L3:Graphic variables and map design

Kraak & Ormeling, Cartography – Visualization of Geospatial Data
- chapter 6: Map design

Kraak & Brown, Web cartography
- chapter 5: Cartographic principles

Topographic and thematic maps

Maps and geospatial images influence people's conception of space.

through

Conventions and traditions → Topographic map

Graphic design → Thematic map

Topographic and thematic maps

Topographic maps

General portrait of the surface

Analog division of map types

Basics for

Thematic maps

Spatial distribution of single phenomena

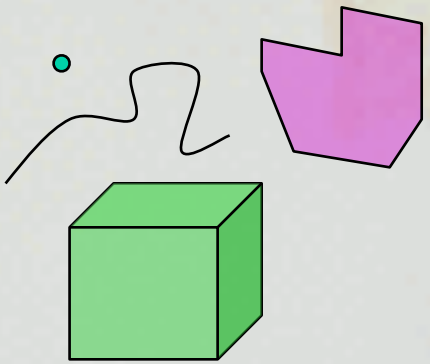
Symbols

Reality

Real objects

Digital landscape model

Points, lines, areas, volumes



Digital cartographic model

Dots, dashes, patches - always a raster when viewed

6 main types of graphic elements in maps

- Points
- Lines
- Surfaces
- 3D-objects
- Text
- Symbols (representing one of the above)

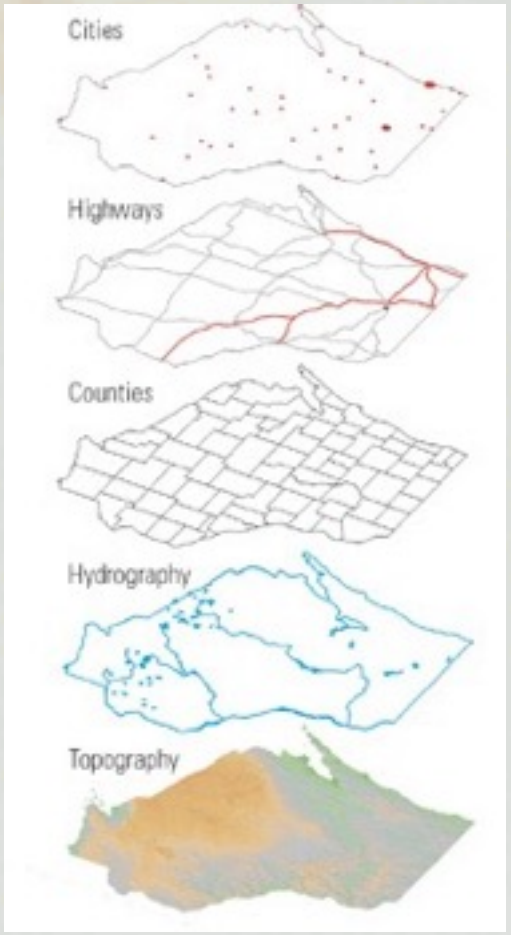
Nile River

In a GIS these elements are represented in different data layers.
In analogue map production they are often represented by different layers in the printing process.

Graphic elements in topographic and thematic maps

Topographic map = terrain (surface) +
roads (lines) +
railroads (lines) +
urban areas (point or surface) +
hydrography (line or surface) +
geographical names (text) +
landuse (surface) +
administrative boundaries (lines)

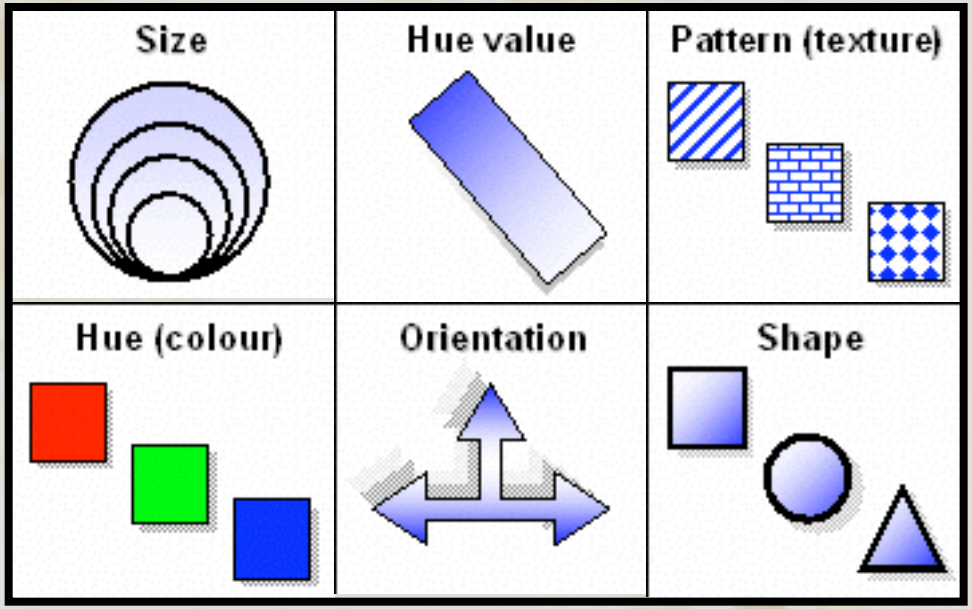
Lager



Each layer is a thematic map on its own.

6 main types of visual graphic variables in maps

- Size
- Lightness/grey value
- Grain/texture
- Color/hue
- Orientation
- Shape



These graphic variables were defined by (Bertin, 1967) as a means to make one symbol different from another one.

Perceptual characteristics of graphical variables

What kind of differences can we perceive by changing graphic variables?

size

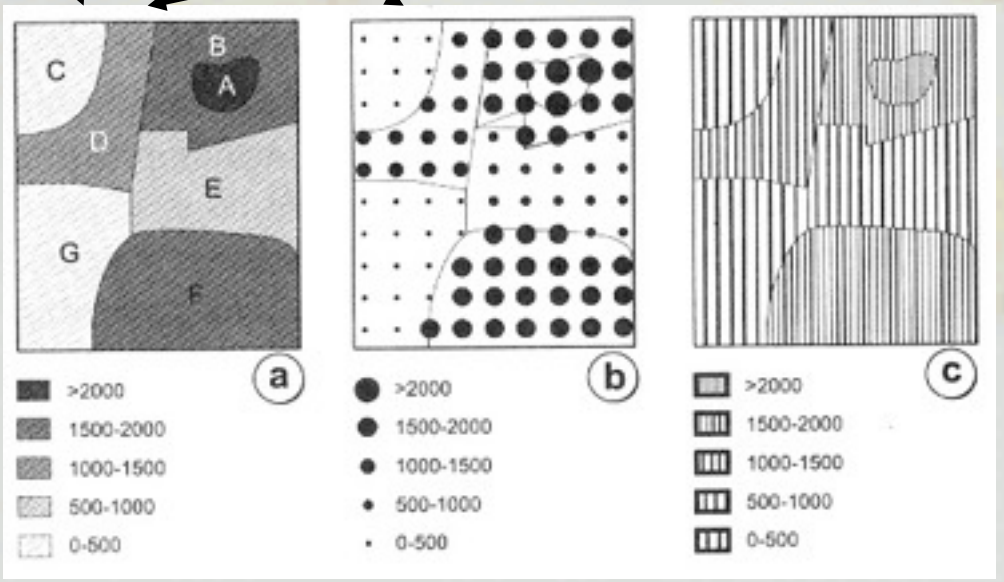
distance

order

quality

differences in colour, texture, grey level

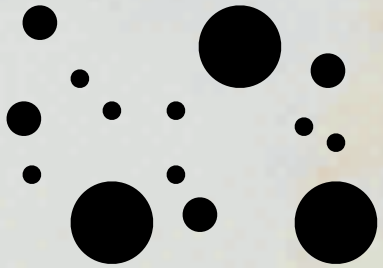
difference in size = difference in numerical value



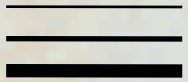
Perceptual characteristics of graphical variables

Size

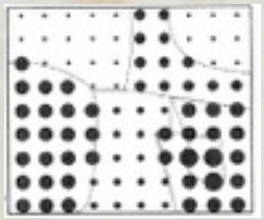
Point symbol size



Line symbol size



Area symbol size:

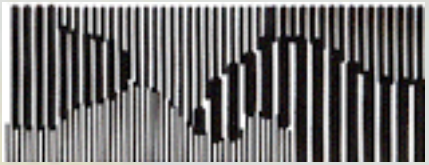


- example: proportional dots in grid patterns
- but this does NOT include the surface of the polygon/area that the symbols refer to!

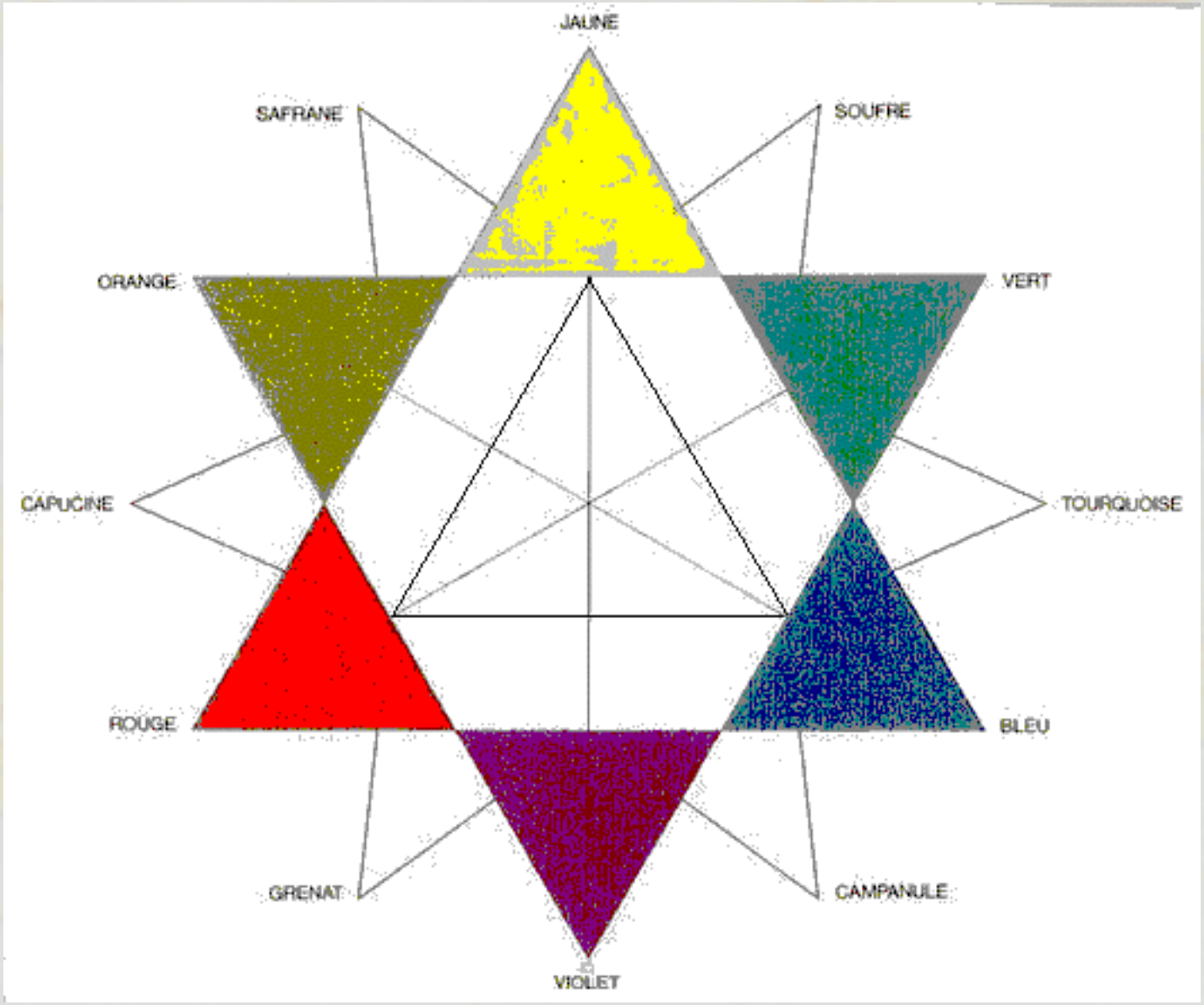
Perceptual characteristics of graphical variables

Grain / texture

Differences emerge when the pattern is enlarged or reduced – the ratio between white&black must remain the same during this process.



Color theory



charles blanc etoile des couleurs 1867

Color theory

Georges Seurat - La Parade (1889) (detalj)

Pointillism

Color theory

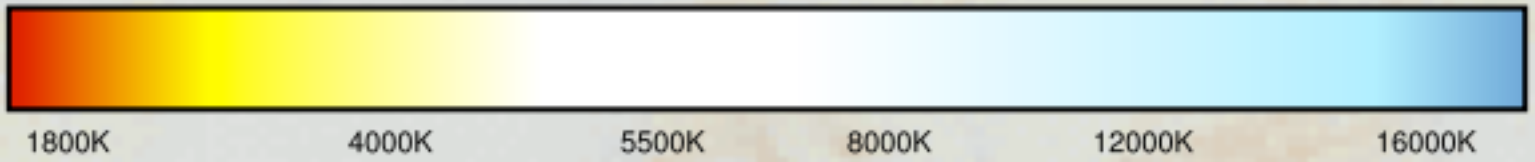
Color theory

Complementary colors

Examples of neutralising complementary colors:

* Yellow - Violet
* Orange - Blue
* Red - Cyan
* Magenta - Green

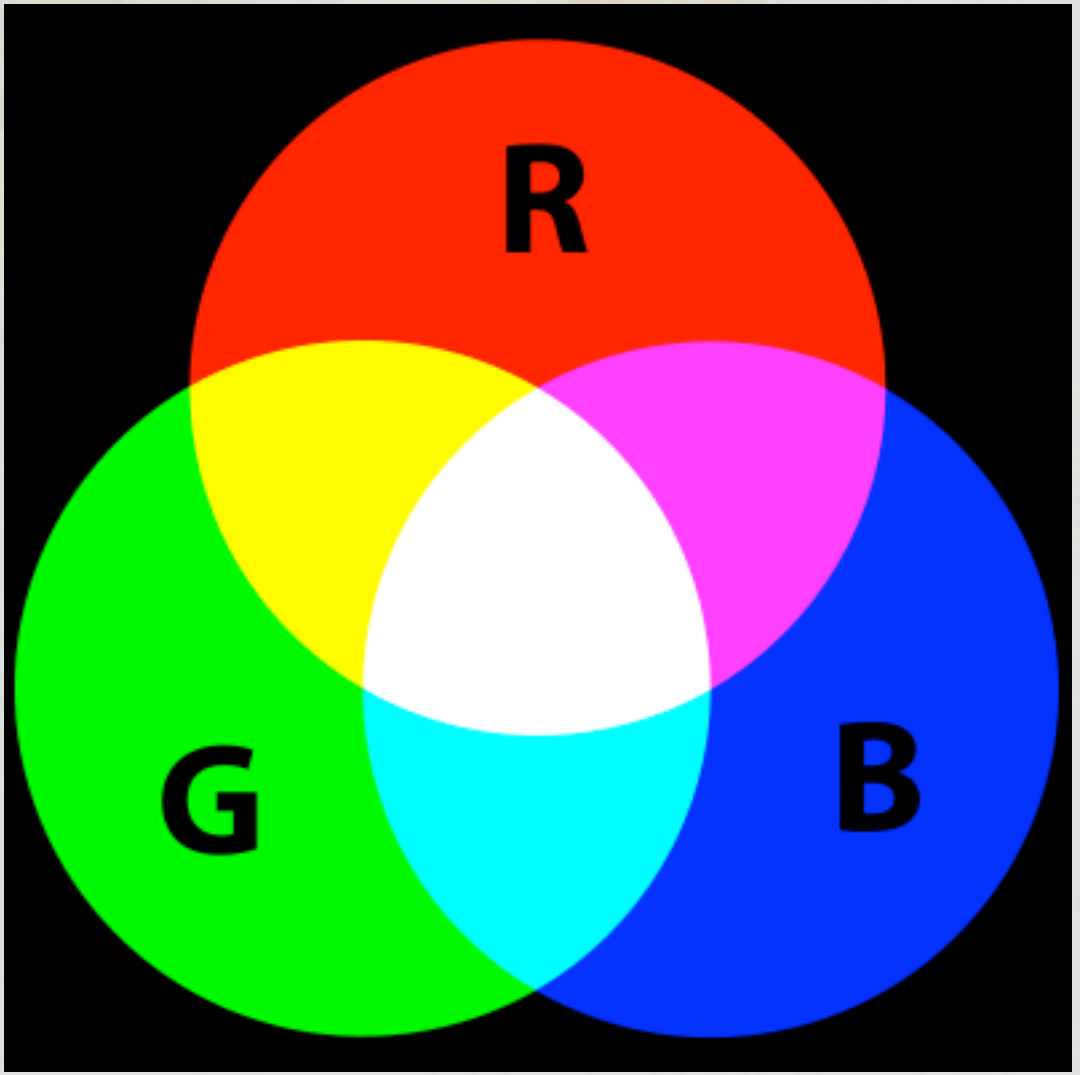
Color theory
Color temperature - cold and warm colors



Georges Seurat. (French, 1859-1891). Evening, Honfleur. 1886.

Additive or optic color mixing (eye)

The most common form of additive color mixing starts with black and then adding of three basic colors - usually Red (R) Green (G) and Blue (B)



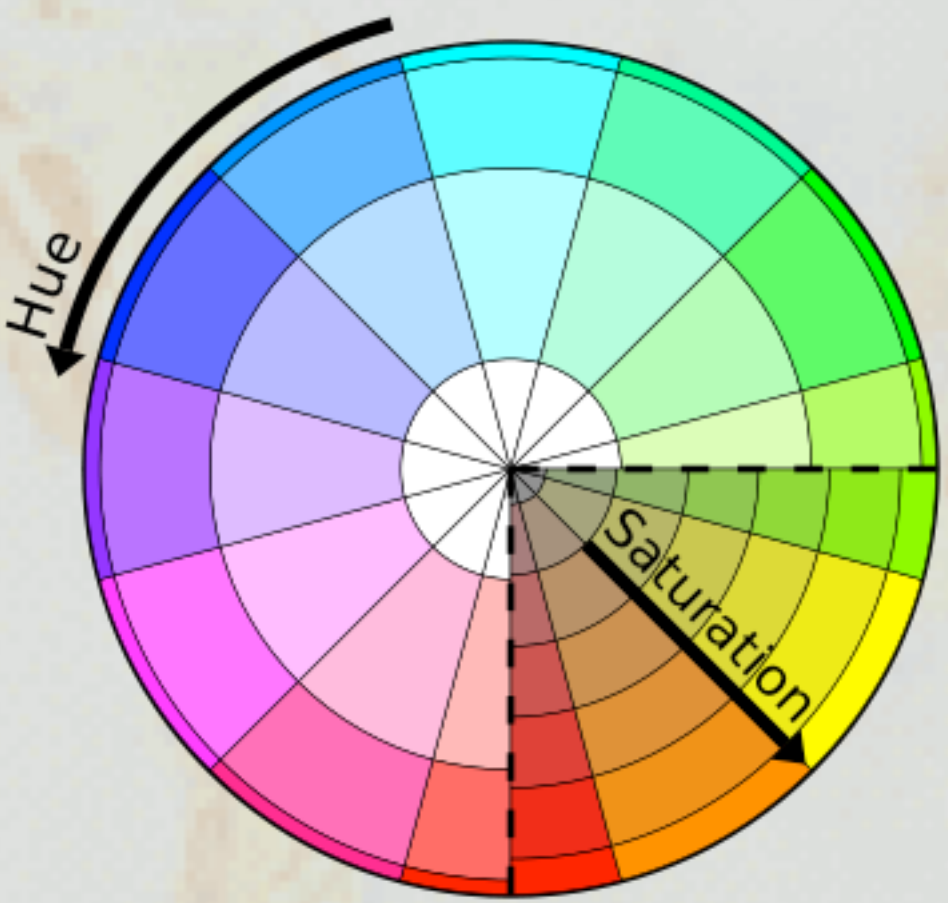
Subtractive color mixing (printing)

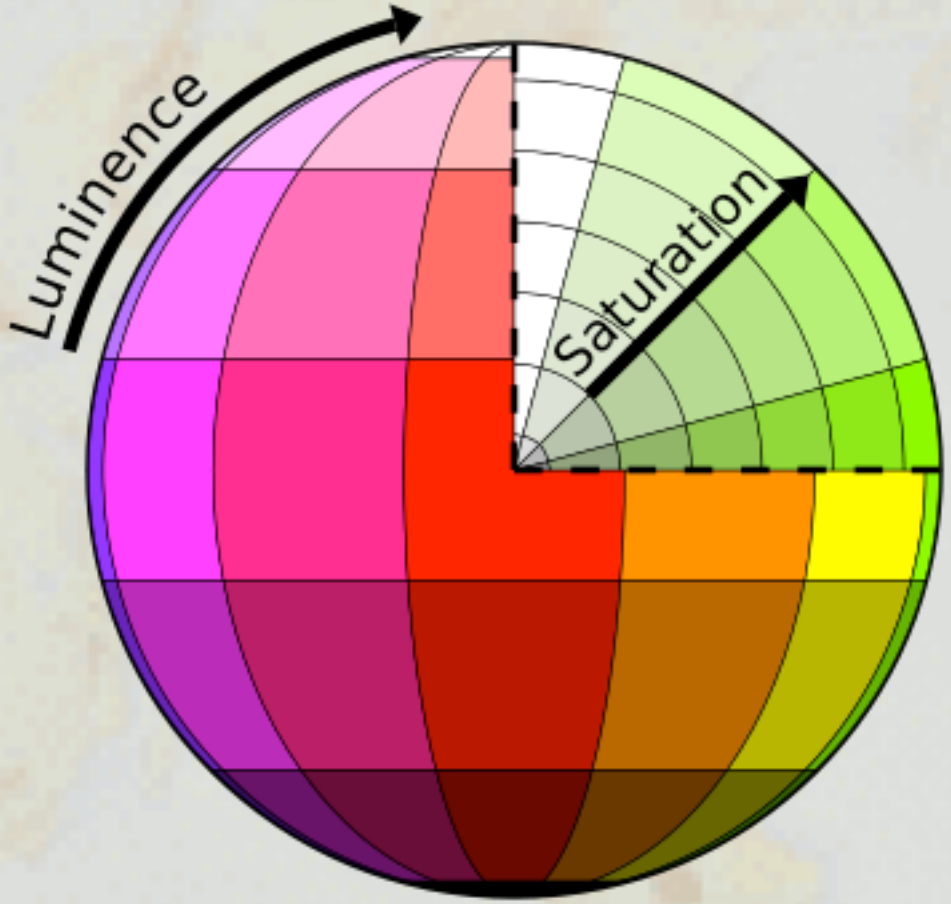
Subtractiv color mixing is a filtering of ligth, either using av reflective media, for example paper, or an optical filter, for example a beamer.

