

# Geomorphological mapping

# Plan

1. What is geomorphology ? What is a landform?
2. Visual media for geomorphology
3. Geomorphological mapping (GM):
  - Guidelines
  - Approaches
  - Legend issues
  - Exercise

# **1. What is geomorphology? What is a landform?**

# What is geomorphology ?

## **Geographic science (space)**

spatiality

Interrelations

## **Science of landforms (description)**

« science or description of landforms, these landforms themselves »

(Brunet & Ferras, 1992)

> description (typologies) > explanation

## **Science of Earth surface processes (time)**

« science of genesis and evolution of landforms »

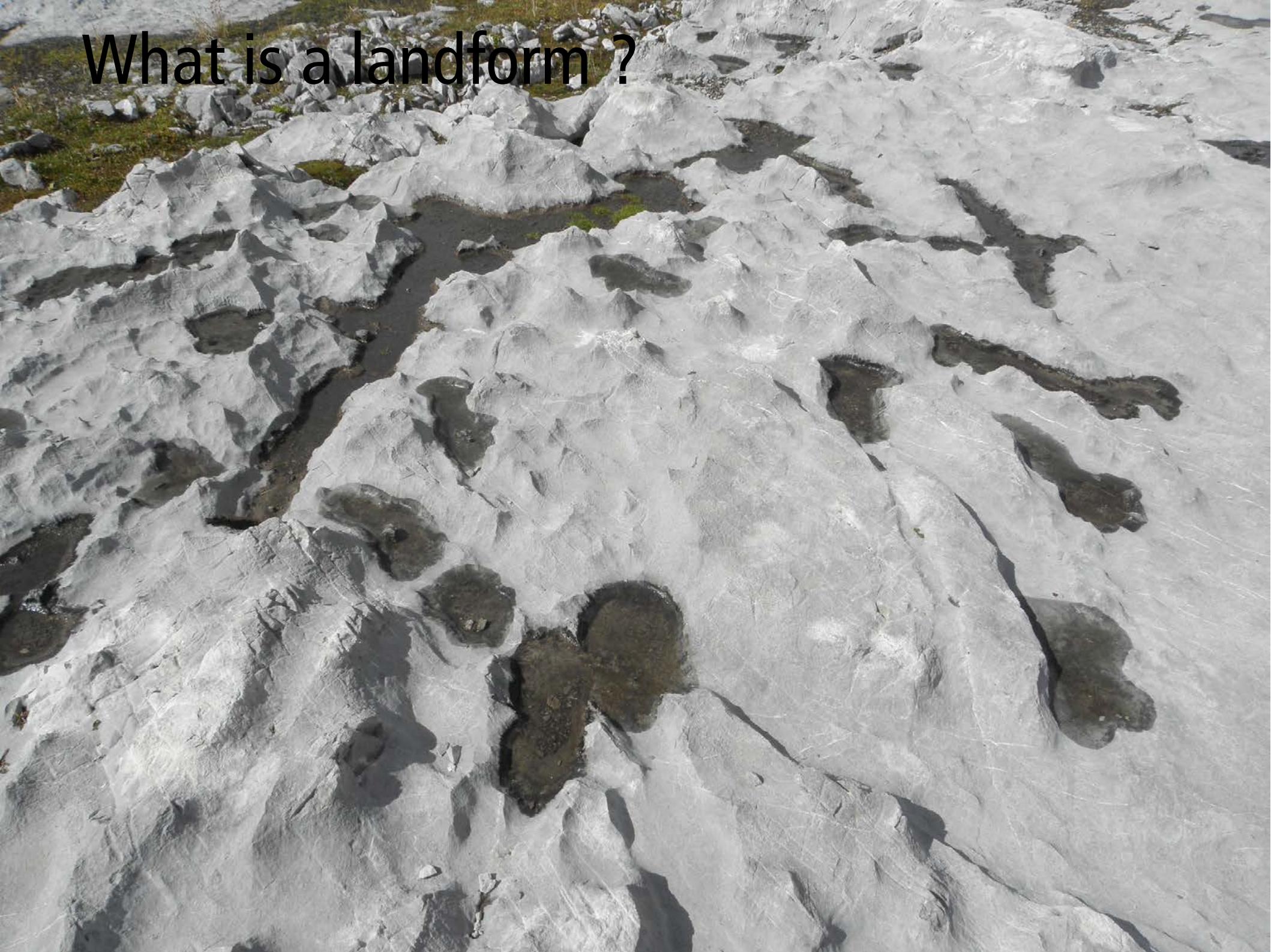
(Godron & Joly, 2008)

> measurements, modelization

# What is geomorphology ?

## Approaches of terrain and objects

		Time scales		
		instant description	chronological analysis	dynamic explanation
Space scales	focused	Form description / localization	Form dating	Morphogenesis of landform
	selective	Landforms group/complex description	Stages of landforms complex	Morphogenesis of landforms complex
	global	Landscape description	History of landscape	Dynamic of landscape system (Martin, 2013)



# What is a landform ?

# What is a landform ?



# What is a landform ?



# What is a landform ?

Appearance, shape... > **morphology (morphography)**

Dimensions, slope,... > **morphometry**

Origin (process) > **morphogenesis**

Age > **morphochronology**

Active processes > **morphodynamics**



# What is a landform ?

## Various typologies of landforms

Based on	Examples
Dimension	Structural units / tectonic units / ... / landforms / microforms / ... (Tricart 1965)
Origin	Fluvial landforms, karstic landforms, ...
Dynamic	Deposit or erosive landform Active, passive, or fossile landform
Structure	Monocline (cuestas), folded, or faulted relief
Climate	Equatorial to polar zone (Büdel 1963, Tricart & Cailleux 1965)
Complexity	Isolated landform / group of landforms (1 type) / complex of landforms (1 process) / geomorphological system (Grandgirard, 1996)

(Martin, 2013)

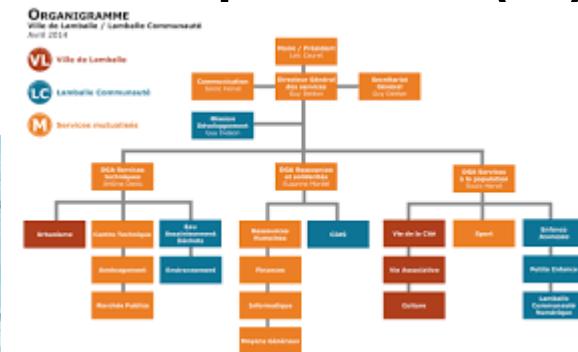
# **2. Visual media for geomorphology**

# Visual media for geomorphology

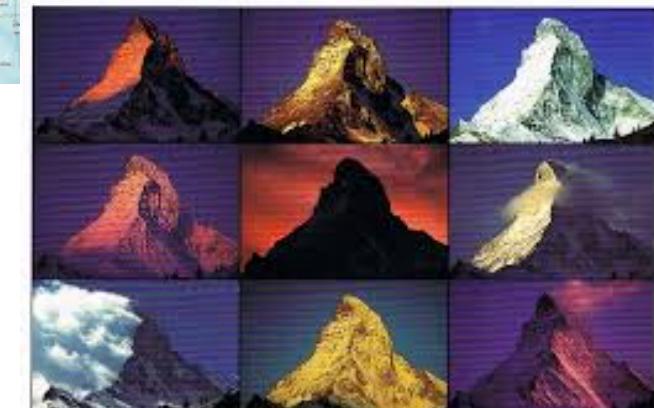
## Iconicity scale (Moles, 1980)

Every abstract representation of an object can be classified, from the textual or algebrical depiction (0) to the object itself (12).

