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PREFACE

From the circle of members of the Swiss Society of Cartography (Schweizerische Gesellschaft für Kartographie, SGK) came the initiative to prepare and execute vocational courses with different themes in the working area of cartography, for trainees, instructors, teachers and all experts active in cartography.

In the autumn of 1972 the committee of the SGK nominated a working group which has directed itself to the broad field of cartographic generalization. With this publication, the working group wishes to outline the broad principles and the essential facts and relationships involved in generalization. To keep the task within reasonable bounds, the presentation is limited to plans and topographic maps. Furthermore, only examples from Switzerland could be considered. The large amount of collected material, for what is a very narrow research area, demonstrates the many-sidedness of the total problem of generalization. The aim in this work has been, first of all, to assist the practical cartographer. The subject matter is presented clearly and in a manner understandable to everyone by means of map examples, sketches and generalizations in series. It is the intention to produce at a later date further similar examples of cartographic generalization for maps at smaller scales and for atlas maps, school maps, road and transport maps and thematic maps. We hope that the result of our combined efforts will arouse the interest of cartographers everywhere and that it will be a useful practical aid.

The Committee of the Swiss Society of Cartography

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The cartographic drawings were made by the apprentice section of the Topographical Survey of Switzerland under the guidance of Ernst Bantel and by the apprentice section of Kämmerly & Frey under the guidance of Claude Vez.

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For the translation of this publication into English, the Multilingual Dictionary of Technical Terms in Cartography, compiled by Commission II of the International Cartographic Association, was of great value. As the German language has a much wider range of terms in cartography than English, paraphrases of the German terms had to be given in those cases where no equivalent in English exists.

All contributors are thanked here for their time-consuming work and for their perserverance and the companies for their free supply of map samples.

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Publications of the Swiss Society of Cartography can be ordered through bookshops or directly at the following address (direct delivery only by advance payment): Mr. Gert Schelling, SGK-Publikationen, c/o Orell Füssli Graphic Arts LTD., P.O. Box, CH-8036 Zürich.
1. INTRODUCTION

Cartographic generalization requires prior knowledge of the essence and the function of the map. Consequently we first of all have to ask ourselves about the purpose of the map, the extent of its information contents and also about the requirements of the map user regarding the power of expression of a map type desired for a specific purpose.

1.1 What is a map?

Since ancient times people have tried to orient themselves within their immediate and more distant surroundings and to retain their experiences and knowledge in many forms. As techniques advanced they arrived at graphic representation of the knowledge of their surrounding world.

In this way the first map-like representations were created, on which topographic features, hydrography, settlements and roads were portrayed in a primitive way. Seafarers and explorers later recorded their observations during their extensive journeys and handed over these documents in early map form to their contemporaries.

Since then geographers, cartographers and geodesists have portrayed on maps the manifold forms of appearance of our Earth and other heavenly bodies, and also the man-made changes. The knowledge gained could be disseminated by means of all kinds of reproduced maps. From the early simple representations, modern cartography has been developed with its often multicoloured, highly detailed and accurate maps. The figures 1-14 following give the answer to the manifold possibilities of cartographic representation.

What do we understand by modern cartography?

Eduard Imhof says: "Cartography is the art and technique of map reproduction. It is in a narrower sense to be characterised as a refining process between the original source material and the reproduction".

The objective of the map has to be a meaningful picture of reality. Therefore, it serves especially the aim of being a help in orientation in the terrain and by its supplementary annotations of conveying multi-faceted information.
Plan

The plan is the graphical result of surveying and mapping on the ground.
The plan is the base for the production of large scale topographic maps.
Aerial photograph

The aerial photograph represents the Earth's surface with all details at the moment the photograph was taken. The quality and legibility depend on the time of the day and the year, the weather conditions and the illumination. With increasing flying height the informative power decreases.

Where are the watercourses? Where are the main roads? Where are the railroads? Where are the tracks in the forest? Where is the highest point? How many houses are there in the village? No lettering.
Map

The map is a meaningful extract of the highly detailed aerial photograph. Its contents are not confined to the mere representation of the planimetry, but undergo at smaller scales corresponding changes, involving the suppressing of unimportant items and the emphasizing and classifying of important features. Details which are not visible are made visible.

Road classification
Railways
Tracks in forests
Contour lines
Rock outcrops
Lettering and height values
Examples of topographic maps

Topographic maps represent form, structure and cover of the Earth's surface.

Fig. 9
Topographic map
1:25 000

Fig. 10
Topographic map
1:50 000

Fig. 11
Topographic map
1:100 000
Examples of thematic maps

In thematic maps those findings of the various sciences, disciplines and research branches are portrayed, which are suitable for graphic representation.

Fig. 12
Thematic map

Fig. 13
School atlas map

Fig. 14
Road map 1:1 000 000
2. THE GENERALIZATION OF TOPOGRAPHIC MAPS

"Only he who is master over the matter and can perform with his hands what his mind wishes, is able to generalize well" (E. von Sydow).