Subtractive color mixing starts with white light (all wavelengths) and the colors are filtered away.

Translating between additive and subtractive color mixing is not straight forward.

Color theory





An extension of the color wheel: the color sphere. Colors nearest the center or the poles are most achromatic. Colors of the same lightness and saturation are of the same nuance. Colors of the same hue and saturation, but of different lightness, are said to be tints and shades. Colors of the same hue and lightness, but of varying saturation, are called tones.

charles blanc etoile des couleurs 1867

Perceptual characteristics of graphical variables

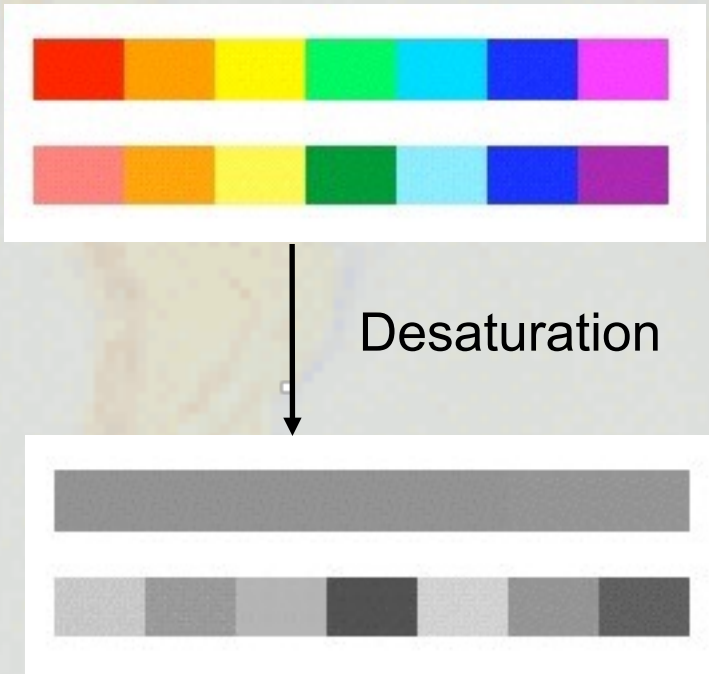
Lightness / grey value

Differences in distance (equal differences between grey values) or in quality.

Perceptual characteristics of graphical variables

Colour hue

Differences in quality, but only with colours with the same lightness value!



Different colours (hues) with the same lightness

Same colours (hues) as above, but with different lightnesses

Desaturation

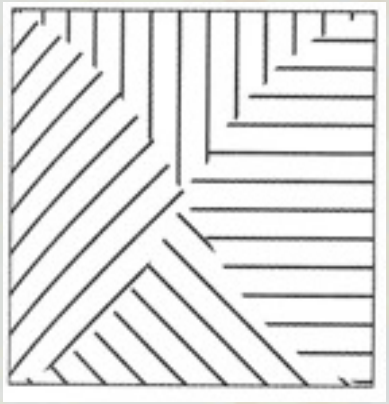
Same lightness

Different lightnesses

Perceptual characteristics of graphical variables

Orientation

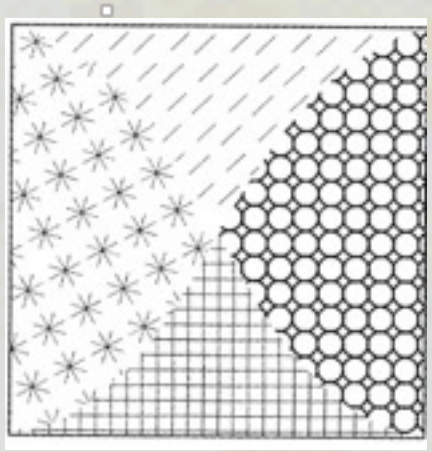
Refers to patterns (line or dot patterns) and NOT to the orientation of line symbols!



Perceptual characteristics of graphical variables

Shape

Refers to shape of dots and lines used in patterns that represent areas and NOT to the shape of the area that the symbols refer to!



The use of colour – distinguishing nominal categories

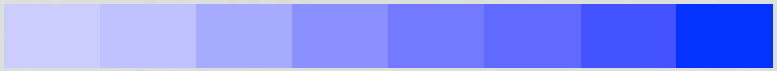
Differentiating aspects of colour in a map

Hue: dominant wavelength

Saturation: percentage of the reflection of light of a specific wavelength from an object

100%

Lightness / grey value: the grey impression the colour would made when displayed on a black&white screen



Desaturation

The number of distinguishable grey values depends on hue:

Blue: 7-8

Yellow: 3-4

The lightness scale is the same for both colours. Only the hue is different.

For mapping purposes: we can obtain a scale with more categories by combining the grey value scale with the saturation scale:

Lightness / grey value scale

Saturation scale

Grey value + saturation scale

3 additional graphic variables

Arrangement: regularity/non-regularity of distribution of symbols

Focus: clarity with which the symbols are visible

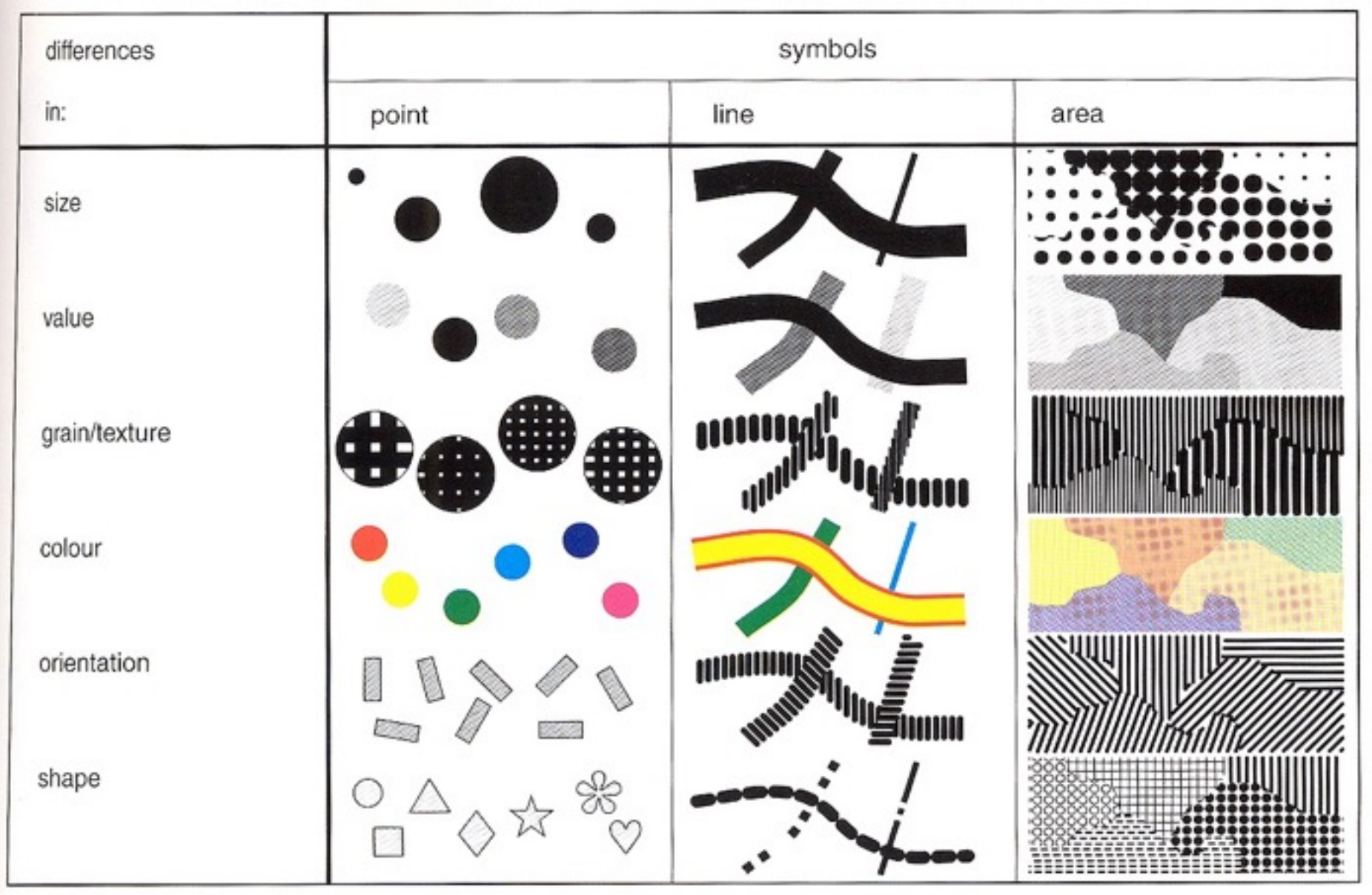
Colour saturation (chroma): percentage of the reflection of light of a specific wavelength from an object (the higher the percentage, the more brilliant the colour).

Changing lightness / grey value

100%

Changing saturation

Visual graphic variables - summary



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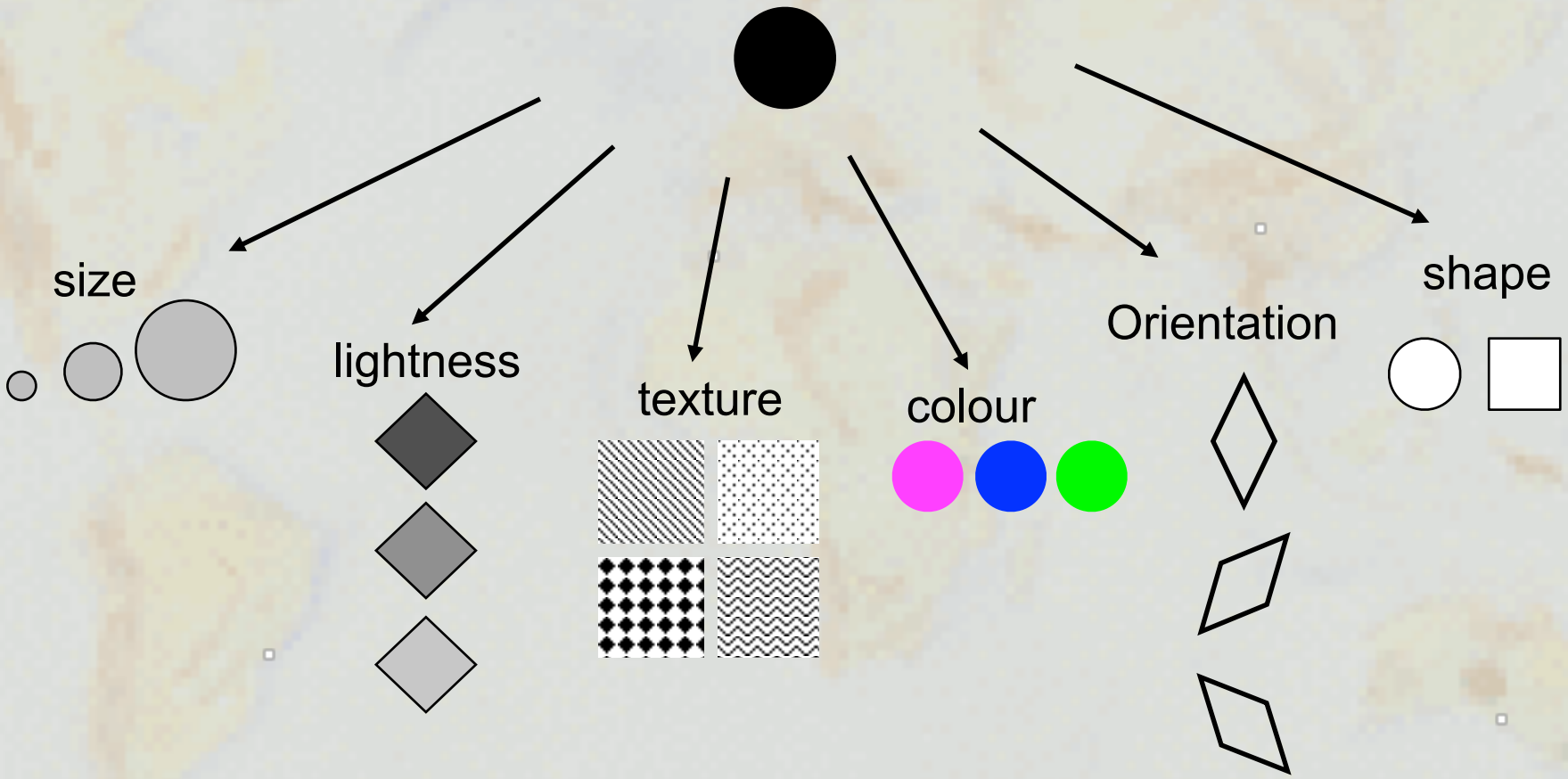
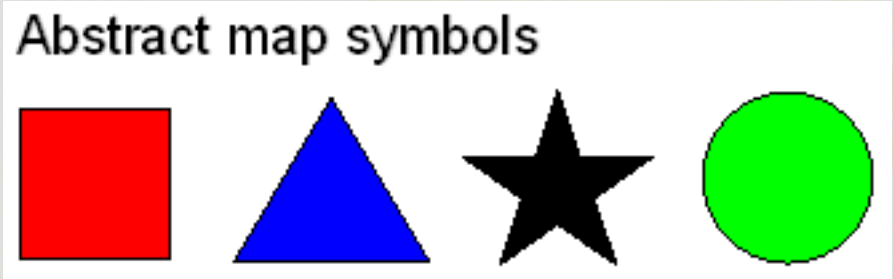
Nile River

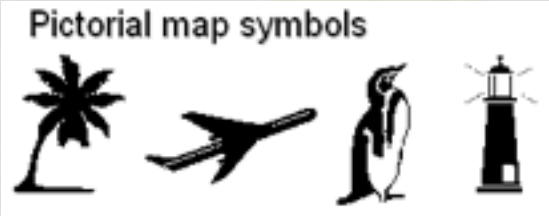
In a GIS these elements are represented in different data layers.
In analogue map production they are often represented by different layers in the printing process.

Point symbols

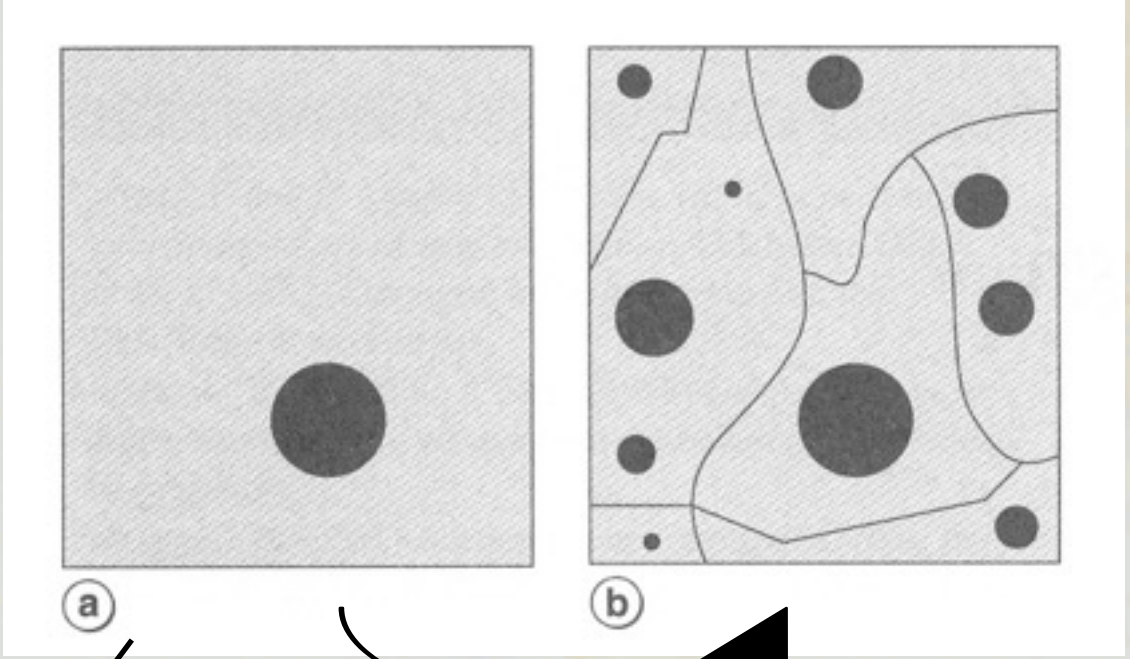


Point symbols





Point symbols



Dark circle on a light grey background – not much information.

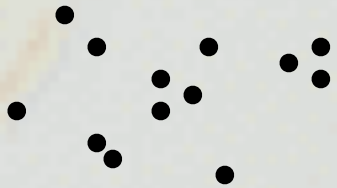
Add a legend: circle = 500000 workers in a car factory.
Still not much information. Would be better to use numerical form.

Put the symbol in a geographical context – variation in graphical cues.

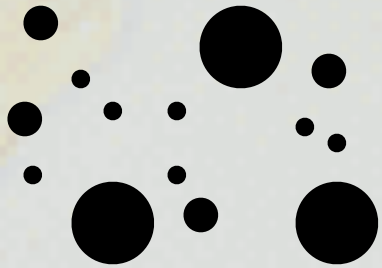
We perceive geospatial information:
- distribution (symbol location)
- hierarchy (symbol size)
- pattern (comparison between symbols)

Dots:

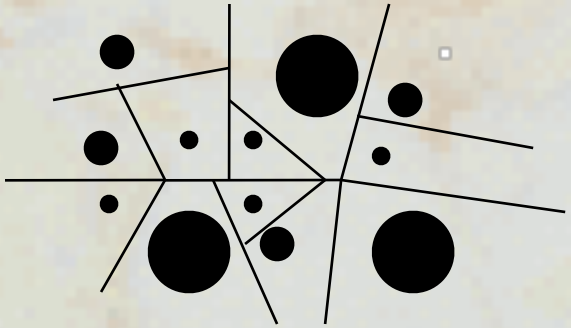
- equal-sized dots: each dot represents the same value, they refer to their locations



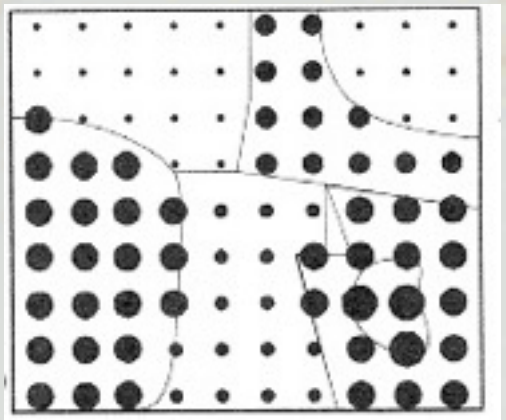
- different-sized dots: dots represent different quantities for each specific dot location



- proportionally-sized dots + boundaries: dots refer to areas, they are area symbols, do not refer to explicite locations, but to areas