*Organigramm* (4)



*Topographical map* (7)



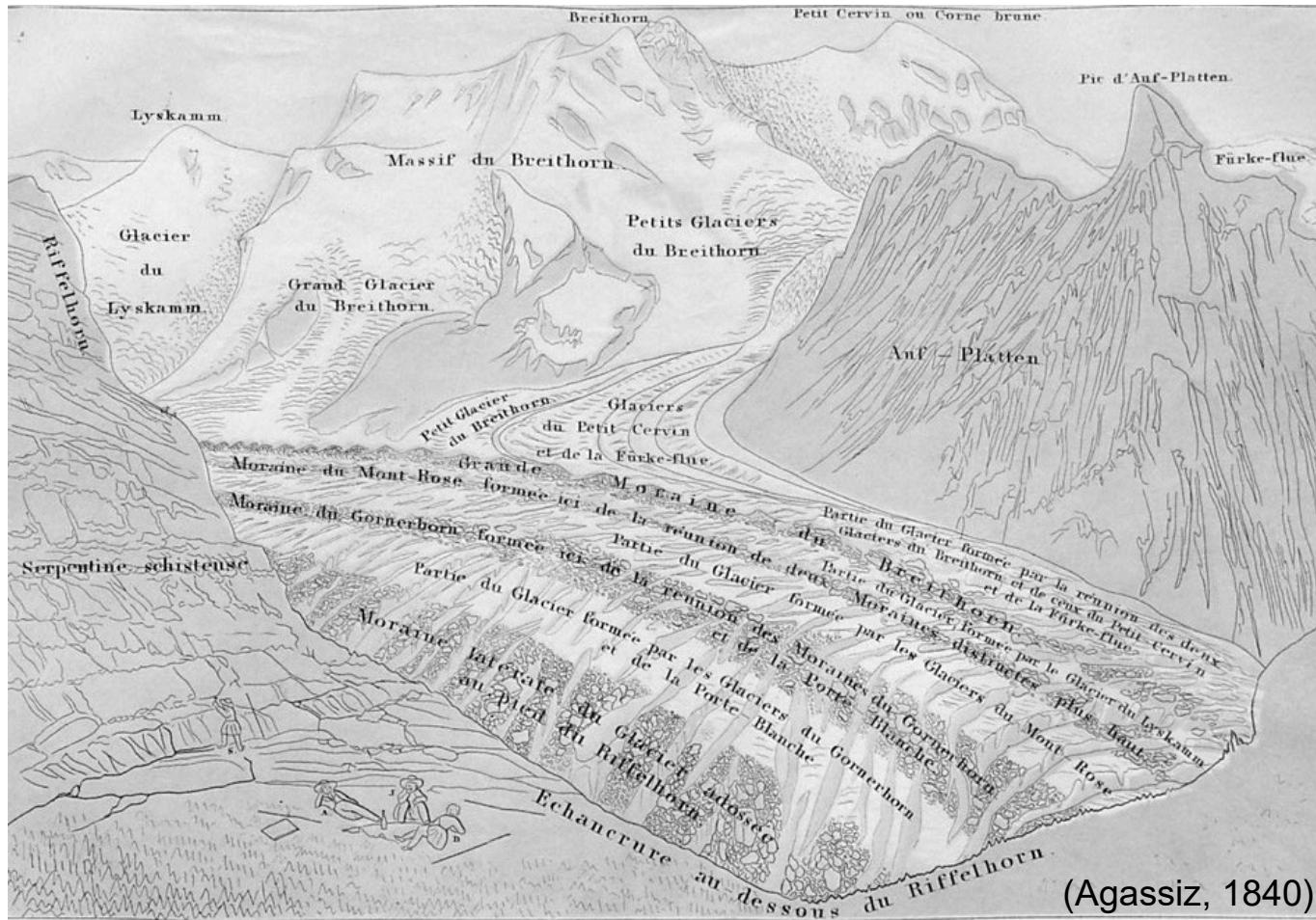
*Photography* (9)

*Globe* (10)



