are there times when the marketing needs outweigh the way-finding purpose of the map? Related to this are the influence of the U.S. Forest Service in promoting ski areas and in providing the land on which many areas in the western United States are built (Frye 2007). In addition, one could take a more extensive look at historical trends in ski mapping and gather samples of maps from different periods for individual ski areas.

An analysis of the new techniques being used and developed and how they attempt to mimic or differ from the old styles would be fertile ground for more research as would an analysis of panoramic view construction in the painted maps. One final area for exploration is interactive maps. In the survey of ski trails maps, a note was made during the visit to each resort website of the existence of an interactive web map. For all ski areas 76 out of 428 (or 17.8%) websites had such an interactive map, for the top 100 areas 52 (52%) had them. This may be the future of ski mapping for the next generation of skiers.

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# Mapping Sediment Transfer Processes Using GIS Applications

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## Abstract

*In alpine environments, debris flows are a very dangerous geomorphic process and the main sediment transport agent in mountainous watersheds. The vulnerability of many infrastructures built on debris fans becomes higher and higher due to increasing intense meteorological events. Causes and factors acting on debris flow triggering are complex and still partly ignored. In small alpine watersheds, topographic conditions and land cover often hinder accessibility to conduct complete field surveys such as geomorphological mapping. Hence, GIS applications using digital elevation models in ArcMap software can be used to analyse specificities of the hydrographical network and, hence, to evidence the localisation and the potential volumes of sediment supply zones. This paper presents some applications in a torrential watershed located on the right side of the upper Rhone river valley and an outline of the developed methodology.*

## 1. Introduction

In alpine environments, floods and bed load transport like debris flows constitute one of the major sources of risk. As an example, in August 2005, an extensive flood event in Switzerland provoked economic losses of 2 billion euros. In small mountainous watersheds, channelised debris flows (or debris torrents) are the main sediment transport agent and a very dangerous geomorphic process (Sterling & Slaymaker 2007). In fact, many infrastructures built on debris fans become more and more vulnerable because of the occurrence of intense meteorological events. In Switzerland, this trend is particularly perceptible since the end of the 1980s. Indeed, catastrophic floods in 1987, 1993, 1994, 1999, 2000 and 2005 in different regions of the country are only the most important national events and do not include local events, for example during storm events. Causes and factors acting on debris flows triggering are complex and partly ignored, depending on meteorological (intensity and duration of rainfall, temperatures, snow cover), topographic (slopes), geomorphological ((in)activity of geomorphological processes, instabilities, particle size and thickness of glacial, gravitational, periglacial or fluvial deposits), thermal (permafrost evidence), geological (faults and lithological characteristics) and hydro(geo)logical (shape of the hydro-

logical network, flow regimes, underground water circulations, glacier occurrence) parameters. All of these elements may be combined, so that it is difficult to define a typology of the events and to model and predict these phenomena. Nonetheless, there are three fundamental parameters acting on debris flow triggering: slope (generally steeper than 15°), water presence and sediment supply zones connected to a main channel or a stream (Zimmermann & al. 1997). The aim of this paper is to discuss the contribution of GIS tools for evidencing sediment supply zones in torrential systems. Spatial analyses performed on high-resolution digital elevation models (DEM) are considered to be a good alternative to field geomorphological mapping in dangerous and inaccessible areas.

## 2. Geomorphological mapping of sediment transfer processes

An analysis of a large panel of geomorphological maps and legend systems revealed that most of the studies undertaken deal with the establishment of simple landform inventories. Some of them have an approach based on natural hazards or phenomena (e.g. Kienholz 1978; Petley 1998; Grecu 2002; Gustavsson 2005) or on sediment production (Bardou et al. 2007), but few authors use GIS applications for geomorphological mapping, even if some simple data derived through GIS spatial analysis (slopes, aspect) might be of high interest in geomorphological mapping. In a previous papers (Theler et al. 2007), some inconsistencies of the global methodology used in hazard mapping in Switzerland were highlighted<sup>1</sup> (Theler et al. 2007; Theler & Reynard 2007), particularly in the geomorphological legend used to map fluvial phenomena (Kienholz & Krummenacher 1995). More precisely, we concluded that there was a need for more detailed information about the volumes of potentially mobilised sediments that are one of the most important parameters of channelised debris flow occurrence, especially in densely populated mountain regions with a high potential of natural hazards.

<sup>1</sup> A "phenomena" map is produced by using geomorphological field evidence. A colour scheme is given to each morphogenic process and different tones of colour or thicknesses of symbols allow the differentiation of the substratum type, the depth of gravitational processes and the evidence, relative age and size of processes. However, the recommended legend for mapping the phenomenon only gives a momentary vision of one single event.

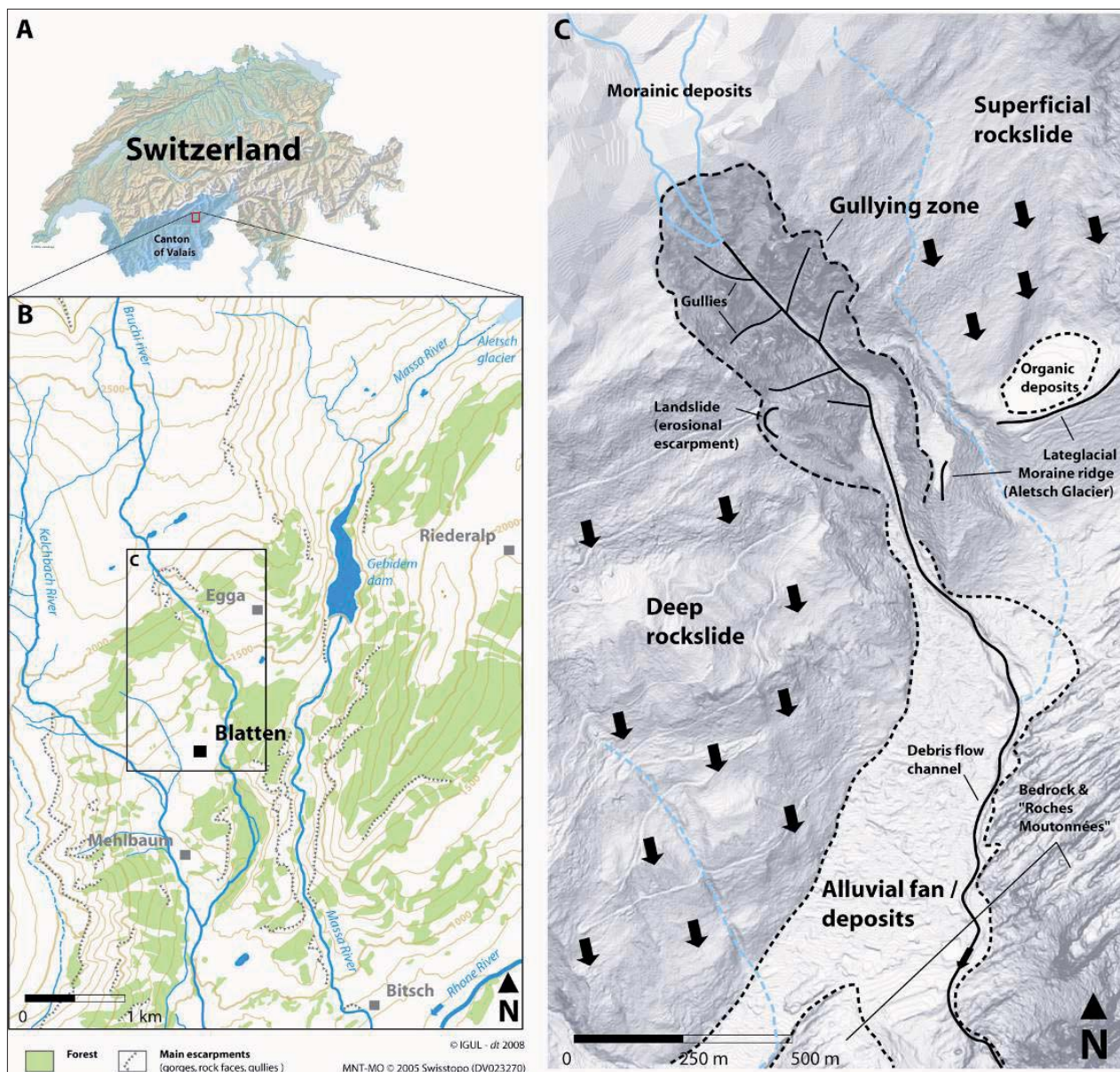


Fig. 1: Localisation map of the study site and main geomorphological features. MNT-MO © 2005 Swisstopo (DV023270)

Then, as return and frequency periods are often used in hydrological studies, we outlined that these parameters are quite random in small torrential watersheds where bed load transport phenomena are common and not always related to heavy rainfall. A better cartographic recognition of the slope system and especially the sediment transfer processes should improve the knowledge on hydrological hazards in alpine environments.

### 3. Research area: Bruchi torrent (Swiss Alps)

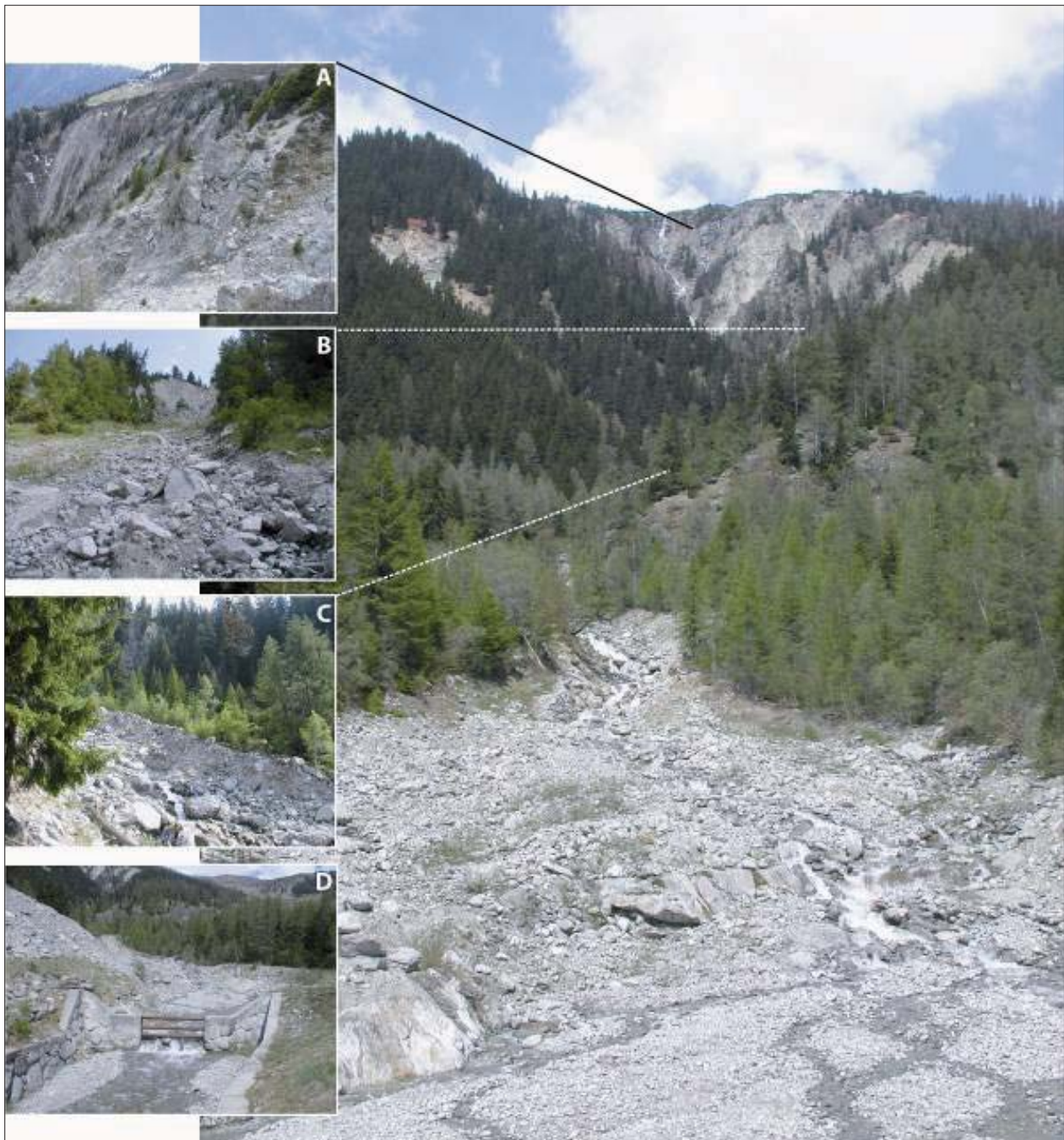
Because of time and financial restrictions, a perfect quantitative evaluation of the sediment storage in torrential systems is not the objective of our study<sup>2</sup>, but a good cartographic recognition can help to understand and detect the problematic zones. Three sites, situated in the Canton of Valais (Switzerland) are currently being investigated:

Bochtür (Agarn), Tsarmine (Arolla), and Bruchi (Blatten). This paper concerns only the latter.

The Bruchi torrent is located north-northeast of the village of Blatten bei Naters (Valais, Swiss Alps, 46° 22' N/7° 59' E) (Fig. 1). It is a perennial watercourse that is the main tributary of the Kelchbach torrent, which drains the right part of the Massa valley that was eroded by the Aletsch glacier, the largest glacier of the alpine range. The Bruchi torrent source is situated at about 2800 m a.s.l. in a depression under the Hohstock mountain (3226 m) (Fig. 1). The watercourse then meanders through pastures developed on granitic "roches moutonnées" belonging to the crystalline Aar massif. In contrast to typical torrential systems, the drainage basin corresponds to a highly gullied zone midfield of the watercourse (1600–2000 m a.s.l.) (Fig. 1). Thus gullies take place in a slope characterised by mass movement fostering gneiss erosion and rockfalls. All the known debris flow events triggered from this instable zone. Archives of past events of the Bruchi torrent are rare and incomplete and

<sup>2</sup> This paper provides results of a PhD thesis project called "Geomorphological mapping of sediment transfer processes in high mountain watersheds" (2007–2010).





*Fig. 2: General view upstream of the three parts of the torrential system of Bruchi with zooms on different parts of the watershed. A: Fractured rocks at the top of the drainage basin; B: lateral supply of sediments by debris flows triggering on a landslide; C: lateral levee in the channel (transport zone); D: deflection dam and sediment bars on the alluvial fan. Zone "B" shows characteristics of a landslide and an erosional escarpment where small debris flows are triggered. The problem is how to map this kind of zone at large scale: is it an erosion or an accumulation zone? Actually both processes are often superposed in the field and complicate distinction of erosional and accumulation landforms. Pictures: David Theler, April 2007.*

only concern two periods (1905-1907) and four events after 1987 (Bollschweiler et al. 2007). Dendrogeomorphological investigations on 401 trees were carried out by Bollschweiler et al. (2007) to retrace spatial and temporal extension of old debris flows. They highlighted 53 different natural levees and 164 frontal lobes. Eleven previously active channels were identified and almost forty events were recognised between 1867 and 2005. In order to prevent future damage to infrastructures (roads, buildings, etc.) caused by debris flows, protection measures were undertaken in the late

1970s (debris retention basin and deflection dam) and the banks of the main channel were reinforced. After significant overbank sedimentation on 4 July 2001 caused by several debris flows, the existing retention basin and the deflection dam were enlarged (Bollschweiler et al. 2007).



#### 4. Outline of methodology

Regarding topographic conditions, accessibility of sites, land cover (vegetation) – that can hide some processes and landforms – in mountainous environments and the expected level of cartographic details, traditional geomorphological mapping based on field surveys becomes difficult sometimes. Topographic attributes derived from DEM are, therefore, more and more often used in geology and in geomorphology (Van Asselen & Seijmonsbergen 2006). Hence, GIS applications in ArcMap software using digital elevation models can be used to analyse the specificity of the hydrographical network and, moreover, to evidence the localisation and the potential volumes of sediment supply zones.

##### 4.1. DEM and ArcGIS tools

Since 2000, the Federal Office of Topography (swisstopo) provides two types of digital elevation models based on very high accuracy laser measurements (one replicating land surface with soil, vegetation and buildings called “MNS” and the other showing gross topography, only below 2000 m a.s.l., called “MNT-MO”). The precision is about  $\pm 150$  cm for the first model and  $\pm 50$  cm for the second one, with, for both of them, a density of points of  $1/\text{m}^2$  (swisstopo 2007). The global approach consists in simulating the hydrographic network and then delineating sub-watersheds in the sediment source zone where debris flows or bed load transport phenomena are triggered. Generally, the triggering area corresponds to the drainage or contributing area, but in our study site, it is located midfield of the stream. We describe the different steps here.