- dots in a grid: render area data, grid is superimposed over an area

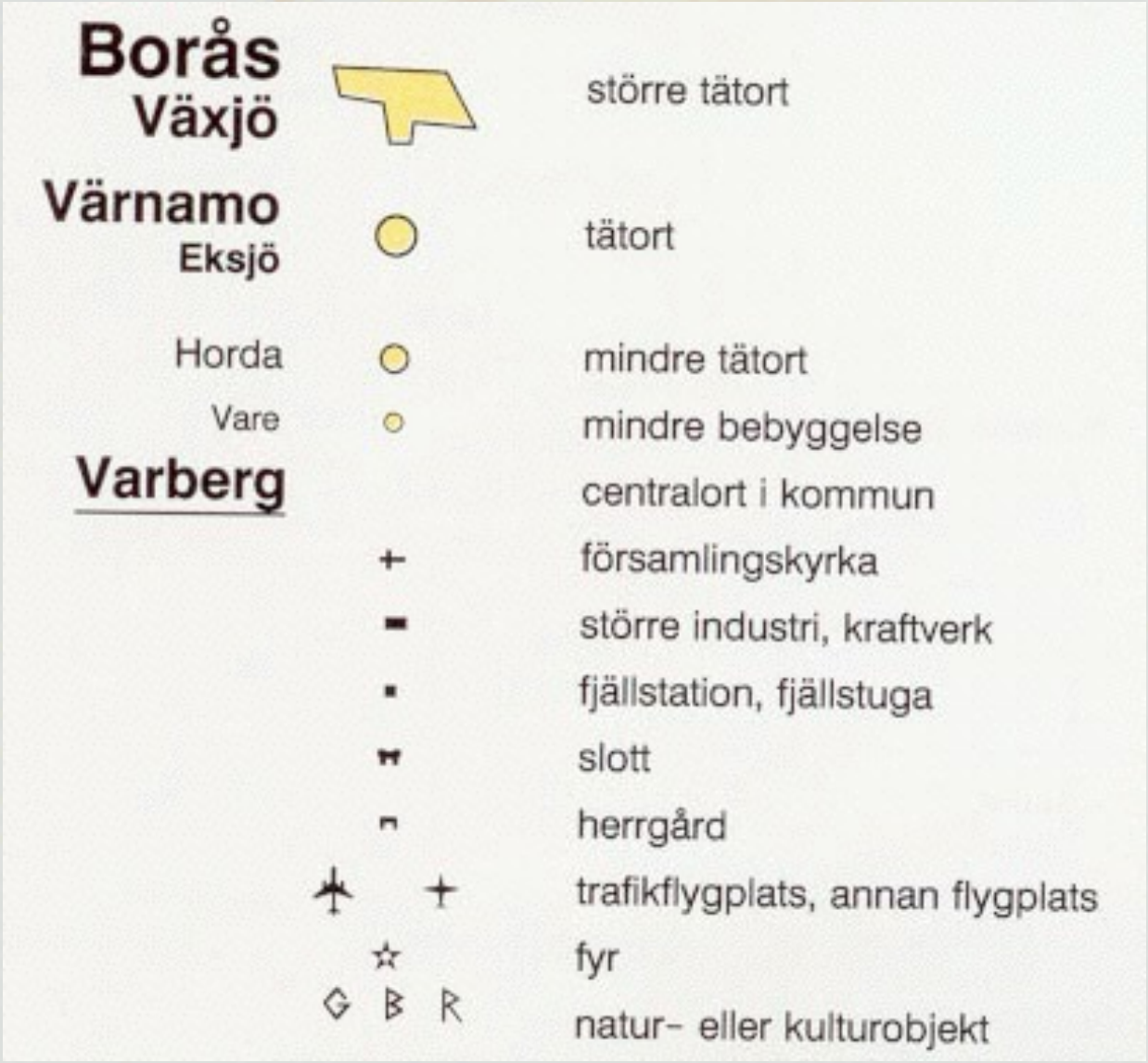


Example: Point symbol

Point symbols in the Swedish National Atlas

Used variables

- Size
- Color/hue
- Shape



Point symbol visualisation

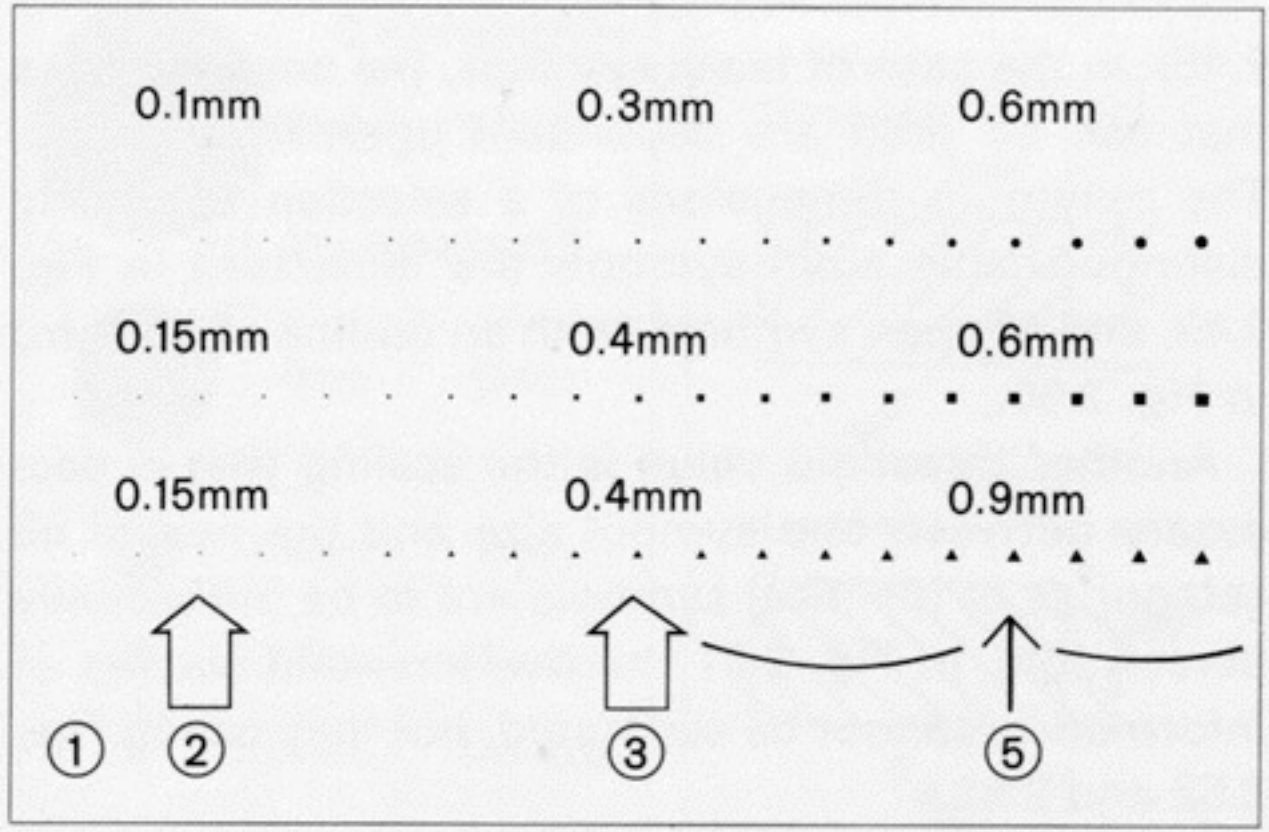


Fig. 2.40 The perception of point symbols (2), and the differentiation of their shapes (3)

Point symbol visualisation

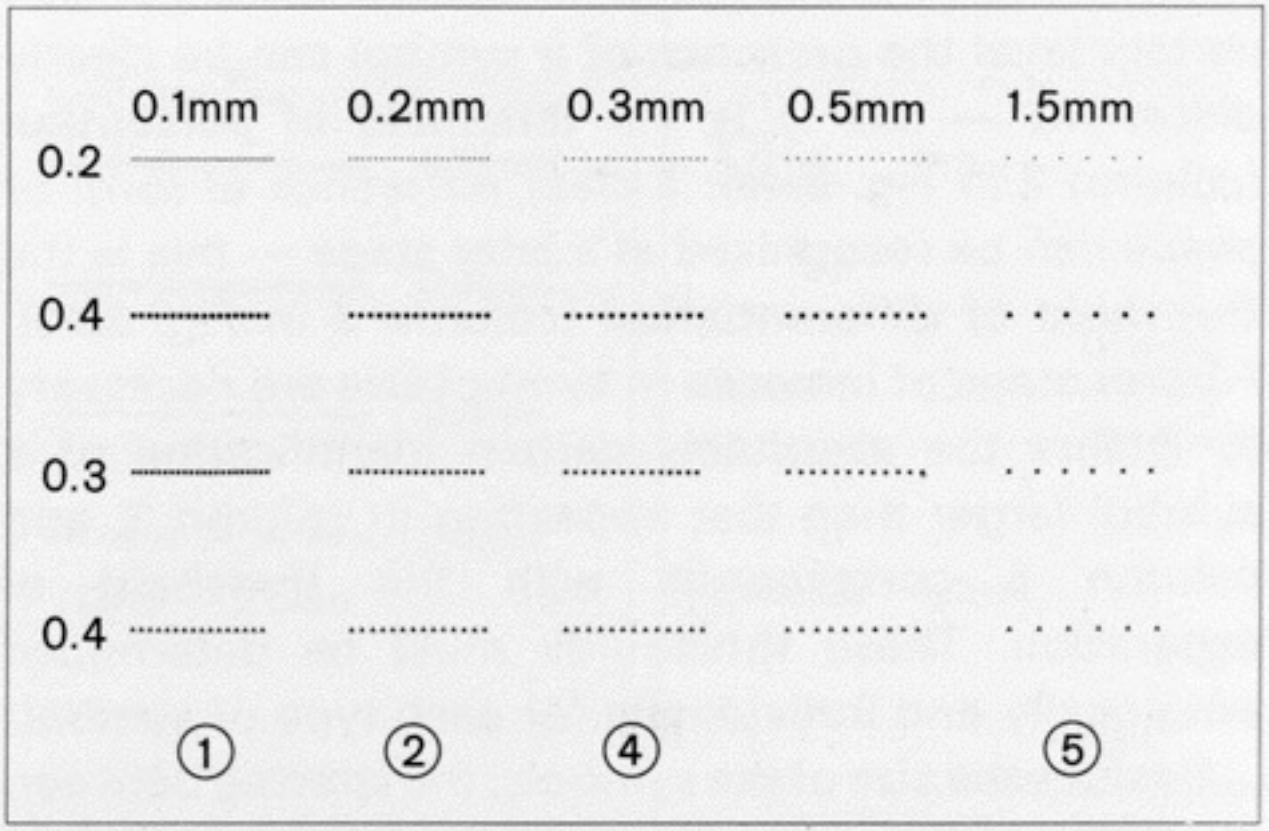
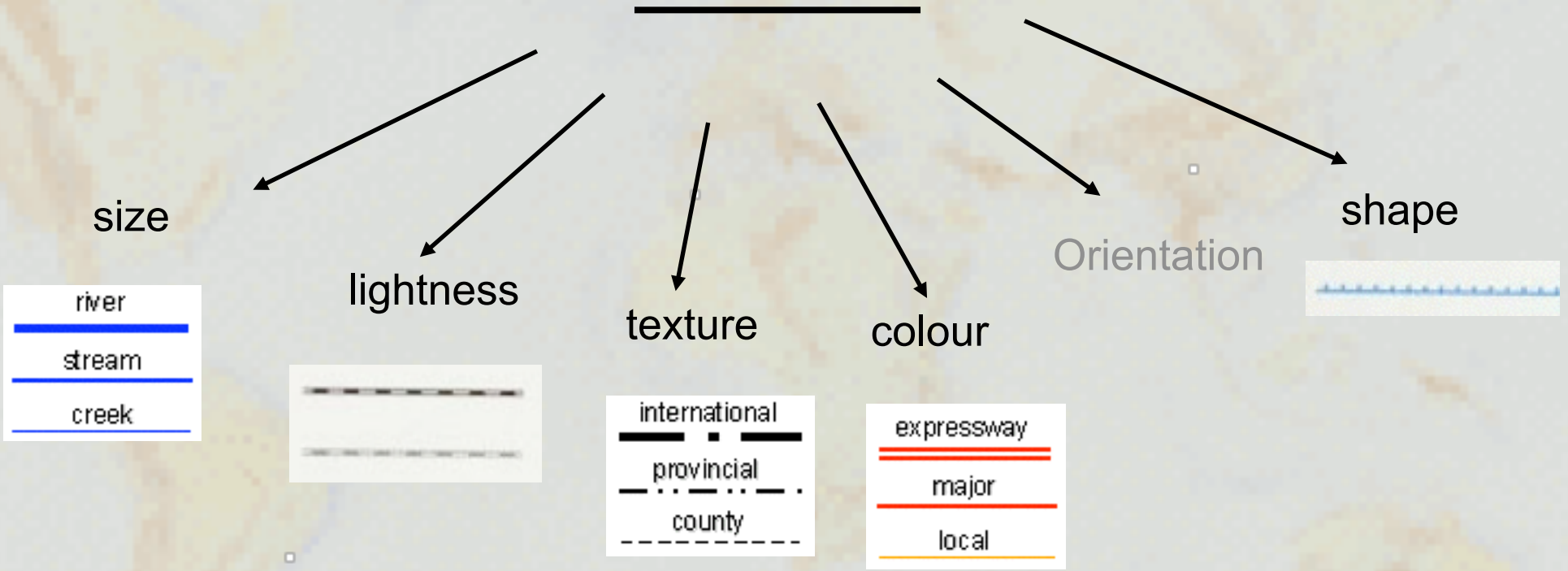


Fig. 2.41 Threshold of separation between point symbols: (1) too little, (2) recommended, (5) too great

Example: thematic map with point symbols

Figure 5. Kazakstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan: Industrial Activity, 1996

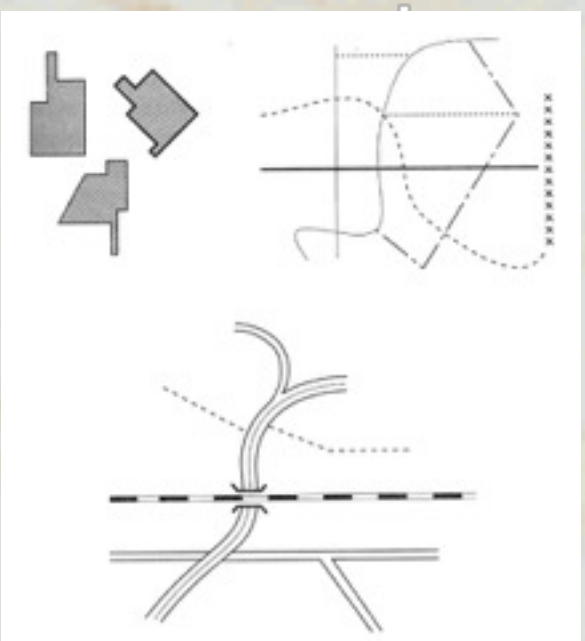
Example: Line symbol



Example: Line symbol

Dashes (texture):

- representing line data: boundaries, roads, railways, flow lines

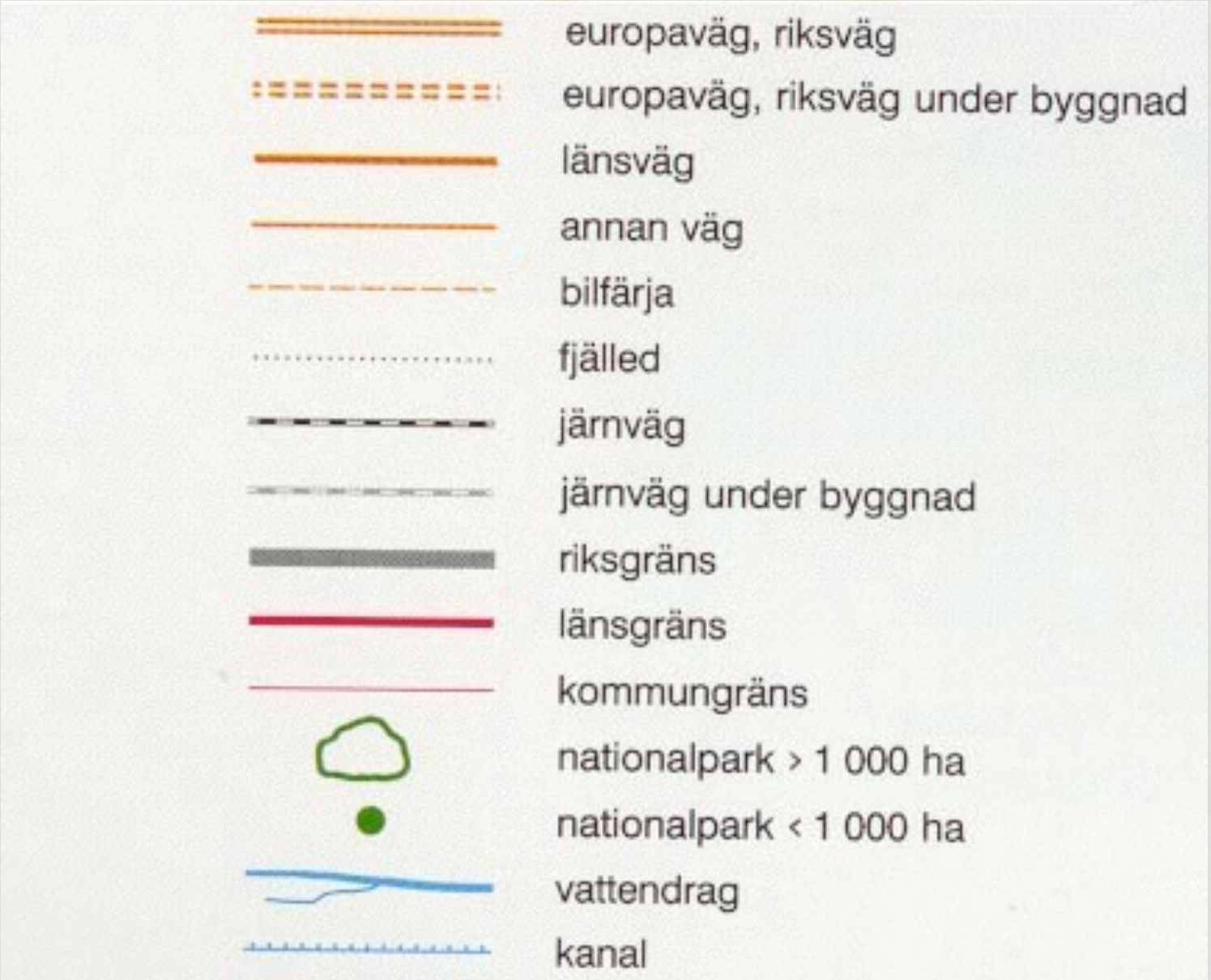


Example: Line symbol

Line symbols in the Swedish National Atlas

Variables used

- Size
- Lightness
- Grain
- Color
- Orientation
- Shape



Line symbol visualisation

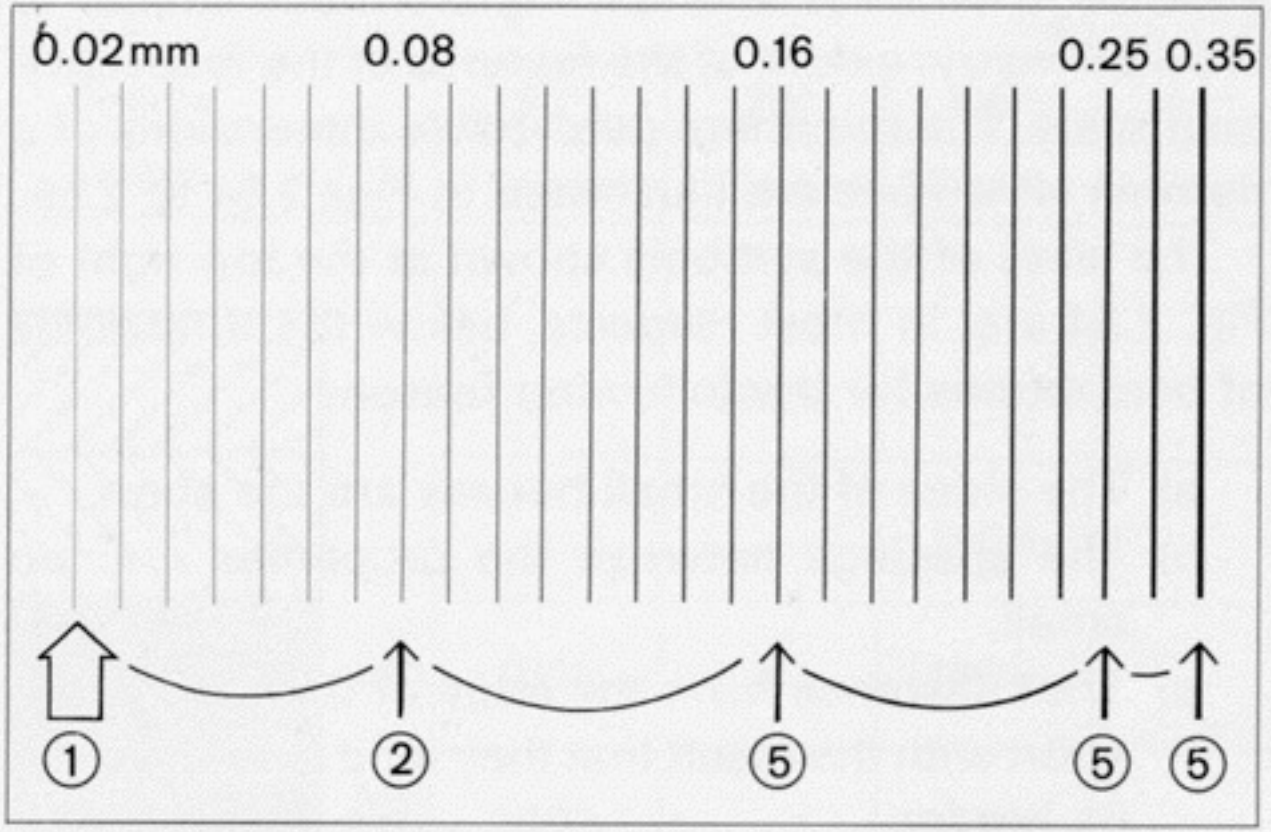


Fig. 2.42 Line symbols: (1) line perceptible, (5) widths sufficiently different to be distinguishable

Line symbol visualisation

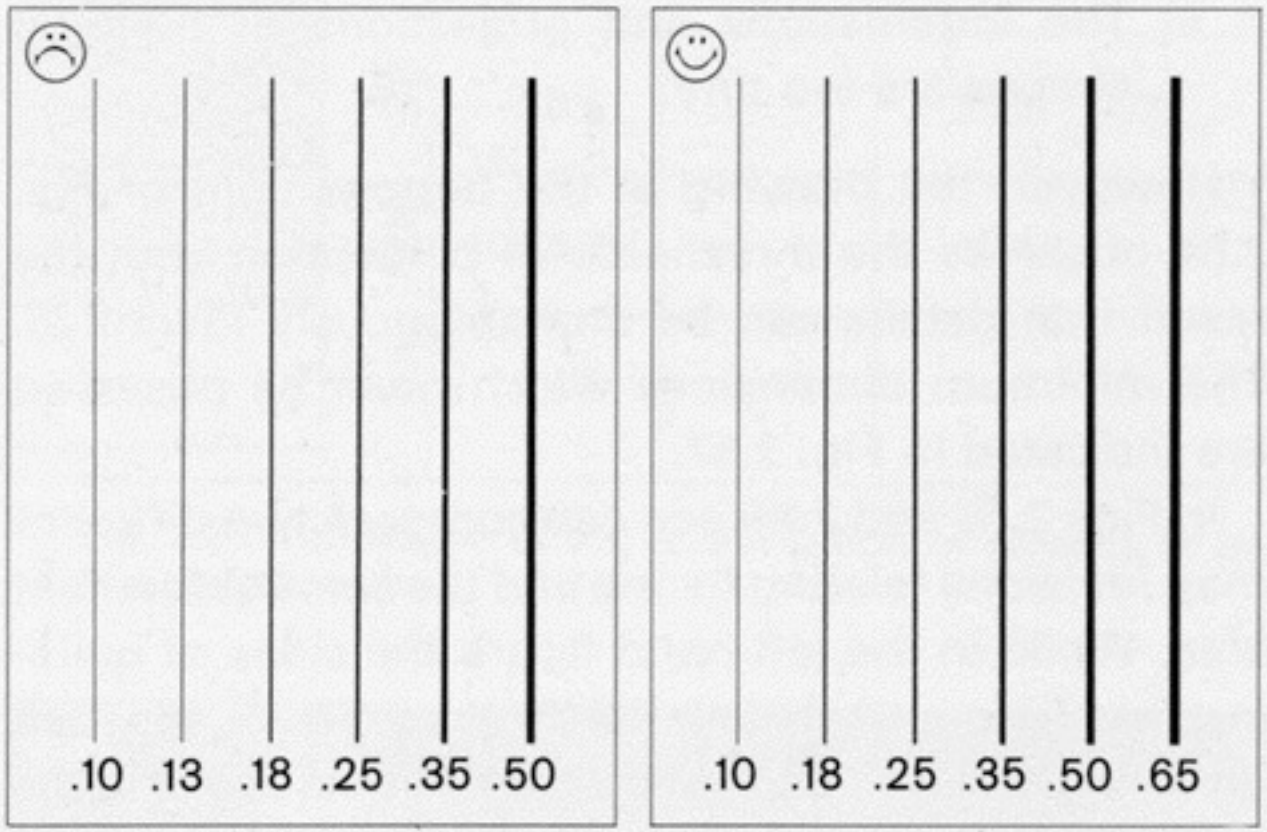


Fig. 2.44 Line width separation too small (left); Good line width separation (right)