2.1 The objective of generalisation

The objective of generalization can be characterised very generally as the production of an unequivocally legible and definite map image (see Chapter 1). The map should be in accordance with its purpose and should really serve the demands required by its users. One of the main conditions therefore, is that it should be consistent, which means that what is qualitatively the same on the ground is also represented in the same way everywhere on the map. In generalization one primarily attempts to achieve a balanced total image.

Professor Imhof gives a concise description of the objective of generalization for topographic maps when he writes: "The objective of generalization is the highest accuracy possible in accordance with the map scale, good geometric informative power, good characterisation of the elements and forms, the greatest possible similarity to nature in the forms and colours, clarity and good legibility, simplicity and explicitness of the graphical expression and coordination of the different elements". (From: "Kartographische Geländedarstellung", page 100).

2.2 Why is generalization necessary?

2.2.1 Increasing density of the map contents due to scale reduction

In every map the objects and the forms of the Earth's surface are represented reduced. Only at larger scales, i.e. at lesser reduction, can the representation be approximately true to the reality. As the map contents do not decrease proportionally in direct ratio to the reduction of the paper surface, an increasing density of the map contents arises at the smaller scale.
2.2.2 Limit of acuity of the eye

The reduction of objects and forms in a map cannot be continued indefinitely. It should terminate where the limit of acuity of the human eye is reached. This is approximately 0.02 mm at a distance of 30 cm from the eye. When the contrast is good, therefore, fine lines with a line width of 0.04 mm can still be distinguished. This is also the approximate limit of printing capabilities.

2.2.3 Minimum sizes

It is not realistic to continue decreasing the size of map elements down to the just perceptible and printable limits.

Reasons for this are:
- Important objects should be immediately obvious, not just perceptible.
- Differences in form should be clearly distinguishable.
- Faint illumination and light printing colours reduce the contrast.
- The best reproduction and printing techniques and equipment are not always available or may not be economical.

Therefore line widths and interspaces in minor landforms should not be less than certain minimal dimensions. For topographic maps and black or very dark printing colours the following values apply:

Fig. 17
enlarged drawing: reduction:

---
0.05 mm line on white paper
---
0.25 mm line separation (somewhat larger when using light colours)
---
0.25 mm area symbol separation (somewhat larger when using light colours)
---
per millimeter 3 lines can be distinguished
---
too small irregularities
---
0.35 mm sidelenath: solid square still distinguishable from a point
---
0.5 mm circle diameter
---
0.25 mm point diameter
---
1.0 mm side length
---
0.15 mm for dotted lines
---
4.0 mm² minimum size of coloured area symbols (fine screens and light areas preferably somewhat larger)

For light colours and special conditions for legibility (see 2.3.3) these values should often be considerably increased.
2.3 Factors which influence cartographic generalization

2.3.1 Scale

Scale determines the image size of the object on the map. The degree of generalization is largely dependent on the chosen scale.

![Fig.18: Map at 1:25 000 scale](image)

![Fig.19: Map at 1:100 000 scale](image)

2.3.2 Source material

The source material for every map, which has to be generalized, should be analysed. It should be either ungeneralized or else correctly generalized. In particular, for a series of scales of derived maps at decreasing scales, attention should be paid to the degree of generalization on the map used as base for the next scale in the series. Differences should, if possible, be reduced and a homogeneous generalization should be aimed at.

2.3.3 Special conditions for legibility

As far as the use of the map is known from the beginning of the production, special map reading conditions should be taken into account during generalization. The use of a map by walkers is a classical example of this. Other possibilities are: dim light, bad weather conditions and map reading while travelling by car. In all these cases particularly high demands have to be made on the readability and clarity of the map image.

2.3.4 Symbol specification

The drawing up of the symbol specification comes at the beginning of every map design. It influences fundamentally the degree of generalization. The map is not simply an image. To make it comprehensible, certain conventions are used. In technical terminology, they are called signs and symbols. In the symbol specification the size and colour of every symbol occurring in the map should be accurately specified and represented. For every change of scale a new symbol specification has to be designed.

![Fig.20: Symbol specification for the map 1:50 000](image)
2.3.5 Choice of colours

The choice, the number and the intensity of colours have their effect on the generalisation. Pale colours require wider lines and not too small coloured area symbols. This again influences the size of the symbols and thus again, the generalization. Special consideration in the choice of colours is necessary where a map is designed for printing in different colour variants, in particular when it should also be effective in monochrome.

2.3.6 Technical reproduction capabilities

The quality of the presently available reproduction and printing processes is indeed sufficient to reproduce the finest, even scarcely identifiable details, but often simpler, less expensive or quicker processes have to be applied. In order that important information is not lost through loss of quality, the reproduction process should be taken into account already during the original design and generalization.