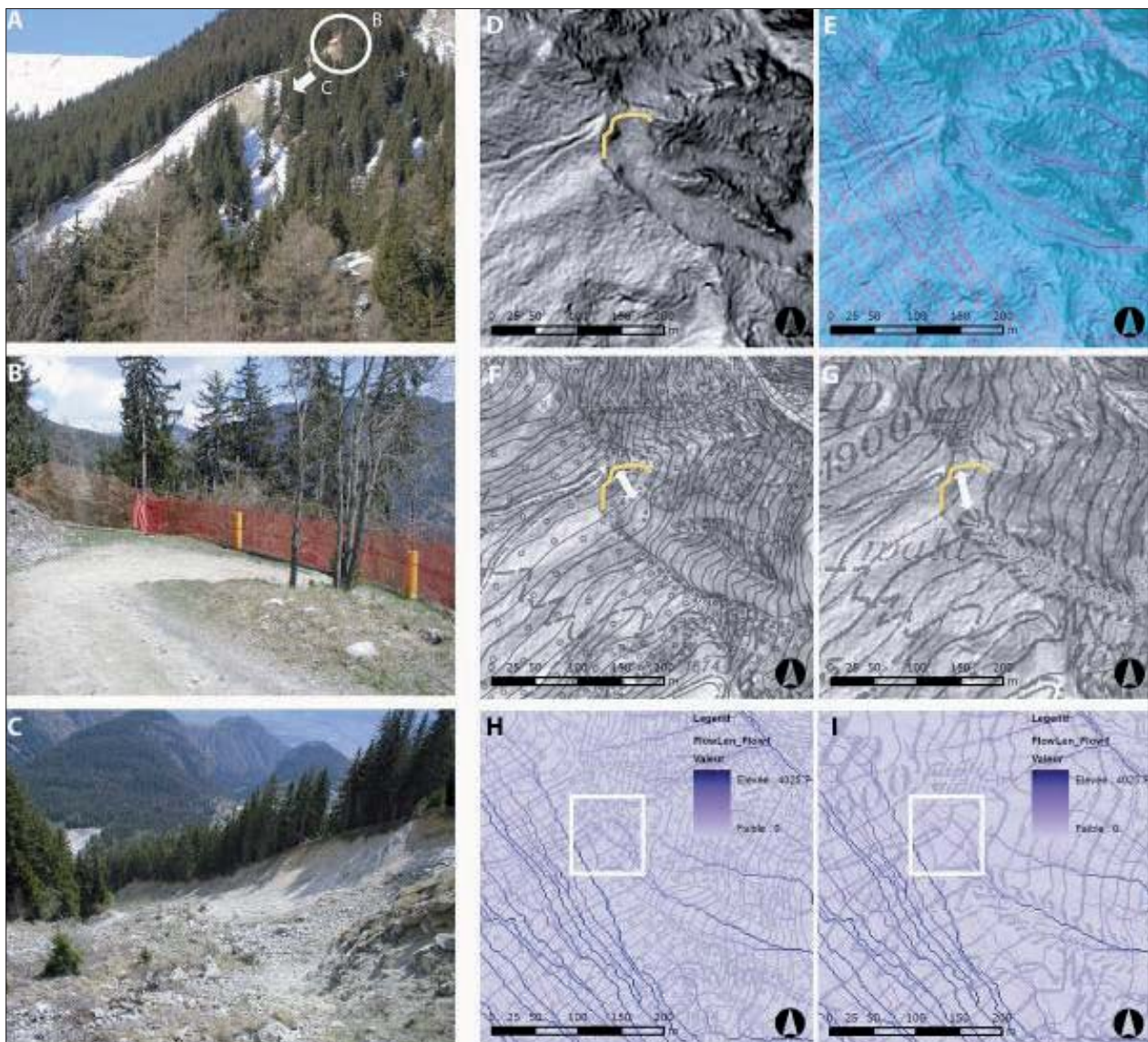


Fig. 3: Use of “Flow\_Length tool” on “MNT-MO” DEM applied in a small landslide acting as a sediment supply zone. A: View of the scarp from the monitoring station (picture: David Theler, February 2007); B: Detailed view of the forestry road safety net; C: View downslope of the landslide. D to I: excerpts of the aerial view of the landslide with - hillshade and scarp (D), - hillshade and Flow\_Length (E), - hillshade and topographic map (1982) at 1:10,000 scale (F), - hillshade and topographic map (1986) at 1:25,000 (G), - topographic map (1982) at 1:10,000 scale and Flow\_Length (H), - topographic map (1986) at 1:25,000 scale and Flow\_Length (I). MNT-MO © 2005 swisstopo (DV023270).

First the “Hillshade” function greatly enhances the visualization of a surface for analysis or graphical display – especially when using transparency – by determining illumination values for each cell in a raster and thus, obtaining the hypothetical illumination of a surface. The “Fill” tool fills sinks in a surface raster to remove small imperfections in the dataset. It creates an elevation grid without depressions that will be used for the other steps. The tool “Flow direction” creates a raster of flow direction from each cell to its steepest downslope neighbour. The output of the Flow Direction tool is a raster map whose values range from 1 to 255. The “Flow accumulation” tool calculates the accumulated flow at a point. As the accumulated weight of each cell is based on the flow coming from the upper related cells, this phase is based on the “Flow Direction raster map”. As explained in the ArcGIS Help “if no weight raster is provided, a weight of one is applied to each cell, and the value of cells in the output raster will be the number of cells that flow into each cell. Cells of undefined flow direction only receive flow; they will not contribute to any downstream flow”. The accumulated flow is based on the number of cells flowing into each cell in the output raster. Output cells with a high flow accumulation constitute areas of concentrated flow and can be used to identify stream channels, and hence, potential erosion and transfer zones. The “Snap Pour Point” tool is used to ensure the selection of points of high accumulated flow when delineating drainage basins using the Watershed tool. Snap Pour Point will search within a snap distance around the specified pour points for the cell of highest accumulated flow and move the pour point to that location. Before using this tool, it is necessary to create pour points (shapefiles) that will determine the watershed. This step is realised by displaying the Flow Accumulation raster. They correspond to the watershed exit, which is the lowest point along the boundary of the watershed. Finally, the “Watershed” tool allows us to determine areas that drain water (and other substances like sediments) to a common outlet as concentrated drainage. This area is normally defined as the total area flowing to a given outlet or pour point.

The above description is just a non-exhaustive overview of some tools that can help the geomorphologist working in difficult environments. Other tools have to be used, like the “Flow Length” tool, whose primary use is to calculate the length of the longest flow path within a given basin (Fig. 4). Using the “UPSTREAM” option, it usually allows the time of concentration of a basin in flood studies to be calculated. In our study, it proves to be better than the Flow Accumulation option, because it allows existing and potential gullied zones and sub-drainage basins to be defined more precisely. It also allows us to predict the evolution of dynamic zones like gullies, by analysing the lag between the DEM and old topographic maps. An example is given below for a small landslide acting as a supply zone in the catchment area of the Bruchi.

## 4.2. Field investigations

In addition to field geomorphological mapping, aerial photograph interpretation and DEM analysis, different methods are used to estimate sediment fluxes and denudation rates, as proposed in the SEDIFLUX manual for debris flows environments (Beylich & Warburton 2007) or by Schrott et al. (2003). These complementary measurements should confirm results obtained by GIS applications. At the Bruchi site, reference coloured lines, painted stones and wooden markers were installed in the summer of 2007. In June 2007, a monitoring station was installed, with a pluviometer, a thermometer and a camera that takes a picture of a sector of the watershed every day. Moreover, at the Bochtür site (site 2), 34 blocks were marked for calculating displacement rates by using real time kinematics GPS. The results obtained by field survey are not discussed in this paper.

## 4.3. Geomorphological mapping within GIS

The insertion of geomorphological maps in GIS is not always easy because of the high number of different landforms, the complex graphics used in classical geomorphological maps, and the rather poor graphical tools of some GIS software (Schoeneich et al. 1998; Gentizon et al. 2001). Nevertheless, recent graphical improvements in GIS software now offer new possibilities in geomorphological mapping within GIS environments (Gustavsson et al. 2006) and even more possibilities in estimating sediment volumes stored in some geomorphological reservoirs (Otto 2006). Nevertheless, it may be very difficult to quantify differences in sediment yields using a geomorphological map drawn with a morphogenetic approach (Schoeneich 1993), because this kind of mapping distinguishes the different landforms according to the processes, but not according to the intensity and frequency of current processes. This problem may be illustrated with three examples. Firstly, in alpine areas, rock glaciers and talus screes containing permafrost potentially represent large storage systems of unconsolidated materials, where collapses or debris flows may occur. The ice content and its distribution within the landform, as well as the thermal regime of ice and sediment, are important factors influencing the triggering processes; geomorphological mapping based only on field observation is not sufficient for evidencing the importance of these factors. The second example concerns moraines that are also important sediment storage systems. Old morainic deposits (Glacial Maximum, Lateglacial) do not have the same sedimentary dynamics as contemporary or Little Ice Age deposits, not covered with vegetation and sometimes rich in ice; morphogenetic mapping is again not sufficient for distinguishing potentially mobilised sediment volumes. The last example concerns the relationship between weathering and the position of the landforms within the watershed. Zimmermann et al. (1997), Bardou (2002) and Veyrat-Charvillon & Memier (2006) demonstrated that the contribution to debris flows by current gravitational accumulations resulting from rock alteration depend on the position of the weathered outcrop in the catchment (connected or not to the watercourse). These examples demonstrate that geomorphological maps



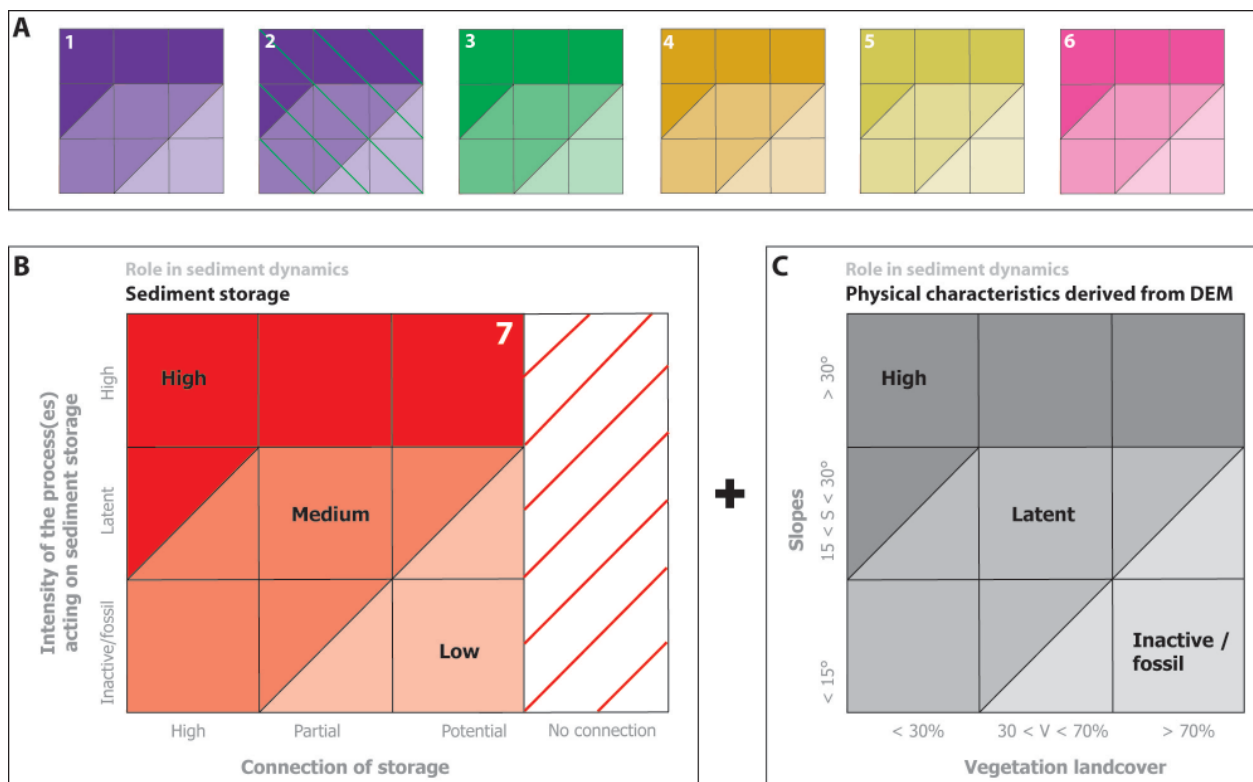


Fig. 4: Two matrixes depicting the importance of the sediment storage in the global sediment dynamics. AB: Sediment storage differentiated depending of the morphogenesis. 1: Glacial sediment storage (morainic deposits and ridges); 2: Fluvio-glacial sediment storage (fluvio-glacial deposits and kames); 3: Fluvial sediment storage (debris fans, alluvial deposits, natural levees etc.); 4: Gravitational sediment storage (talus screes, landslides, rockslides etc.); 5: Organic sediment storage (different types of soils); 6: Periglacial sediment storage (rock glaciers, talus screes etc.) and 7: "Structural" sediment storage (free faces, rock escarpments). C: Physical characteristics derived from DEM (slopes and vegetation). For example, high altitude screes (pink matrix) where traces of debris flows are visible will be classified as sediment storage of high importance because of the potential of unconsolidated material that could be mobilised by overflow. Free faces directly connected to a main debris flow channel, without vegetation and composed by highly fractured rocks will be drawn in dark red.

are only basic information for sediment transfer evaluation and that processing within a GIS (e.g. classification of landforms according to their dynamics or their position in respect to the watercourse) opens new opportunities for a more quantitative use of classical geomorphological maps.

In this study, two matrixes were established (Fig. 4) – inspired by hazard mapping in Switzerland (OFAT et al. 1997) – in order to compare the importance of the (or several) storage in each sub-drainage basin. The nature of the sediment storage is differentiated depending on its morphogenesis (Fig. 4A). A distinction is made between glacial, fluvial, fluvio-glacial, gravitational, organic and structural sediment storages. We consider free faces or rock escarpments on fractured or much folded rocks, which have quite the same behaviour as unconsolidated materials, as structural storages (Fig. 4B). The colours (Fig. 4AB) used to represent the morphogenesis of the sediment storage are the same as in the IGUL geomorphological legend (Schoeneich 1993). For this purpose we use a typical panel of colours in

reference to principles established in the 1960's (July 1962) and recommended for unifying geomorphological mapping legends<sup>3</sup>. Connections of the sub-basin(s) with the main catchment area are also taken into account. Vegetation land-cover is derived automatically from MNS and MNT-MO, as well as slope distribution (Fig. 4C). Homogenous polygons between vegetation land-cover and slopes are derived from GIS spatial analysis. Information is entered in the second matrix to characterise the role of the sediment storage in the global sediment dynamics.

We present two examples of sub-basins influenced by debris flows here (Fig. 5).

<sup>3</sup> Currently, there are almost as many geomorphological legend systems as geomorphologists! Few of them use the official colour system rigorously i.e. pink for periglacial landforms and processes, light blue for karstic ones, dark green for fluvial ones, beige for gravitational ones, red for structural features etc. Choices of colours also depend on the type of information contained in the map: morphogenesis, morphochronology, morphodynamics etc.

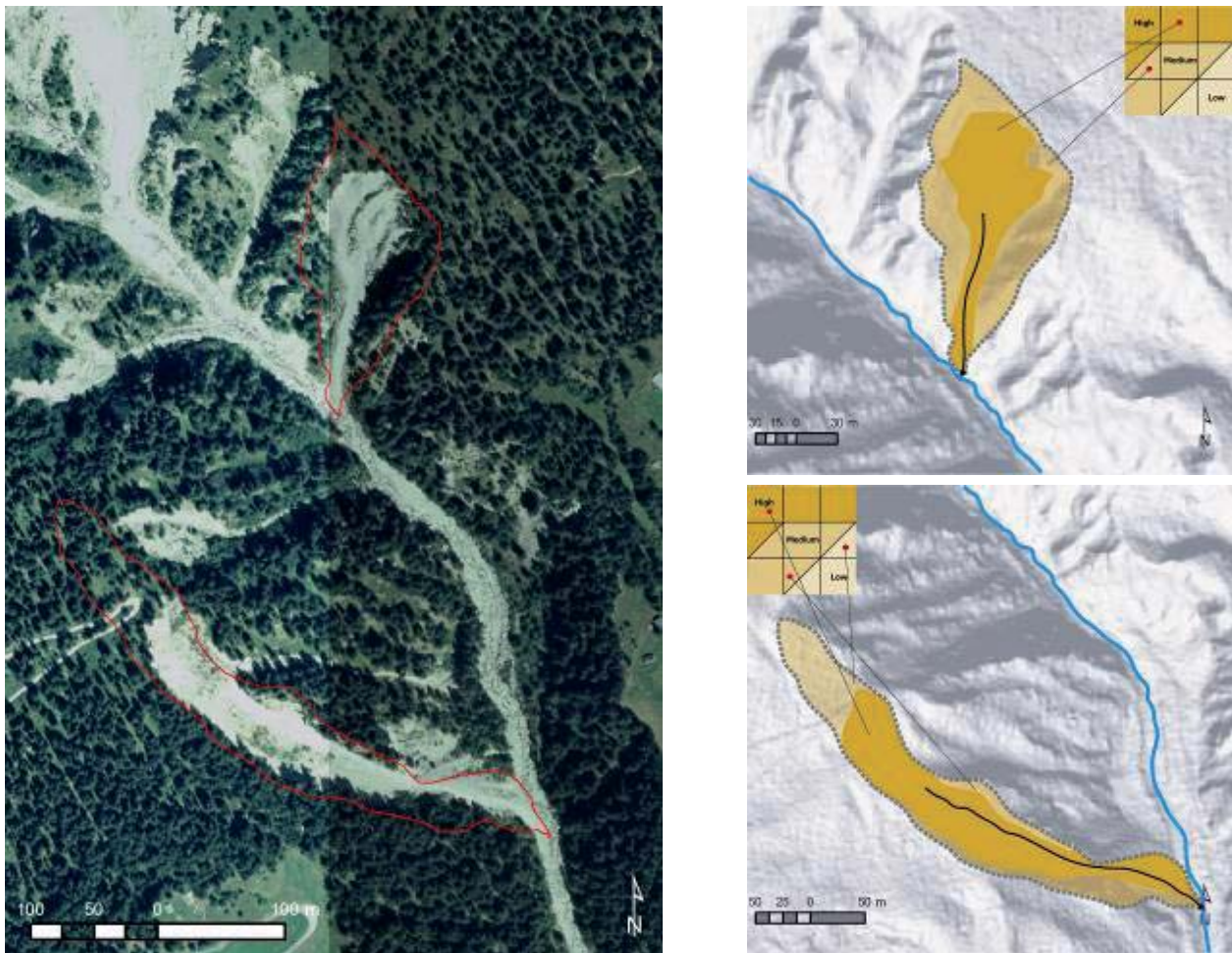


Fig. 5: Two examples of mapping sub-basins influenced by debris flows. Colours represent gravitational accumulations. Black arrows depict debris flow channels. MNT-MO © 2005 swisstopo (DV023270) and Swisssimage © 2005 (DV023268).

## 5. Research perspectives

This simple approach provides another geomorphological approach of slope systems. Slope distribution analysis has to be performed to evidence specifically deposit and transfer zones and hence to map transitory deposits. The matrixes presented above are not definitive and have still to be tested in a complete drainage area especially for gravitational processes that have not the same behaviour as debris flows and interfluvies where superficial overflow is the dominant process. Estimations of potential sediment volumes that may collapse in the main channel or transported by geomorphological processes are still not effective. Mapping of transitory deposits as natural levees has to be developed. Finally, results will be compared to field investigations and monitoring stations measurements and photogrammetric analyses

will be carried out on pictures taken every day by a camera on a sector of the gully zone.