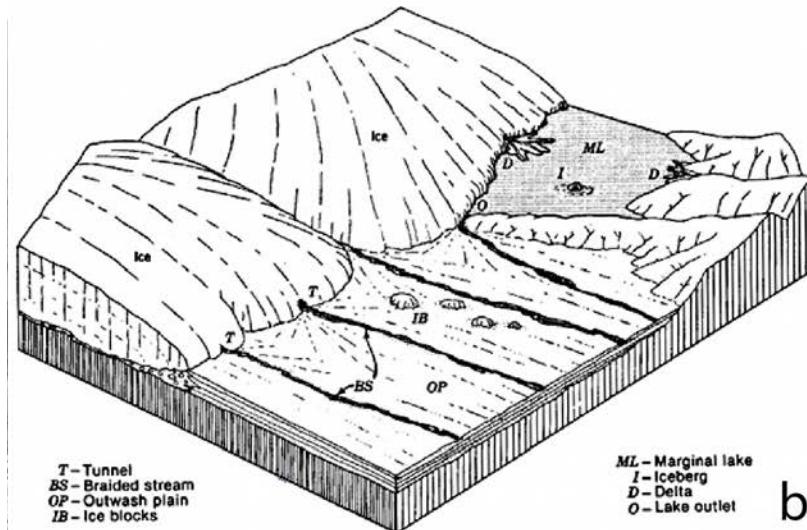
# Visual media for geomorphology

## Descriptive schemes: drawing on picture, block-diagramm

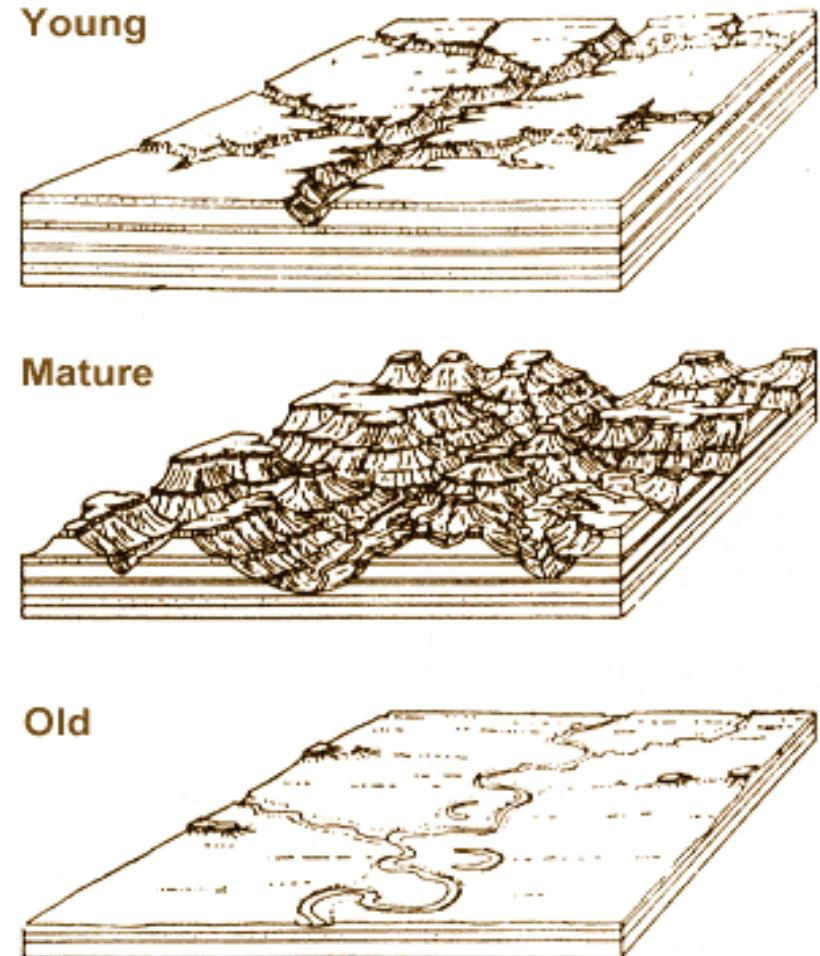


# Visual media for geomorphology

## Descriptive schemes: drawing on picture, block-diagramm



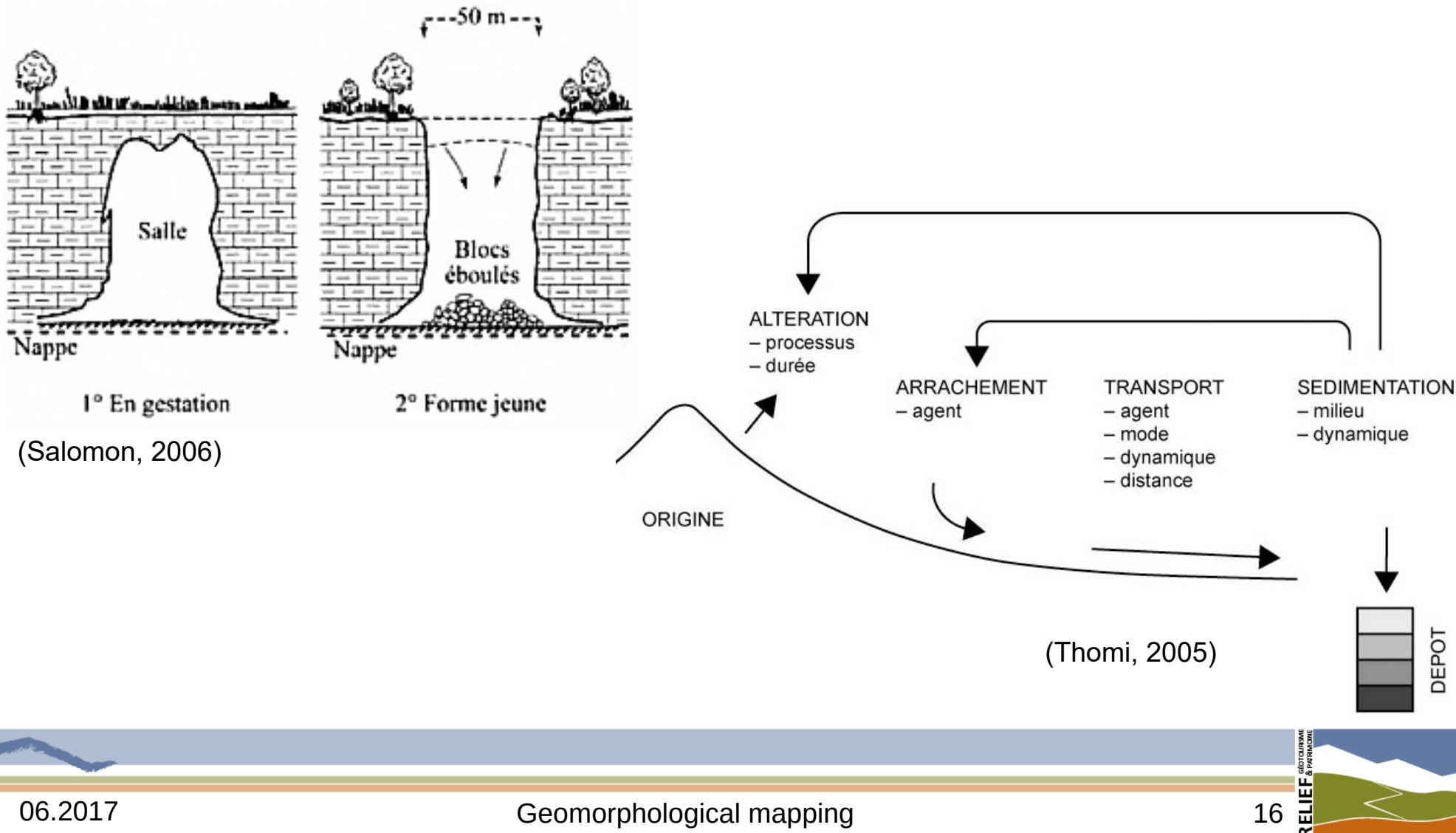
(Strahler, 1960)



(WM Davis)

