

# 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.

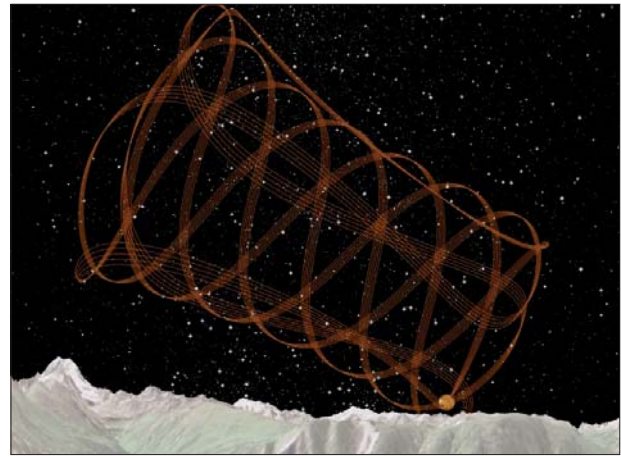
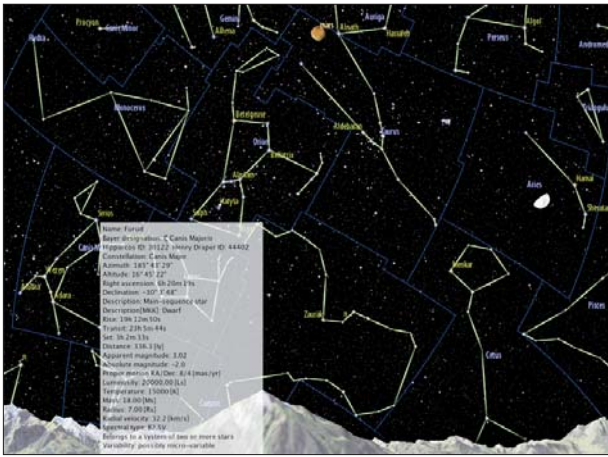


Fig. 2: Screenshots of the Atlas of Switzerland. Left: Stars and constellations visualised and labelled over the Bernese Oberland. Date, time, degree of cloudiness as well as the sector and the requested line of vision can be chosen. Additional information is available for every displayed astronomical 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.

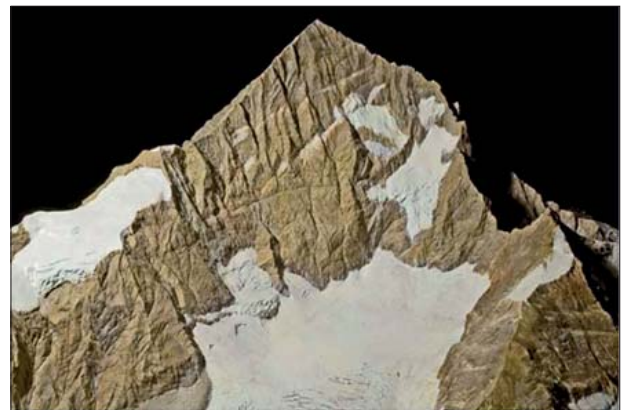
The construction of handmade relief models has a long tradition in Switzerland. In the middle of the 19<sup>th</sup> century, after Switzerland was surveyed and mapped by the Swiss National Survey, relief modelling was booming. Creators of such splendid alpine relief models are, among others, Xaver Imfeld, 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.



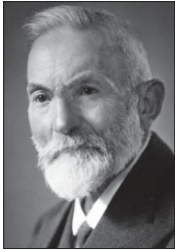


Fig. 7: Jakob Oberholzer (1862–1939).

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. In 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 an 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 swisstopo<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 different elevation models lead to the conclusion that the