Copying of fine lines, printing of fine lines

Infilling intersecting lines

Merging of lines and area symbols

Fig. 21

Further problems may be:

Loss of quality due to photographic processes, rounding off and loss of contrast, repeated copying procedures and register problems, rough paper surface.

2.3.7 Revision

For topographic maps in particular, a need exists to bring the map up to date. To safeguard revision at larger scales, certain elements of the contents, e.g. trigonometrical points and objects which are used for topographic surveying should not be displaced. It is logical that this influences the generalization (Fig. 47).

A map should be designed and generalized in such a way that the revision elements can be inserted among the existing ones without technical difficulties.

What has been deleted in the original generalization should not be thoughtlessly re-inserted during a later revision.
2.4 Interconnections of cartographic generalization activities

As has been mentioned in 2.1, the aim of generalization is to produce a map image which is clearly legible and interpretable from a superabundance of information. Therefore the map contents should first be reduced to what is necessary and possible and secondly, the most important emphasized and the less important repressed. This interaction between omitting and repressing on the one hand, exaggerating and emphasizing on the other, accompanies all the construction stages of the map, from the conception to the final reproduction original. Most essential in this is good interplay of all measures with a view to producing a balanced total image of the greatest possible consistency.

2.4.1 Flow diagram for the map design and the production of the original

In the following flow diagram, the necessary decisions in the design of a map are arranged in 5 steps. From the last step, it is possible to return to any of the preceding ones if the provisional result is not yet satisfactory. By so doing, the factors which influence the generalization (in the diagram, represented by ellipses – see also chapter 2.3) can be varied until it is finally ascertained that in the continuing interaction of the steps four and five, a good map image must result.

START: Need for a map

Step 1: Aim

Scale

Source material

Special conditions for legibility

Revision

Setting of specific requirements for the map

Deciding on the types and classes of objects or concepts which have to be represented

Drawing up of symbol specifications (legend) including colour choice

Size and form of symbols

Colour of symbols

Application of the symbol specification, taking into consideration all the influencing factors, especially selection of the appropriate objects from the source material and representation within a positional tolerance corresponding to the aims.

good

Result

not yet satisfactory

END: Fair drawing for reproduction
2.4.2 Cartographic generalization in the narrower sense

By this we understand very simply everything which happens after deciding upon the seven influencing factors, namely the graphic generalization, the continuous assessment of this and any necessary corrections.

In the preceding diagram, these are the two last steps, four and five, but now without the possibility of going back to steps one to three, since these have already been established. The last two steps, as a rule, still have to be done for a map series by the cartographer and it may be that many map sheets have to be edited following the same graphic and conceptual principles. The following chapters, three to ten, treat only this narrower aspect of cartographic generalization, very important in topographic maps. Although positional tolerances in topographic maps are in principle kept small (seldom more than approx. 0.5 mm), there still remains significant scope for carrying out generalization, that is making the essentials clear, by geometric and graphic measures. The condition is, of course, that the cartographer has a good notion of what is more or less essential for the map which is to be edited. He should know the aim of the map as far as it has been decided on beforehand (see Step 1 in diagram) and be able to apply his graphic techniques accordingly. The particular techniques he has available for this will be described in the following chapters.

2.4.3 The degree of generalization

This is realised by the degree of application of both basic operations, namely omitting - repressing and exaggerating - emphasizing. The same source material at the same scale for

a lesser degree of generalisation will be changed as little as possible and will thus result in a detailed fine map image with a relatively high positional accuracy, while for

a greater degree of generalization, the relatively few selected content elements will be represented by strong expressive forms, which can be relatively far away from their original positions.

Concerning the choice of any particular degree of generalization, the aim of the map settles the matter, especially the consequently derived graphical form of the symbol specifications and the allowed positional tolerance. The degree of generalization should be approximately the same for all the content elements of the map.
3. PRACTICAL GENERALIZATION EXAMPLES

3.1 Where does generalization begin?

Every map is, in principle, generalized. The finest details of structure and arrangement of natural and man-made features cannot be truly and accurately represented. At scales of 1:5 000 and larger, the planimetric accuracy of the original survey data can be maintained. In the drawn plan, single lines representing tracks and railways, are already symbols. At the 1:10 000 scale, the double-line road symbols are no longer true to scale. Every reduction of plans and maps gives rise to an increasingly dense image and to a large number of barely legible irregularities in the linework. That which the eye can no longer clearly and unequivocally recognize and explain should be graphically simplified and legibly represented. Generalization should, in any case, begin at the point where self-evidence of the graphic statement and legibility become insufficient.