Line symbol visualisation

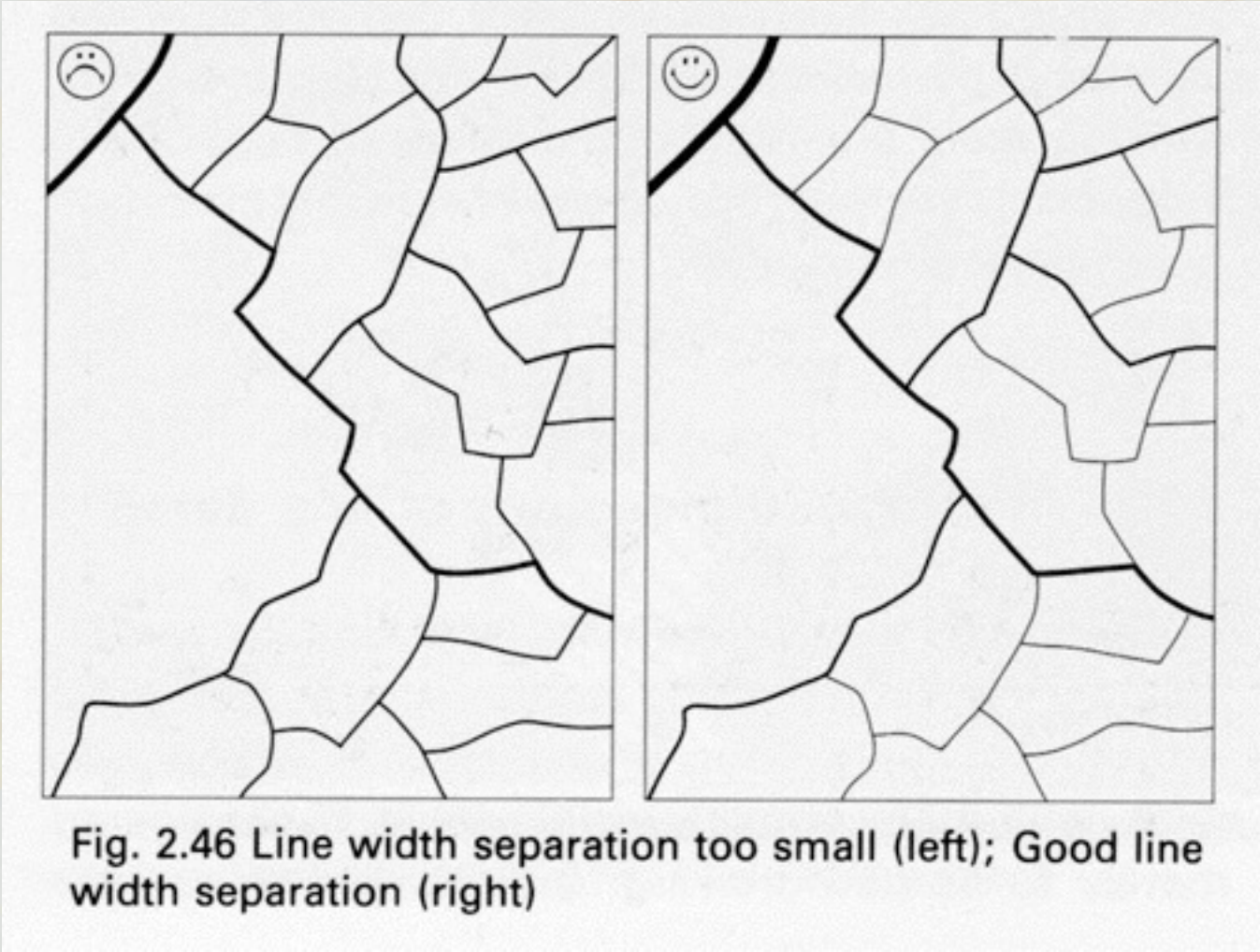


Fig. 2.46 Line width separation too small (left); Good line width separation (right)

Line symbol visualisation

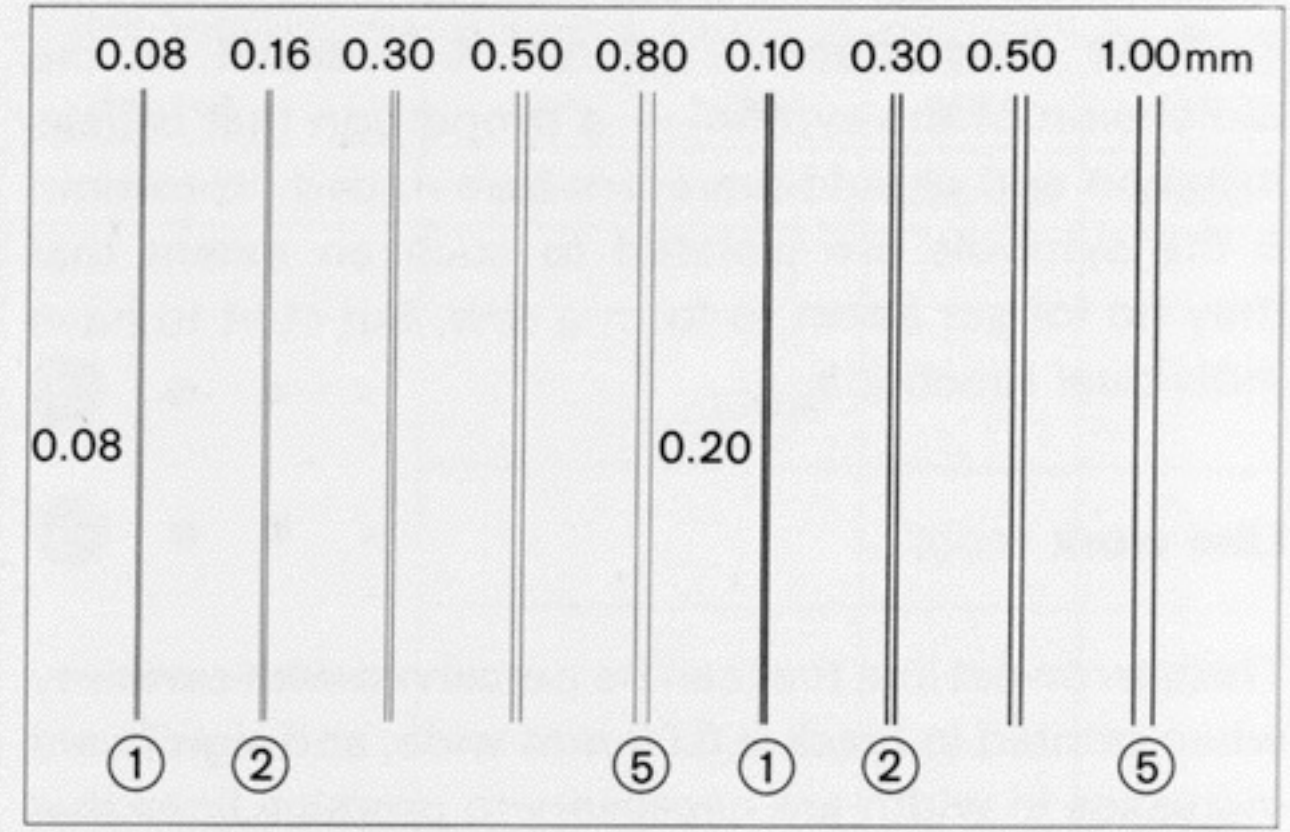


Fig. 2.43 Double lines: (1) spacing too small, (2) minimum spacing, (5) spacing too wide

Line symbol visualisation

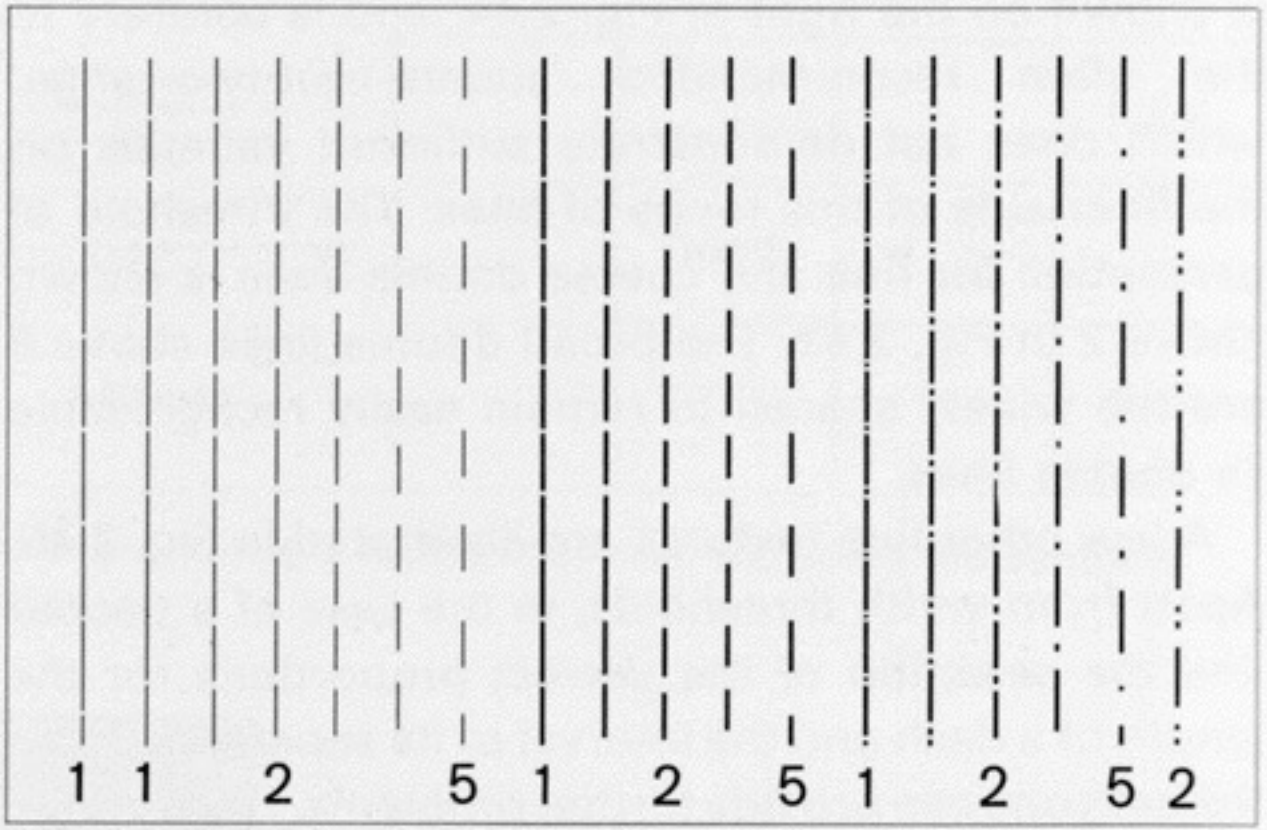


Fig. 2.45 Pecked lines with too small an interval between solid elements (1), recommended (2), too large an interval (5)

Line symbol visualisation

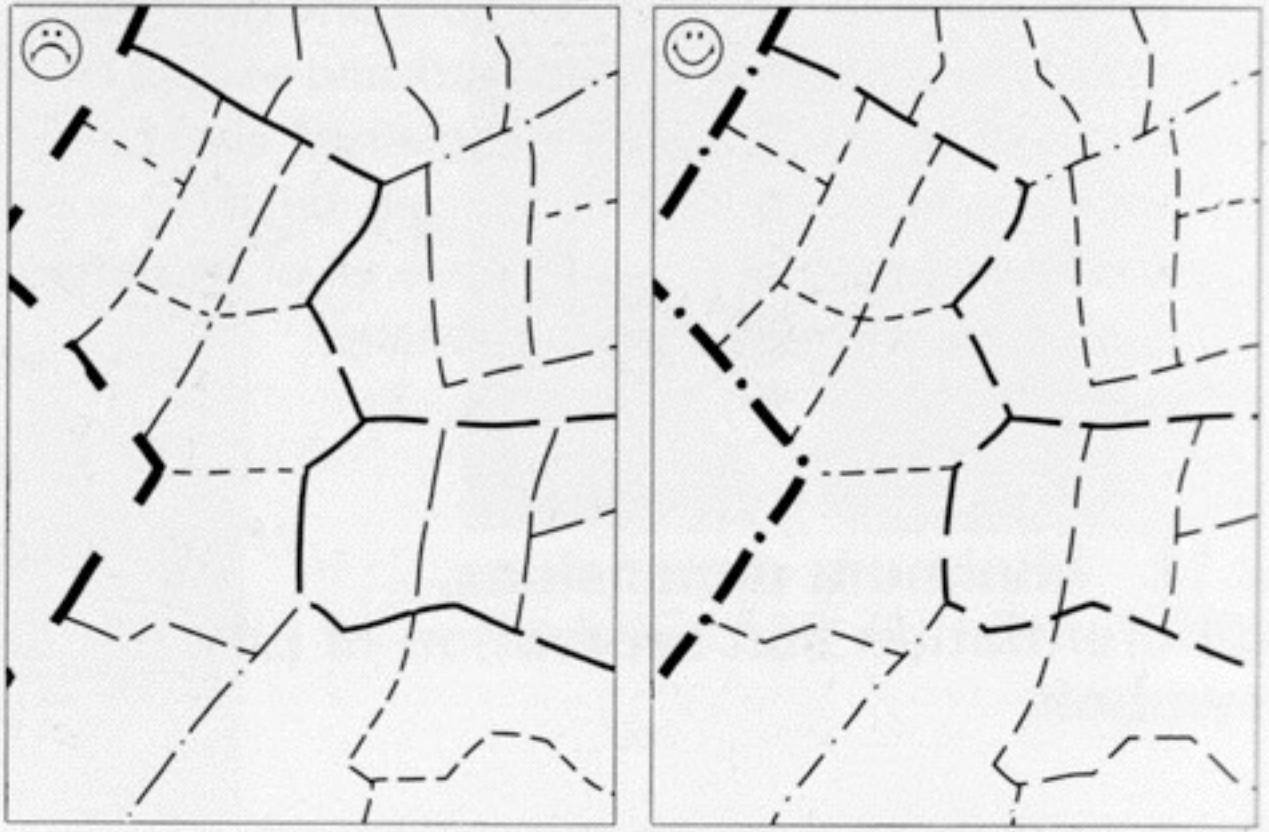
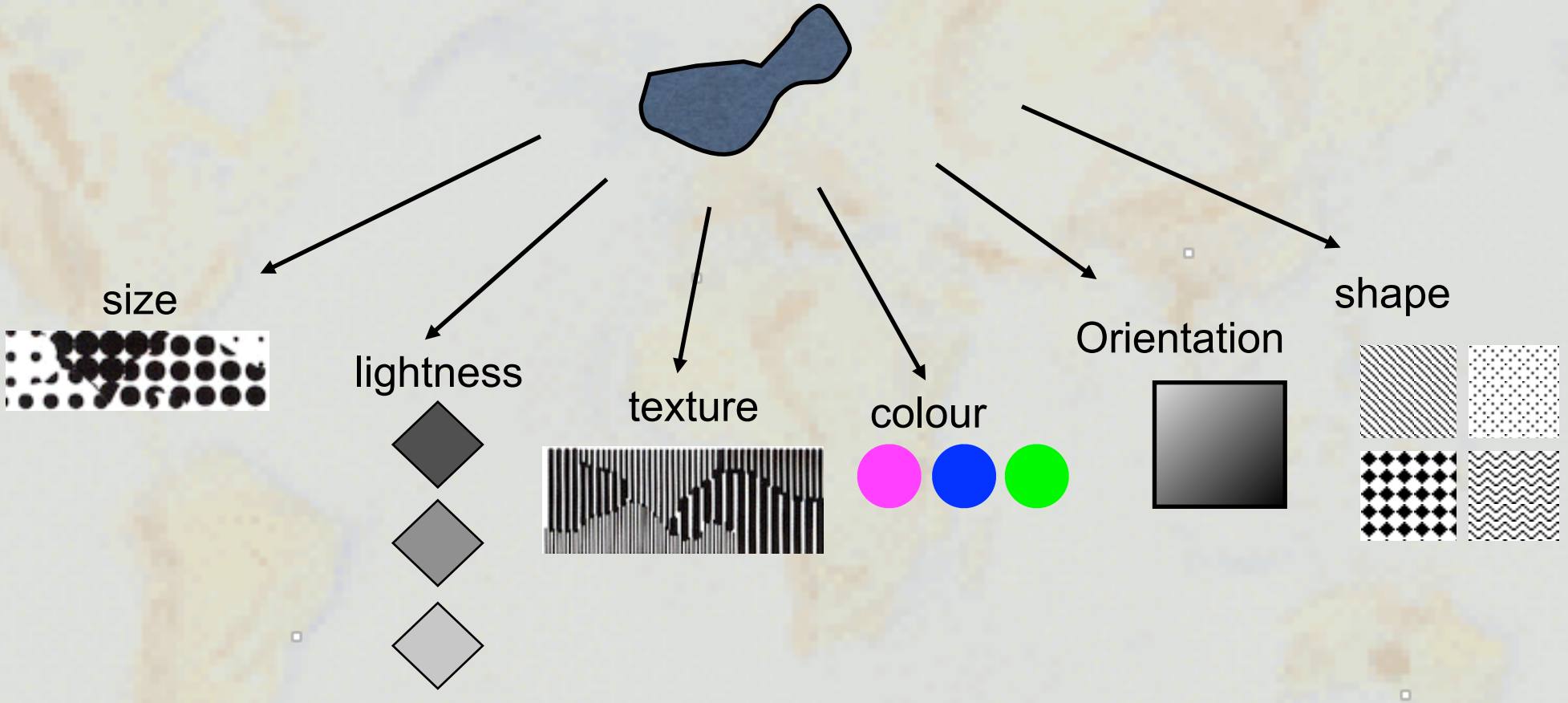


Fig. 2.47 Poorly proportioned line work (left); Well proportioned line work (right)

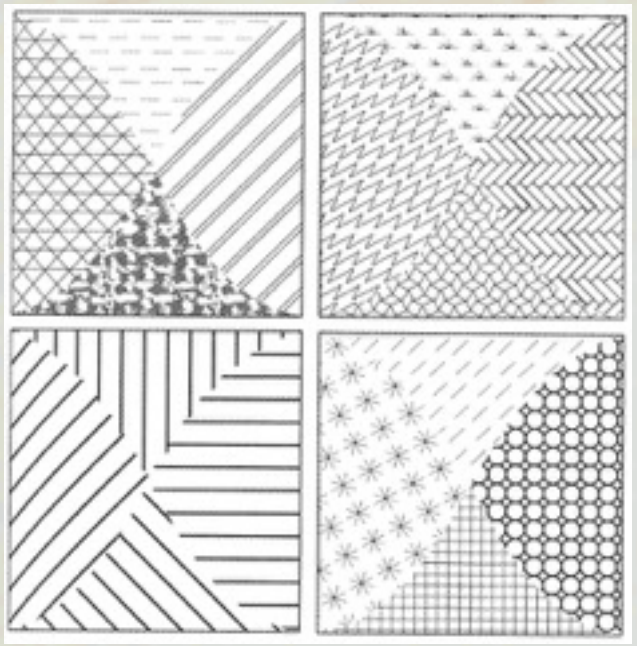
Example: thematic map with line symbols

Example: Surface symbol



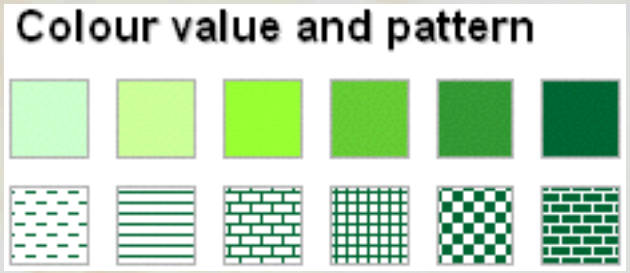
Surface symbol visualisation

- Texture in surface maps: combined into patterns, must NOT be perceived as individual lines (same for dots if they combined into patterns)

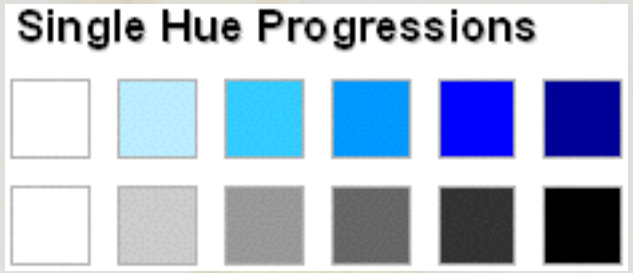


Non-homogeneous patterns are used to indicate volumes – hill shading:

Surface symbol visualisation

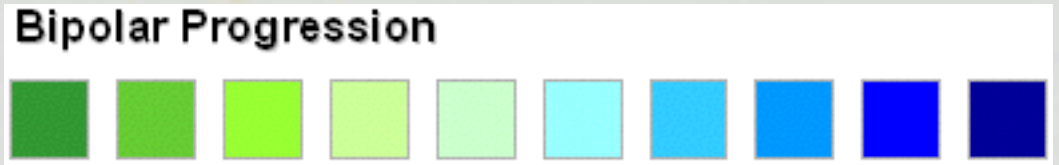


Area symbology depicting interval and ratio data can use variations in colour value and pattern to show a gradual progression of data values.