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# ViViTo

## An Interactive Information Tool for Mountainous Protected Areas

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### Abstract

*ViViTo (Virtual Visit Tool) is an information tool for visitor centres of protected areas in the Alps. The objective of ViViTo is to allow users to inform about ecology and cultural landscapes of the Alps as well as the nature conservation policies in an attractive and enjoyable way. The application is based on a virtual globe, a 3D software model of the Earth. One of the main challenge was the design of the user guidance which account for the heterogeneity of the users in respect to media and language skills, educational background, age etc. The development of ViViTo was lead managed by the Swiss National Park and is a result of the Interreg III B project ALPENCOM.*

### 1. Introduction

Alpine protected areas have several functions to fulfil. In the first instance they are habitats for flora and fauna – human decided to be worth of protection. Furthermore, in some of them the preservation of historical land use forms is in the foreground. They shall contribute to the recreation of the population and shall generate income by tourism. Even if the priorities of the alpine protected areas may differ, all of them have the idea to sensitize their visitors for the necessity of the protection of alpine wildlife, nature landscapes or historical cultural landscapes.

During the last decades managers of protected areas have realised the need of networking with other protected areas, the need of common strategies and knowledge exchange of method and experiences. Their awareness grown that protected areas could not concerned anymore as blissful islands – habitats are linked, wildlife migrates, the environment is changing permanently and tourism is no local phenomenon. A common appearance and representation of interests towards policy, society and decision makers got more and more important.

Based on an initiative of the French government the Network of Alpine Protected Areas (Alparc) was founded in 1995. Nowadays Alparc is the task force of the Alpine Convention. Within the last years the network developed rapidly. One of the most important projects up to now – ALPENCOM – was launched in 2005. „ALPENvironmental COMMunication“ was financed through the Com-

munity Initiative Programme „Interreg III B Alpine Space“. The project consortium is formed by 10 alpine protected areas from France, Italy, Slovenia, Austria and Germany. The overall objective of the project is the establishment of „a global information and communication exchange system for sustainable management of natural resources and public relation for alpine networks of protected areas.“ Work package 5 of the project deals with the development of a virtual globe application for visitor centres of protected areas. The Swiss National Park was commissioned by the consortium for the development of the application, whose objectives and realisation is presented in this paper.

### 2. Aim of the Application

A virtual globe application for the visitor centres was considered as an attractive way to communicate the common objectives of the Network of Alpine Protected Areas on the one hand and to offer visitors' information about ecology, landscapes and culture of alpine protected areas and the Alps in general on the other hand. Around 800 points of interest (POI) on local, regional and alpine level have been defined by the project partner who are suitable to represent the spectrum. They are related to the topics nature protection, landscapes, flora and fauna, cultural heritage and environmental education.

To show the totality of the Alps and therewith the (physical and institutional) network of the Alps as well as geographical entities at small scale was regarded as precondition for the application. The divergent requirements pose a challenge to the application:

- The Alps with its protected areas have to be visualised and perceived as a whole.
- The themes which are related to the whole Alps have to be shown and accessible within this context.
- The protected areas have to be visualised with high resolution aerial views and digital elevation models. Otherwise, the impression of the virtual landscape would not be realistic.

Any text information of the application has to be provided to the user in one of the main alpine languages (French, German, Italian and Slovenian) and in English as well.

### 3. Users and Use Cases

Basis of the design of the application – baptized to the name Virtual Visit Tool (ViViTo) – was the determination of the potential users and the specific situation in a visitor centre of a protected area.

In respect to the potential user the result showed that there is no standard user. Visitor centres are frequented by children, youngster and elderly people, families, single travellers or participants of organised bus trips like scholars on school trip. All of them have different levels of media and language skills, educational background etc. Some may be more interested in discovering the Alps and protected areas from the air independently – in virtual visits of parts of the parks which are not accessible due to law restrictions or because of remoteness. Other may be more interested in the information provided to predefined POI. However, for all potential users the application should be attractive as possible.

In respect to the situation of the place of installation of ViViTo it could be divergent as well and could change quickly. If the visitor centre is crowded, for instance if the participant of a bus trip gushed into the exposition spaces, users get stressed if a waiting queue emerged in their back. Only in times of few visitors users have the time to deal with the application for longer time. However, the experience of the persons in support the visitor centres is that most visitors do not spend more than 10 minutes at one and the same exhibit. Generally most visitors lose interest if an

exhibit is information overloaded or if the interaction with the module is very complex. Easy to learn user interfaces and an adequate reduction of information are essential for a visitor information tool as ViViTo.

### 4. Approach of Complementary User Interfaces

In consideration of the heterogeneity of potential users and changing conditions in visitor centres we decided to provide the users two different but complementary kinds of interfaces: a joystick and a menu based on a clickable map which is accessible with a touch screen.

The idea of the joystick is to enable users to flight freely over the whole Alps and the protected areas. With a crosshair users can activate symbols showing theme and location of POI to open an info box with a textual description of the selected geographical entity, enriched with a photo or a video. The joystick interface should oblige those users which prefer to have a high degree of freedom in navigation. Furthermore, using a joystick as hardware interface gives users the feeling of flying a helicopter, which is fascinating and attractive for most people. However, handling a joystick with several functions, while orientating and navigating in a virtual 3D is a complex task, which may be difficult especially for those users which are not common with virtual globe application like Google Earth or 3D computer games.

The complementary approach of a touch screen menu based on a clickable map enables interface designers to implement a higher degree of user guidance functionalities. A good designed menu would allow an intuitive access to geographical areas and themes. Such an interface would support those users which are not accustomed to navigate in virtual

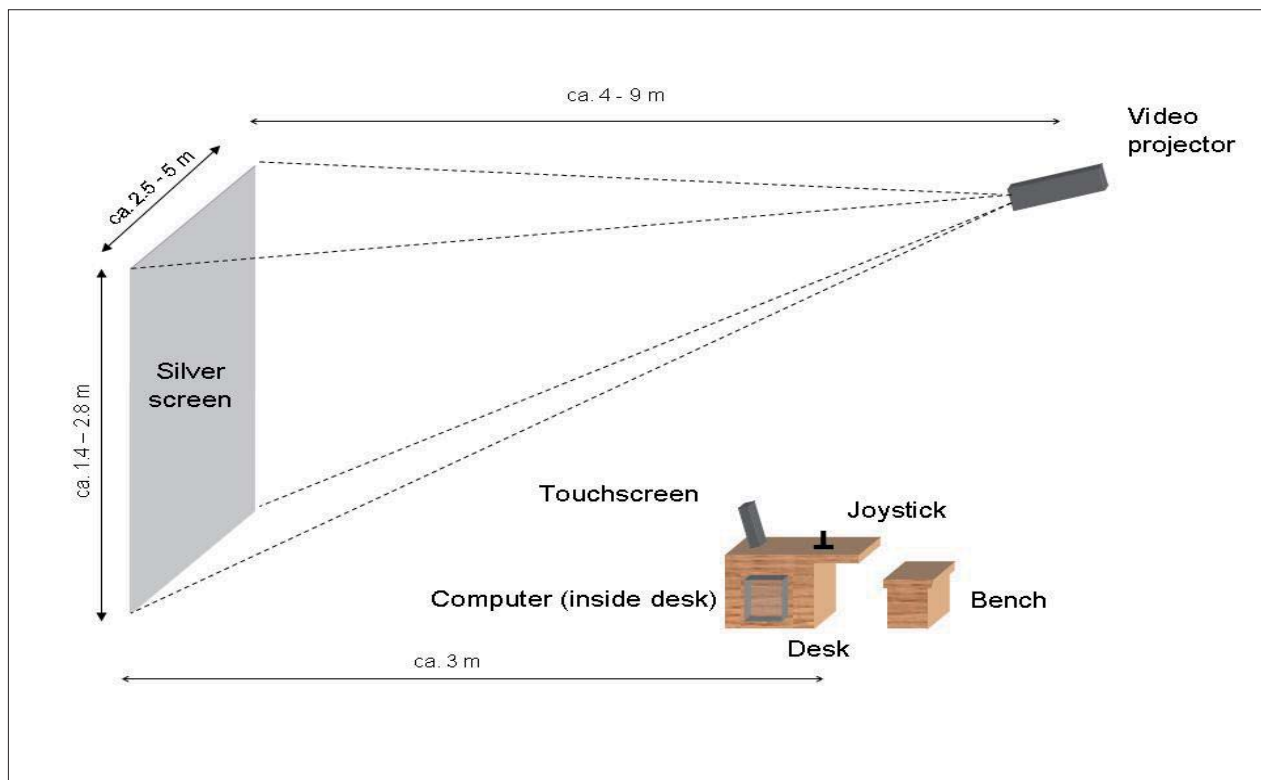


Fig. 1: Hardware components of ViViTo

3D worlds or which like to get to the information without indirections.

An exemplary installation of ViViTo with all hardware components is shown in Fig. 1.

## 5. Development of User Interfaces

The final design of the user interfaces is based on practical tests and the results of a visitors' evaluation of an advanced, completely operational prototype of ViViTo. Several weeks in summer 2007 we received feedback from guests of the Swiss National Park visitor centre. The general feedback was quite positive – 71% of the visitors liked the application very much, 26% answered that they like the application. However, in respect to the usability of the user interfaces a need of amendment got obvious. One third of the interviewee indicated to have a problem with the handling of the application. Half of the interviewee responded that they could not open the info box using the joystick. The result of the visitors' evaluation confirms our observations of the users whereby we determined the main obstacles for a high usability:

- The user guidance of the touch screen menu was too complex. Even if the user guidance followed a stringent philosophy, it was not transparent enough to allow users a quick understanding about how to use the menu.
- Beside such conceptual aspects the graphical design of the touch screen menu was not appropriate. The difference between clickable control elements and non-clickable graphical elements was not clear enough.
- A help menu explaining how to use the touch screen menu was provided, but on a separate page. An attending help which informs the users about the system status and about possible next steps was recognized as much more suitable for the users.
- A functional overload of the joystick overstrains the users as well as a very high degree of freedom in navigation. Automatism which restricted the possible view angles and flight automatism are useful for a virtual globe application used in public space.
- The sensitive area of a POI symbol was dimensioned too small. Users have to point on the sensitive area very precisely otherwise the info box did not open.

In the following we will introduce the revised user guidance of ViViTo and the joystick without dwell into the analysis of the tested and evaluated prototype.

## 6. The Touch Screen Menu

Entrance is the welcome page (Fig. 2), where users can select a language. All clickable control elements have been designed as buttons, similar to those control elements known from menus of cash points or ticket machines.



Fig. 2: Welcome page



Fig. 3: Overview Alps

While the welcome page is active, an overview of the whole Alps is shown (Fig. 3).

Immediately after the selection of a language, a virtual flight starts to the protected area which is related to the visitor centre where the application is installed. In the same time the touch screen switch to main menu, which is composed by a clickable map on the right side for the selection of geographical areas of interest and a menu which allows the access to themes? Pressing on such a theme button opens a context menu with a list of POI (Fig. 4). POI could be selected and a flight starts to the POI in the virtual landscape (Fig. 5).

At any time users can switch between themes, POI, geographical areas (Alpine arc, Eastern Alps, Western Alps, and Central Alps) and protected areas. In any case there will be a respond of the system and the user will be informed about the system status and possible next steps.

In the lower part of the menu is the status and help information. Three buttons on the lower right-hand corner brings the users back to the welcome page (home-button), to a help page explaining the joystick (question-mark-button) and to a page with continuative information (i-button).





Fig. 4: Selected POI in context menu

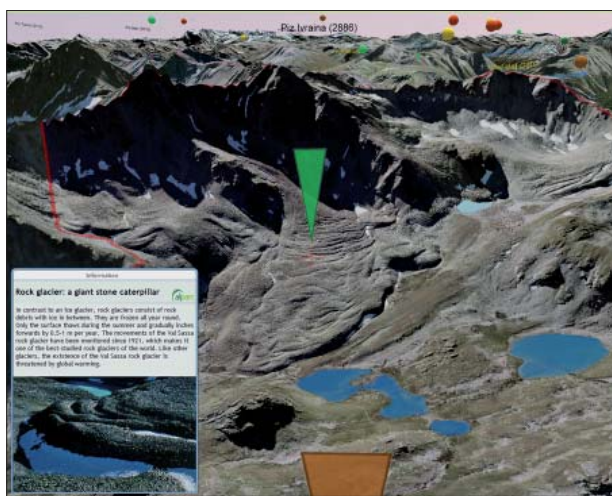


Fig. 5: View of selected POI with info-window

## 7. The Joystick

The joystick for the ViViTo application has to be robust and should be usable for all potential users. After several tests with usual gaming joysticks and prototypes we decided to use an industrial joystick with 2-axis (Fig. 6). The joystick is designed ergonomically and could be used by left-handed and right-handed persons as well as children (small hands). Only three additional control elements are integrated: a thump wheel for altitude changes, a trigger button which allows rotating the view angle and two buttons which trigger a special overview function.

Beside the (hardware)-ergonomics of the joystick an automatism is implemented on software side, which facilitate users' to navigate with the joystick. Once users start flying, the view angle is captured – the degree depends on the flight altitude – so that the horizon of the virtual landscape is always visible.

## 8. Discussion

In computer science usability is a term used to denote how easy user interfaces are to use (cf. Nielsen, J., 1994; Norman, D., 2002; Shneiderman, B. and Plaisant, C., 1987). There are several methods used to evaluate usability. User-focused methods (e.g. thinking aloud method) make use of data gathered from users. Traditional user-focused usability testing is performed in a usability-laboratory which allows recording the interaction of the users with the system for the analysis afterwards. Cheaper and faster are expert-focused methods, like the heuristic evaluation, which are relying on expert reviewers.

Jakob Nielsen (2005), referred as the guru of web page usability by the New York Times, defined ten general principles for user interface design. We have proofed, if the design of the ViViTo touch screen menu is consistent with these general rules or if specifics of the use cases necessitates digressing from one of these general rules.

*„The system should always keep users informed about what is going on, through appropriate feedback within reasonable time.“* The user gets always informed about status and possible next steps. Furthermore, each user action results immediately in a reaction of the system.

*„The system should speak the users' language, with words, phrases and concepts familiar to the user, rather than system-oriented terms.“* We avoided technical jargon and expressed us clear and simple.

*„Users often choose system functions by mistake and will need a clearly marked „emergency exit“ to leave the unwanted state without having to go through an extended dialogue. Support undo and redo.“* With the home-button user can come to the welcome site at any time. However, undo and redo functions are not necessary and would increase the complexity of the application.

*„Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions.“* The complete design and vocabulary follows a stringent logic.

*„Even better than good error messages is a careful design which prevents a problem from occurring in the first place.“* The system gets by without any error message.

*„Minimize the user's memory load by making objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate.“* We regard rule 6 as a consequence of the first and fourth rule.

*„Accelerators – unseen by the novice user – may often speed up the interaction for the expert user such that the system can cater to both inexperienced and experienced users. Allow users to tailor frequent actions.“*



Fig. 6: ViViTo joystick

This rule is not applicable for ViViTo. The application is designed for non-experts.

*„Dialogues should not contain information which is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility.“* The menu is reduced to the essential – textual and graphical.

*„Error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution.“* The system gets by without any error message (see rule 5). Operating errors of the menu in terms of faulty insertion are not possible.

*„Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation. Any such information should be easy to search, focused on the user's task, list concrete steps to be carried out, and not be too large.“* The users are supported with a very concrete, clear and short help.

In respect to the usability of the joystick for the ViViTo application it was not possible for us to find literature, which gives us a feasible method for its evaluation. However, we considered the general recommendation about design and usability of hardware and software given by Stapelkamp (2007). We hope to get new findings about the usability of the joystick for the ViViTo application with a further visitor evaluation in June 2008 with the guests of the new visitor centre of the Swiss National Park, which opens on May 31st, 2008.

## 9. Summary

The ViViTo application is a virtual globe application for visitor centres of alpine protected areas. It allows virtual flights over the Alps and virtual visits of alpine protected areas. Around 800 points of interest about nature protection, landscapes, flora and fauna, cultural heritage and environmental education are integrated in the virtual landscape.

In consideration to the heterogeneity of the potential users and changing conditions in the visitor centres two complementary user interfaces have been developed. Users which prefer a high degree of freedom in navigation could use a joystick. A touch screen menu meets the demands of those users which are not familiar with virtual reality applications and the use of joysticks, or for those which just like to get information without indirections.

A visitors' evaluation of a prototype in summer 2007 shows a need of amendment of the usability of the ViViTo application, even if the general user feedback was very positive. Based on the results of the visitors' evaluation we developed the final version of the touch screen menu. The new design is consistent with 9 of 10 general principles for user interface design – the 'usability heuristics' of Nielsen (2005). The rule which was not considered refers to expert users and is not applicable for ViViTo.

We hope to get new findings about the usability of the user interfaces, especially the joystick, in a further visitors' evaluation of the ViViTo in June 2008.

## Acknowledgements / Project Partner

The authors thank all partner and institutions which supported the project. ALPENCOM financed through the Community Initiative Programme „Interreg III B Alpine Space“.

The Swiss National Park was commissioned for the development of the application by the following project partner: Réseau Alpin des Espaces Protégés, France; Parc National des Ecrins, France; Nationalpark Berchtesgaden, Germany; Parc National de la Vanoise, France; Nationalpark Hohe Tauern, Austria; Parco Nazionale Gran Paradiso, Italy; Parco Naturale Mont Avic, Italy; Autonome Provinz Bozen-Südtirol, Amt für Naturparke, Italy; Park Škocjanske Jame, Slovenia; Triglavski Narodni Park, Slovenia; Ville de Chambéry, France.

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# Accidental cARTographer

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## Abstract

*Professor Eduard Imhof once said that, “To create beauty, a purely technical, practical arrangement of things is not sufficient. Beauty is, to a large extent, irrational”. With that in mind, this will be a non-technical presentation of my experiences during the more than forty years of pencil, airbrush, acrylic, and digital relief production. Space limitations will allow us to touch on only the most significant samples within these four categories.*

## 1. Background

At age eighteen, as a nationally recognized gymnast in Hungary, my intention was to go to college to become a physical education teacher. Had that plan come through, today – at age seventy-one – I would be long retired and reminiscing of the days of somersaults and handstands. Instead – through one of life’s happy accidents – I learned about an eighteen-month cartographic training program that made me miss out on college education, but gave me a great profession with the possibility to continue learning and growing in it, even at my age.