Fig. 23  1:25 000 not generalized (reduction of the 1:10 000 map)
### 3.2 Change of geometry

Size-ratio of a footpath on the map and on the ground

<table>
<thead>
<tr>
<th>Width of path on the ground 1:1</th>
<th>Graphical representation on the map</th>
<th>Converted to size on the ground</th>
<th>Exaggeration: x broader than on the ground</th>
</tr>
</thead>
<tbody>
<tr>
<td>1m</td>
<td>0.15mm</td>
<td>3.75m</td>
<td>3(\frac{3}{4})x</td>
</tr>
<tr>
<td>1:25 000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1m</td>
<td>0.15mm</td>
<td>7.5m</td>
<td>7(\frac{1}{2})x</td>
</tr>
<tr>
<td>1:50 000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1m</td>
<td>0.15mm</td>
<td>15m</td>
<td>15x</td>
</tr>
<tr>
<td>1:100 000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1m</td>
<td>0.15mm</td>
<td>30m</td>
<td>30x</td>
</tr>
<tr>
<td>1:200 000</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig. 24

Size-ratio of a 2nd class road on the map and on the ground

<table>
<thead>
<tr>
<th>Width of road on the ground</th>
<th>Graphical representation on the map</th>
<th>Converted to size on the ground</th>
<th>Exaggeration: x broader than on the ground</th>
</tr>
</thead>
<tbody>
<tr>
<td>4m</td>
<td>0.6mm</td>
<td>15m</td>
<td>3(\frac{3}{4})x</td>
</tr>
<tr>
<td>1:25 000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4m</td>
<td>0.6mm</td>
<td>30m</td>
<td>7(\frac{1}{2})x</td>
</tr>
<tr>
<td>1:50 000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4m</td>
<td>0.6mm</td>
<td>60m</td>
<td>15x</td>
</tr>
<tr>
<td>1:100 000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4m</td>
<td>0.6mm</td>
<td>120m</td>
<td>30x</td>
</tr>
<tr>
<td>1:200 000</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig. 25
Mountain pass road with hair-pin bends

Fig. 26

1:25 000

Fig. 27

1:50 000

Fig. 28

1:100 000

Fig. 29

1:200 000

Fig. 30

1:500 000
3.2.1 Simplification of lines (line smoothing)

Delete small irregularities: All the irregularities on the guide image (in red), which are covered by the line width, should be ignored. An original line which is not completely straight, however, should never become a geometrically straight line.

The character of a line should be maintained.

Correct

Generalization by mean position gives a wrong impression

Incorrect

Two bends may be combined as one, while three bends may be represented by two, etc.

The number of bends is reduced, lesser irregularities, which can be disturbing, are deleted.

Example of Gemmipass:
Increasing simplification of the line as scale decreases

Simplification of a coastline (Fjord)
3.2.2 Simplification of areas

Fig. 35

The measured area of the simplified outline should remain roughly the same as the area of the original.

General form maintained

The original form should be maintained despite a decreasing number of objects. A square remains a square, a rectangle remains a rectangle, etc. Exceptions are the representation of blocks of houses at smaller scales.

If possible, draw rectangles

Exception

Combine areas

Delete areas
Maintain the same colour to white ratio
3.2.3 Decreasing number of objects

Area (e.g. a house) on the map compared to the size on the ground

<table>
<thead>
<tr>
<th>Scale</th>
<th>Side length and area on the ground</th>
<th>Side length reduced to scale</th>
<th>Minimum size on the map</th>
<th>Map symbol converted to ground size</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:25 000</td>
<td>7.5m 56m²</td>
<td>0.3mm</td>
<td>0.3mm</td>
<td>7.5m 56m²</td>
</tr>
<tr>
<td>1:50 000</td>
<td>7.5m 56m²</td>
<td>0.15mm</td>
<td>0.3mm</td>
<td>15m 225m²</td>
</tr>
<tr>
<td>1:100 000</td>
<td>7.5m 56m²</td>
<td>0.075mm</td>
<td>0.3mm</td>
<td>30m 900m²</td>
</tr>
<tr>
<td>1:200 000</td>
<td>7.5m 56m²</td>
<td>0.0375mm</td>
<td>0.3mm</td>
<td>60m 3600m²</td>
</tr>
</tbody>
</table>

Change in number and area (rows of houses)

Fig. 37

At the scale 1:200 000 only one house remains.
(If the row were represented by two houses, then the perimeter would be far exceeded).
3.2.3 Decreasing number of objects

When omitting objects, due to scale change, the original character should not be changed in its essentials. The original form, size and spaces should be maintained despite decreasing number.

Incorrect

Correct

Two houses become one house

Three houses become two houses

Squares should not be converted to rectangles

Exception:
At a road junction the object is moved to the street corner

For any row alignment, objects are decreased in number in the same way.

Generalization is not only deletion but also the graphic representation of the true situation by fewer and coarser means.

Fig. 38
Decreasing number of minor streets

Where residential buildings are irregular in form and situation and the streets to be omitted cannot be indicated by houses, the building shapes and the black-white ratio, can be maintained by geometrical displacement of the streets still remaining.