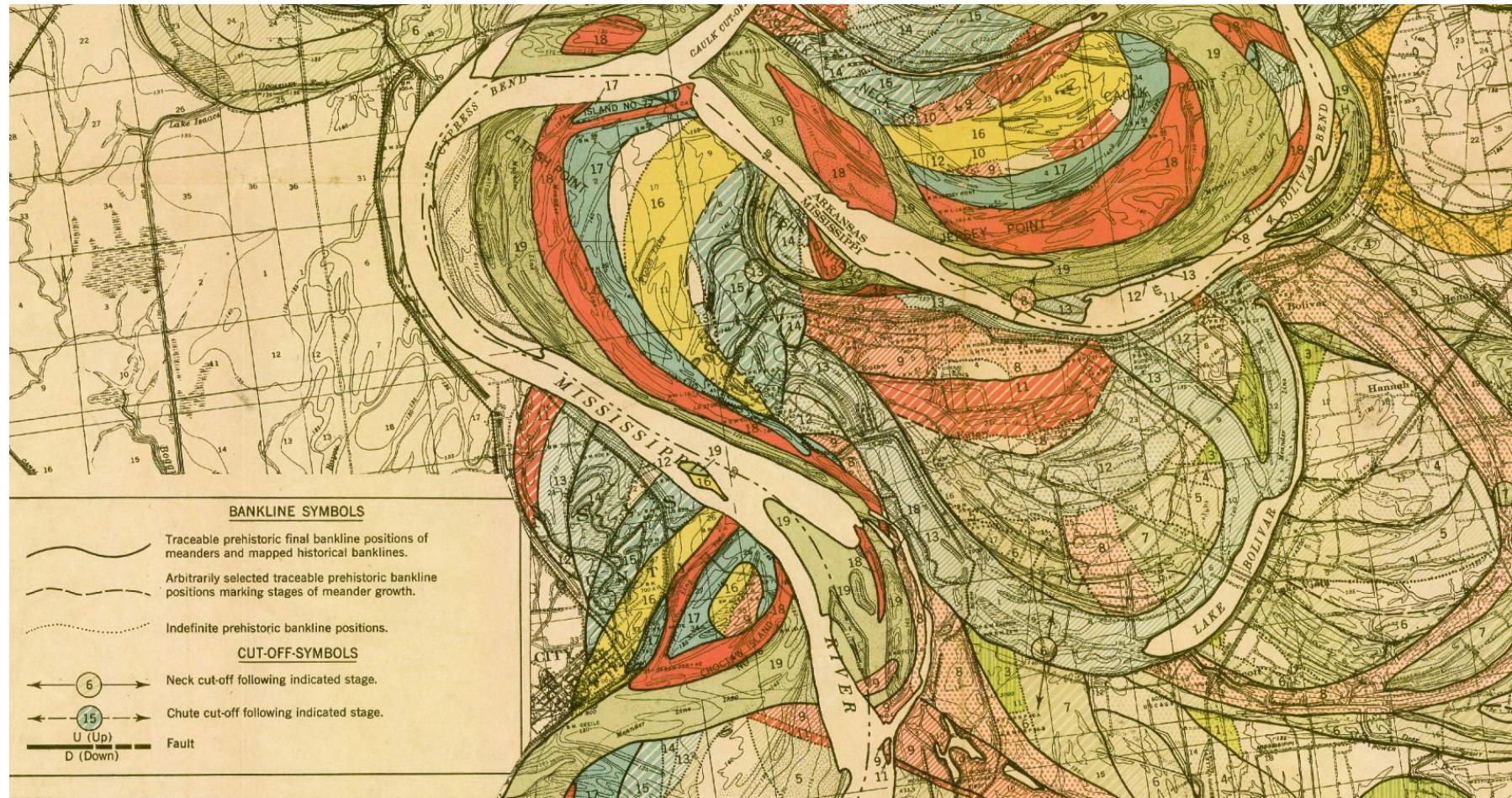
# Visual media for geomorphology

## Explanative schemes: string of schemes, functional schemes



# Visual media for geomorphology

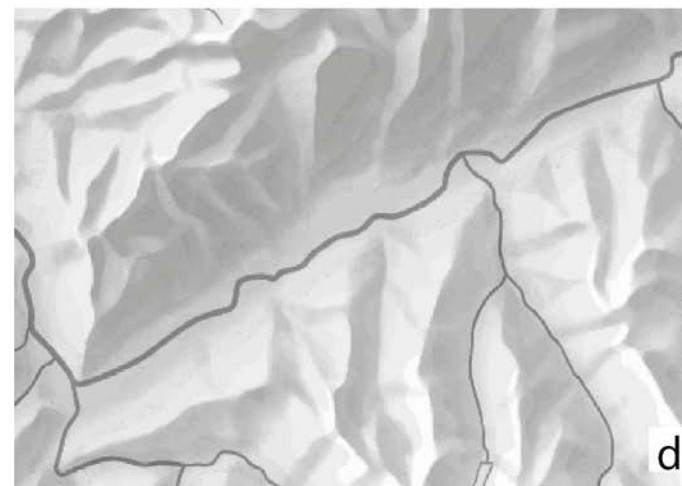
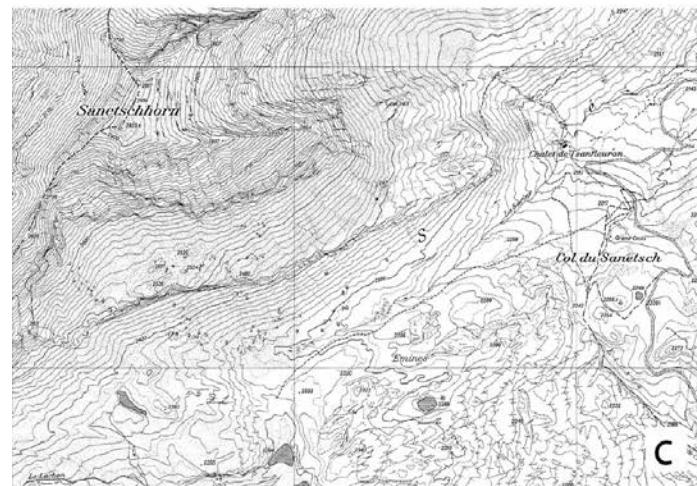
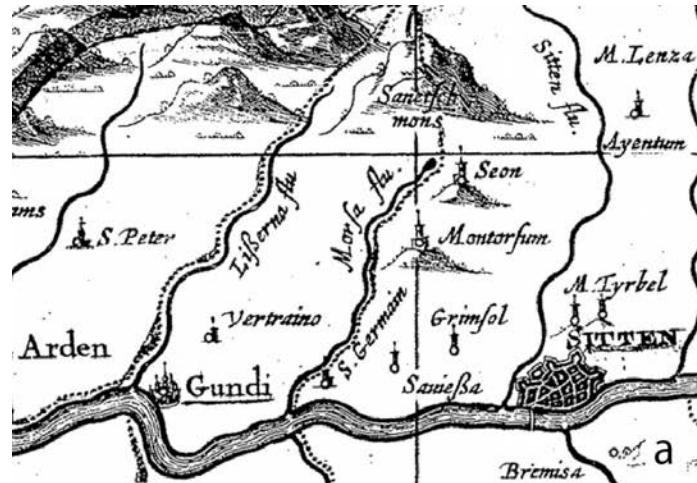
## Spatial schemes: maps



(Fisk, 1944)