## 2. Pencil Relief

The cartographic training program gave me a minimal exposure to “Schummerung” – or relief shading – by using a smudge stick dipped into graphite powder to create rather crude looking relief images. For the first ten years I worked as a cartographic draftsman at Freytag-Berndt und Artaria, American Geographical Society, and the National Geographic Society, and only there did I finally have a chance to put that very limited training to use by producing a few pencil relief originals. Then came the map of Mount Kennedy region, which turned out to be the pinnacle of my pencil relief phase. To produce it in the Swiss topographic relief style was a significant challenge for us at NGS. In order to acquire the necessary capabilities, the Society engaged the services of a retired Swiss cartographer, Mr. Paul Ulmer. During his stay in Washington, D.C., in addition to scribing the rocks for the map, he instructed a number of us in the Imhof relief shading style. At the end of the training program, Mr. Ulmer selected me to draw the relief for the map published in August 1968 (Fig. 1a).

The production method may be boiled down to the following: 1) contrary to the prevailing practice of drawing relief at 150% size, for the first time at NGS the relief was produced at reproduction scale; 2) I drew the relief on Cronaflex, using KOH-I-NOOR leads ranging from 4H to 6B; and 3) I applied the “higher the more contrasty” aerial perspective principle learned from Paul Ulmer and Professor Imhof’s “Kartographische Geländedarstellung”.

## 3. Airbrush Relief

Our next major project was a map of the Moon. First, using the pencil technique, I produced a prototype but it had a rigid, chiseled look, so – as the result of a one week training at the Lowell Observatory in Flagstaff, Arizona – I ended up painting the Moon relief with the Paasche Type AB airbrush (Fig. 1b).

To produce high quality relief, there were certain important requirements: 1) pressure gauge controlled clean and dry compressed air; 2) ability to taper and sharpen the less than ideal quality factory produced needles; 3) create the right ink mixture, using black Pelikan T ink, distilled water, and a drop of ammonia to further break down the ink particles; and 4) small hand-held, adjustable speed electric eraser to eliminate any slight overspray and sharpen highlights.

As terrain source, I depended on the 1966-67 U.S. Lunar Orbiter photographs that covered 99.5% of the Moon’s surface.

## 4. Full Color Relief

After producing numerous additional black-and-white airbrush relief originals, eventually there came the time when we felt the need to do relief in full color. Rather than try to develop a technique on our own, the Cartographic Division contacted Mr. Hal Shelton, the American master of relief paintings, and arranged that I pay him a two-day visit at his Golden, Colorado studio.

To simply say that the visit was useful would be a gross understatement. There was only one negative that I could think of – I did not have the opportunity to see any of his relief originals because they were stored in a vault at some other location. Yet, the technique that he verbally shared with me was priceless, and immediately upon my return to

Washington I was able to start work on our new set of Continental Physical Maps (Fig. 2a).

The land cover was broken down into eight categories: tundra, evergreen forest, mixed forest, deciduous forest, grass, shrub, desert, and ice. Following Hal's palette as general guide, I used Cadmium Red Medium, Pthalo Blue, Cadmium Yellow Medium, and Titanium White Liquitex acrylic paints in creating the NGS Physical Map Palette that we used for several years thereafter.

The "potential vegetation" zones were compiled from a wide variety of sources – A.W. Küchler being the most prominently used. For land features I depended on another Hungarian's, Erwin Raisz' landform maps along with Jet Navigation Charts, and the 1954 Edition of Atlas Mira maps, which I found to have very good small scale contour information.

As it was Hal Shelton's practice, initially I painted the relief originals on so-called "deep-etched" offset press plates where base lines appeared as shallow cuts in the metal. With a low angle top left illumination these lines were visible, but disappeared when illuminated from the front.

After two or three maps, the use of the metal plates was dropped in favor of blue-line on Bainbridge 80 Illustration Board.

People frequently asked me, "How do you paint color relief?" but I found it difficult to give a satisfactory answer because it all boiled down not as much to technique as to "visualizing and feeling" the terrain. When pressed, I would give the following non-technical answer: "As step one, the flat vegetation tints are lightly airbrushed over the blue-line base. Then comes the detail work: after carefully studying the terrain characteristics – and imagining that I am viewing the area to be painted from high up in space – I start sketching in the relief using modeling and highlight colors. Always referring to the contour and other relief sources, I continue building that image until I am satisfied with the result. Then, sometimes after hundreds of hours of effort, comes the last step: using bleach, I remove the still visible blue-line base in preparation for color-separation."

In the early 1970s, the Austrian artist, Heinrich Berann made a short visit to National Geographic. His beautiful, brilliantly colored panoramas were and still are unmatched by anyone's work, and his ocean floor paintings brought to life a yet unexplored part of our world. That meeting, and extensive studying of his work eventually enabled me to start the production of the Society's new set of ocean floor maps (Fig. 2b).

With the obvious difference of a limited blue palette, the process basically was the same as that of the physical continental maps. As source for relief detail, I used the GEBCO Charts along with the Berann maps, and the earlier charts produced by Marie Tharp and Bruce Heezen.

"The Heart of the Grand Canyon" was the largest (36 x 36 inches) and most time consuming (1,075 hours)

acrylic relief that I painted during my twenty-two years at the National Geographic. I like to think of it as my "relief thesis" because it effectively incorporated all that I have learned about relief shading up to that point (Fig. 3). It was produced approximately half-half with airbrush and brush. The contour base was the result of a 1972 aerial photography and field survey, so I am confident that the relief is the most accurate and detailed acrylic painting even to this day.

## 5. Digital Relief

In 1986 I left the employ of National Geographic, and moved on to doing free-lance work, but the positive professional working relationship with NGS continued on without missing a beat.

My digital era started in 1993 when, during a visit to National Geographic, I saw someone airbrushing grayscale relief on a Macintosh computer. I was eager to find out more about this new technique. Since I had no prior computer training, it was through the courtesy of the Cartographic Division that I learned the computer basics, the use of the WACOM tablet and the Adobe Photoshop airbrush tool. I immediately purchased my first Apple Macintosh, and on the day when that computer was up and running I "retired" my airbrushes, brushes, and paints. Since then all my work is done digitally.

At the occasion of another visit to NGS I learned about DEMs and Bryce, and that using them one could produce computer generated relief images. So, the learning curve started all over again, but this time it was with the invaluable assistance from my mentor friend Tom Patterson at the U.S. National Park Service. Tom has been there for me since my very first stumbling attempts at digital relief rendering, and I can still count on his advice and guidance, for which I am truly grateful.

My favorite application for rendering relief is Natural Scene Designer Pro. In order to start out with the best possible base relief image, I use resolution-bumped DEMs. As good as these images may appear at first glance, there are always some data-related image challenges, requiring retouching or more extensive corrective re-painting, making me very grateful for all those years of conventional relief experience. The oblique relief of Hispaniola (Fig. 4a) may be a good example because here I spent more than half of my production time on re-painting the relief with the Adobe Photoshop airbrush tool. As a result of the lower level data quality of the 30 pixels per degree ETOPO2 (or even CleanTOPO2), this is especially true with ocean floor relief that generally receives disproportionately more of my attention than the land (Fig. 4b).

I hope that I was able to express how much I love what I do. To me relief portrayal is not only a job but also an enjoyable and challenging artistic activity. The more projects I work on the more I realize that there is no definite work routine to this wonderful madness of digital relief production. Each project presents a different set of challenges, and will require their own solutions. Be it an illustration depicting the sun-

rise over the Mediterranean (Fig. 5), the oblique view map of the Alps for the National Geographic Magazine (Fig. 6), a physical map of Europe produced for COLUMBUS Verlag in Germany (Fig. 7), or getting hold of the WACOM stylus simply to airbrush relief reminiscent of the old hand painted styles (Fig. 8), this “Accidental cARTographer” is always happy and ready to face the challenge.

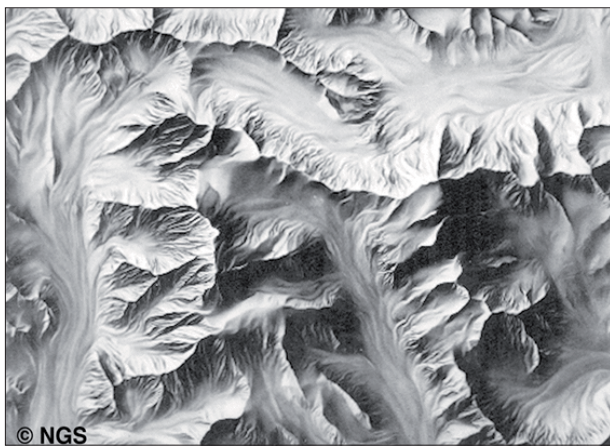
## 6. Conclusion

I can state with confidence that through the years every professional challenge that I encountered became a growth opportunity, and that my development in relief shading paralleled that of NGS’s growth in the field. I consider myself extremely fortunate to have met and learned from two of

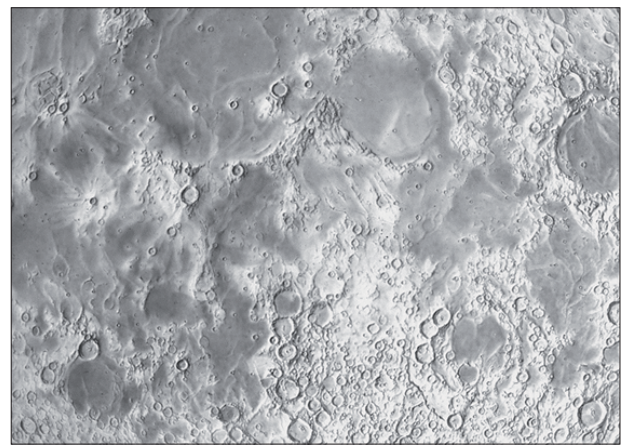
the world’s greatest cARTographer artists, Hal Shelton and Heinrich Berann. Both of them came from a fine art background, and merged their wonderful talents and visions with their love of cartography.

Hal Shelton clearly recognized, and was not hesitant to politely point out the lack of art in my work, and specifically suggested that I get some training. On the strength of his advice I took the Famous Artist correspondence course, hoping to gain exposure to and experience in landscape painting. Instead, the course led me to the love of portraiture, and to the realization that every time I create a relief, I am not only making a map but also am painting a portrait of our Earth’s old, wrinkled, beautiful face.

## Illustrations



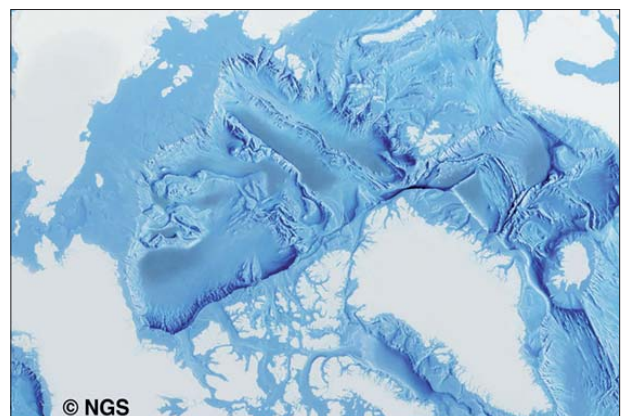
*Fig. 1a: Mount Kennedy – pencil relief.*



*Fig. 1b: Moon relief – airbrush. (© NGS)*



*Fig. 2a: Painting acrylic physical relief.*



*Fig. 2b: Arctic Ocean relief – acrylic.*





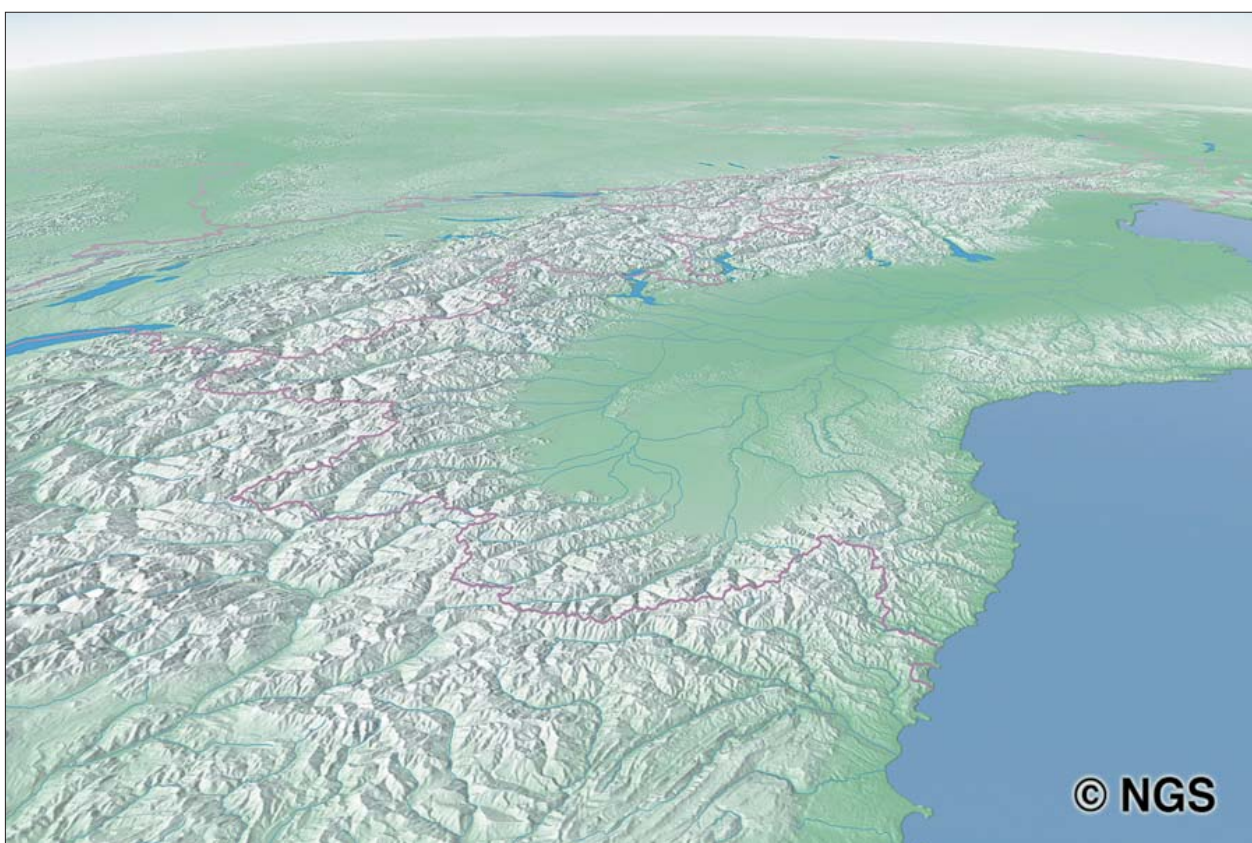
*Fig. 3: Airbrushing Grand Canyon relief.*