Colour progressions in a single hue have data values increasing as the colour value increases from white to the pure colour.

Partial hue spectral progressions blend one colour with another.



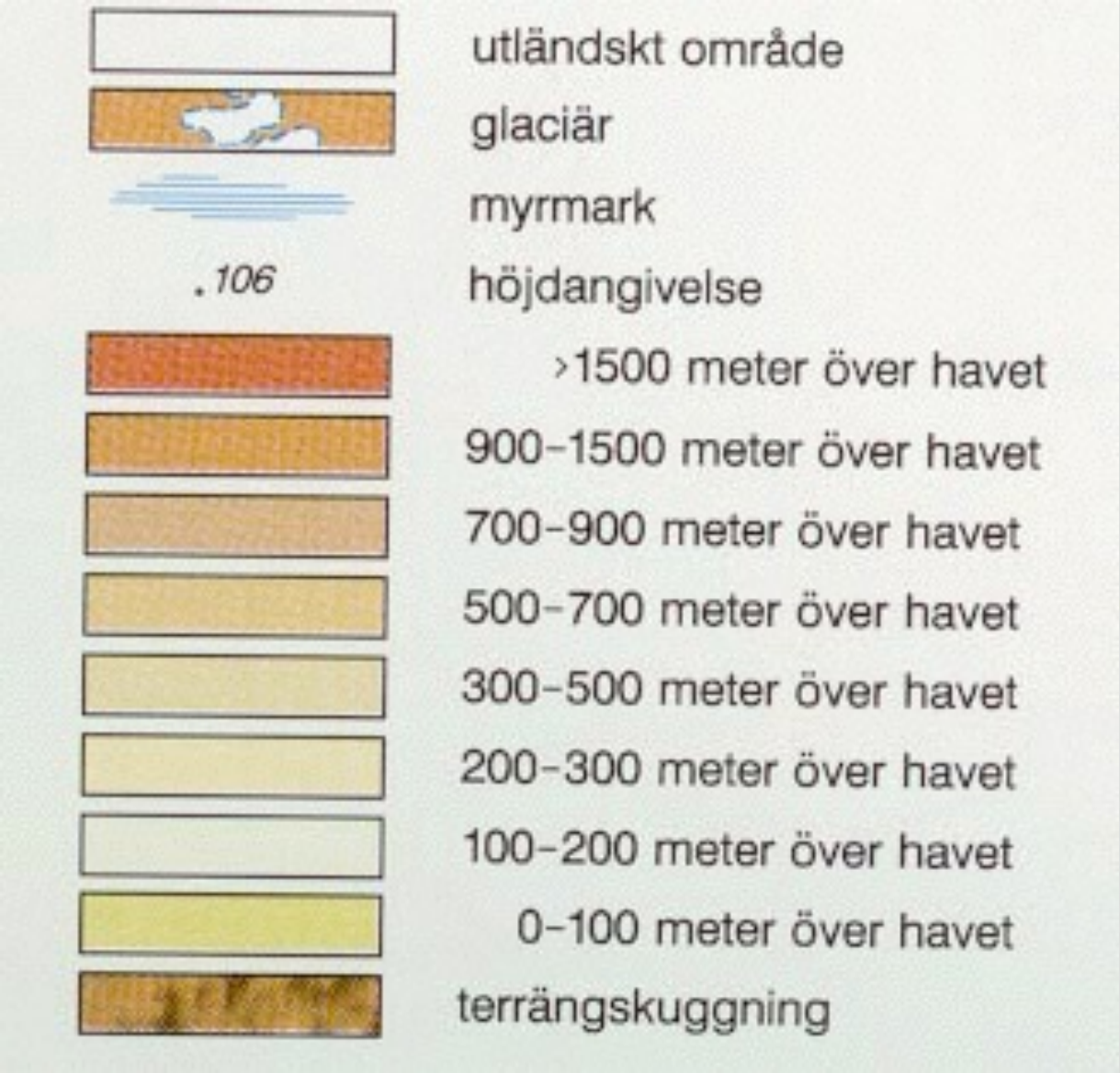
Bipolar progressions display data that range from positive to negative.

Example: Surface symbol

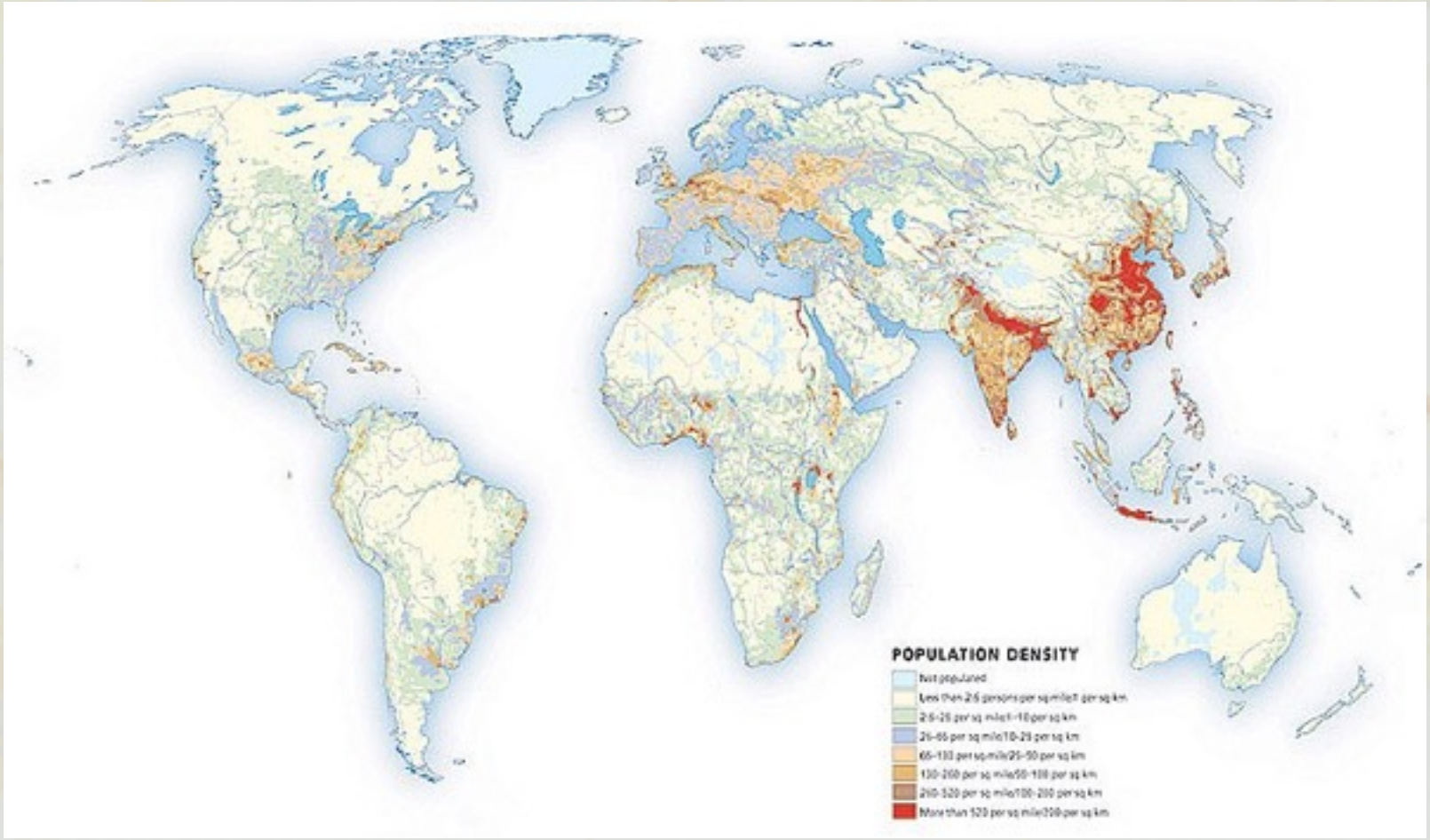
Surface symbols in the Swedish National Atlas

Variable used:

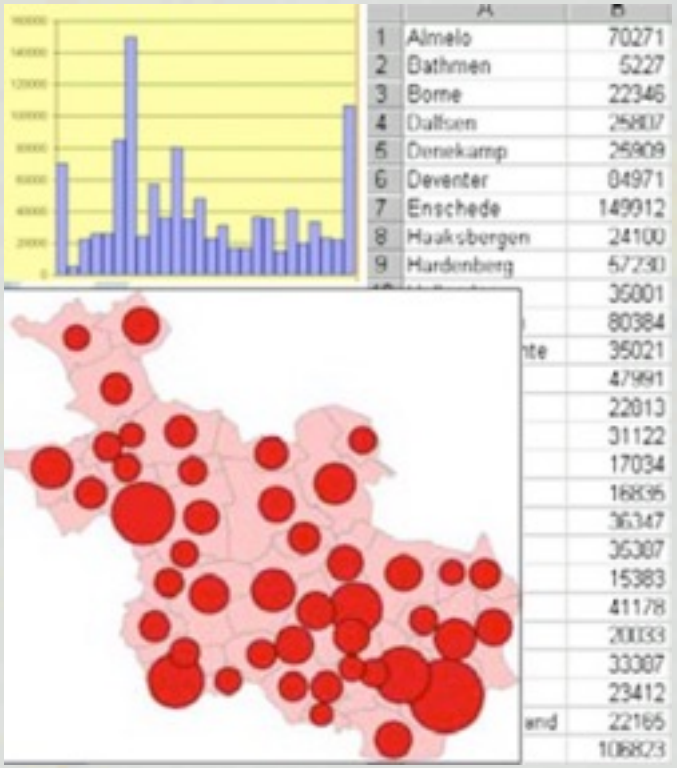
- Lightness
- Grain
- Color
- Orientation
- (Shape)



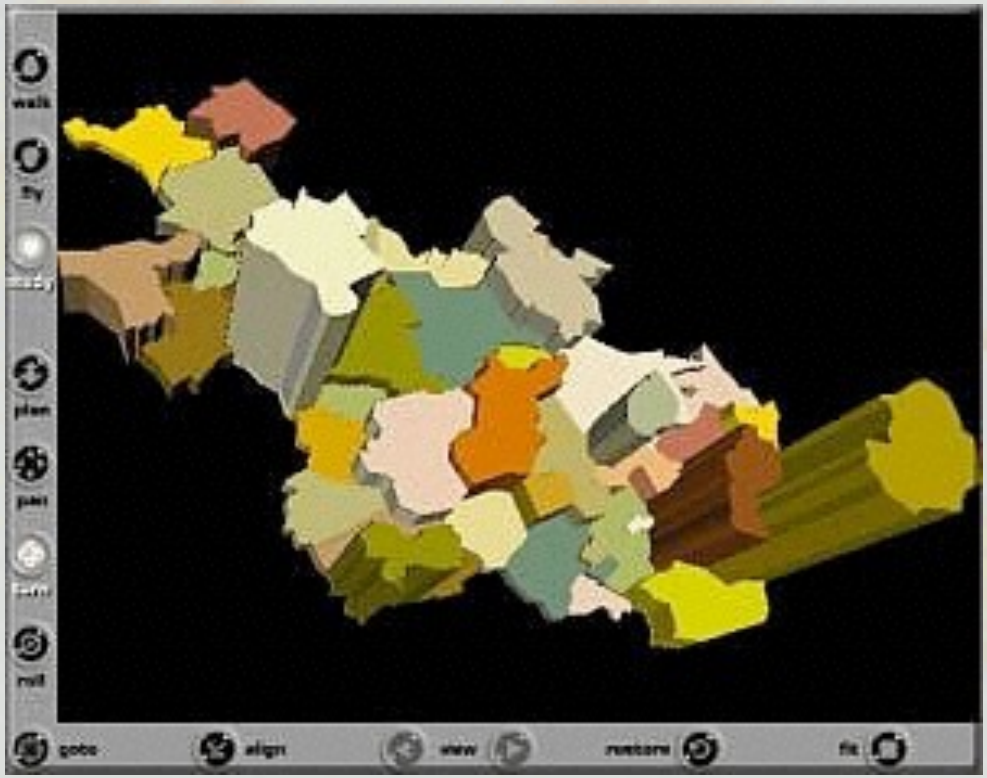
Example: thematic map with color symbols



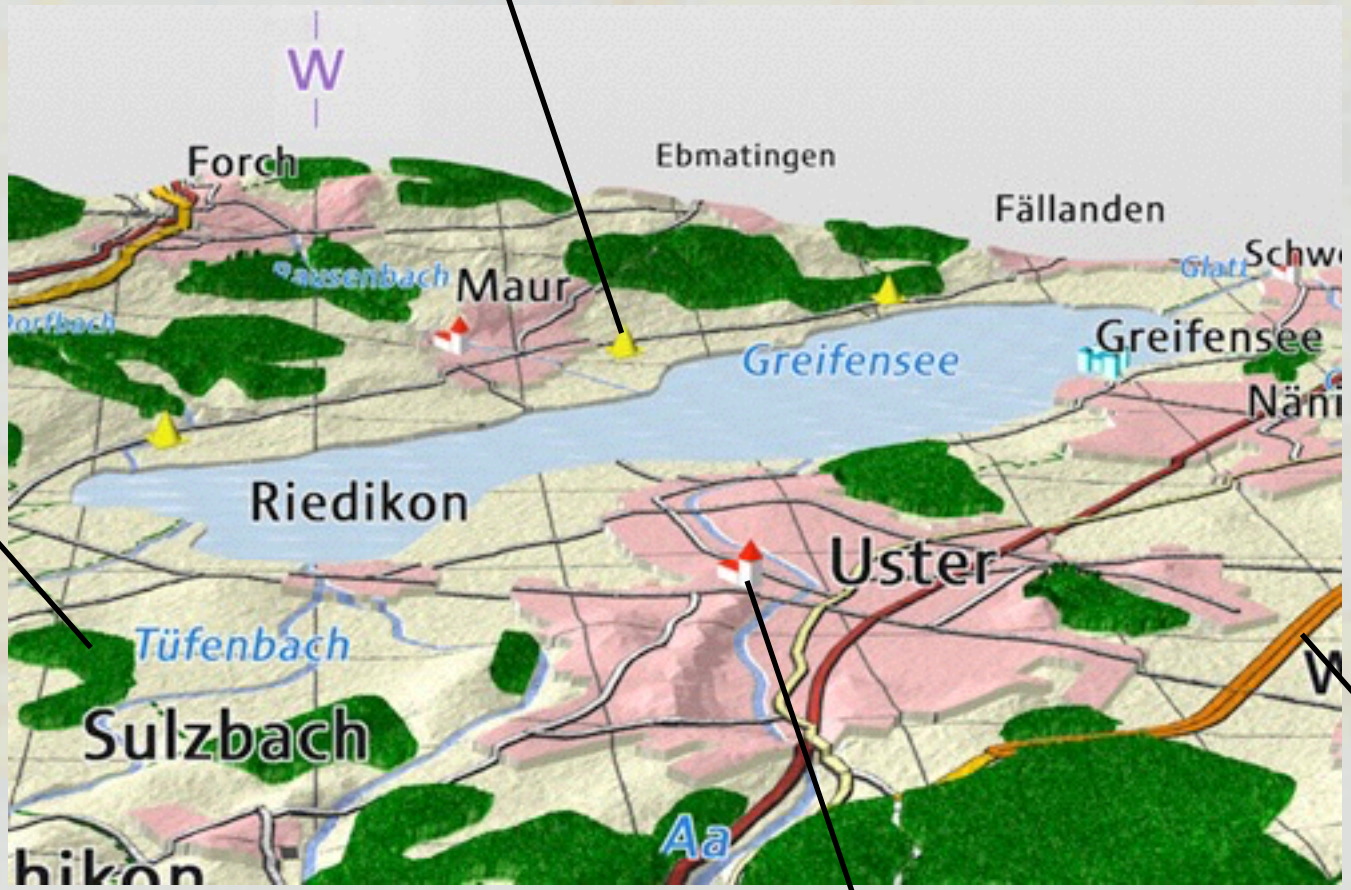
Example: 3D symbol



1	Almelo	70271
2	Bathmen	5227
3	Borne	22346
4	Dalfsen	26807
5	Denekamp	26909
6	Deventer	84971
7	Enschede	149912
8	Haaksbergen	24100
9	Hardenberg	57230
		36001
		80384
	nte	35021
		47991
		22013
		31122
		17034
		16835
		36347
		35307
		15383
		41178
		20033
		33307
		23412
	end	22165
		1068823



Example: 3D symbol



Text symbols

Text in cartography – conceptual and design aspects

Text within the map frame (NOT additional info on the margin!)

Primary function:
provide geospatial address
(naming various map objects)

Geographical names - toponyms

Secondary function:
indicate nature of
objects (’factory’,
’cemetery’, ’airfield’,...)

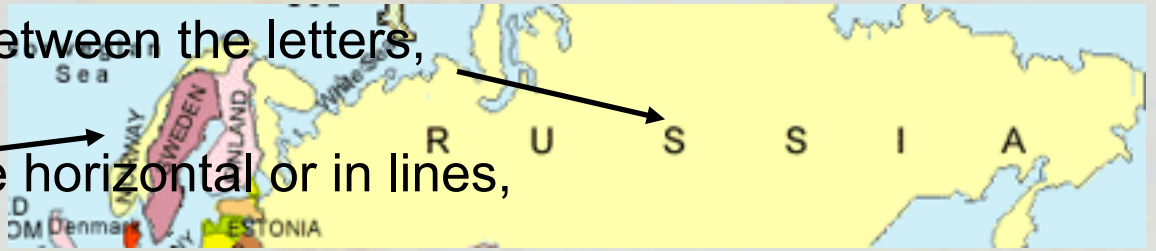
Characteristics of the text on the map:

- individual words instead of sentences,

- unfamiliar words,

- l a r g e s p a c i n g between the letters,

- names do not have to be horizontal or in lines,



- different Styles and SIZES,

- words refer to symbols (not to each other),

- text superimposed over lines and patterns.

Extra requirements for the text on the map:

- easy identification and legibility (even with large i n t e r s p a c e s),

- lettering styles should be differentiated by using boldness and size,

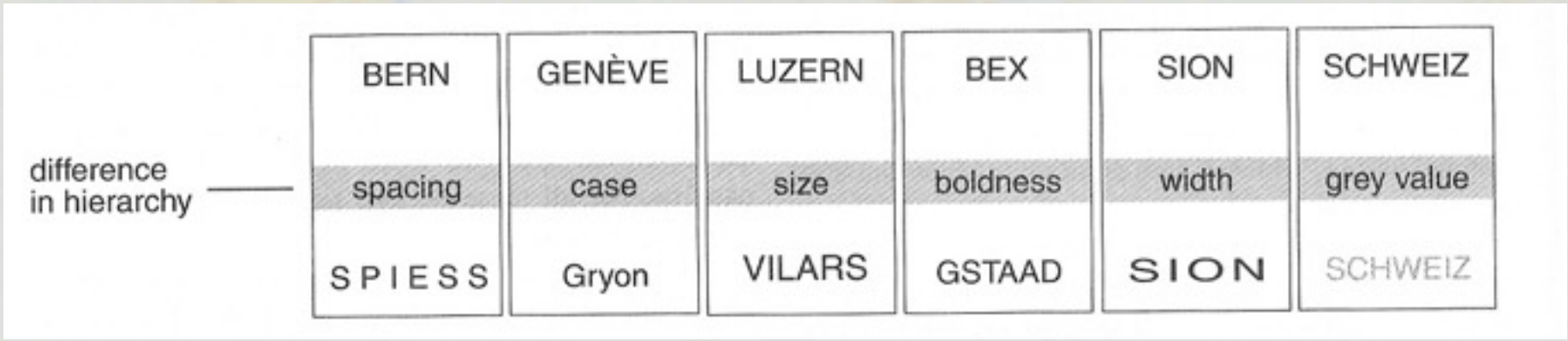
- ability to convey hierarchies (differentiating between more and less important objects),

- ability to show nominal differences between different data categories,

- ability to relate to point/line/area objects.