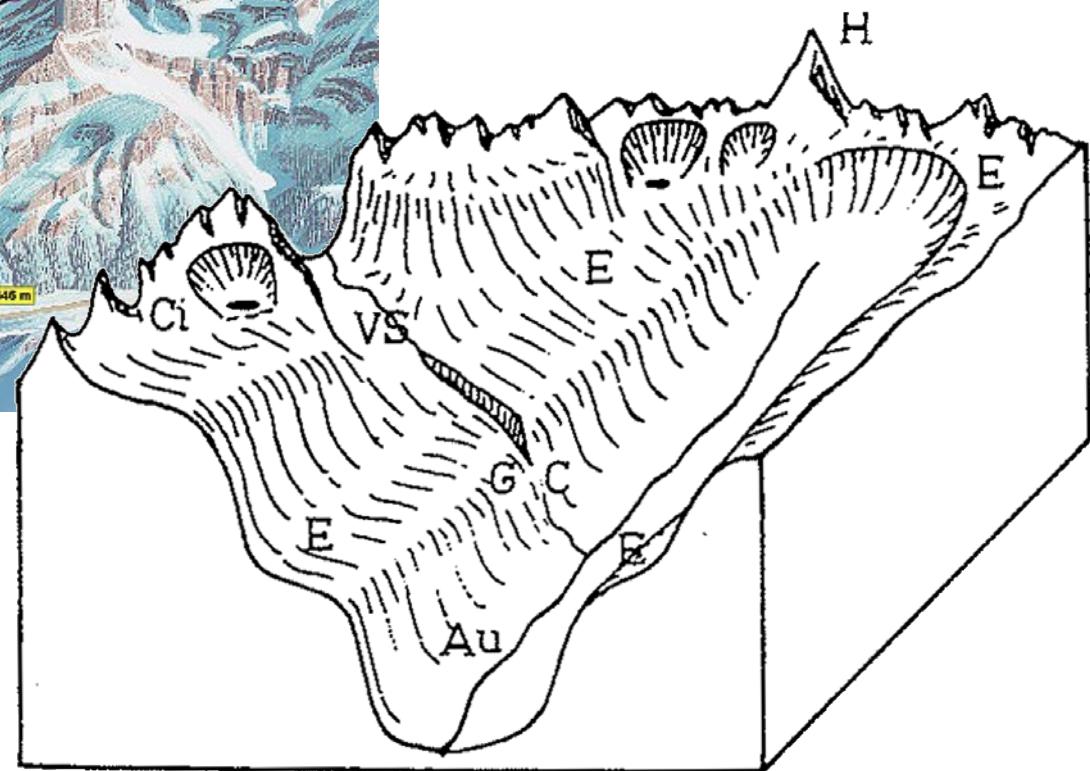
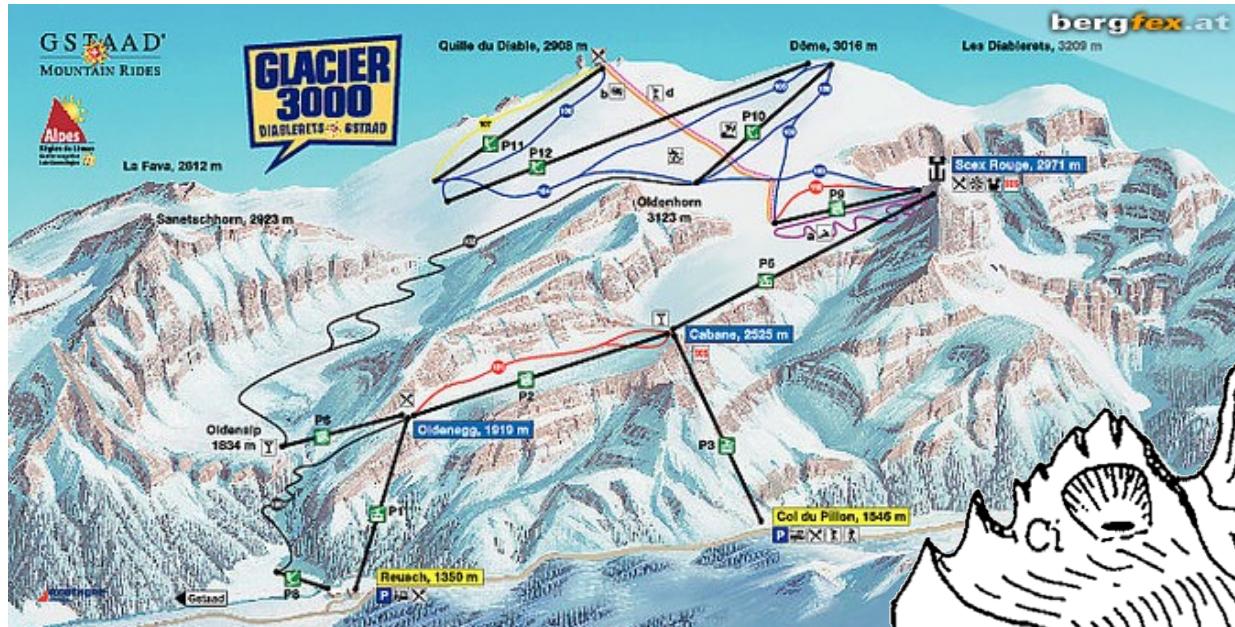
# Visual media for geomorphology

## Showing the 3rd dimension



# Visual media for geomorphology

## Showing the 3rd dimension



# Visual media for geomorphology

## Showing the 3rd dimension



# Visual media for geomorphology

Showing the 3rd dimension



(Imhof, 1939)

# Visual media for geomorphology

## Media and tools suitable for each approach

		Time scales		
		instant description	chronological analysis	dynamic explanation
Space scales	focused	Photography Inventory map	Historical timeline Stratigraphic column	(animated) Scheme
	selective	Thematic G.M.	Thematic G.M. Stages map Animated map	Thematic G.M. Relational scheme System scheme
	global	Comprehensive G.M. Geodatabase (GIS)	Comprehensive G.M. Temporal geodatabase (T-GIS)	Comprehensive G.M. Model

(Martin, 2013)

# Visual media for geomorphology

## Media and tools suitable for each approach

		Time scales		
		instant description	chronological analysis	dynamic explanation
Space scales	focused	Photography Inventory map	Historical timeline Stratigraphic column	(animated) Scheme
	selective	Thematic G.M.	Thematic G.M. Stages map Animated map	Thematic G.M. Relational scheme System scheme
	global	Comprehensive G.M. Geodatabase (GIS)	Comprehensive G.M. Temporal geodatabase (T-GIS)	Comprehensive G.M. Model

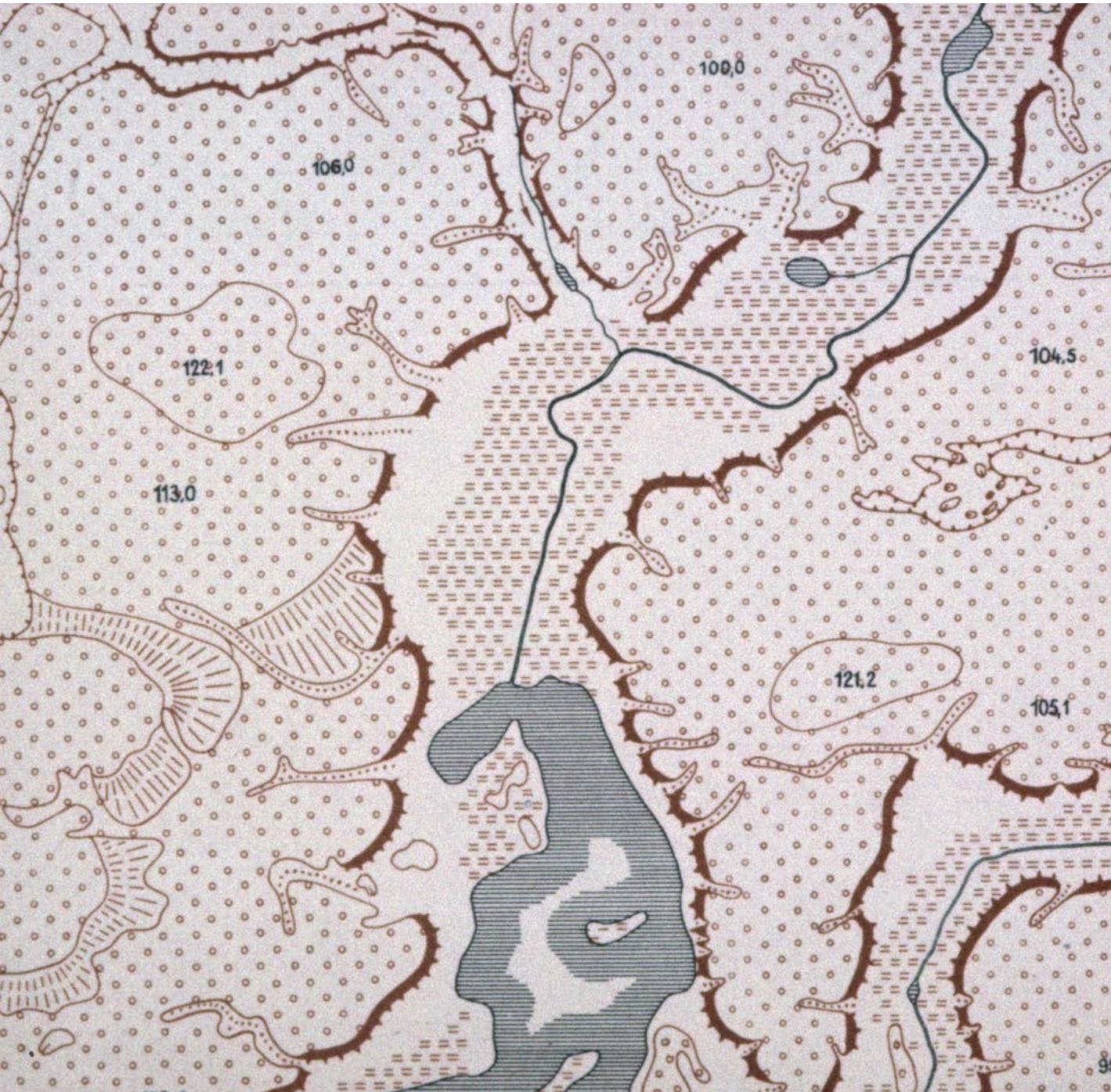
(Martin, 2013)