In doing so, despite the decreasing number of building symbols, these should be placed in such a way that the general impression of the reduced representation is still in accordance with the character at the original scale.

All scales are enlarged

At the scale 1:25 000 all streets and the adjacent houses are approximately correctly represented.

Fig.39 1:25 000

At the scale 1:50 000 one street in this small area is deleted. The two remaining are positioned in such a way that the shapes of the building symbols and the black-white ratio are maintained. The two streets have been moved from their original position.

Fig.40 1:50 000

At the scale 1:100 000 the general impression of the original scale is maintained only with one street in this small area. The impression of black-white is mainly obtained by the representation of the houses.

Fig.41 1:100 000
These three examples show that at smaller scales the width of streets and sizes of houses should remain in the correct proportion with respect to each other.

Fig. 42

1:25 000, 10 times enlarged.
Approximately true positional representation. Due to the standard widths for the streets the houses along the street are already displaced somewhat. Due to the use of specified symbol sizes, all buildings are represented somewhat larger than true size to scale. Very small objects and shape details are omitted.

Fig. 43

1:50 000, 20 times enlarged.
The enlargement of the main streets causes a further displacement of the houses along the streets. To maintain the black-white ratio, the two minor street with single houses along them are deleted. In doing so, six rows of houses are reduced to four and the number of houses in the rows from eight to five. The two deleted streets are, however, graphically indicated by the remaining rows of houses. The houses along the main streets should, as much as possible, be truly represented.

Fig. 44

1:100 000, 40 times enlarged.
Further enlargement of the main streets compared to the 1:50 000. The minimum size of the houses is redoubled. Because of this the available area for the residential area becomes again smaller and this causes proportional problems with the black-white ratio. The number of rows and the number of houses in each row is therefore reduced further. The houses along the main streets should, as much as possible, be truly represented.
3.2.4 Displacement

In winding roads over mountain passes, the change in gradients due to displacement should be as small as possible.

The different slope angles between the road terraces (A) should remain in the same relation to each other when the terraces are widened as scale decreases (B).

The contour lines (to be imagined from the profiles in the figure) should be displaced, due to the greater space needed for the map symbols, in such a way that no topographical changes will take place. Trigonometrical points (see pyramid) should not be displaced. Topographical points might be displaced a little.

1 Railway (single track)  
2 3rd class road 
3 River 
4 Footpath (eliminated in smaller scale) 
5 Railway (double track) 
6 1st class road

Due to the increase of the different line widths in a smaller scale (black), the road junctions can't be shown realistically (A). With the change of the axis of the road fly-over, we can keep the position of the road junction in compliance to the base map (red) very accurate (B).

Space should be reversed for elements which have to be represented in other colours.
3.3 Graphical distinction of the map elements

Confusion of elements in the same colour due to insufficient differentiation

Possibilities of confusion of wall and road
Differentiation by line width is necessary

Freeing symbol from other detail
Symbol is too similar to other detail
Change of symbol

Poor distinction of house symbol and embankment hachures
Railway becomes illegible

Fig. 50
Fig. 51
Fig. 52
3.3.1 Relative proportions of map elements

Incorrect

Trees too small compared to houses

Correct

Balance of elements

Fig. 54

Wrong proportion of road to houses

Fig. 55

Wrong proportion of settlement symbol to road

Fig. 56

Wrong proportion of double line road symbol to single line symbol

Fig. 57

Embarkment hachures conceal road
3.3.2 Minimum distances between objects

The separation should be at least 0.2 mm or the house should be displaced up to the road. When drawing for reduction, the minimum distance should be correspondingly greater.

Topography should be taken into account.

Depending on scale and character of representation either place alongside road (A) or at an angle of 45° (B).

Fig.61

Narrow angles and small spaces fill in when printed
Move symbol away from road
Fuse symbol with road

Fig.62

Original outline

Not readable: Houses fuse with road, giving a wrong impression of outlines

Too much space: Distance between rows of houses too large

Good: The character of the built-up area is maintained
3.3.3 Graphical details

poor representation  good representation

Spot height in 3rd class road

Spot height at road junction

Spot height in 1st class road

Spot height in road bend

Spot height in road fork

Spot height on footbridge and bridge

Spot height at road junction

Spot height at road crossing

Spot height represented by a cross at crossing of municipality boundary and road is more legible than a point symbol

Spot height where municipality boundary crosses road not readable
Spot height is clearly legible, when the boundary is interrupted
Spot height (cross) in double line road symbol is graphically not aesthetic

Spot height in municipality boundary illegible
Spot height (cross) clearly visible

Spot height in district boundary poorly legible
Spot height (cross) clearly visible

Spot height in canton boundary correct but if at meeting with municipality boundary, then a cross is more legible

Spot height in state boundary is correct

Spot height (cross) in state boundary only correct where municipal boundary meets it