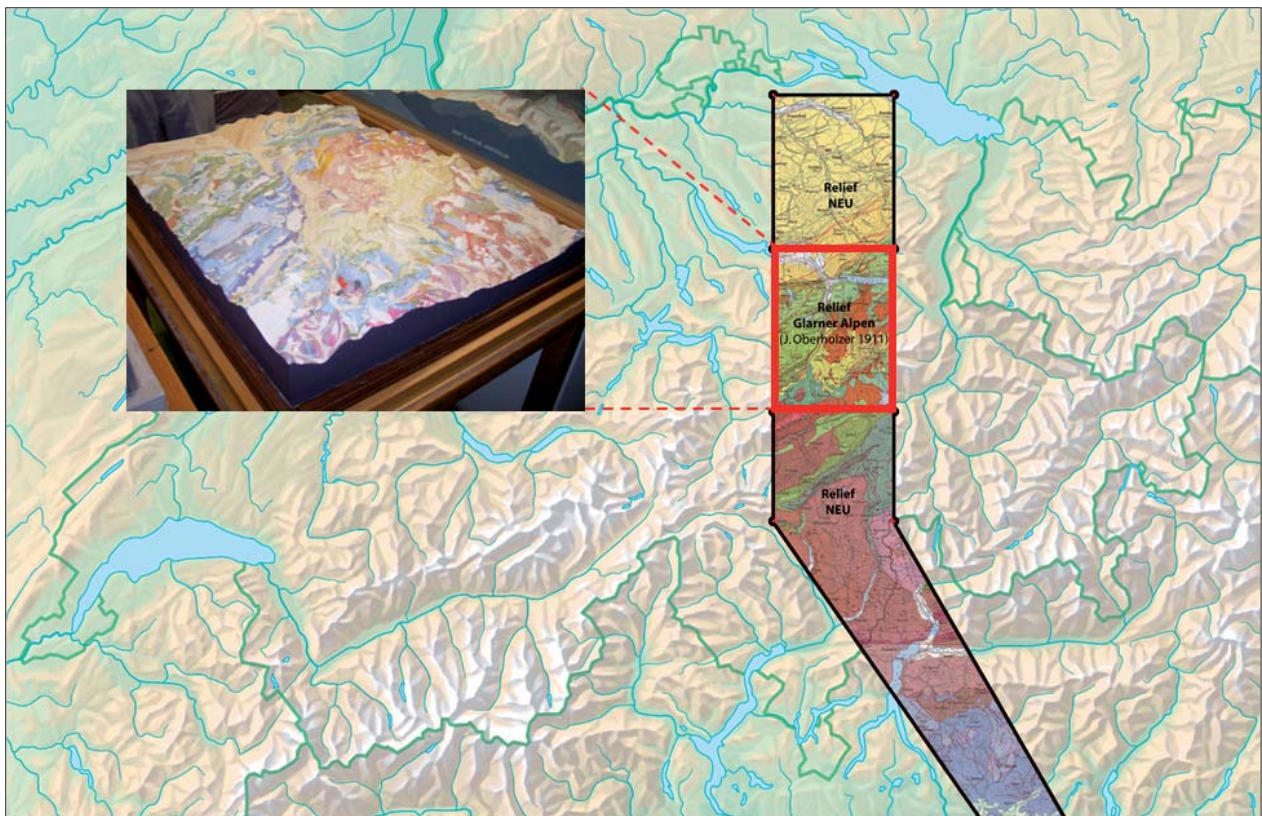


Fig. 8: Extension of the relief model: in red the Oberholzer relief, in black the automatically carved section.

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)

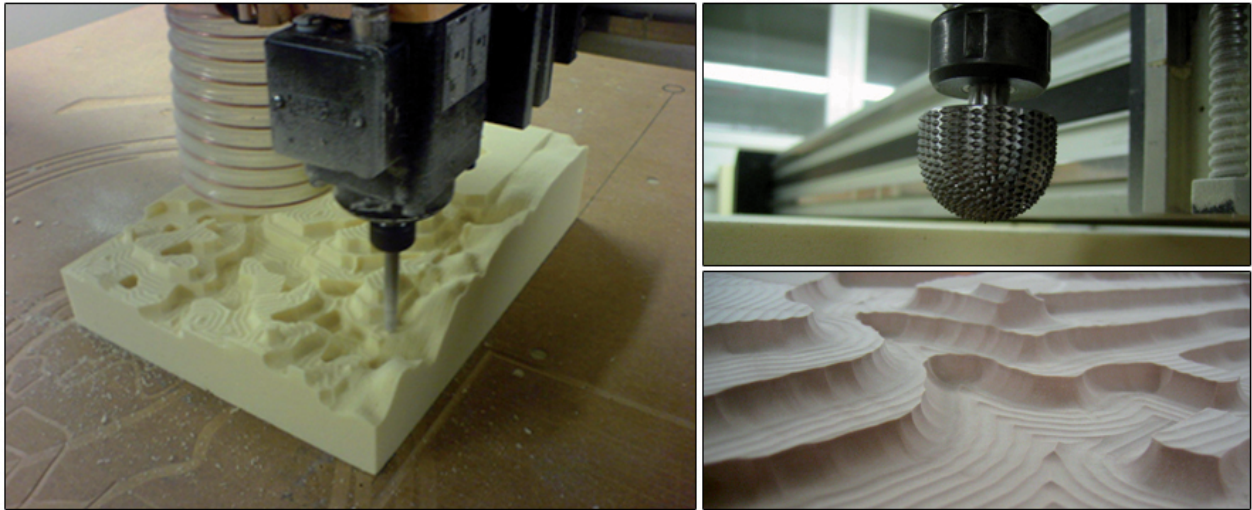


Fig. 9: Left: Test by a CNC milling machine, Raplab ETH Zurich. Upper right: Selected milling bit with ball nose. Bottom right: milled surface after horizontal roughing.



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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