*Fig. 4a: Hispaniola – digital.*

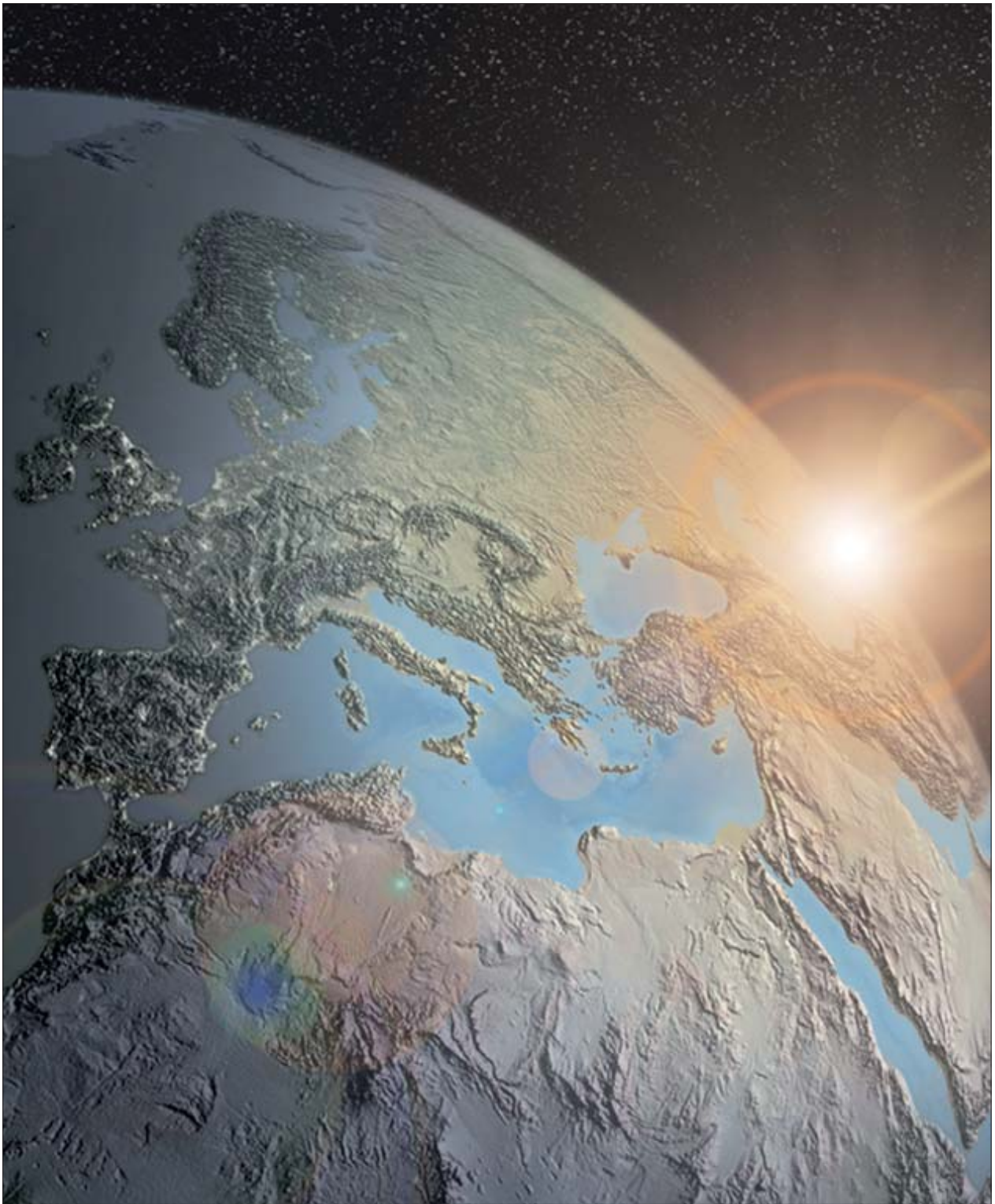


*Fig. 4b: Caribbean – digital. (© Tibor G. Tóth)*

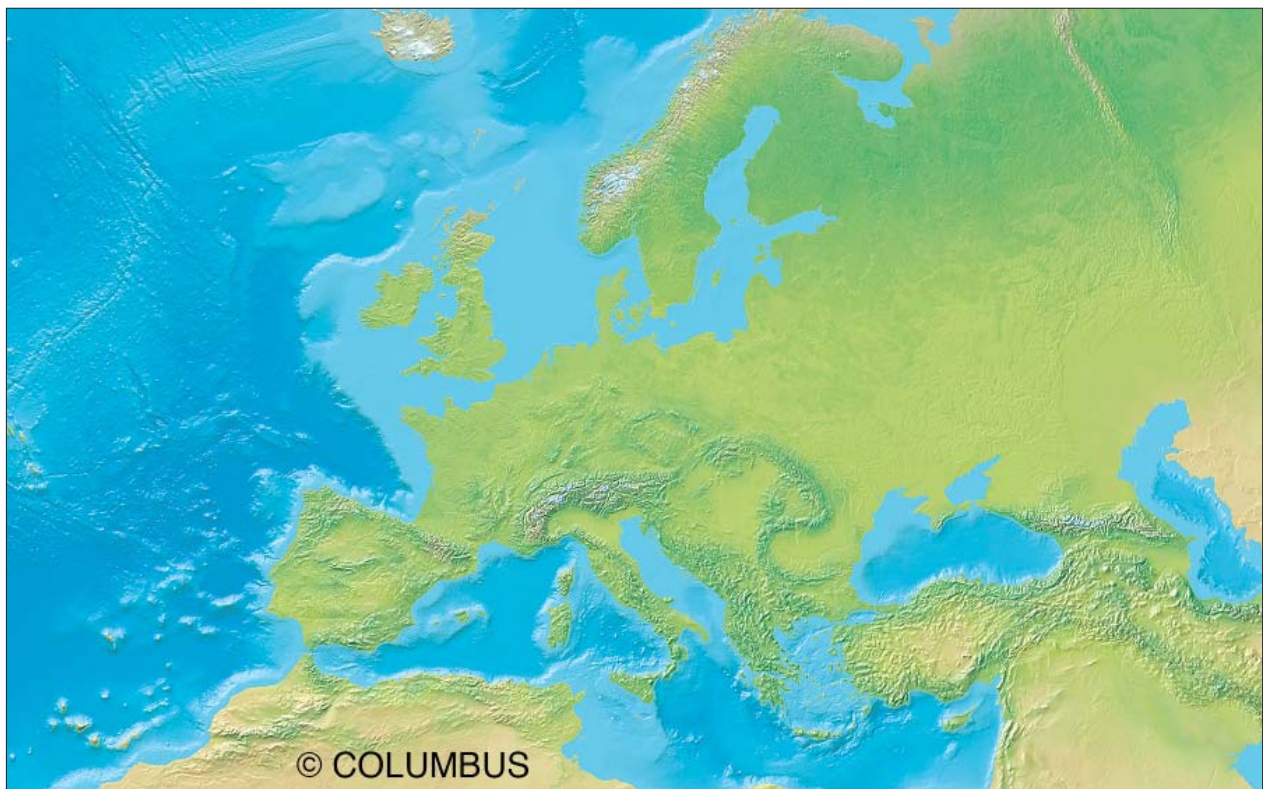


*Fig. 6: Alps page map for National Geographic Magazine – digital.*





*Fig. 5: Mediterranean Sunrise – digital. (© Tibor G. Tóth)*



*Fig. 7: Europe Physical for COLUMBUS Verlag, Germany – digital, NSD and Adobe Photoshop airbrush.*



*Fig. 8: Airbrush, hypothetical land relief sample – digital.*



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# High Precision LiDAR Mapping for Complex Mountain Topography

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## Abstract

*During the last decades, the arrival of new mapping technologies such as Lidar brought new possibilities for the mapping of complex or inaccessible areas. The development at EPFL of a hand-held helicopter based mapping system relying on Lidar-photogrammetry issued on a commercial production system: Helimap system®. The integration of the Lidar, Direct georeferencing techniques and digital photogrammetry into a hand-held unit permits to fit the topography with a flexible oblique mapping and provides high accuracy and resolution Digital Terrain Model and orthoimages. Then the use of the helicopter allows mapping extremely complex terrain such as high cliffs or steep slopes. Several practical experiments lead in geology or natural hazards studies during the last years confirm the potential of the technique and its accuracy of 10-15cm.*

## 1. Introduction

Over the past the years, emergent new mapping technologies such as LiDAR altimetry or GPS-INS direct georeferencing changed the world of classical airborne mapping occupied by photogrammetry and then propagated to end-users.

Thanks to the high spatial resolution of the laser data and digital imagery, invisible details of shape and topography can be identified. The direct georeferencing permitted the suppression of the usual required ground control points. Thus, it is possible to affordably remotely map with high resolution inaccessible or very complex areas.

The development of Helimap system® started in 1998 in the photogrammetric and geodetic laboratories of the Swiss

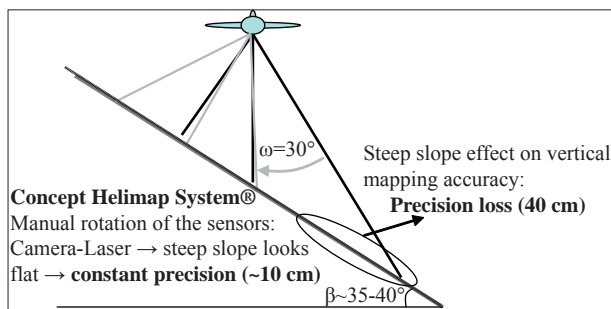


Fig. 1: Crucial concept of the design: a handheld operation to fit the slope.

Federal Institute of Technology of Lausanne (EPFL), in collaboration with the Swiss Federal Institute for Snow and Avalanche research of Davos (SLF) and Ulrich, Wiesmann + Rolle SA. The initial goal intended to provide a mapping technique to measure the snow volumes on large avalanche experimental field (Vallet, 2002, Gruber, 2000). The harsh environment, the complex topography and the sporadicity of the events required a fast deployment, accurate (~10 cm) and affordable mapping technique for such small areas. Initially based on hand-held helicopter photogrammetric measurements, combined to direct georeferencing technique, the system integrated a Laser Scanner unit and a high resolution digital camera in order to automate the terrain model acquisition and the orthoimagery production. The system is manually operated from a helicopter and provides a flexible maneuverability to fit the most complex terrain.

Since 2005, the system is commercially used and about 40 flights were realized in the domain of natural hazard mapping and Mountain topography.

## 2. System design

### 2.1. Basic concept

The design of system is based on five key points:

- A flying flexibility provided of the helicopter in complex topography
- Get a constant accuracy of the data whatever the inclination of the slope. The accuracy of standard vertical mapping operated from fixed-wing aircrafts strongly decreases at the bottom of steep slopes (Fig.1). Only oblique mapping avoids this effect. The handheld operation of the system confers a free motion and rotation of the sensors to fit the slope. The system can be used either in vertical or oblique configuration within the same flight (Fig. 2).
- Allow the mapping of dangerous or inaccessible areas with remote access. This can be achieved thanks to the direct georeferencing GPS-Inertial technique providing a mapping accuracy of 10-15cm.



- Fast deployment in a short time notice and independent of the type of helicopter. Most of the conventional airborne mapping system requires a complex setup. The manual operation of the system allows being in the field in few hours.
- Fast delivery results thanks to LiDAR technology. Digital terrain modeling is then highly automated. First results can be available few hours after the landing.

### 2.2. Components of the system

To meet the needs, the system presents a modular assembly composed of four sensors assembled with a rigid aluminum frame (Fig.3):

- A 22 Mpixels CCD camera with 22 wide angle lens (FOV of 57°)
- A Riegl 2D Scanner laser measuring 10,000 points/sec. The measurement range spread from 50m to 300 – 400 m with a field of view of 60° similar to the camera. The wavelength of 900 nm allows good performance of measurement on snow, bare ground, vegetation or urban areas.
- A dual frequency GPS receiver and an Inertial Measurement Unit (IMU) for the direct georeferencing of the system.

The setup of the system takes about 30 minutes on most of the helicopters.

### 2.3. System performance

The main output data are composed of high density Digital Terrain/Surface Model (DTM/DSM) (1 to 10 points/m<sup>2</sup>) and high resolution orthoimages (ground sampling dimension of 3 to 10 cm). Then derived products can be extracted for 2D or 3D analysis (volume, object classification, etc.).

In order to estimate the reliability and performance of the system, terrestrial control measurements were conducted on

numerous flights (Skaloud et al. 2005). The diagrams in Fig. 4 represent the mapping accuracy from the photogrammetric and LiDAR vs. surface aspect.

### 3. Practical experiences in mountain and natural hazard mapping

Initially designed for snow volume measurements on steep slopes, the application field widened considerably to other domains such as corridor mapping (river, coast, road and power lines). Nevertheless, the original use of a hand-held system represents a unique advantage for complex terrain mapping. It is in the precise context that most of the flights were conducted.



Fig. 3: Components of the Helimap System. A camera, GPS receiver, Inertial Unit and laser scanner.



Fig. 2: Vertical (nadir) and oblique configuration of the system



### 3.1. Volume / mass balance

The high density and accurate Laser DTM's involves precise volume measurements when comparing two or several episodes. This can be applied to any mass transport or surface evolution such as avalanche, landslide, debrisflow or glacier mass balance, snow melt. The experiences conducted over the avalanche study of the SLF, ice and rockfalls in the east face of Monte Rosa (University of Zürich), or on the snow melt modeling (ETHZ) shows that it was possible obtain a volume measurements with an error inferior to 5% even on very complex terrain such as the Haut Glacier d'Arolla watersheds (2000 ha). The differential error between the two episodes did exceed 10 cm (comparison made on common areas) (Fig. 5).

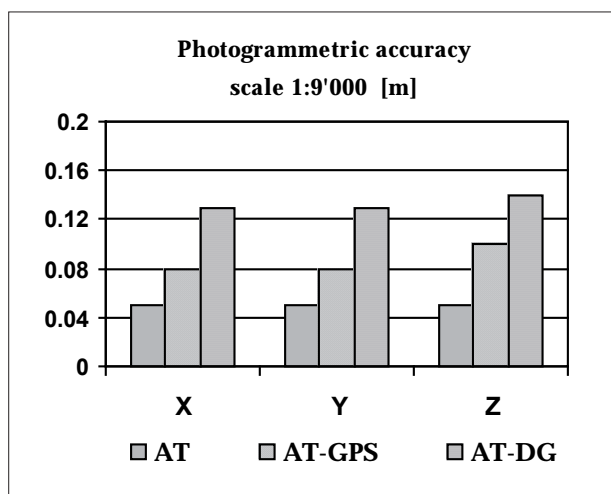


Fig. 4: Left: Photogrammetric mapping accuracy according to georeferencing used (AT : standard technique with ground control points (GCP), GPS : Use of GPS only with no GCP's, AT-DG : Direct georeferencing using GPS-IMU). Right: Mapping accuracy of the laser scanner vs. the surface aspect - relative precision (inner noise between several overlapping scans) and absolute precision extracted from Ground measurements.

### 3.2. Morphology

The high resolution of laser data shows morphologic details that were invisible with the use of conventional photogrammetry because the cost to get such density was too high.

Then those high resolution DTM's are particularly useful for geologist either in terms of monitoring of instable regions or for geo-structural analysis.

The Fig. 6 depicts a landslide area near the Lac of Monteynard (France) studied by the CISM (University of Savoie). A local height variability analysis permits to identify waves characterizing the unstability of the flank.

High resolution DTM's permit to identify surface deformation or faults. Combined to geophysical data (ground penetrating radar...), it is possible to model the 3D structure of the subterranean layers. Several oblique projects were

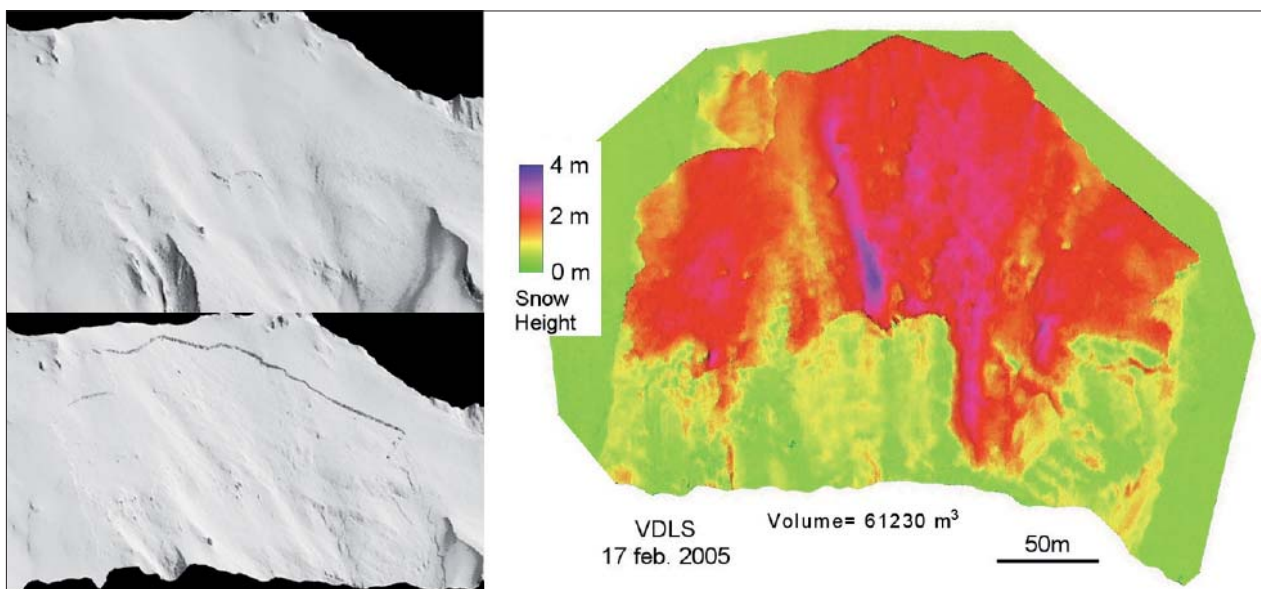
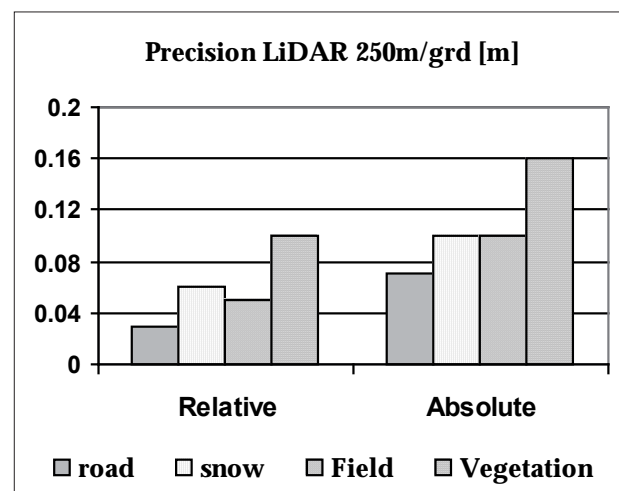


Fig. 5: Snow volume measurement of avalanche. Slope surface before and after the release of the avalanche. Snow height distribution of the slab (release area) (SLF).



lead to bring high resolution data in vertical areas. Then every detail even in overhanging zone is captured. The Fig. 7 represents a DTM of cliffs acquired for geo-morphological studies in Svalbard (CIPR-Uni. Bergen/UNIS) that will be used to validate a 3D geo-structural model.

### 3.3. Damage inventory

Damage inventory after a catastrophe is a useful task to first have precise measurements of the phenomenon in order to better understand it and mitigate it, and secondly to document the damage for insurance companies for example.

The flexibility of the system offers the possibility to be deployed on a very short time notice. It is then possible to map an event just after its occurrence.

The Fig. 8 illustrates the post debris flow event occurred in June 2007 in Grossbach (Canton of Schwyz, Switzerland). The flight was made one day after the event to cover the damage areas (deposition zone) and the watershed that feed the catastrophe. It required only one and a half day to produce the orthoimages, DTM and a comparison with the swiss national laser DTM before the events.

## 4. Conclusions

LiDAR mapping technique is a very efficient tool for alpine mapping in such different domains as natural hazard study, land management or alpine environment monitoring.

Data acquisition realized with Helimap system in the field of mountain mapping brought accurate and high resolution topographic data in inaccessible areas and complex terrain. The reduction of the data processing time, related the

conventional photogrammetry, reduces drastically the costs while the spatial resolution increases. The high flexibility of the system allows mapping quickly any type of surface until the critical area of 1,500 – 2,000 ha. Beyond this size, the system is less adapted because of the numerous flight lines required to cover the area. The use of more powerful laser, but also bigger and less flexible to handle could be an alternative that is in development.

## Acknowledgements

Helimap system SA thanks Thierry Villemin from the CSIM of the Université of Savoie in Chambéry for the results of the dtm analysis on the landslide of Hamelière. We also thank Dr. Jan Skaloud and the laboratory of Geodesy of the EPFL and the SLF-Davos for their long collaboration to the system development.

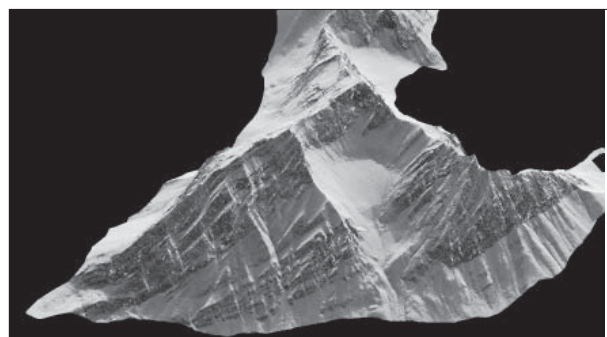


Fig. 7: 3D model of the Mediumfjellet cliff (Svalbard). The identification of the different layers and their shape, combined to geophysical data, offer the possibility to calibrate and validate numerical model.