Fig. 63
3.3.3 Graphical details

Poor representation  good representation

Fig. 64

Road under single track railways

Road under double track railways

Road- and street fly-overs
Road- and street underpasses

The continuity of the railway line should not be interrupted

Road alongside narrow-gauge railway

Road alongside normal-gauge railway

Boundaries along a road should be represented by finer symbols

Representation of narrow road bends
The broadening effect is less
3.3.4 Interruption of lines

poor representation  good representation

Fig. 65

Peck-dot lines:
Dots should, if possible, be placed at the corners

Boundaries:
Interruptions should not be at the corners as they disturb the connectivity

Dotted lines:
The course should be clear

The interruptions should not form a linear gap

For small zig-zag roads the line segments should be extended

Curves should not be interrupted

No interruptions at corners and forks

A road crossing over a water-course without a symbol for footbridge should always be represented with a line segment crossing the water-course. Substitution effect

A road bridge should not be represented by a broken line
Streets in a built-up area must be represented by thinner lines, or even deleted when using certain symbols. In doing so, more space is gained for the houses. The black part of the image does not increase.

Junction with streets and roads, represented by one line, should be kept open. The legibility of the course of streets is thus improved.

At smaller scales, where the distances between houses are at minimum, streets can partly be represented by houses alone. Substitution effect.

The course of a foot path can be represented by houses. Substitution effect.

Continuity of the path is maintained. Substitution effect.

Representation of houses along paths represented by pecked lines.

Path too broken up, illegible.
4. PLANIMETRY (MAN-MADE FEATURES)

On topographic maps, settlements, roads, streets, railroads, boundaries and other man-made constructions form the major part of the planimetry. Normally it is produced first and consequently determines the degree of generalization of all other map elements. An inexpert generalisation is very detrimental to the remaining map contents.

What do we require of the generalization?

- Positional accuracy of points and objects within the limitations of the scale
- Maintenance of planimetric accuracy within the limitations of the scale
- Representation of all elements appropriate to the scale
- Correct classification of road- and street network
- Maintaining the character of the built-up area, in spite of generalization (e.g. typical residential character, town centers, squares, etc.)

To meet these requirements properly, in the first place attention should be paid to the black-white ratio.
As the map elements at the smaller scales are proportionally coarser compared to the larger scales, their number decreases as scale diminishes.

Example:

<table>
<thead>
<tr>
<th>Number of houses</th>
<th>densely built-up area</th>
<th>open built-up area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air photo</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>1:25 000</td>
<td>- 95%</td>
<td>100%</td>
</tr>
<tr>
<td>1:50 000</td>
<td>50% - 60%</td>
<td>60% - 100%</td>
</tr>
<tr>
<td>1:100 000</td>
<td>30% - 35%</td>
<td>35% - 100%</td>
</tr>
</tbody>
</table>

The degree of generalization cannot purely be mathematically determined. The above-mentioned percentages should be aimed at, but cannot be achieved in all cases. Isolated houses or roads in empty areas are often, also at smaller scales, up to 100% represented. In built-up areas and defiles, generalization begins with the most difficult parts, i.e. where the least possibilities for displacement are available. In practice, this implies generalization outwards from these areas.
The black-white ratio, especially concerning the density of built-up areas should, as far as possible, be maintained at all topographic map scales. Dense town centres, industrial plants, etc. should be distinguished from town districts with single houses. Squares, parks and sports fields should not be eliminated due to lack of space. The simplification and enlargement of the symbols reduce the possibilities of their differentiation. The resultant tendency to increase the black area should be compensated for by omissions.
Practical generalization examples

1:25 000

1:50 000

1:100 000

Decreasing number of single houses and house rows. Relative relationships are maintained and the general impression should not be changed.

Fig.70

Fig.71

Geometrical displacement of street lines in cases where a reduction of house rows is required.

Fig.72

In a district where different types of houses occur, the character and relative sizes of the houses should also be maintained.

1:200 000 constructed from the reduced 1:100 000 map

Fig.73

Fig.74
Street and road pattern at 1:25 000

The map still mostly represents the true situation. Smallest details and houses are omitted.
Simplified forms, decreasing number of objects, small enlargements of outlines, differentiation of forms and sizes of houses. Displacements and simplifications.

Simplified forms, decreasing number of objects, enlarged outlines. Differentiation of large buildings and groups of houses. The character of different types of built-up area should be maintained. Main roads should be accentuated.