# 3. Geomorphological mapping

# GM: brief history

- Relief depiction on many "primitive" maps during the Antiquity, but no uniform legend.
- **Early 1800**: first geological maps (USA, UK)
- **Early 1900**: first geomorphological map (in 1914 by Passarge, D)
- At that time, the majority produce only sketch map at small scales (structural, physiographic, limited to one phenomenon).
- **1950s**: developpement of modern concepts of GM (CH and Poland, with Klimaszewski and Galon)
- **1960-1980**: golden age of GM, especially in Europe.
- **1990s >**: use of GIS, remote sensing, etc.

# GM: brief history



Detailed  
geomorphological  
map of an  
outwash  
landscape of the  
Poznan state, NW  
Poland  
(Galon, 1962)

# GM: brief history



Detailed  
geomorphological  
map of Southern  
Poland  
(Klimaszewski, 1956)

# GM: guidelines

**Defined by the IGU Subcommission on GM  
in Krakow (1962):**

1. Based on field work + aerial photography
2. Scales from 1:10'000 to 1:100'000
3. Mapping all aspects: morphography, morphometry, genesis, chronology, dynamic (past, present and future development of relief)
4. Color + symbols as legend
5. Chronological order of landforms
6. Include lithological data
7. Arrange the map legend in a genetic-chronological order

# GM scales (Dramis & Bisci, 1998)

## Large-scale GM (> 1:25'000)

- maps essentially based on systematic field survey.
- > correct representation of the features (morphometry etc.) of most landforms; morpho-evolution and morpho-dynamic maps.

## Medium-scale GM (1:25'000 to 1:250'000)

- compilation/generalisation of larger scale maps;
- maps derived from aerial photography.
- > representation of large landscape unites in full (cuestas, volcanic hills, alluvial plains); smaller forms are grouped and reproduced by not-to-scale symbols.

## Small-scale GM (< 1:250'000):

- compilation/generalisation of larger scale maps;
- maps derived from satellite imagery.
- > education purpose and land management at country level

# GM: two approaches... or more

## **Holistic / Synthetic maps**

Geomorphological data combined with other parameters: soil, vegetation, hydrography

## **Analytical / Basic / Comprehensive maps**

Descriptive information on morphometry, morphogenesis, chronology, etc of landforms >>  
morpho-evolution or morphodynamics maps

## **Pragmatic / Derivative / Thematic maps**

Limited information, selected according to a specific purpose

# GM: two approaches... or more

## Holistic / Synthetic maps

Subdivision of the territory into a number of characteristic regions and sub-regions (called site, facet, ecotop or region).

Based on aerial photography or satellite imagery.  
Focus on geomorphology, or botanic.

Christian (1958) – Australia

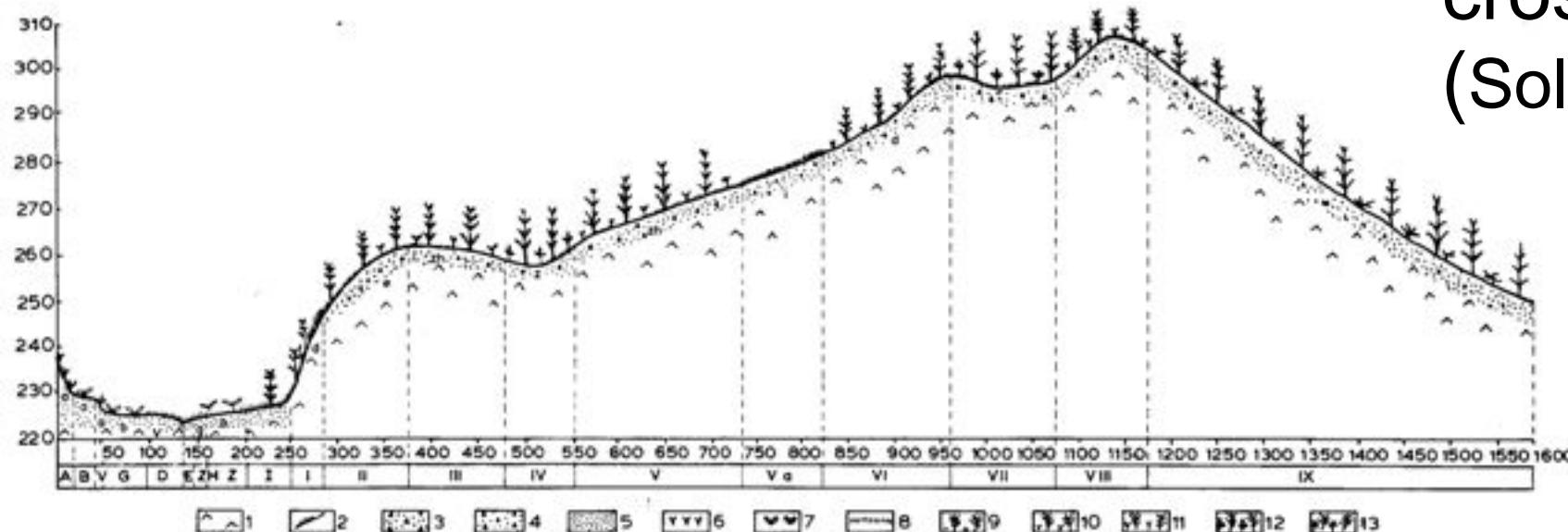
Solntsev (1962) – USSR

Gimbarzesski (1966) – Canada

Rey (1968) – France

# GM: 2 approaches... or more

## Landscape cross-section (Solntsev, 1962)



Facies of the Lower Patrushikha Valley Urochishche (Cyrillic capital letters):

- A - Escarpment between first and second left-bank terrace; weeds on site of original pinewood.
- B - First left-bank terrace; gardens on site of pinewood.
- V - Escarpment between first terrace and upper left-bank floodplain; weeds on site of pinewood.
- G - Upper left-bank floodplain; gardens on site of floodplain woods.
- D - Lower left-bank floodplain; wet meadow on site of floodplain woods.
- E - Stream channel.
- ZH - Lower right-bank floodplain; wet meadow on site of floodplain woods.
- Z - Upper right-bank floodplain; gardens on site of floodplain woods.
- I - Transitional facies between upper floodplain and right-bank valley wall; dry mixed-grass-and-cereal-grass meadow on site of pinewood.