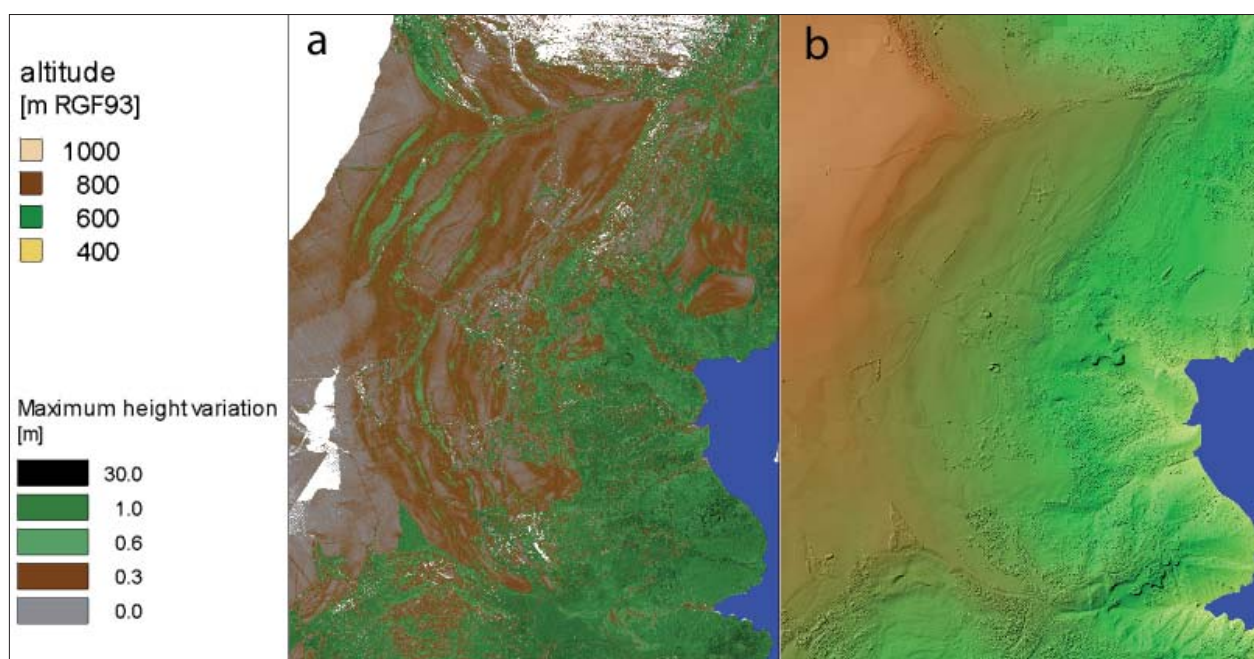


Fig. 6: Landslide of Hamalière (Trièves). Fig. a illustrates the local height variability. These analyses show the micro or local relief. The waves in green and brown depict the sine shape of the landslide. Perpendicular lines (brown) to the slope represent the nose of the laser measurements. The Fig. b shows the shaded relief of the area color-coded with elevation.



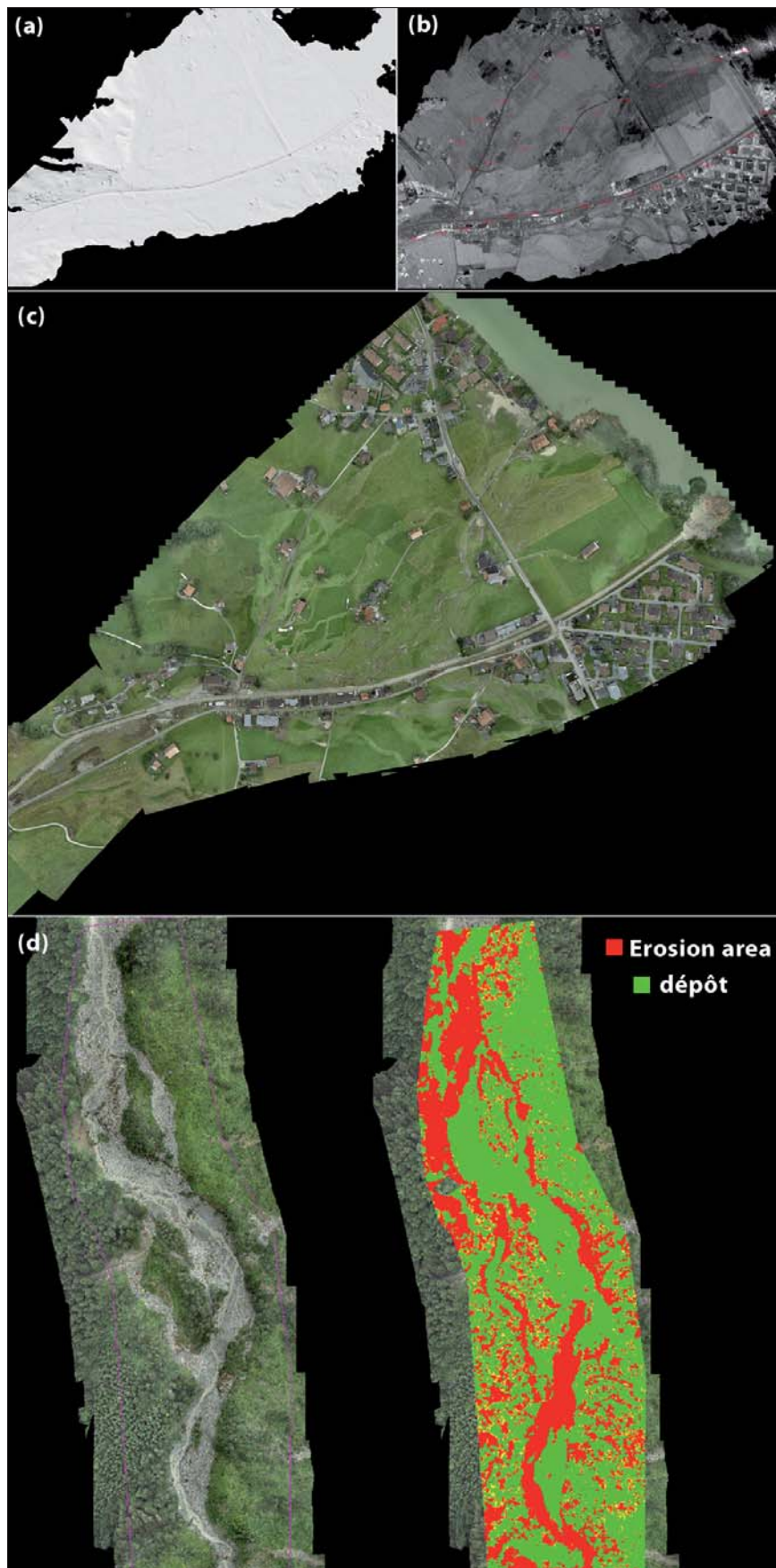


Fig. 8: One day after the catastrophe, a flight over the damaged area permits to capture the topography of the debris flow. First the DTM is extracted from the laser point cloud (a), flooded areas and buildings can be identified on the intensity image (b) and refined on the high resolution orthoimage (c). In the upper part of the river, it is possible by comparison of DTM's to map the eroded/deposition areas (d).

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# Use of NASA World Wind Java SDK for Three-Dimensional Accessibility Visualization of Remote Areas in Lao P.D.R.

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## 1. Introduction

Laos is characterized by large mountainous regions with poor transportation infrastructure. The various dimensions of accessibility remain a crucial determinant of socio-economic development. Even nowadays a large share of villages is only accessible by foot. It is hence crucial to communicate issues related to accessibility in an easily understandable manner to a broad public. Thereby a three-dimensional visualization is a very attractive approach. This paper presents a prototype for visualizing three-dimensional geographical data and the achieved results.

## 2. The enclosing project in Laos

The currently ongoing project „Poverty Mapping and Socio-economic Atlas for Lao P.D.R.“ offered a framework to address issues of accessibility in spatial explicit manner. This project aims at generating spatially disaggregated poverty maps and developing a comprehensive socio-economic atlas of Laos. At the same time it follows the goal of building capacities of selected Lao government agencies in the domain of spatial analysis and finally disseminating the results to policymakers and the wider public (Epprecht et al., 2006).

The project is financed by the Swiss Agency for Development and Cooperation (SDC) and is implemented by the National Centre of Competence in Research NCCR North-South located at the Centre for Development and Environment (CDE) of the University of Berne in cooperation with Lao government agencies.

In the frame of this project the accessibility to and from district capitals has been computed. In this context the accessibility is measured in travel time to reach specific destinations and is used as an index for the remoteness of places. It substantially depends on cost-distance surfaces delineated mainly based on the transportation infrastructure, the relief and further natural obstacles e.g. water bodies.

The socio-economic development in remote areas is essentially dependent on the accessibility to markets, educational and governmental institutions and service provision. Acces-

sibility may hence be considered an important criteria in the field of development cooperation.

## 3. State of the art in 3D visualizations

Three-dimensional visualizations are a popular way to illustrate the topography for a general public. A relief represents the given terrain very descriptively and supports the imagination of the viewer. It helps to understand the topography better than an ordinary two-dimensional map.

Traditional relief modeling is a costly handcraft, so nowadays most of the three dimensional terrain visualizations are virtual only. Since powerful computer hardware is affordable for personal computing, three dimensional visualization applications are also increasing for home use.

An example for such an application is the wide spread Google Earth software (Google, 2005). Since Google released its Google Earth application, a broad public has come in contact with three-dimensional representations of geographical data. These data are not only obtainable for experts anymore, but became available for everyone. Only a few years after the first release a lot of applications are already based on Google Earth. Meanwhile Google Earth has a lot of users who are familiar with the explorative navigation over the earth's surface and most of them do not want to miss this tool anymore.

Another interactive world viewer is the open source application World Wind, which is developed and maintained by NASA staff and community developers (WorldWind, 2008). NASA released the first ready-to-install World Wind desktop application in mid-2004. The latest version is 1.4 and was released in February 2007. This desktop application is comparable with the Google Earth software, but with a particular focus on educational aims. NASA delivers World Wind with Blue Marble and Landsat 7 satellite images, the SRTM elevation model, place names, country boundaries, etc. Beside the delivered data, users can import their own data and, due to the open source developers, can even code own add-ons with any functionalities.



The World Wind desktop application has been developed within the Microsoft .NET Framework. This framework is a part of the Microsoft Windows operating systems and thus the World Wind desktop application is only executable on Windows (WorldWindCentral, 2008). The fact that this application is not cross platform is a probable reason why NASA staff started to develop World Wind in Java, which is cross platform, and released an open Java software development kit (SDK). Unlike a ready-to-install application, a standard development kit is a library, which allows developers to create own applications using this library. With the first early release of the World Wind Java SDK, subsequently referred to as WWJ, developers were able to easily include the virtual globe in any Java applications and finally run it on any platform. However, NASA developers are not planning to develop a World Wind Java desktop application similar to the above described .NET software, but to continue and expand the SDK (WWJ FAQ, 2008).

## 4. Results

### 4.1. Three dimensional accessibility visualization

As mentioned above the computed accessibility refers to district capitals. Highly accessible regions are colored in green and poorly accessible areas in red. Travel times range from less than two hours (green) to seven hours (yellow) to more than twelve hours (dark-red). The accessibility layer is set semi-transparent so the underlying satellite image is visible. Thereby the three-dimensional impression can be strengthened.

Fig. 1 shows extracts of the three dimensional accessibility visualization. It highlights clearly the decrease of the accessibility where the terrain gets mountainous. In contrast, regions along the main road, which mainly follows the valleys, are quite easily accessible from district capitals.

Combined with other geographical data these travel times form a base for different analyses. A simple visual analysis is shown in Fig. 1c where the accessibility is linked with the village points. This analysis points out which areas are poorly accessible and how many villages are within these areas. A more sophisticated analysis is the buffer query. Opposed to the accessibility, which is based on travel-time cost, the

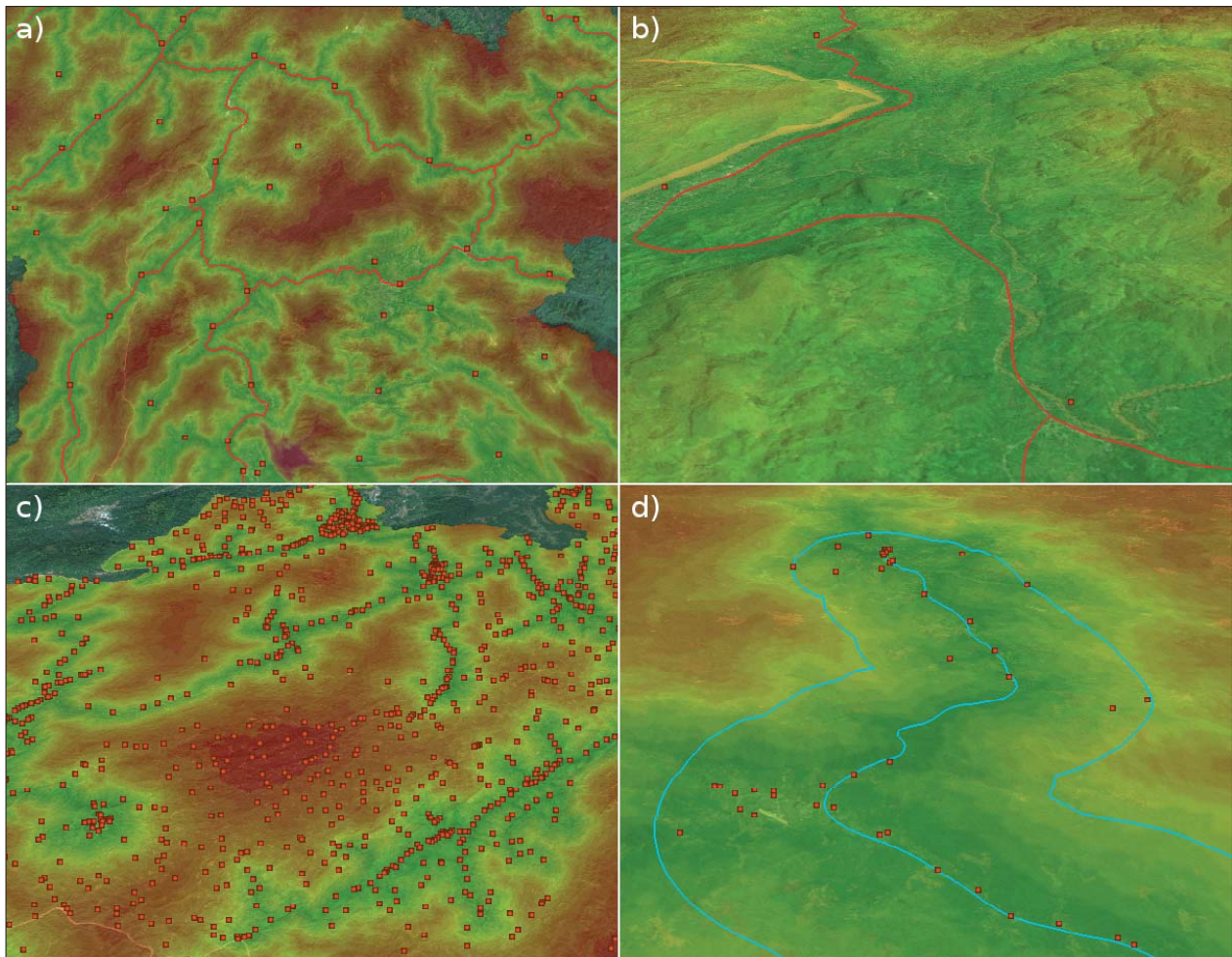


Fig. 1: Three-dimensional accessibility visualizations a) overview of northern Laos with main roads and district capitals b) close-up view around Luang Prabang with main roads and district capitals c) overview of northern Laos with villages d) close-up view around Phongsaly with 5 km buffer around main roads and enclosed villages

buffer query is computed with the geometric distance. The results shown in Fig. 1d answer the question, which villages are within a distance of five kilometers from a main road.

The showcase illustrations in Fig. 1 approve that three-dimensional visualizations are a very attractive way to display the accessibility. The representation is better than in conventional two-dimensional maps. In maps the topography is represented by techniques like contour lines or relief shading. While this representation is sufficient to practiced map readers to imagine the topography and combine it with thematic data, it is often quite hard for untrained readers to interpret the map. Especially these readers benefit from three-dimensional visualizations. Considering that the socio-economic atlas of Laos addresses not only GIS experts but also to untrained readers the three-dimensional visualization adds value to the interpretation.

#### 4.2. The Lao-Atlas prototype

To realize the above shown visualizations an atlas prototype has been developed. Available accessibility data shall be visualized in an attractive and three-dimensional way for a broad public of experts and non-experts. In addition it has to be possible to add any existing geographical data, like infrastructure, administrative borders, capitals, etc. to enable the user to make comparisons and interpretations. Thus the prototype development follows the goal of imple-

menting an open architecture with the possibility to add data from different file formats.

To reach a wider public the prototype has to offer an easy understandable and intuitive graphical user interface (GUI) and navigation.

Fig. 2 shows a screenshot of the prototype. The main window contains the 'Globe' panel and the 'Wikipedia' panel.

The design and concept of the 'Globe' panel is strongly inspired by common GIS designs. The main part of the panel is filled with the globe view. In this view the current visible area and layers are drawn.

An improved layer management is a typical and important concept in GIS. This approach is adapted in the left hand layer panel. All loaded layers are shown in a list, upper layers are drawn later, i.e. they are in the model on top. Like it is known from other GIS the prototype provides adding, removing and reordering of layers through the 'Layers' menu. Additionally the properties of the currently selected layer are shown in the layer panel. Loaded layers can be turned on and off by the 'Visible' property and the raster layers can be set opaque or transparent with the 'Opacity' property.

The 'Wikipedia' panel shows any additional information like describing text or related metadata.