Hierarchy shown with variations in

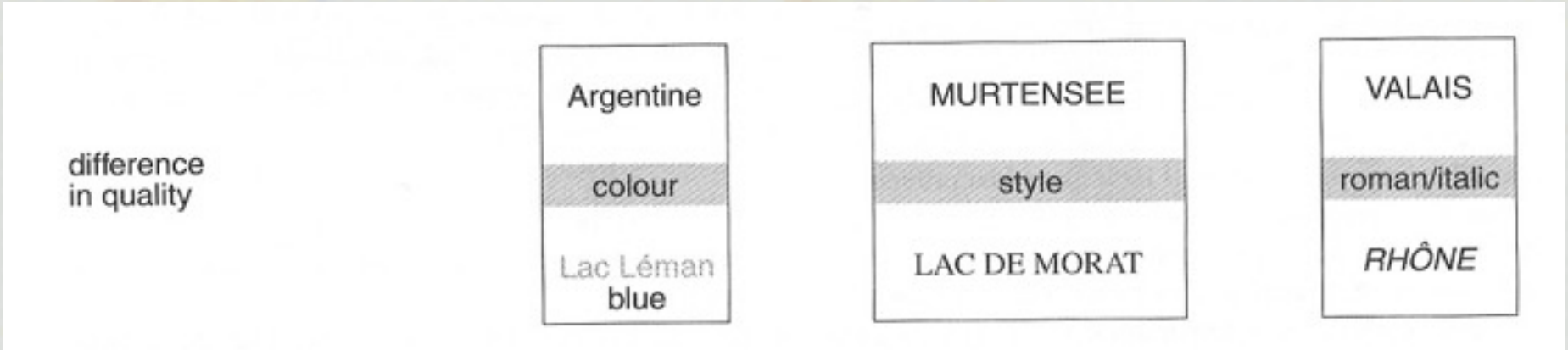
- boldness
- size
- Spacing
- colour
- lower and UPPER case



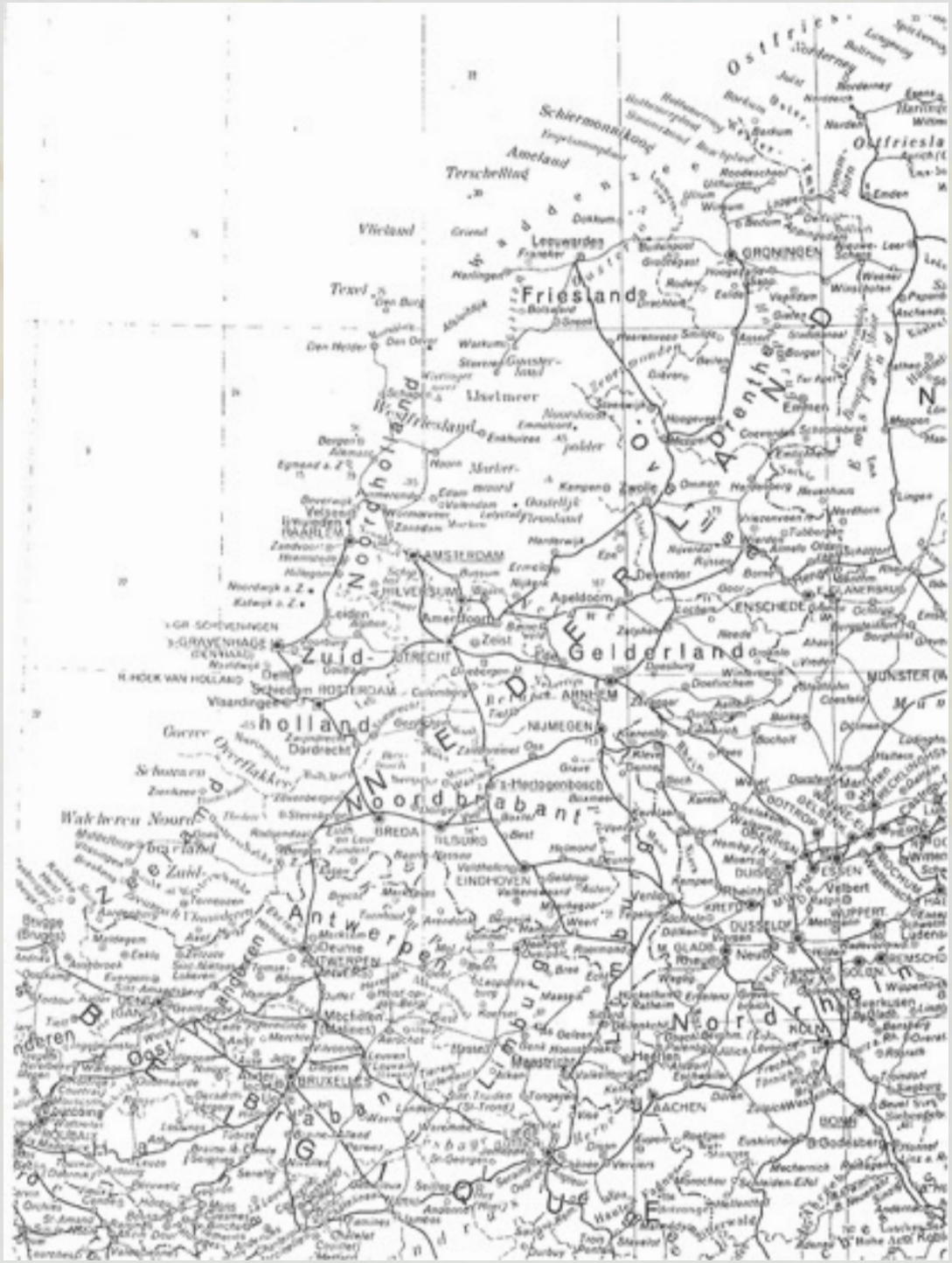
Nominal differences shown with variations in

- colour
- style
- Normal script / *italics*

Argentine Murtensee - Arial



Lac Leman Lac de Morat – Times New Roman



Visualisation using text

Requirements for printed maps:

- text has to be large enough to be visible,

- text must not be **too thick** or *too thin*,

- there must be good differentiation between similar letters and symbols:

e – c
u – v
3 – 5 – 8
1 – 7

Text and objects:

- point objects (cities): text should be slightly above or slightly below the horizontal line the point object is on and to the right of it

- line objects (rivers): text should be parallel to line, close to line and following the bends (difficult to implement in GIS software!)

- area objects: text should show the extent of the object (large interspacing and tilted text – difficult for GIS software)

Stockholm on the map of Sweden from the Swedish National Atlas.

Symbolisation can change with scale

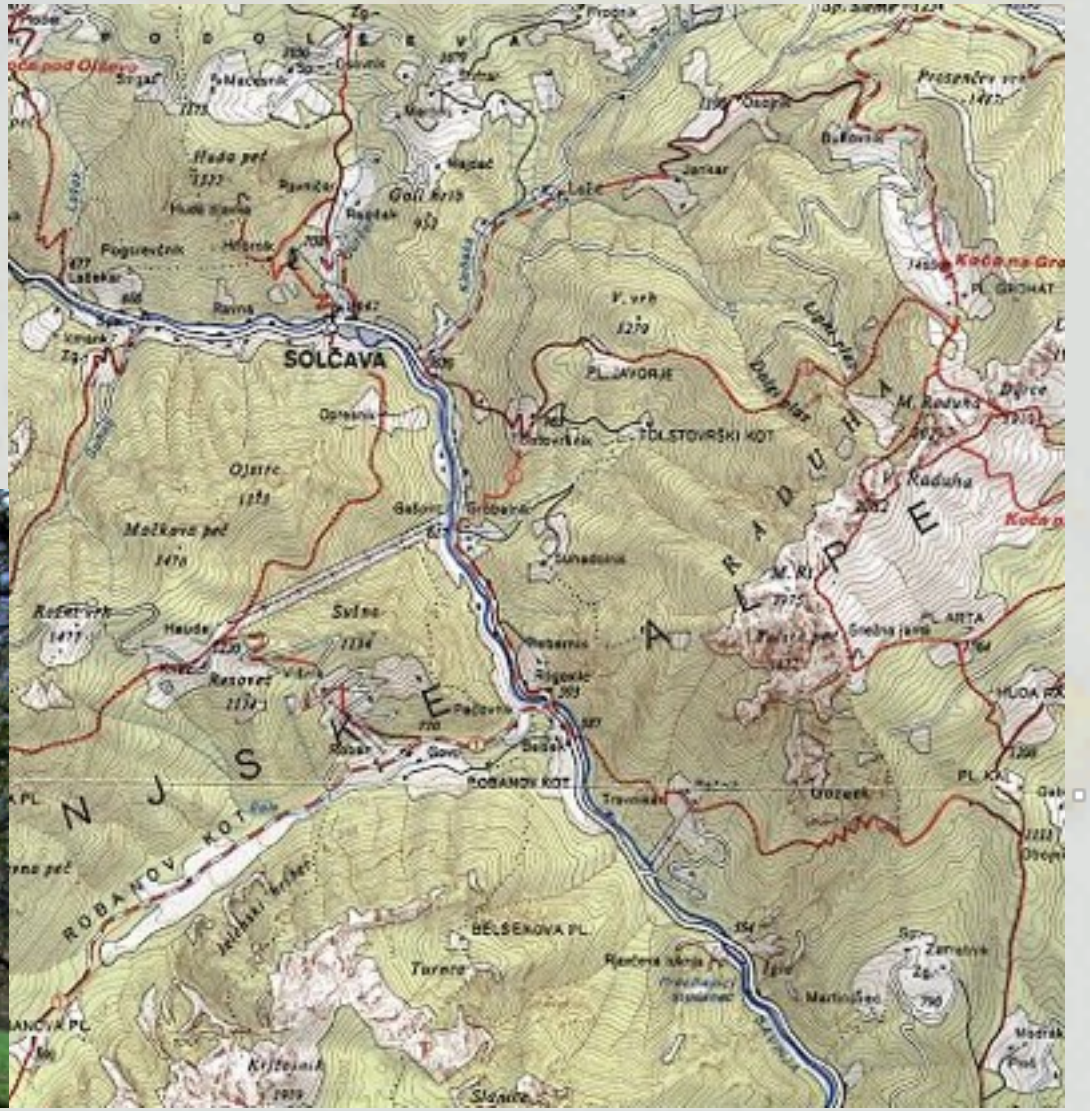
Definition of point/line/surface is dependent on scale and visual perception :

A town → Surface on large scale map

A town → Point on small scale map

Topographic maps – a standardised **conventional collection** of symbols:
- from 19th century - purpose of topographic maps: infantry warfare
- collection for: buildings, infrastructure, terrain, hydrography,...

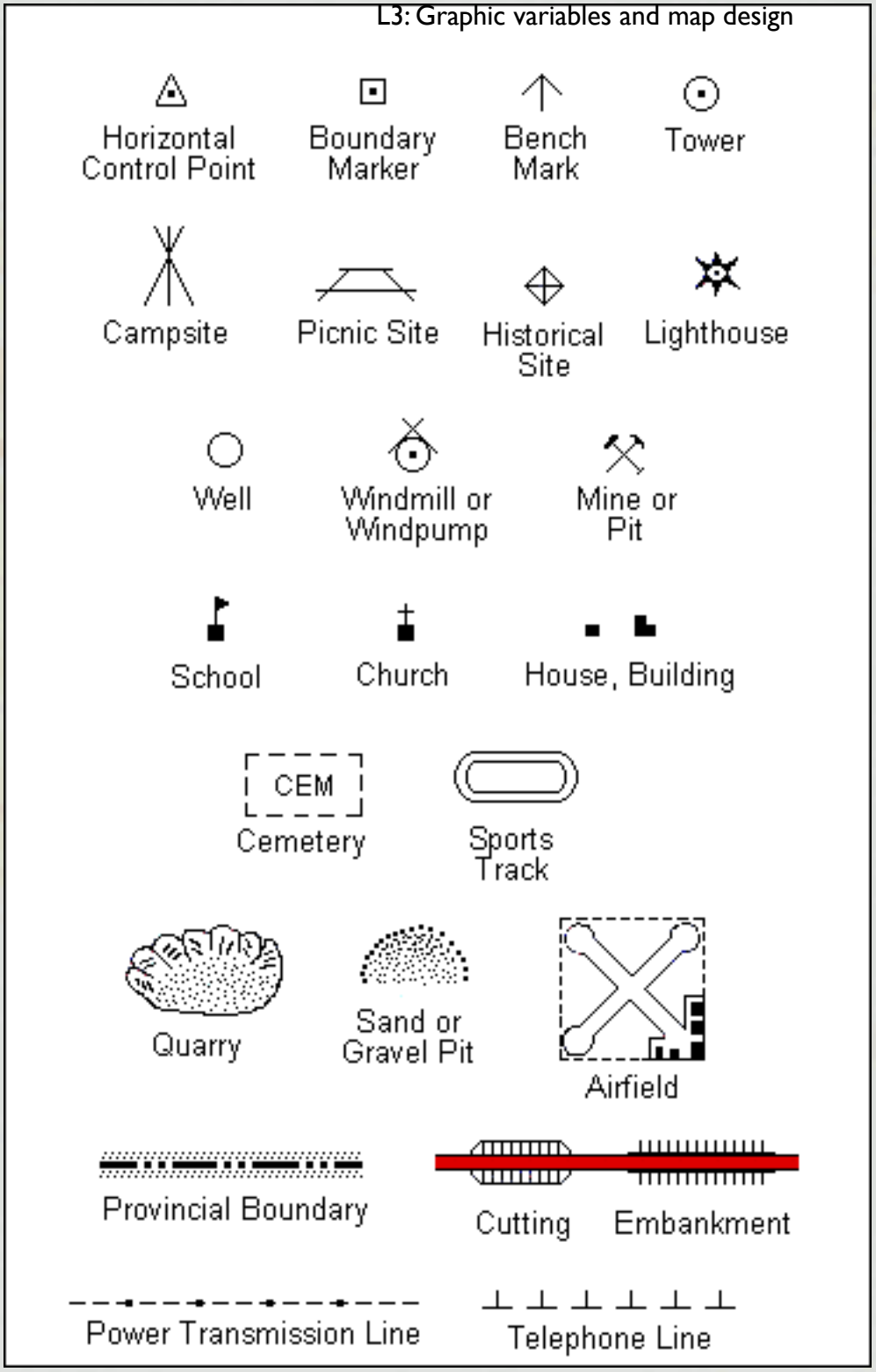
Use of **traditional symbols**:
- blue colour for water,
- green colour for forests,
- red/grey/pink for built-up areas, etc.



Topographic maps – people are used to this symbology

You recognize (most of) the symbols, even if the map is not from your country/culture and is in another language.

Symbology Typically Found on a Topographic Map



Thematic maps – there is NO standard symbology:
- thematic maps are communication-oriented
- information transfer depends on the variation in graphic characteristics of the symbols

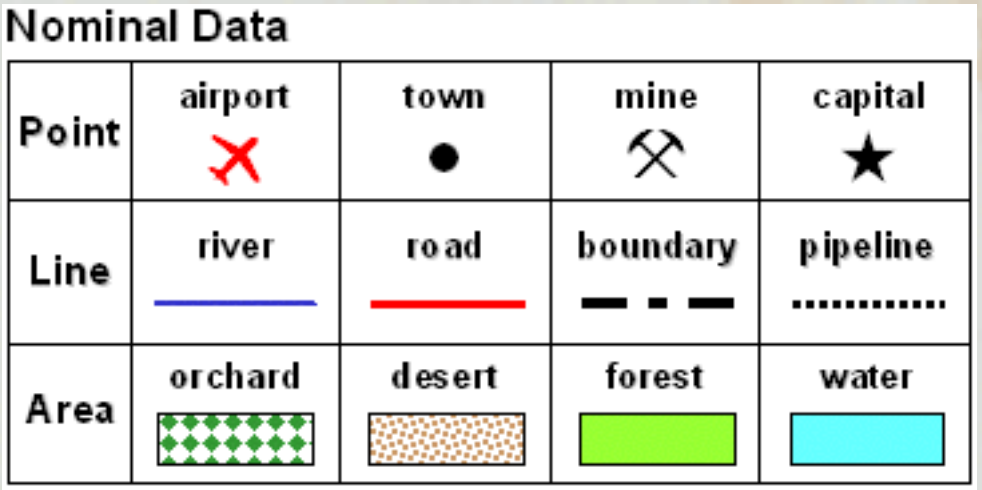
Which data variables can be shown with different graphic variables?

	Nominal	Ordinal	Interval	Ratio
Size		X	X	X
(Grey) value		X	X	X
Grain/ texture		X	X	
Colour hue	X	X		
Orientation	X			
Shape	X			

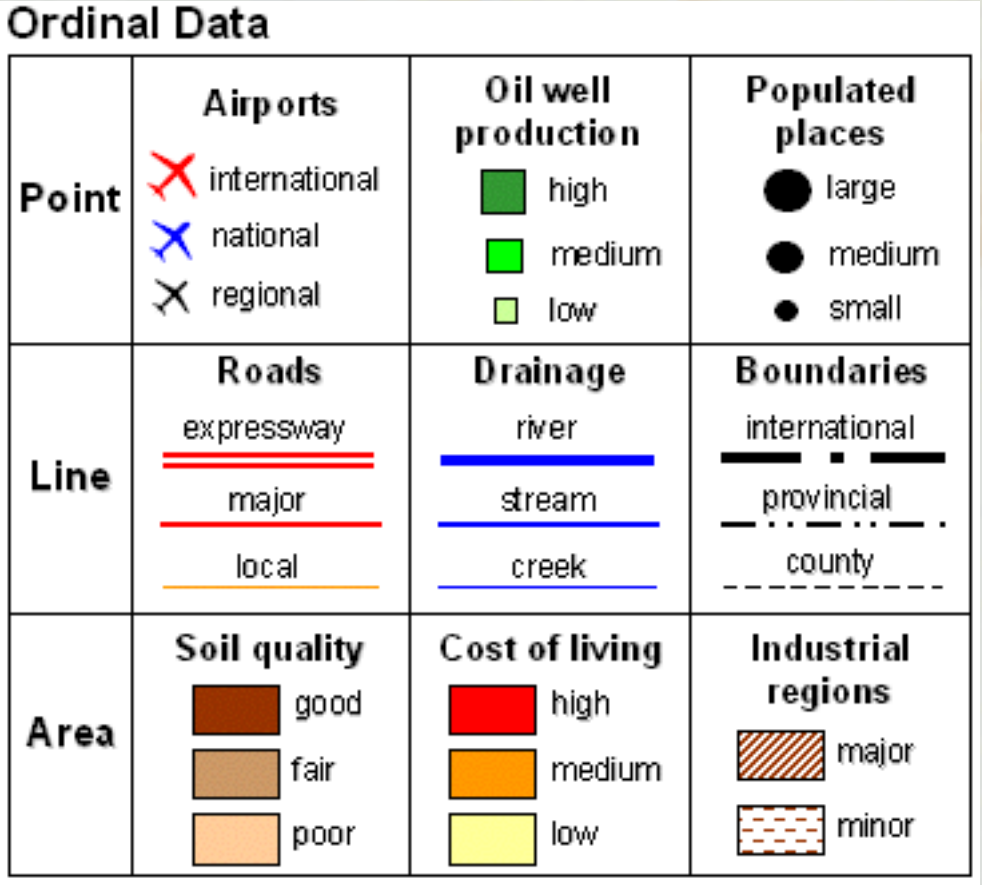
← Data variables

↑ Graphic variables

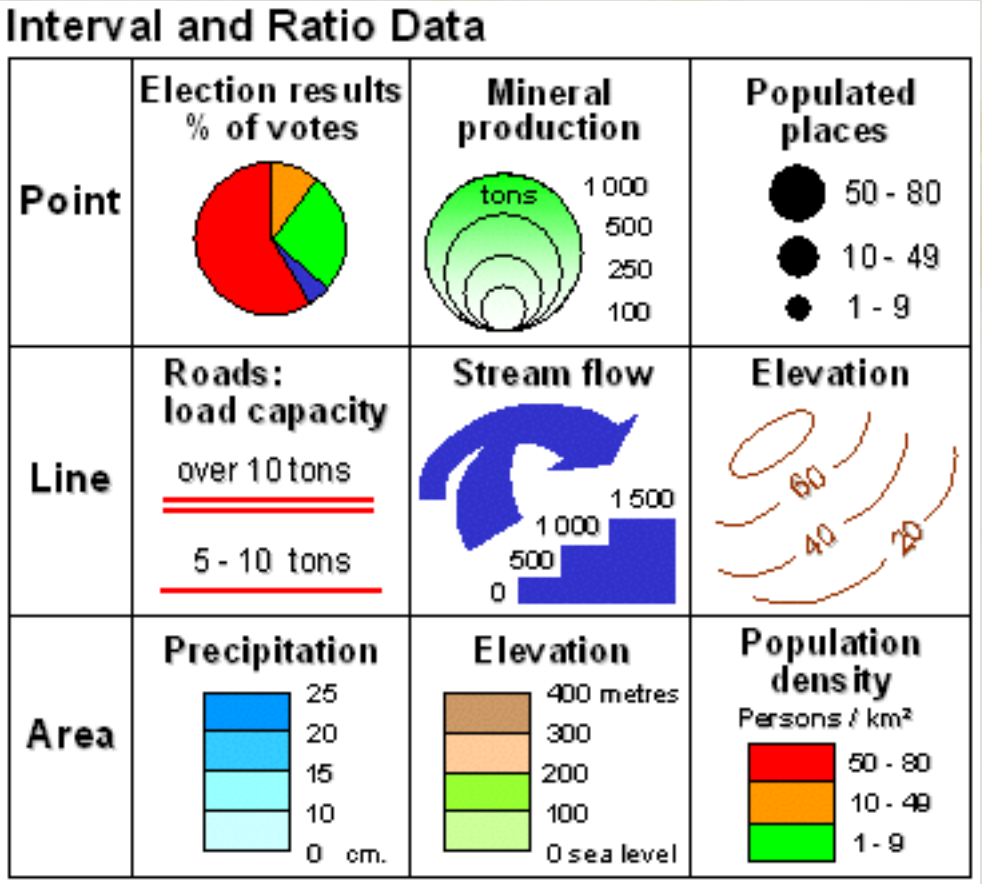
Symbolisation of nominal data



Symbolisation of ordinal data



Symbolisation of interval and ratio data



Correct impression has to be gained with a minimum of exertion:
visual isulation – can all the relationship, which can be perceived between various categories, be perceived at a glance?