Decreasing number of large objects and in this case, entire groups of houses. Enlargement of outlines, shifting, displacement and simplification of line elements. Differentiation: on the one hand large buildings (factories) and on the other hand private houses (in residential districts). Beginning of the combination of houses into blocks.
5. HYDROGRAPHY

The Earth's surface is by no other element so obviously modelled and divided into parts as by the hydrographic network. This can be quite different in its form of appearance, depending on the geographical situation or topographic formation. The climate and the amount of precipitation have a far-reaching effect on the density of, and the amount of water in, the hydrographic network. The selection of streams and rivers cannot be performed according to a fixed key or a predetermined system, as a small stream in an area lacking in water is possibly more important for the map user than a river in a well watered area. In the selection, the given facts of any landscape must be taken into account. As the streams in general have to be less exaggerated in width than other map elements, there will be also fewer difficult problems in their generalization. The hydrography in topographic maps is the first element to be adapted to fit the other elements, when features have to be displaced (Note: this is the Swiss system).

What do we require of the generalization?

- Positional accuracy within the limitations of the scale used
- Accuracy of forms of lines within the limitations of the scale
- Inclusion of all watercourses appropriate to the scale
- Lively representation of streams
- Simplification of forms of lines corresponding to the generalized terrain forms
- Visually correct widening of watercourses downstream
- Relationship of the hydrographic network to the other map elements

To meet these requirements properly, the blue-white ratio at all scales should, above all, remain approximately the same.
A. Watercourse too stiff and unnatural or else canalised
B. Watercourse lively and natural looking

A. Source and widening of a watercourse
B. At a larger spring, begin with thicker lines
C. Watercourse issuing from a glacier

Omitting and shortening lesser tributaries at smaller scales

If contour indentations marking the course of a stream are no longer shown, then the stream itself should be omitted.

A. A road or railway following a steep lakeshore should be displaced towards the lake. The contour lines in the lake must be displaced accordingly.
B. Stream confluences may have to be displaced.
Generalization examples for the representation of hydrography

Fig. 86  1:10 000 reduced to 1:50 000  Fig. 87  1:50 000

Fig. 89  1:100 000

Fig. 88  1:25 000 generalization based on the reduced 1:10 000 (see top left)
Generalization examples

1:200 000, 1:500 000, 1:1 000 000 and 1:1 500 000

As scale decreases, lines should become less irregular. The number of hydrographic features decreases and the streams are shortened appropriately (Fig.91). The representation of streams by double lines is used less at smaller scales. At the smallest scales only single lines are used.
Contours are the most important element in the cartographic representation of terrain. They are, however, only a graphic device which does not exist in reality. With contours the three-dimensional terrain surface has to be represented as a two-dimensional image. The area between two contours is not defined with respect to situation and form. A single contour does not explain much. Only a series of contours shows a form or a plane. Every map portrays the terrain in a simplified form, because it is not possible to represent graphically unchanged, the detailed structure of the Earth's surface. The degree of contour generalization depends essentially on the degree of generalization of the other map elements and on the vertical interval of the contours.

What do we require of the generalization?

- Positional accuracy of the contours
- Correctness of situation with respect to the other elements
- Well selected line width and vertical interval of the contours
- Typification of the terrain by emphasizing of lines of breaks of slope and erosion lines
- Maintaining the terrain slope angle in cuttings, defiles and where there are displacements due to exaggerated map elements
- Maintaining the original form with a smaller number of lines and irregularities.

To meet these terrain representation requirements properly, a certain amount of geographical and geomorphological knowledge is of great advantage. Furthermore, the degree of generalization of the original contours should be known. The contour image should indicate the topographic relations in an easily readable way and should blend harmoniously with the other map elements.
Simplification of detailed contour forms in flat terrain. The main characteristics should be emphasized and smaller forms combined.

Relationship of road or track generalization to contour generalization

Exaggeration of very small summit contours

Supplementary contour lines

The topography is made more clearly legible by supplementary contour lines

Irregular slopes, cols and reverse slopes can be emphasized by supplementary contour lines

Supplementary contour lines are very helpful in flat areas for representation of small elevations
Contour indentations should fit streams. Reproduction technicalities (i.e. correct register) should be taken into account. It is important to leave enough room for the streams by rounding off the contour lines.

Contours form surfaces. A single contour line does not give much information. To represent the Earth’s surface a series of contour lines is required. If contours are drawn changing direction at previously sketched ridge lines, then each plane of the surface becomes more distinct.

A small vertical interval (A) allows more land forms to be shown than a larger vertical interval. When the vertical interval is larger, tiny details appear unconnected with each other.

Stepped slopes should not be smoothed.

If a slope has a terraced form, the terraces should remain emphasized and the slope should not be smoothed.
Plotted contours with all details

Suppression of small forms (line smoothing)

Fig. 106

Base map

Redrawing for smaller scale, omitting smallest gullies

Fig. 107

Decreasing number of gullies by combining them at smaller scale

Fig. 108

Emphasizing of planes (ridge lines) 10 m vertical interval

Generalised image with 20 m vertical interval

Rounding results in loss of original character

Fig. 109
Generalization examples for contours

Fig. 110

Photographic reduction of the 1:10 000 general plan to scale 1:25 000. Basic map for the scale 1:25 000.

Fig. 112

1:50 000 generalized from the reduced 1:25 000 map.