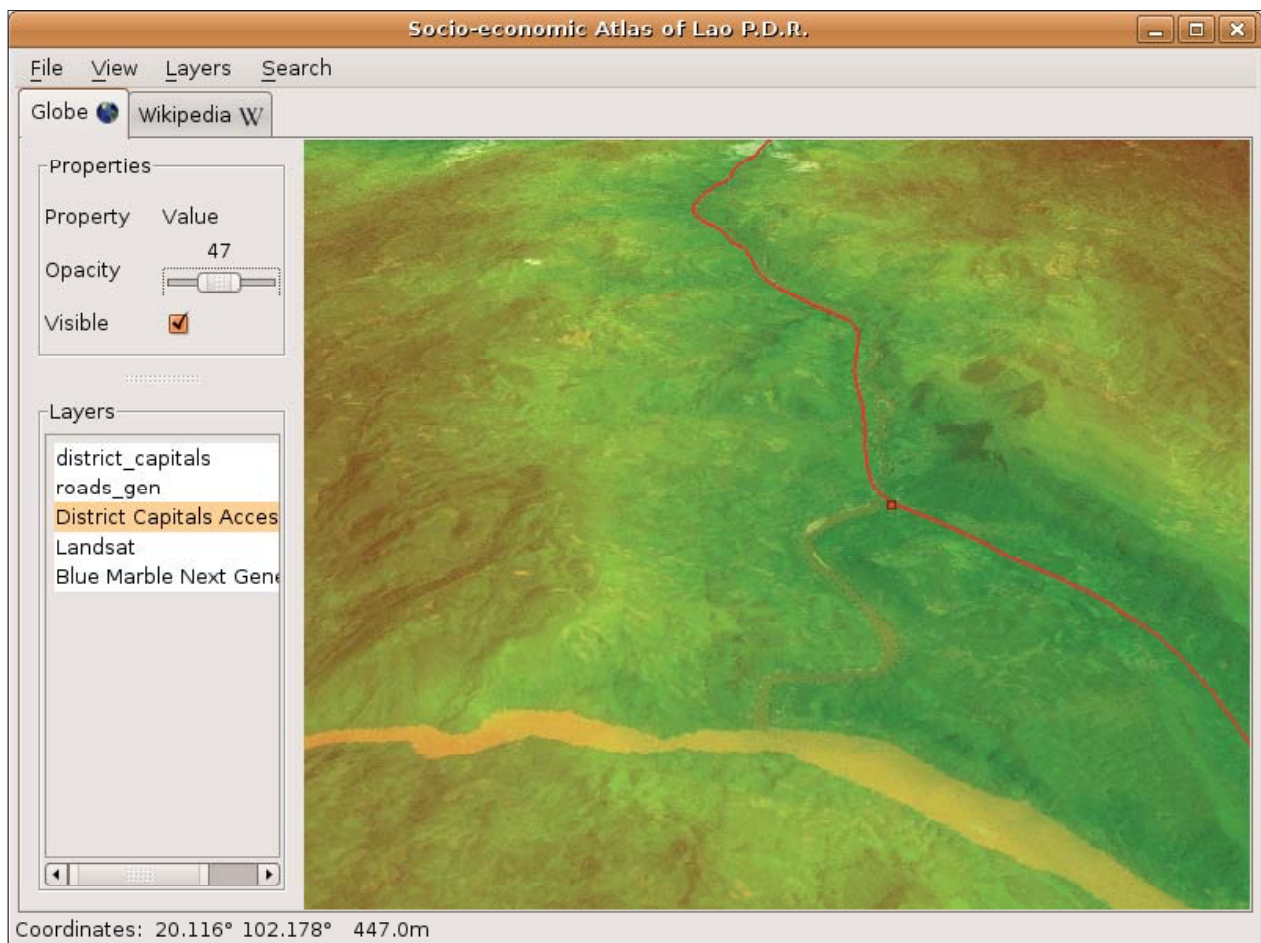


Fig. 2: Screenshot prototype showing accessibility and generalized main roads.



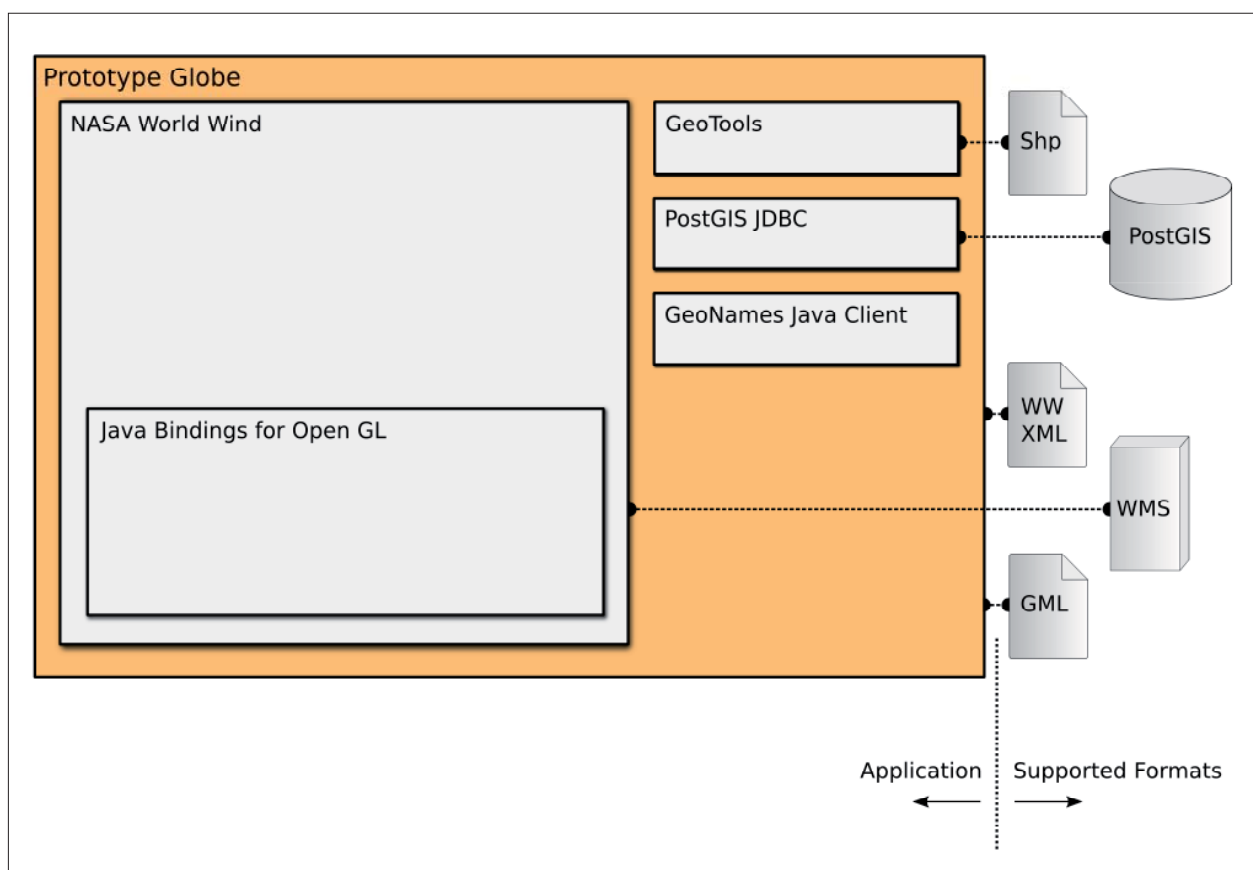


Fig. 3: Overview of used libraries and supported formats in the prototype

Fig. 3 illustrates the scheme of the prototype architecture and shows the used libraries and supported formats. The prototype is mainly based on the World Wind Java library but also uses other open-source Java libraries.

The WWJ library provides a Java Abstract Window Toolkit (AWT) canvas, which implements the rendering of the virtual globe. The model view in the 'Globe' panel contains such a WWJ canvas.

WWJ itself is based on OpenGL through the Java bindings library JOGL. Furthermore WWJ supports Open Geospatial Consortium (OGC) compliant web map services (WMS).

Through the Java Database Connectivity (JDBC) interface PostGIS databases can be connected. Thus tables with geometry data like the district capitals, villages and main roads in Fig. 1 can be loaded. Additionally the prototype GUI allows the user to invoke PostGIS functions and therefore to execute spatial queries, e.g. the buffer analysis relative to main roads shown in Fig. 1d is performed on PostGIS (PostGIS, 2008).

Other possible data sources to display vector geometries are Geography Markup Language (GML) files or ESRI Shape files. The latter file format is read by the included GeoTools library (GeoTools, 2008).

Last but not least, data can be loaded which are described by a World Wind XML file. This XML grammar is defined

by NASA for the World Wind desktop application and supports raster as well as vector data (EarthIsSquare, 2007). The data source of the accessibility raster image is described by a World Wind XML file. The accessibility image has been pre-tiled in different zoom levels and saved on a web server. The tiles are delivered to the client application depending on the current extent and zoom level by a server script.

In order to orientate and find geographical features like villages the prototype offers a reliable location search based on the widespread GeoNames database. GeoNames is a geographical database that contains over 6.5 million unique geographical features and a lot of alternative names. This database is accessible free of charge through a number of web services (Wick, 2008). One GeoNames web service is the locating of geographical features.

## 5. Conclusion and outlook

A three-dimensional visualization is an appropriate way to illustrate the accessibility situation in Laos. In combination with infrastructure, administrative and socio-economic data the presented Lao-Atlas prototype is a solid analysis tool for policymakers in the government as well as in development cooperation.

Nevertheless there are different possibilities how this tool can be improved towards a more powerful application for visualizing and studying the socio-economic situation in Laos. Due to WWJ's native support of web map services (WMS), not only the accessibility but every socio-economic



indicator, which has been calculated during the project, could be visualized three-dimensionally without any programming work. For that purpose only a web map service would have to be set up.

At the moment the GUI for accessing PostGIS functions is very rudimentary, so an improved user interface would simplify the invocation of these functions. To implement more GIS functions the use of the GeoTools library is possible as well. This library allows not only to read GIS formats but also to include sophisticated GIS analysis functions.

Beside these GIS functionalities the prototype can be expanded to an information system of non-geographical data with spatial relation. The prototype implements the link to Wikipedia articles, but it would be possible just as well to attach any other information. A database could be

installed with links to these additional resources. For every resource a validity area would be defined, so the user can query related information for the currently visible area.

Finally, the World Wind Java SDK is a reliable development kit to build advanced applications with sophisticated three-dimensional visualizations. Although this library is only in its early release stage, it provides already a highly developed application programming interface (API) with a wide range of functionality. If the WWJ development progresses in the same pace as until now, this library has high potential to become a wide used library in the geographical information science.

In combination with other open-source libraries WWJ enables the developer to implement comprehensive applications.

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# Combination of Traditional Hill-Shading and Digital Cartography on Small Scale Maps

**Gizella Bassa**

**GiziMap, Budapest, Hungary**

## Abstract

On the maps issued by GiziMap Publisher the depiction of the relief is of exceptional importance. Our maps usually show whole countries on one sheet. An important element of showing the country in question is the correct presentation of its relief.

The scale chosen usually depends on the dimension of the country and the standard size of the paper used for printing. The scale of the base maps employed is usually 1:200,000, 1:500,000, and 1:1,000,000.

The topographical maps were mostly published several years ago, so they should be updated even concerning the hydrography, especially when new water reservoirs. In their surroundings sometimes even the reinterpretation of the relief is needed. Further information should be collected to compile the other topographic elements.

However, the relief is a rather lasting information on topographical maps

Based on the above mentioned topographical maps we are compiling the elevation contour design with a proper density which is necessary to present the relief of the given country. This contour design is serving as a basis for the colouring of layers and hill-shading.

Most of our maps were published in two versions:

The so-called "Geographical Map" containing the relief with elevation tints, and the "Road Map" with hill-shading.

Other components of the maps are identical, with the exception that some of their colours are different on the two versions, since on the hypsometrically contoured background maybe the selection of differing colours is suitable (e.g. in the case of boundaries).

We also have prepared the background of some former maps with this method (Caucasus, Central Asia, Libya, e.t.c.). Even in the 1990's the maps were still prepared using traditional scribing techniques. The processing of the hill-shading originals was also made with traditional photographic methods.

The map of Central Asia was our first product in 1999, where we had to combine the traditionally prepared hill-shading with electronically designed elements. The hill-shaded original was scanned and matched by computer to the hydrography and to height points. After this, several proofs were made to find the appropriate grey grade and contrast of the shading.

Beside our own maps we have prepared hill-shading for other map-publishers, too. In these cases we have received the hydrography at the scale of the planned map. We have chosen the topographical base of the required area. The customers received the traditional hill-shading original or its scanned variation.

Our greatest job was the preparation of the hill-shading of the pages of Reader's Digest World Atlas. Several sample pages were prepared in order to choose the most appropriate shading style.

The finding of the proper elevation contoured base map and its adjustment to the hydrography concerning each page of the Atlas required much preparatory work before the traditional completion of the hill-shading. For some regions, the shading was prepared jointly, and it was cut into pieces during later processing, as in the case of Africa, Australia, etc. This method ensured that the shading is identical on the pages of the same scale. For some maps of different scale but of the same area, only one shading was made and it was reduced or magnified to the appropriate scale. The reason of this was first of all the reduction of the costs and production time.

The traditionally prepared hill-shading originals were scanned and adjusted to the hydrography. The customer received both the originals as well as the scanned variations which could have been altered by them in order to select the optimal grey grade.

During this job we had the opportunity for a detailed study of the relief of the whole Earth.

It was a considerable task to find a proper topographical basis for the pages of a definite scale. An appropriate base map (in scale and elevation contour density) ensured that



the shading was not too detailed or too sketchily. In several cases, the scale of the base map used to prepare the hill-shading differed from the scale of the relevant World Atlas page. In those cases, the base was either reduced or enlarged to fix the Atlas page. The differences originating from projections were also adjusted to the projection of the Atlas by means of reduction or enlargement.

The Reader's Digest World Atlas was already published in about twenty languages. Hopefully the hill-shading design prepared by our company was a considerable contribution to the success of this publication.

Currently, the majority of map publishers do not prepare the hill-shading of maps and atlases in the traditional way - they are seeking more rapid methods. In Hungary also the number of traditional hill-shading cartographers is gradually reducing. So we have to find a faster way to keep the quality of hill-shading compared with traditional hillshading.

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# A Retrospective Look at National Geographic Magazine's Mountain Depictions in Maps, Panoramas and Perspective Views

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**Martin Gamache**

**National Geographic Magazine, Washington D.C., USA**

## **Abstract**

National Geographic Magazine has been publishing maps since its earliest issue in 1888. Through its coverage of mountaineering history and global exploration the magazine has needed to map vertical terrain. As early as its third issue (July 1889), it had published its first map with relief as well as an article discussing relief depiction. The magazine has gone on to publish work by such luminaries as Bradford Washburn (supplement maps of Mt. Everest, Mt. Kennedy, and the Grand Canyon), Heinrich Berann, Tibor Tóth, John Bonner as well as new artists such as Eckhard Zeidler. I propose to critically examine the magazine, map output with a focus on mountain depiction in maps, panoramas and perspective views. I will discuss the magazine attempts at integrating cartographic approaches and influences from both sides of the Atlantic. I will catalogue both the successful and less so methods and discuss highlights from the magazine's pages while identifying design solutions and techniques that may still be of interest to 21<sup>st</sup> century cartographers.





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# Building Smart Interactive Maps: Enabling Map Projections in Adobe Flash

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**Nathanial V. Kelso**

**The Washington Post, Hyattsville, USA**

## **Abstract**

Adobe Flash allows cartographers the opportunity to build interactive graphics with rich user experiences. However, there are few cartographic tools available for Flash. Most are limited to merely integrating Google Maps, Yahoo! Maps, and Microsoft Virtual Earth services into the Flash display. What if you have created your own map with a custom graphic style and a more appropriate, non-Mercator projection?

This presentation demonstrates several working examples that read data from external files and then plot features onto world, continent, and country level maps. Choropleth map shading is also supported with several classification options. Using a generalized component tool, maps can quickly be "registered" in Flash by setting several control points and providing projection parameters. More than 10 common projections are supported, including several interrupted forms. Map users are able to interact with the map by reading specific feature names, descriptions, and even data values.

Flash's ability to spatially enable your maps and its many graphic tools allowing interface customization give it a real advantage over generic online services.



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# The Future of Terrain Presentation at National Geographic Magazine

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**William E. McNulty**

**National Geographic Magazine, Washington D.C., USA**

## **Abstract**

National Geographic Magazine has been representing terrain in our maps for nearly 110 years. Throughout that time we have continually worked to develop new styles, refine our methods, and improve the processes for depicting mountainous terrain. Periodic updates of our techniques for terrain presentation have yielded some spectacular successes and, to a lesser degree, some failures. This paper examines the magazines current efforts to improve our terrain presentation in the light of that history. Explanation of our goals for the future and what we need to do to achieve them are offered. I will analyze specific topics like the challenge of keeping our terrain presentation unique and the role hand cartography plays in our production processes. The current status of terrain presentation in the freelance cartographic world, as well as technological advances we see as important in the future of terrain presentation will be reviewed. The paper will finish with examples of the terrain presentation in development and illustrations of the process we'll use to produce it.





# Rwenzori Meteo and Geodetic Network

## An Introduction

**Giorgio Vassena<sup>1</sup>, Gregorio Mannucci<sup>2</sup>, Giuseppa Cipriano<sup>2</sup>, Gustavo Corti<sup>2</sup>, Costante Bonacina<sup>3</sup>, Matteo Sgrenzaroli<sup>3</sup>, Bob Nakilesa<sup>4</sup>**

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<sup>3</sup> **University of Brescia, Dipartimento di Ingegneria Civile, Architettura, Italy**

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### Abstract

A long-term multidisciplinary research project on Rwenzori Mountains started in June 2006 when a team of twelve Italian researchers and one researcher from the Mountain Research Centre of Makerere University, made up an expedition trucking around the Rwenzori Mountains National Park. The studies have been organised thanks to the coordination of the Uganda Wild Life Authority, the L'Umana Dimora Environmental Association, the Italian Alpine Club, the University of Makerere, the University of Brescia (Italy) and the Italian Embassy in Kampala. The research project concerns the evaluation of changes on high altitude environment on Rwenzori Mountains compared to global warming effects and the study of the georeferencing geodetic network on the Rwenzori mountains.