↓

Depends on the number of perceivable categories:

	Dots	Dashes	Patches
Size	4	4	5
(Grey) value	3	4	5
Grain/ texture	2	4	5
Colour hue	7	7	8
Orientation	4	2	-
Shape	-	-	-

Visual hierarchy

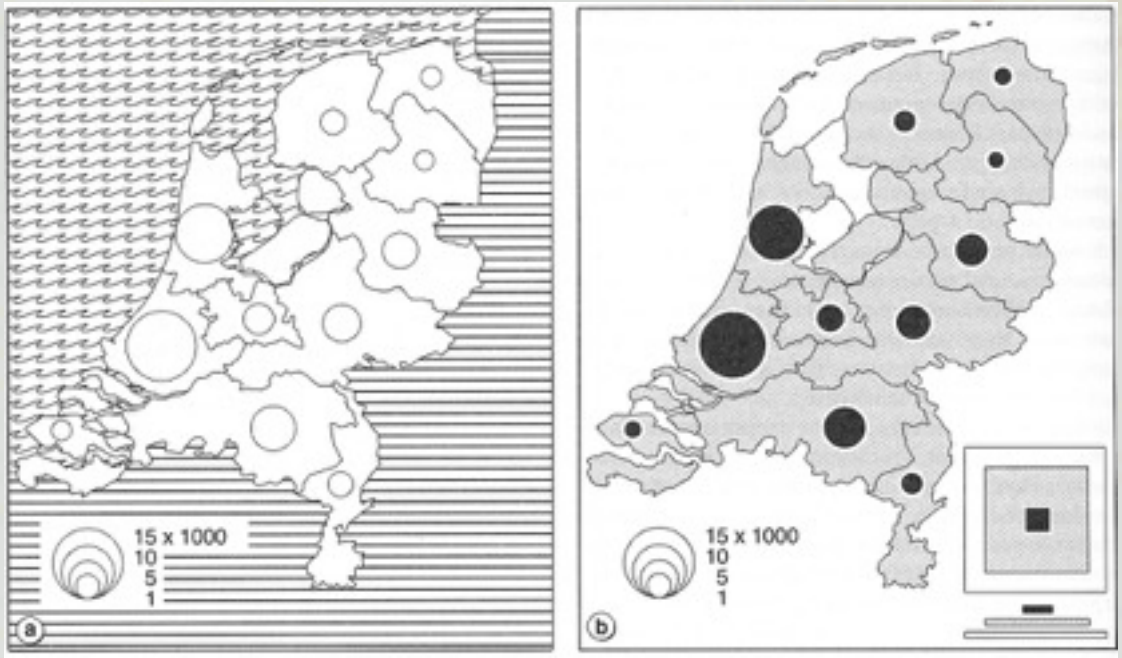
Selection of the most suitable graphic variables to display a particular data type is not enough!

Legibility considerations

- Angular differentiation
- Graphical density
- Contrast

Used to portrait the data from the most to the least important aspect

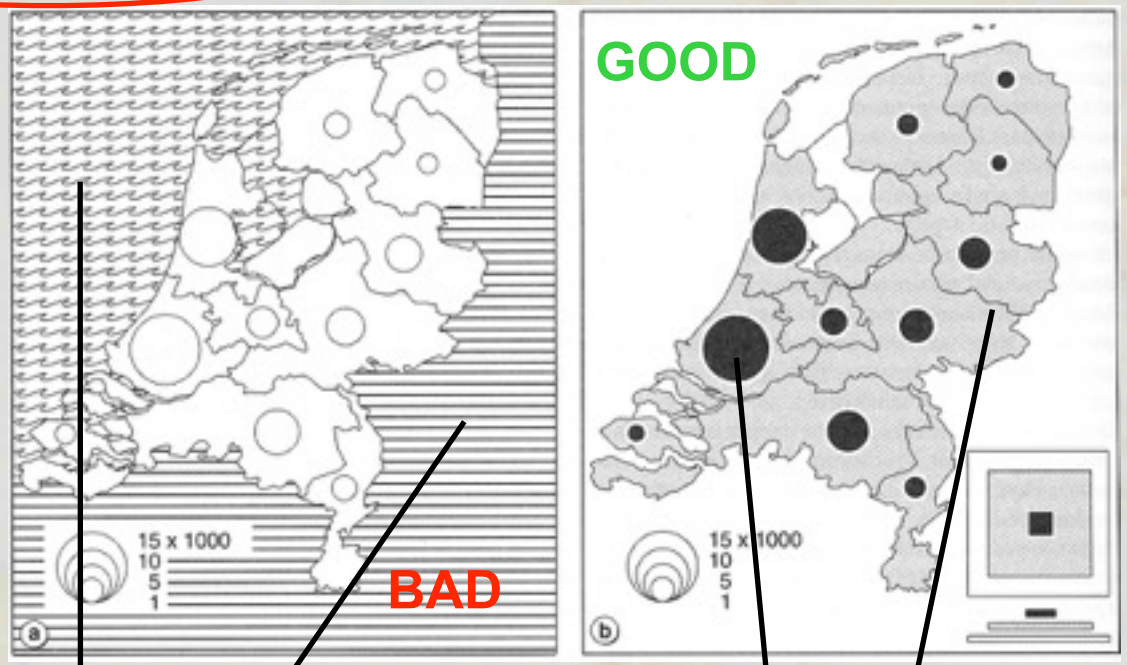
A visual representation of the hierarchy in data.



Visual hierarchy

The number of employees in the service industries in the Netherlands

The most important aspect of data

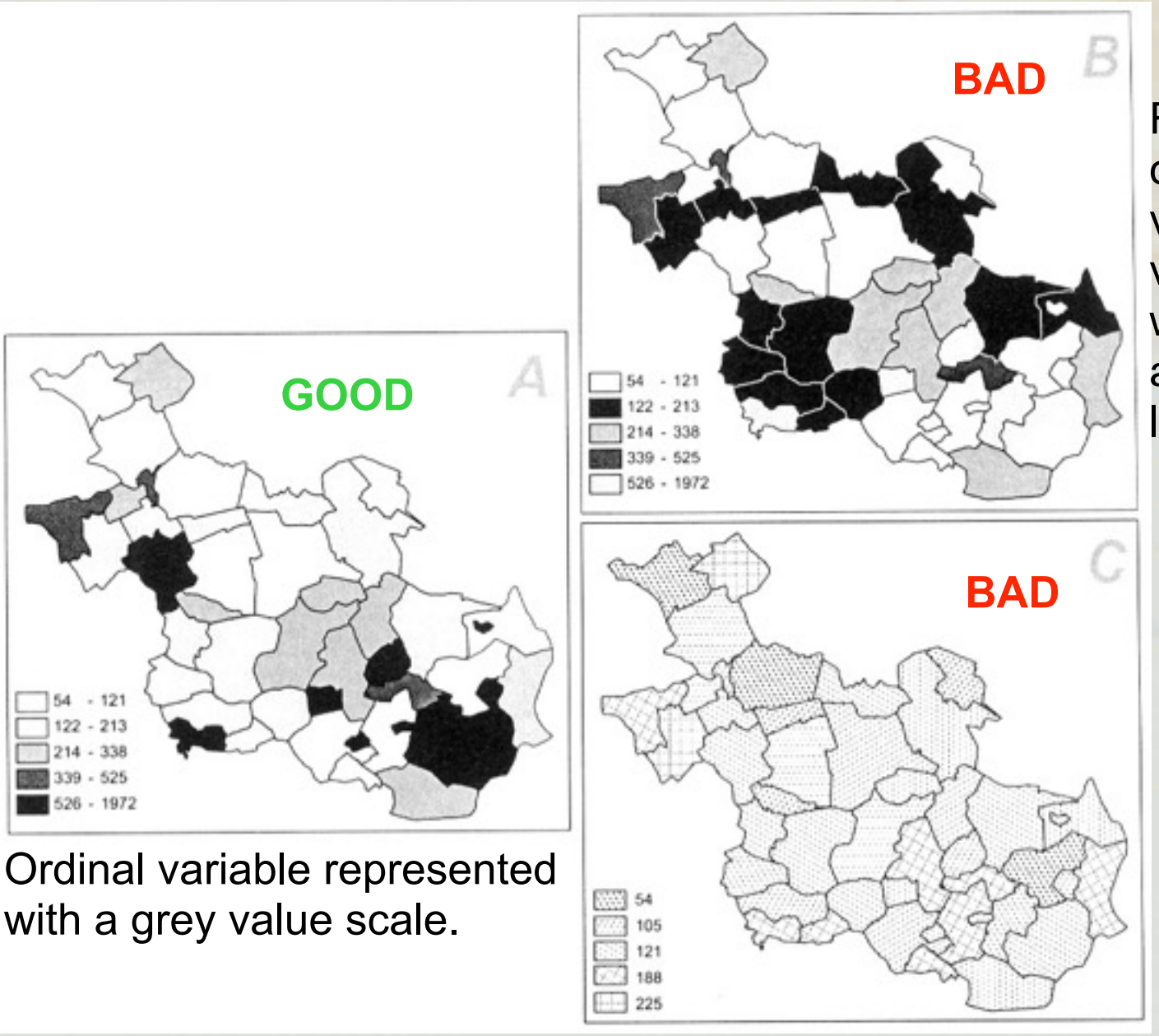


Lost in the representation

Good use of contrast to emphasize hierarchy in data:
the number of employees and the provinces (the next most important aspect) stand out against the rest of the data.

The sea and surrounding areas (relatively unimportant data aspects) stand out the most

Visual hierarchy



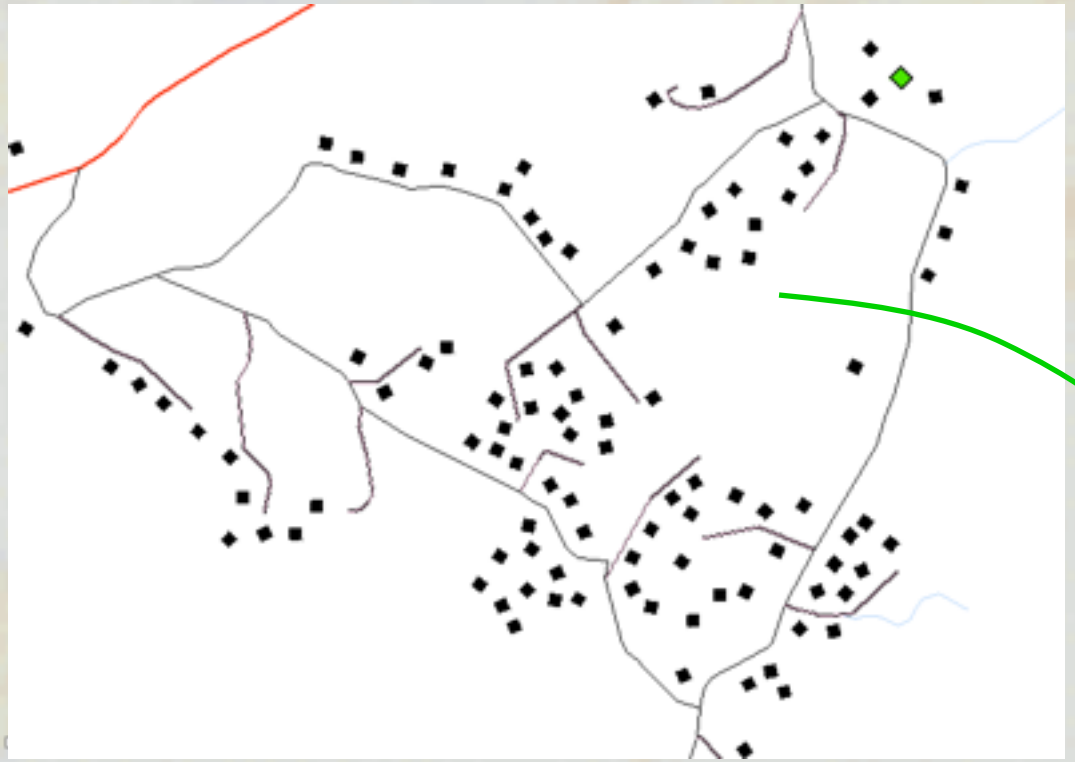
Ordinal variable represented with a grey value scale.

Right choice of the graphic variable (grey value), but wrong scale (dark areas are not the largest value).

Wrong choice of the graphical variable.

Generalisation

Details are lost, objects are displaced, etc.

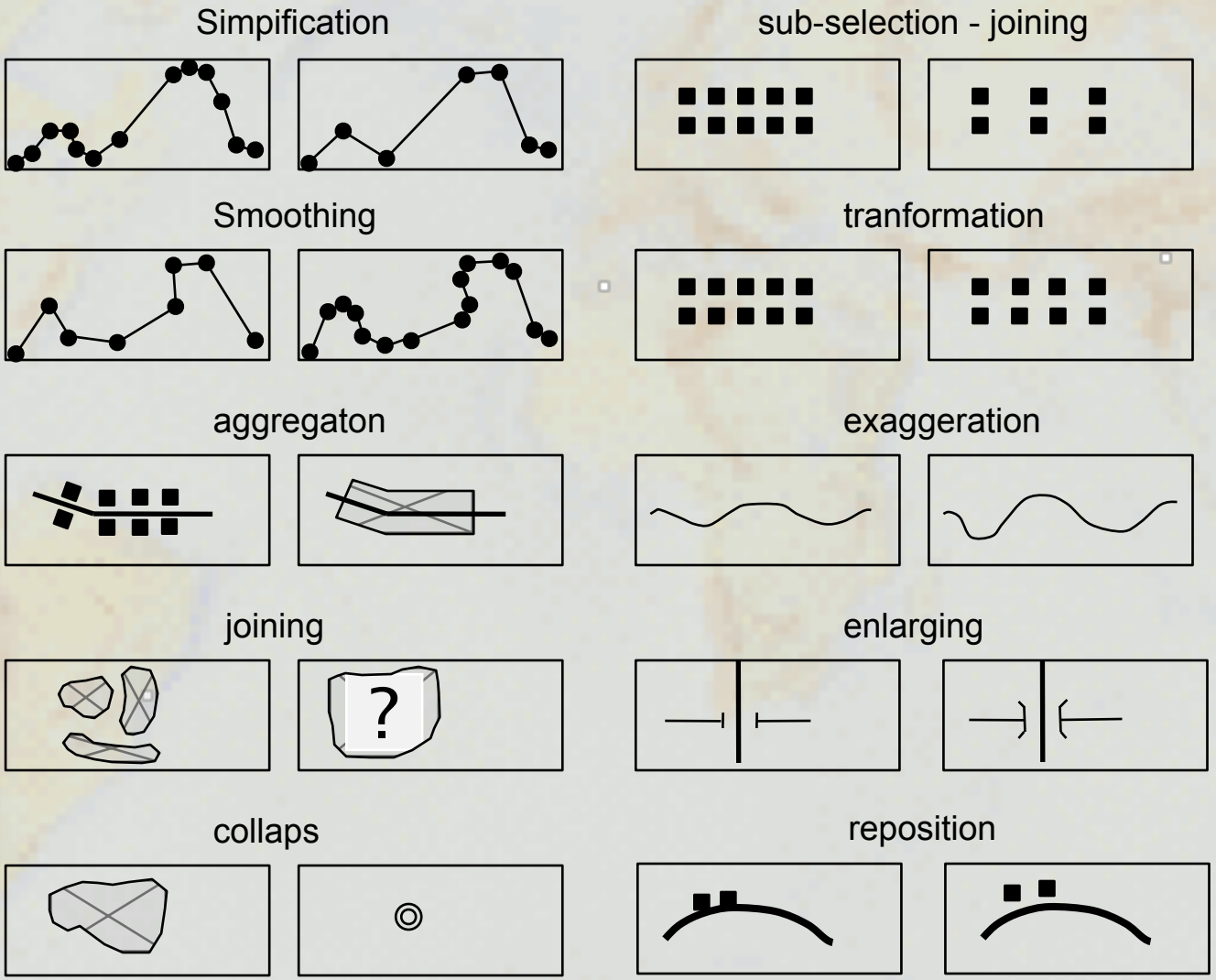


Changing between scales = **geographic generalisation**

How to find the optimal selection of real objects to visualise them on the map of a certain scale?

Reducing the level of detail in geographic data

Generalization



Which factors governs map generalisations

Scale – The scale determines what can be fit into the map

Map purpose – The purpose determines what is important to show.

Quality and quantity of available data

Graphical limits:

- choice of symbol specification
- technical reproduction capabilities

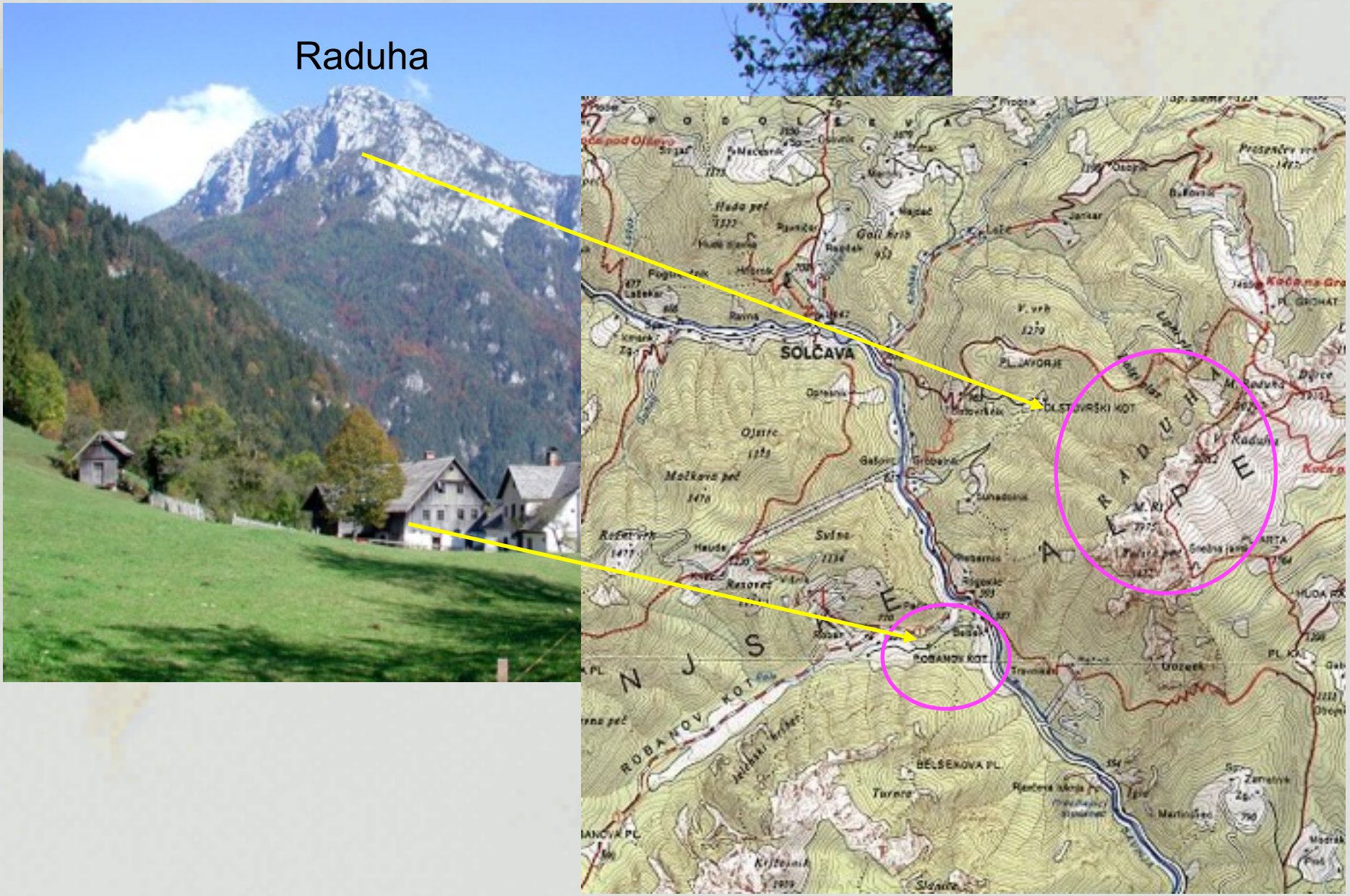
Generalisation in vector data

3. Visualising topography

Mapping the terrain

A relief display is a geometrically accurate view of the terrain and its shapes (morphology).

3D



Visualisation of elevation

In older maps with less accurate topography line density (hachuring) was commonly used to visualise steepness - general military map over Bohuslän.

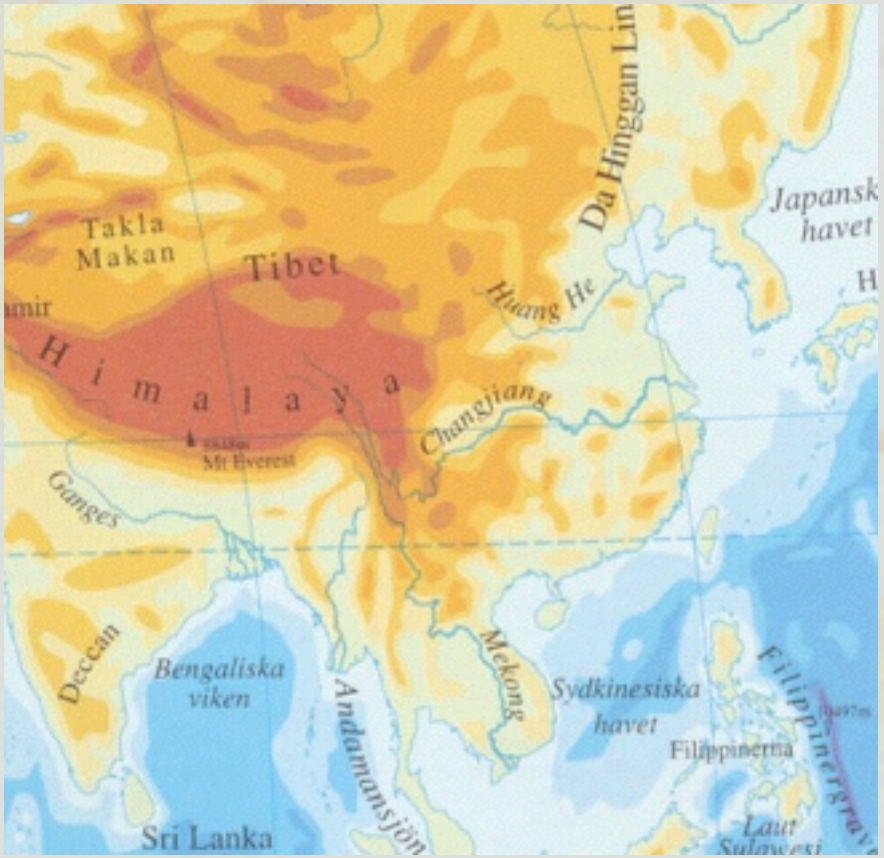
Hachuring

Visualisation of elevation

Maps made from orthorectified aerial photos have better geometry, and stereo interpretation of topography can be visualised as isolines of elevation (5m).