Fig. 111

Generalized contours at 1:25 000.

Fig. 113

1:100 000 generalized from the reduced 1:50 000 map.
7. FORESTS (VEGETATION)

One of the striking features on the Earth's surface is forest, which in addition renders very good service as an orientation element in the terrain. To obtain the best possible natural effect, it is necessary to have considerable skill in representation.
This applies above all in those forest areas which are very much broken up or have intricate outlines. The visual strength of forest areas on maps decreases rapidly with scale, due to considerable combining, which sets limits to their representation.

What do we require of the generalization?

- Positional accuracy of forest and brushwood areas, hedges, groups of trees and isolated trees
- Accuracy of forms of the area outlines within the limitations of the scale
- Characterisation and combination of forest and brushwood areas
- Simplification and typification appropriate to the scale of the defined and undefined forest outlines
- Good visual relationship to the other map elements.

These requirements imply that one must pay attention in the first place to the visual effect of the vegetation in the map image. Legibility depends on the size of the symbols, their line width and the chosen colour.
A too detailed forest representation makes the map illegible.
Simplify when using dotted line

Represent very small or narrow forest areas by groups of single tree symbols

Deleting and combining of small areas

Including of small areas within the larger areas

Separation of dense and scattered forest areas in accordance with the scale. Undefined and defined forest outlines will be separated with less detail at smaller scale or eventually represented only by the dominant outline.

Forest in gullies or forest belts along a stream should be widened or represented by single tree symbols. Very narrow shelter belts along roads or railways should be omitted or widened at a smaller scale.

In accordance with scale, very narrow fire breaks should be represented by implication or else omitted altogether.
Generalization example of forest area outlines
Aerial photograph reduced to 1:25 000

Generalization of forest outlines in very steep terrain. Representation of areas by single tree symbols and dots. Separation of high and low forest.

Fig. 125

Fig. 126 1:25 000

Fig. 127 1:50 000

Fig. 128 1:100 000

Fig. 129  Reduction of the 1:100 000 map to 1:200 000

Fig. 130 1:200 000 map generalized from the reduction of the 1:100 000
8. ROCK OUTCROPS

The degree of generalization has to be in accordance with the scale.
At small scales one may be forced to draw simple outlines, perhaps even "Gerippe" lines only (i.e. ridge and valley lines), especially on the illuminated slopes.

Fig.131 1:25 000

Fig.135 1:100 000

Fig.136 1:200 000

Fig.132 1:50 000

Fig.133 1:100 000
enlarged to 1:50 000

Fig.137 1:25 000

Fig.138 1:50 000

Fig.139 1:100 000

Fig.140 1:200 000
enlarged to 1:100 000

Fig.134 1:200 000
enlarged to 1:50 000

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9. SHADED RELIEF

The representation of shaded relief and its generalization has to be based on the contour image. Angular and rounded forms, steep and flat terrain with transition forms, should be represented in accordance with the contours. The main forms should not be lost, but should be more emphasized as scale becomes smaller.

Fig. 142

Fig. 143

Fig. 144

Fig. 145

Fig. 146

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10. LETTERING

Lettering assists orientation on the map.
The conditions under which the lettering is read are approximately the same
for all topographic maps and require for the letter height a relatively large
minimum size of 1.2 mm. The general appearance of lettering on the map is
that of a veil covering the other map elements and it is detrimental to them.
The lettering should be placed in such a way that its attribution is unequivocal and the other map elements are disturbed as little as possible. Where
line and area elements are interrupted, the eye should be able to complete
the missing parts logically.

The general appearance of lettering on the map should not dominate at the
smaller scales. For that purpose one has in the first place, various possibilities in the choice of appropriate types of lettering. Soon, however, for graphic and conceptual reasons, a limited selection from all the names is necessary. From the graphic point of view, the lettering of objects having a point form is no longer possible, as in doing so, too much of the rest of the map image is disturbed. Only the still sufficiently important linear objects and objects represented by outline can be lettered at the smaller scales. This is,
in general, in accordance with the changing character of the map, which, with decreasing scale, becomes more and more a general map covering larger areas. 1)

It is a task for a specially trained editor to perform both the conceptual and
the graphic transformation of the lettering from the original map in the form of a names guide for the smaller scale. He decides, with reference to all valid rules of graphic representation, which names have to be deleted, abbreviated, combined, emphasized or even added.

Literature concerning map lettering:
Eduard Imhof: "Die Anordnung der Namen in der Karte", Internationales Jahrbuch für Kartographie 1962, pages 93-129, on page 127/128 further literature refe-
rences.
Institut für Kartographie der ETH Zürich 1971 (M. Bühlmann): "Grundlagen zur Kartenbeschriftung mit serifenloser Linear-Antiqua".

1) Note: The above remarks apply only to typical topographic map scales.
At atlas scales, settlements are depicted by point symbols and are named.