(of all the 6 main peaks of the Rwenzori Mountains) and the first of the evaluation on meteorological environment of Rwenzori Park as an example of global change effect. The future planned environmental and cooperation projects in the Rwenzori will also be presented.

The research program focused about:

- Glacier retreat studies using a 3D laser scanning survey of the Speke glacier, that allowed to evaluate within 5-10 cm accuracy, by 3D model of the glacier front, the glacier's mass balance and the change of extension of frontal moraine;
- Materialization and survey of a geodetic network between the main peaks of the Rwenzori National Park.
- Realization of a GPS CORS (Continuously Operating Reference Stations) in the Makerere University – Department of Geography. The aim of this project is the realization of a GPS Permanent Station for the IGS (International GNSS Service) network.
- Meteorological studies about global warming by the installation of a lot of meteorological station around the Mount Speke and all around the park. The meteorological local model is developed by integration of meteo data and GIS based spatial evaluation.

This paper reports about first results about measurements on the glacier dynamics and the GPS and geodetic network





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# Mountain Mapping and DSM Generation Using High Resolution Satellite Image Data

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**Kirsten Wolff, Armin Gruen**

**Institute of Geodesy and Photogrammetry, ETH Zurich, Switzerland**

## **Abstract**

The accurate 3D image processing of stereo satellite images constitutes a potentially powerful method to produce the primary data for a high quality mountain modeling, mapping and visualization. The efficiency of such satellite image data with stereo capabilities was already shown for georeferencing and DSM generation using image data from different satellites like IKONOS, SPOT-5, EROS and Quickbird, and by applying SAT-PP, our in-house developed software package for high resolution satellite image processing. Also, the first results of the evaluation of the recently launched satellites like ALOS and Cartosat-1, both with a GSD of 2.5m, give good results for both purposes. All results show, that subpixel accuracy is realistically achievable for georeferencing and for DSM generation we get an accuracy of one to five pixels, depending on the land-use, topography, image texture and image quality.

Especially with the low cost satellites, the prices for high-resolution image data have been considerably lowered, such that this technology is becoming available for more and more users, applications and research fields. This opens also new opportunities for innovative applications in mountainous areas, be it with respect to DSM generation, topographic and thematic mapping, glacier monitoring or the tracking of other dynamic processes over time and space.

With this paper we want to show the latest results of our investigations of 3D image processing of stereo satellite images with a special focus on DSM generation and with a new focus on the task of 3D mapping in mountain areas. We will give a detailed analysis of the potential of different high-resolution satellite imagers for DSM generation and 3D mapping.



# Report of the 6<sup>th</sup> ICA Mountain Cartography Workshop at Lenk im Simmental (Switzerland), 11–15 February, 2008

**Christian Häberling, Lorenz Hurni**  
**ETH Zurich, Institute of Cartography, Zurich, Switzerland**

From February 11 to 15, 2008, the 6<sup>th</sup> edition of the traditional ICA Mountain Cartography Workshop took place for the first time in Switzerland. The workshops focused on mountain-related topographic and thematic aspects and their depiction on maps and map related representations. Every second year since 1998, cartographers and representatives of other fields related to cartography and GIS (like geology, natural hazards, tourism, biology, etc.) are meeting in an inspiring mountain region to discuss their current scientific projects and work.

Under the lead of Prof. Lorenz Hurni, the Institute of Cartography at ETH Zurich was in charge of the organisation

of the event, which took place at Lenk im Simmental. Lenk is a small village in the Bernese Alps, and is situated in a wide valley north of the Wildstrubel massif (Fig. 1). It is surrounded by mountains with altitudes between 2000 and 3500 metres. The skiing areas of Lenk are connected to those of the famous ski resorts of Gstaad (west) and Adelboden (east) by aerial passenger tramways and chair lifts.

The sports and recreational complex KUSPO (“Kurs- und Sportzentrum”) was selected as workshop location (<http://www.kuspo.ch>), providing a convenient infrastructure and an advantageous accommodation (Fig. 2). These conditions



*Fig. 1: View towards the upper end of the Simmental (Image: C. Häberling, Zurich).*





Fig. 2: Conference room (Image: C. Häberling, Zurich).

made it the ideal place for a successful meeting of both professionals and friends.

During the whole week, the weather was perfect with blue skies and very mild day temperatures. For all participants, these conditions enormously inspired the discussions and activities.

Almost 60 participants and single-day guests from 15 countries participated at the workshop (Fig. 3). Besides long-term members of the commission, also many new experts attended the workshop. We are therefore very pleased and hope for an increasing interest in the Commission on Mountain Cartography also in the future. The workshop and its participants were honoured by welcome addresses of William Cartwright, the President of the International Cartographic Association (ICA), and Stefan Arn, the President of the Swiss Society of Cartography (SGK).

The workshop was comprised of three different kinds of presentations: classic presentations by the participants talking about their latest scientific results and developments, short presentations according to the Pecha-Kucha system (see [http://en.wikipedia.org/wiki/Pecha\\_Kucha](http://en.wikipedia.org/wiki/Pecha_Kucha)) covering production processes and new products, and last, a small map and relief exhibition allowing to show and compare the newest map products (Fig. 4).

The 34 presentations were structured in the following five main thematic blocks: „Physical Geography“, „DEM and Terrain Modelling“, „Relief Depiction“, „History“ and „Multimedia and Mobile“.

In the “Physical geography” block, a number of scientific mapping and cartography projects as well as case studies from all over the world were described in detail (Michaela Kinberger, Uni Vienna; Manfred Buchroithner, TU Dresden; Giorgio Vassena, Uni Brescia; Richard Ladstätter, TU Graz; Sabine Stäubli, Uni Lausanne). Other presentations covered concepts for terrain evaluation or monitoring techniques (Igor Drecki, Uni Auckland; Melanie Kunz, ETH Zurich; David Theler, Uni Lausanne). Finally, developments of new interactive map and 3D-visualisation applications were discussed (Alexander Thimm, Swiss National Park; Karel Kriz, Uni Vienna; Christophe Lienert, ETH Zurich).

In the session „DEM and Terrain Modelling“, projects making use of latest laser technologies or high resolution satellite image data (Julien Vallet, Helimap.ch; Kirsten Wolff, ETH Zurich) as well as new approaches for the visualisation of hidden geological structures (Peter Jordan, Böhlinger AG) or for the derivation of contour lines for small scale maps (Anna Leonowicz, ETH Zurich) were presented. A presentation by Maria Pla and Blanca Baella (ICC, Barcelona)





Fig. 3: Participants at the 6<sup>th</sup> ICA Mountain Cartography Workshop at Lenk (Switzerland). (Image: K. Kriz, Vienna).

focused on requirements for database-driven relief representations for topographic maps.

The sessions on „Relief Depiction“ covered the broadest variety of presentations. First, the needs of mountain map users, especially members of Alpine Clubs, concerning the accuracy and symbolisation of topographic maps were evaluated (Martin Gurtner, swisstopo). Two authors were dealing with the evolution of classic relief maps or perspective views for different cartographic purposes (Alex Tait, International Mapping; Martin Gamache, National Geographic). Similar, but more technically oriented projects covered the development of new tourist maps with an integrated shaded relief (Roger Smith, Geographx NZ; William McNulty, National Geographic; Tom Patterson, US National Park Service). David Schobesberger (Uni Vienna) presented an evaluation of the use and effectiveness of 2-D or 3-D representations in National Park maps. Loïc Gondol (IGN Paris) talked about tests for new cliff drawings and scree representation in topographic maps. The latter method could be compared with scree representations generated by a software developed by Bernhard Jenny (ETH Zurich). Tibor Tóth (Tóth Graphix) demonstrated his relief shading methods using Photoshop and a tablet device. Stefan Räber (ETH Zurich) presented various physical relief depiction techniques, including the production of physical relief models with modern computer-driven drilling machines for an Earth Science exhibition at ETH Zurich.

The session on the history of mountain mapping started with a biographical presentation of the Swiss topographer and cartographer Jacot-Guillarmod (1868–1925) and his influential cartographic cliff representations (Hans-Uli Feldmann, swisstopo), followed by a presentation about the cartographic tradition and the latest technological developments at the Institute of Cartography of ETH Zurich (Lorenz Hurni). Alistair Pearson (Uni Portsmouth) reported about laser measurements and geometric analysis of the accuracy of a historic relief model.

A session on multimedia application and mobile devices for mountain mapping comprised presentations about Web applications for data acquisition (Dusan Petrovič, Uni Ljubljana), spatial communication using Google tools, (Karel Kriz) and accessibility visualisation (Adrian Weber, ETH Zurich). Furthermore, an implementation of GPS technology for mountain mapping and tour planning was demonstrated by Juan Galera (Uni Leon).

The topics of the eight short presentations, which were grouped in two sessions, were obviously more diversified. The authors covered topics like representation principles of rock representations (Jürg Gilgen, swisstopo), tourist mapping activities in Romania (Gabriela and Marin Ilies, Uni Cluj-Napoca), the historic development of panoramic maps (Arne Rohweder, Gecko Maps), mobile trekking guide devices for the Rwenzori National Park, Uganda (Constante

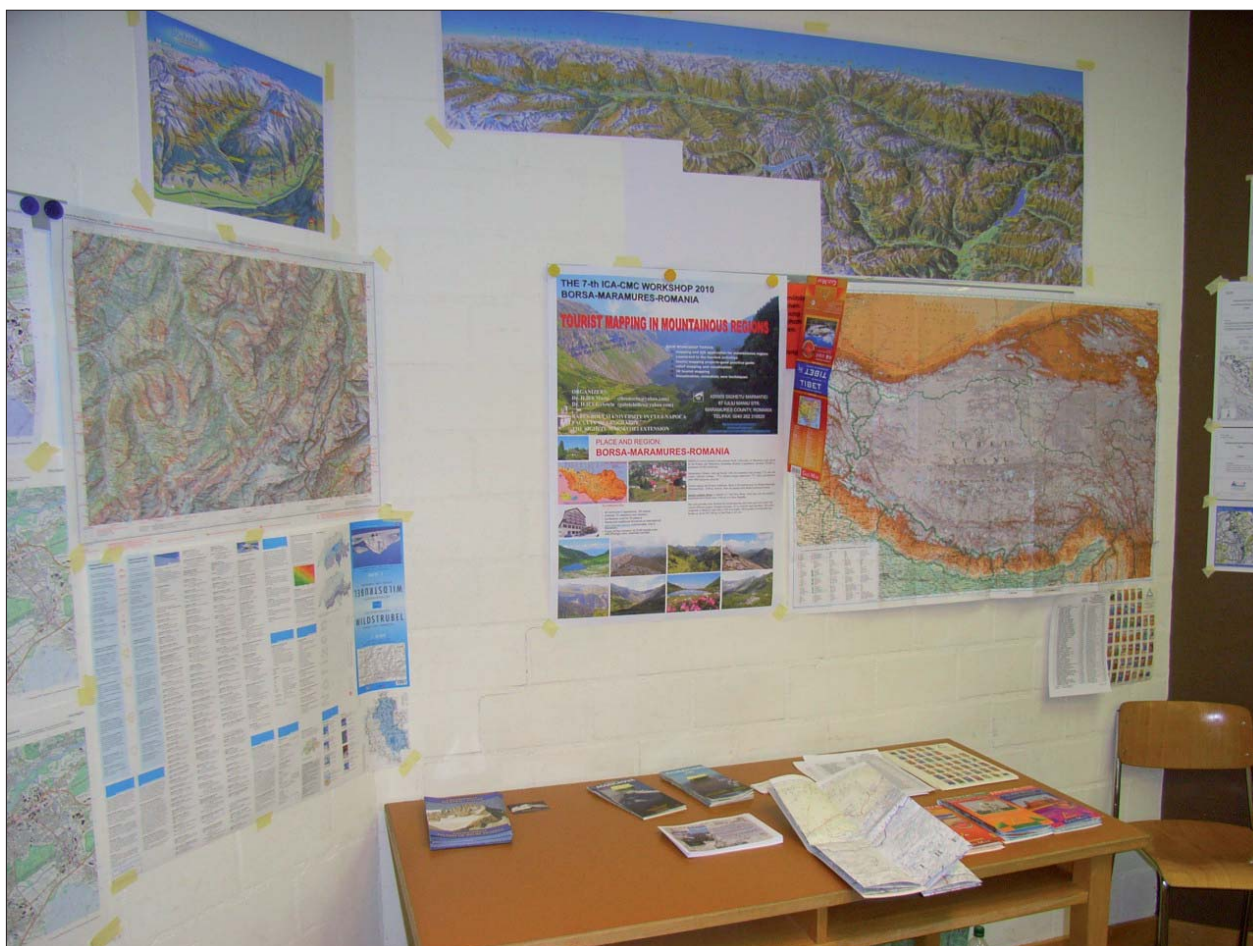


Fig. 4: Exhibition of mountain maps (Image: C. Häberling, Zurich).

Bonacina, Uni Brescia), smart interactive maps (Nathaniel Kelso, The Washington Post), Multidate habitat mapping approaches in Quebec (Guillaume Fortin, Uni Moncton), a topographic map of the Tatra Mountains (Rafal Jońca, RJ Carto) and traditional hill-shading for digital maps (Gizella Bassa, Gizimap).

A new kind of discussion forum was tried out for the first time in the workshop series and immediately attracted the special interest of the audience due to its topic: The new graphic design of the National Swiss topographic maps. Led by Lorenz Hurni (ETH Zurich), Hans-Uli Feldmann and Martin Gurtner (both swisstopo), the participants discussed vividly the new structure of the map content with new object classes and the displayed design specimens with different symbolisation and labelling options.

The workshop was accompanied by various social events and activities which fostered the personal contact among the participants (Fig. 5). On Tuesday evening, the welcome drink at the “Cinema Lenk” was accompanied by the display of two recent Swiss films: “Heimatklänge” (“Homeland Sounds”) about contemporary yodelling and „Marmorera“ about scary events in the aftermath of the flooding of a mountain village by a reservoir. Due to the excellent weather on Wednesday, the opportunities for various outdoor like skiing, snow walking or simply relaxing on a restaurant’s sun deck used by everyone. At the curling

event on Wednesday evening, many newly formed international teams were established to master this challenging sport. Finally, the „Raclette dinner” – a traditional Swiss cheese dish – was very much appreciated by everyone on Thursday evening (Fig. 6).

All papers and contributions for the workshop will be published in the workshop proceedings in Summer 2008. The contributions will also be accessible on the commission website.

The next ICA Mountain Cartography Workshop will be organised by Gabriela and Marin Ilies (Babes-Bolyai University of Cluj-Napoca, Romania) and will take place in Borsa in the Maramures Mountains, Romania on 1–5 September 2010.

For more information about the workshop please visit the website of the ICA Commission on Mountain Cartography (<http://www.mountaincartography.org/>).





*Fig. 5: Participants discussing during a walk near the conference centre (Image: C. Häberling, Zurich).*



*Fig. 6: Everyone enjoyed the raclette dinner (Image: C. Häberling, Zurich).*





# A "Wild" Thing

## Post Conference Tour

**Martin Gurtner**

### 1. February 15

The weather forecast says it will be fine for the following 4 days! Seven participants and two guests climb from Lenk to the Iffighore, 2378 m, ski down to the lake and reach the Wildhornhütte. The warden is not there, so we start cooking dinner (and heating the small winter room at the same time). With a few more people coming, it gets rather crowded...

### 2. February 16

Fortunately we have melted enough snow last night, breakfast is ready soon. For the first hour, it is quite cold and we climb in the shade. On the saddle, we come out into the sun. We make a break and enjoy the view to the south. The glacier has a gentle slope, only the last part to the Wildhorn is steeper.

From the summit, we can see the entire panorama of the Bernese Alps and of the Valais. A cold breeze prevents us from staying longer at the top; down at the saddle it is much warmer. Two of us have to go back, they work on Mon-



*Fig. 1: The last metres to the Wildhorn, 3246.3 m*





*Fig. 2: Skiing down from the Schnidehorn to the Rawilpass*

day. We stick the skins again to our skis and climb to the Schnidehorn, 2937.3 m. On the way down to the Rawilpass, we curve through powder snow (although there has been no snowfall for more than two weeks!).

The last climb to the Wildstrubelhütte, 2791 m, requires the last bits of energy from some of us. But the warm welcome compensates that quickly. The old hut and the new addition harmonize perfectly. A beautiful sunset concludes the day.

### 3. February 17

It is only a short climb to the Wisshorelücke, and then we ski down to the Glacier de la Plaine Morte and push along the track in the flat for another kilometre and a half. At the



*Fig. 3: At the top of Wildstrubel, 3243.5 m, with the Wildhorn in the background.*



*Fig. 4: Crossing the creek in the Ammertentäli.*

bottom of the Chli Schneehore we rest before starting the steep slope. We ski down on the east side and climb to the summit of the Wildstrubel in half an hour. The view is just perfect – and still there is no cloud in sight!

On the glacier there is powder snow again. The slope beside the icefall is more than 40 degrees steep, everyone skis down safely. We put on the skins again for the last few metres to the Lämmernhütte, 2501 m. There are not many visitors, and we have a sleeping room for our own. But first of all everybody is thirsty. After dinner, most of us go to bed early.

### 4. February 18

As we leave the hut, the sun has just arrived. We climb to the Mittelgipfel (of the Wildstrubel massive, it has exactly the same height as the “west peak” Wildstrubel!). We ski along the ridge to the east. As we are so close, we climb the Grossstrubel too – that’s the third summit of 3243 metres! There follows a descent of almost 2200 m, through an icefall, narrow gullies, shrubs, trees and a creek bed.

At the bottom we miss the bus by a few minutes. But by skating on the cross country track we reach the KUSPO in a short time. We get our luggage out of the locked room; have a shower and a drink. Then we get on the bus, take the train to Zweisimmen, where we have only a few minutes to change to the train to Spiez, there again a quick change to the train for Berne. The “giants” of the Bernese Oberland, Eiger, Mönch and Jungfrau are glowing red in the last sun-rays as if they wanted to say good-bye...

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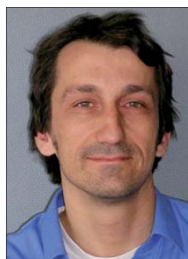
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