Facies of Uktus Urochishche (roman numerals):

- I - Steep, rocky slope of southwest exposure; pinewood with steppe grasses.
- II - Southwest-facing slope of medium gradient; pinewood with sparse grasses.
- III - Gentle slope; pinewood with mixed grasses.
- IV - Shallow depression; pinewood with tall grass.
- V - Gentle slope; pinewood with mixed grasses.
- Va - Dry meadow with cereal grasses and mixed grasses. (This is an anthropogenous part of Facies V.)
- VI - Southwest-facing slope of medium gradient; pinewood with sparse grasses.
- VII - Shallow depression; pinewood with tall grass.
- VIII - Southwest-facing slope of medium gradient; pinewood with sparse grasses.
- IX - Northeast-facing slope of medium gradient; pinewood with ferns.

Landscape Cross-Section Through the Valley of the Patrushikha River

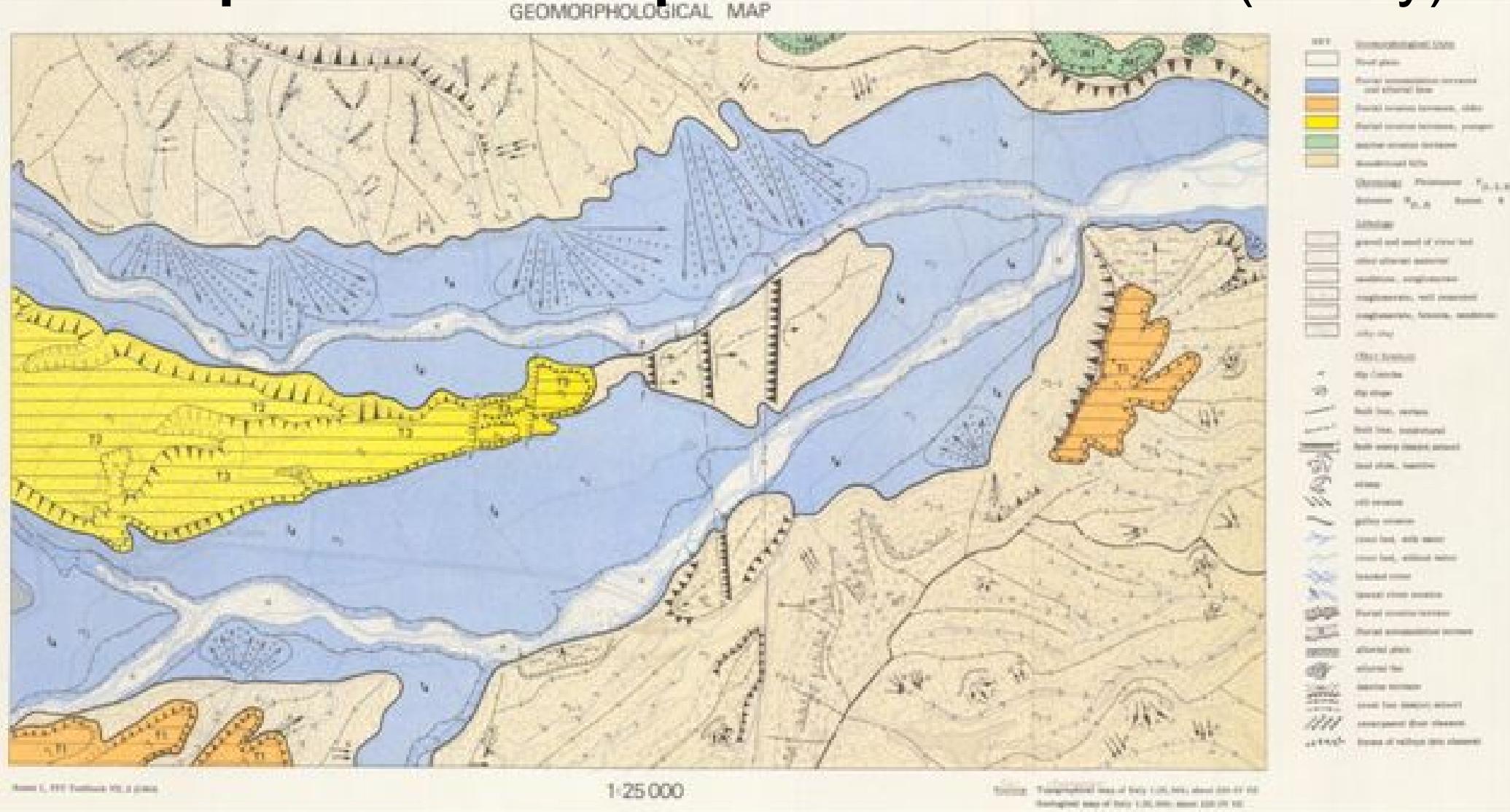
and the Uktus Mountains (horizontal scale 1:5,000; vertical scale 1:1,000).

Conventional symbols:

- |                                  |  |
|----------------------------------|--|
| 1 - Pyroxenites and dunites      | a - Cultivated, truncated  |
| 2 - Rock outcrops on slopes      | b - Humic gley   |
| 3 - Eluvium                      | v - Alluvial meadow  |
| 4 - Drift                        | g - Thin, stony humic gley                                       |
| 5 - Alluvium                     | d - Undeveloped gray-brown forest                                |
| 6 - Weeds                        | e - Thin, stony, moderately podzolized gray-brown forest         |
| 7 - Vegetable gardens            | zh - Thin, stony, weakly podzolized gray-brown forest            |
| 8 - Meadow                       | z - Moderately thick gray forest                                 |
| 9 - Pinewood with steppe grass   | i - Moderately thick, stony, weakly podzolized gray-brown forest |
| 10 - Pinewood with sparse grass  |  |
| 11 - Pinewood with mixed grasses |  |
| 12 - Pinewood with tall grass    |  |
| 13 - Pinewood with ferns         |  |