Visualisation of elevation

In small scale maps topography and bathymetry is sometimes visualised as the main theme (chloropeth map)



Visualisation of elevation

Mountain map with isolines and shadows with light falling from North West. In Sweden the sun never creates these shadows, but the visualisation represents the most common light setting of a study desk.

Visualisation of elevation

Older mountain tourist map with vertical shading

The choice of the terrain mapping method depends on the **purpose of the map**:
- do we want to represent terrain globally (as in a tourist map or a skiing map) or
- do we need to be able to determine the heights to 10cm accuracy (when planning a large site, a dam, for example)?

Height

Absolute – numerical values at contour lines or height points

Relative – is a certain location higher/equal/lower than other locations?

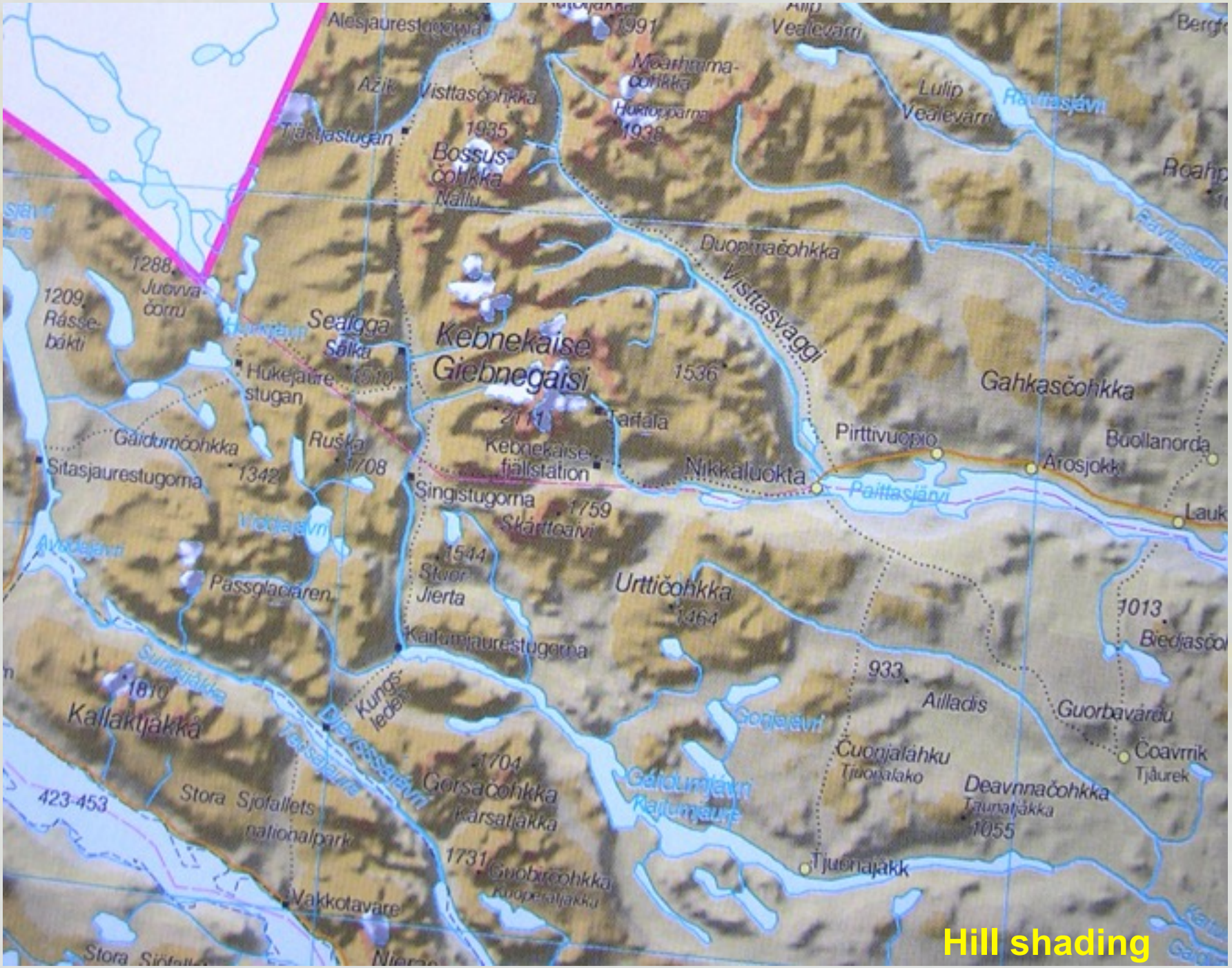

Layer tints – relative height
Absolute height
Bovški Grintavec
2347
Triglav
2864
Arnoldstein
Podklošter
Korensko sedlo
Finkenstein
Tarvisio
Kranjska Gora
Mojstrana
JESENICE
BLED
Mangart
2679
Predel
Log pod Mangartom
Visoki Kanin
Bovec
Kobarid
Tolmin
Trenta
Škrlatica
Razor
Bohinjska Bistrica
Stara Fužina
Podbrdo
Matajur
Kal-Koritnica
Čezsoča
Soča

Three common methods of relief display

Hill shading – display the shades on the slopes, produced by a ficticious light source.

Contour lines – draw isohypses (contour lines), the lines that connect the points with the same elevation.

Layer tints – assign a cetrain colour to layers between two contour lines (green = low relief, red-brownish = high relief).

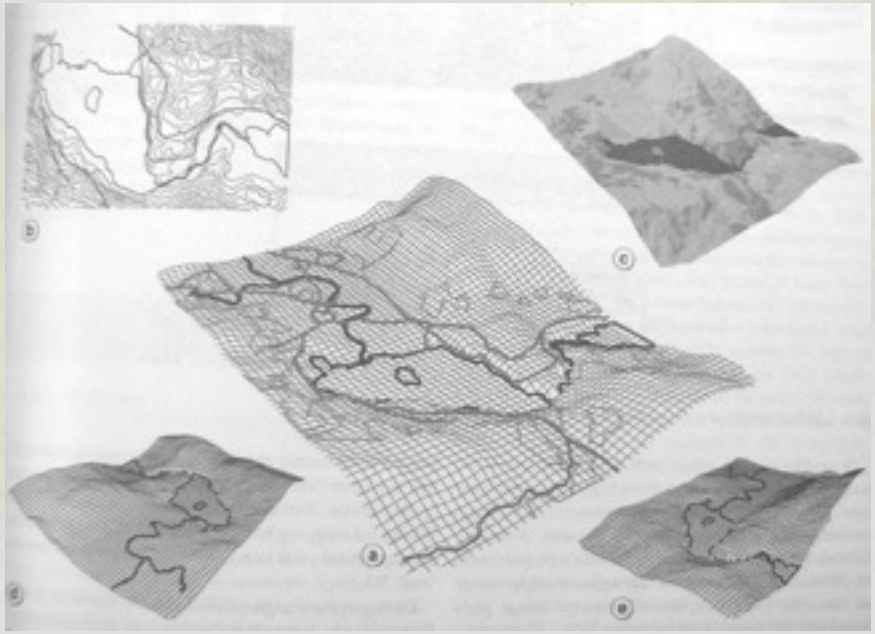

Hill shading


Jättesås
Högalid
Ökren
Tuvern
Jättesåsm
Madema
Ödegårdshagen
45,74
Bohusleden
67
Ryra
Vassbo
Vassbosjön
43,5
Backen
Barrlindekasen
Bjälledal
Sjöhagen
Kläppevattnet
66
Pölemaden
Funneshult
Tegen
125
113,78
Torpet
Bukullen
174,71
Björkebacken
Sågen
Djup
Buvattnet
Krokevattnet
Aspekärr
Åsen
Hälleröd
Ulvehed
Galten


Layer tints

Other methods of relief display

Hachuring

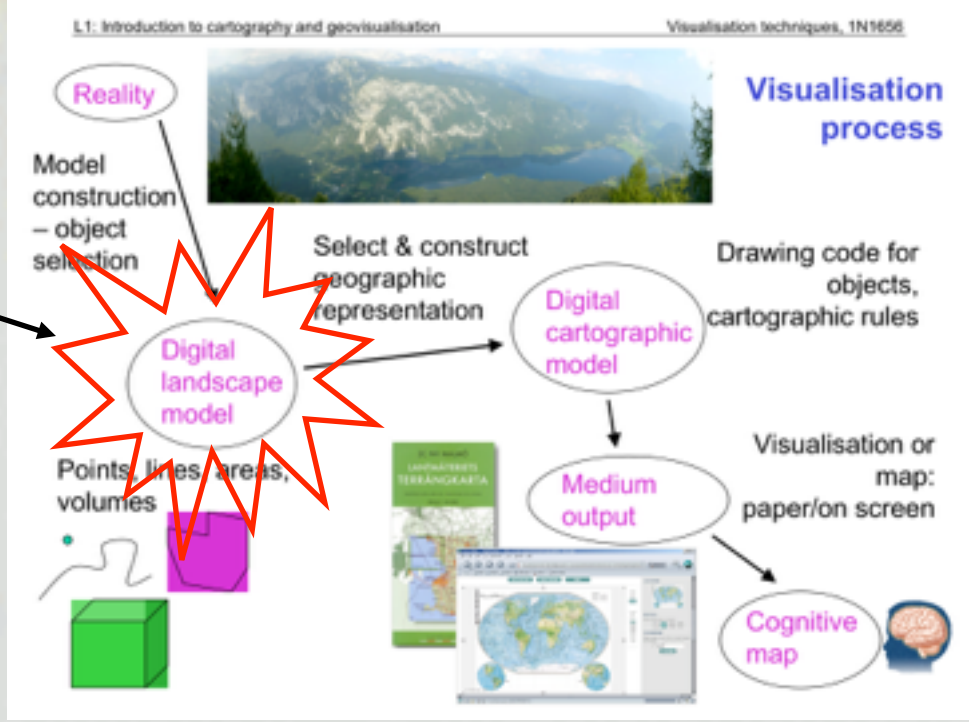


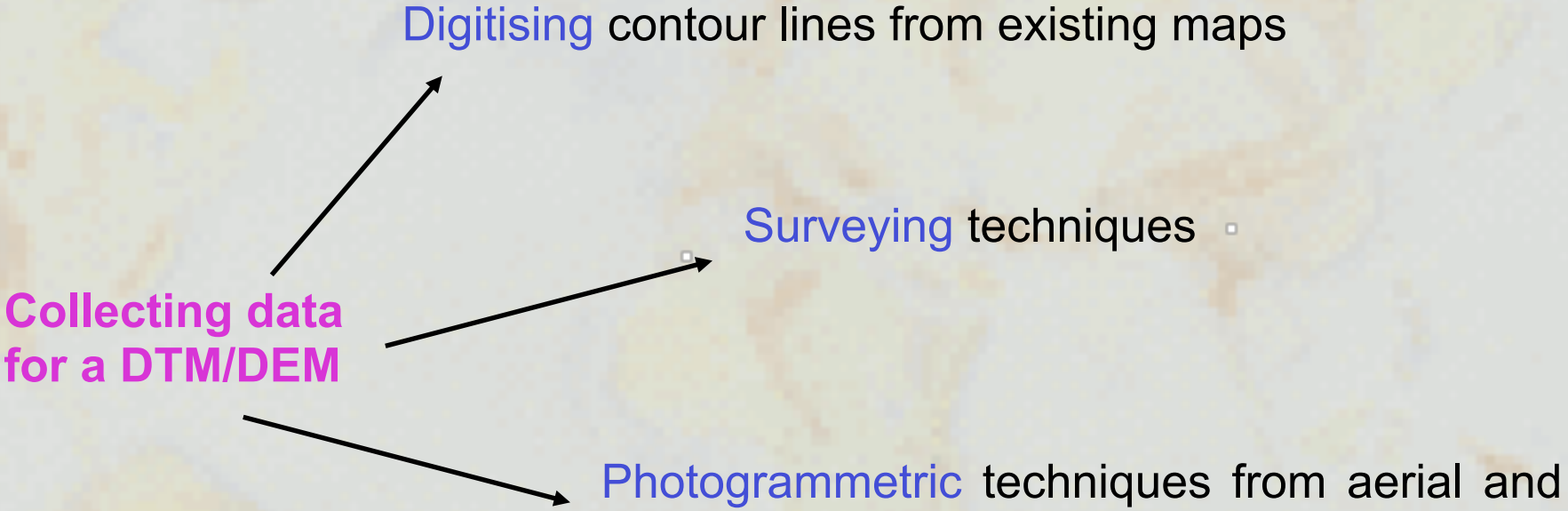
Perspective views

A relief display in a computer – **a digital terrain model, a DTM**: a digital 3-dimensional representation of the terrain surface and selected 0-, 1-, 2- and 3-dimensional objects that are related to the surface.

If only elevation is represented, we get **a digital elevation model, a DEM**.

Both are digital landscape models.





Model quality depends on:
- density of sampling points (spatial resolution),
- interpolation method (estimating the elevation between the sampling points).

Applications of DTM/DEM – surface analysis

A slope map – shows the maximum rate of change of elevation.

Aspect – the orienation of the slope.

Hydrological maps

A flow direction map – into which direction the water would flow from each sampling point/raster cell.

A drainage network – a network map of the runoff on the terrain, where the water will flow on the surface.

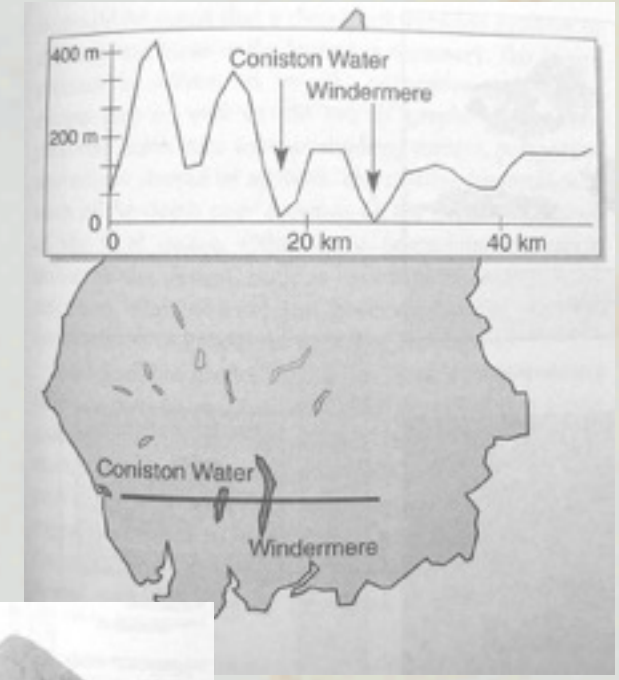
A flow accumulation map – which neighbour points/cells drain into a particular point/cell.

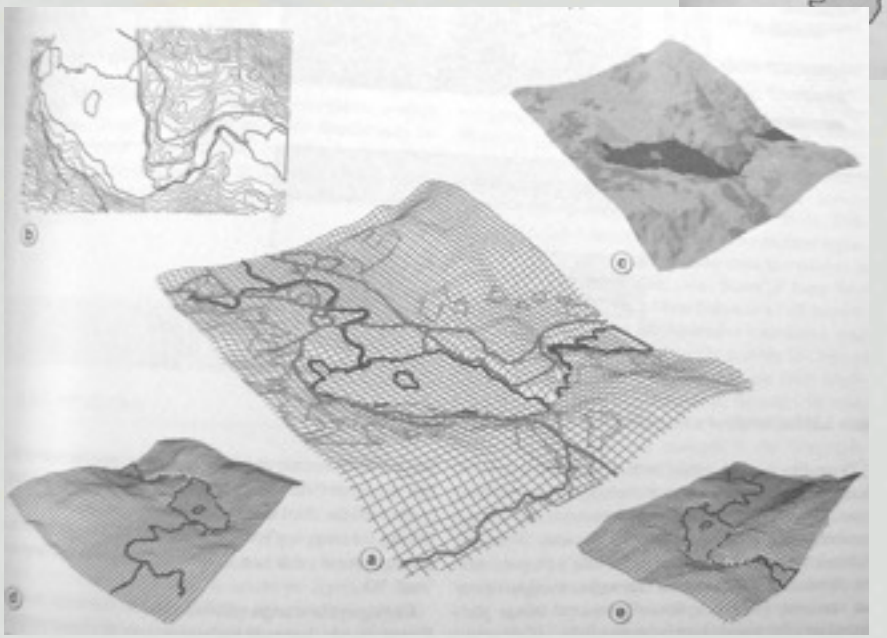
Terrain visualisations from DTM/DEM

Shaded relief maps

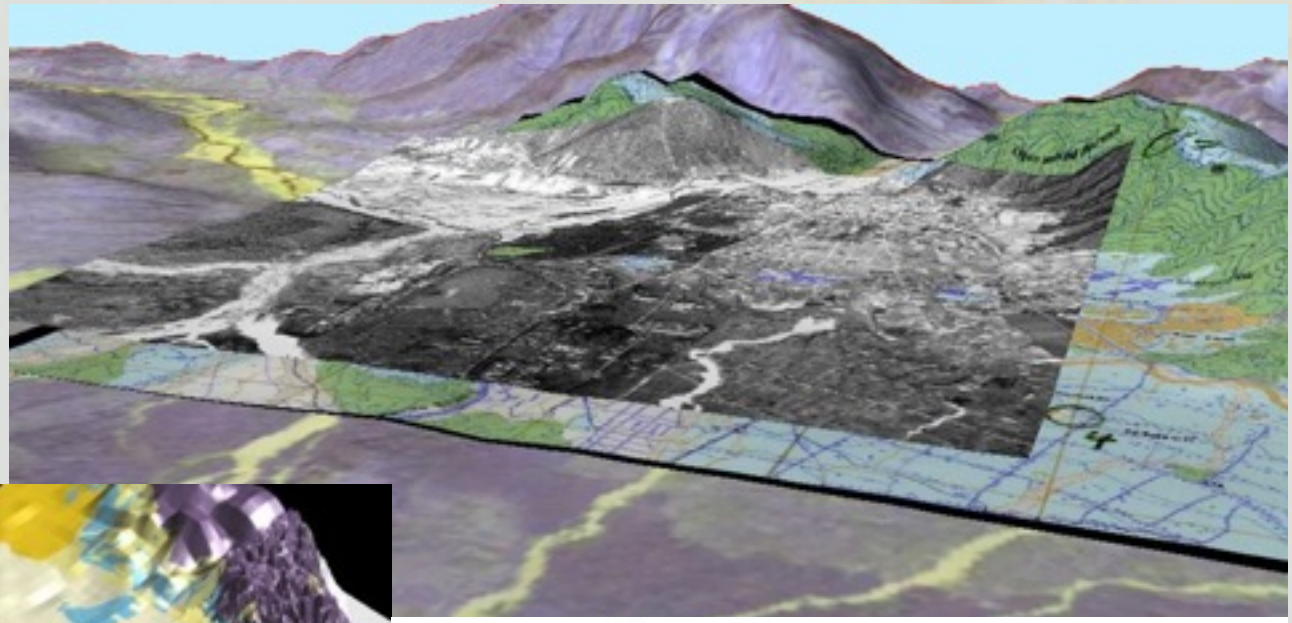
Profiles

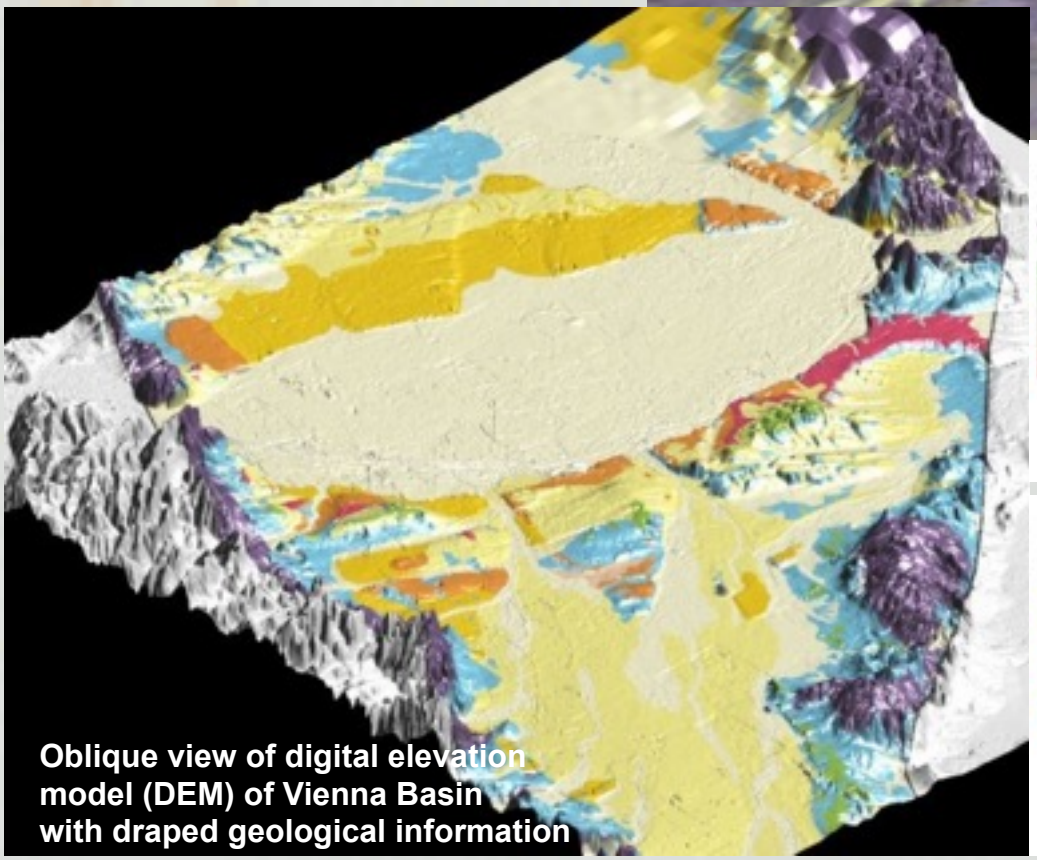
Perspective maps





Terrain visualisations from DTM/DEM – draping a satellite image or a thematic map over a 3D visualisation of the terrain





Oblique view of digital elevation model (DEM) of Vienna Basin with draped geological information