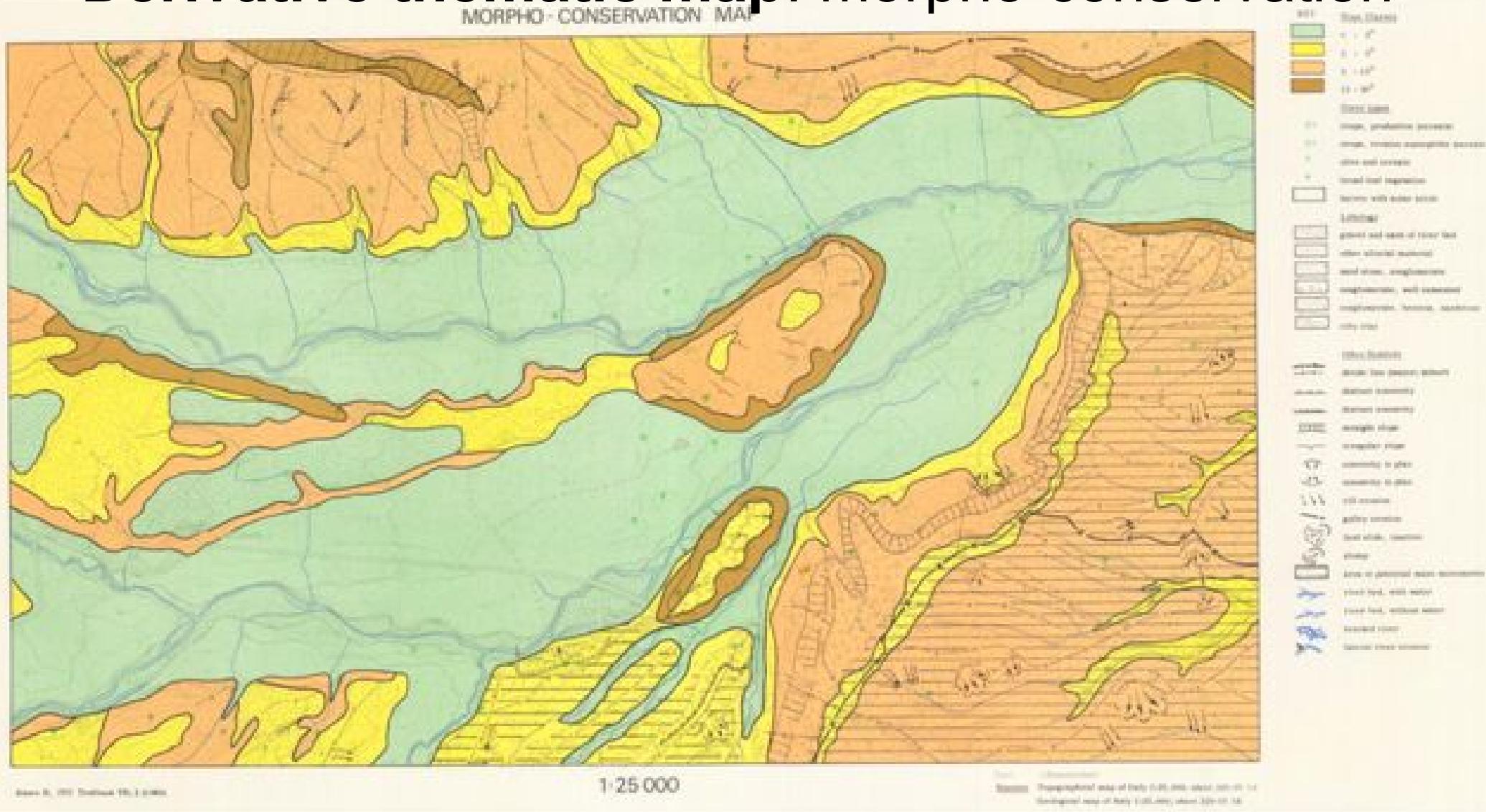
# GM: 2 approaches... or more

# Comprehensive map: GM of Crati Basin (S Italy)



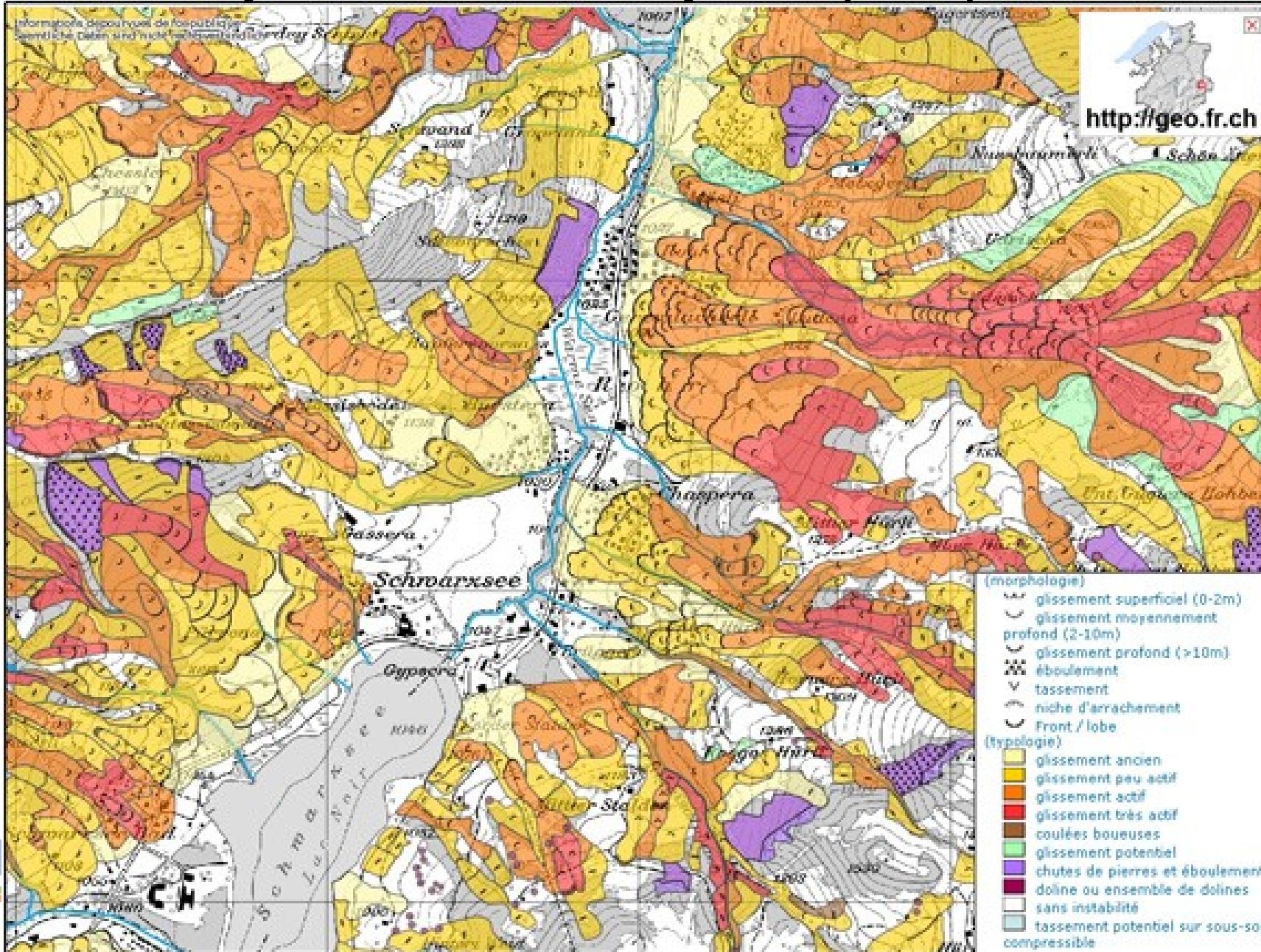
# GM: 2 approaches... or more

## Derivative thematic map: morpho-conservation



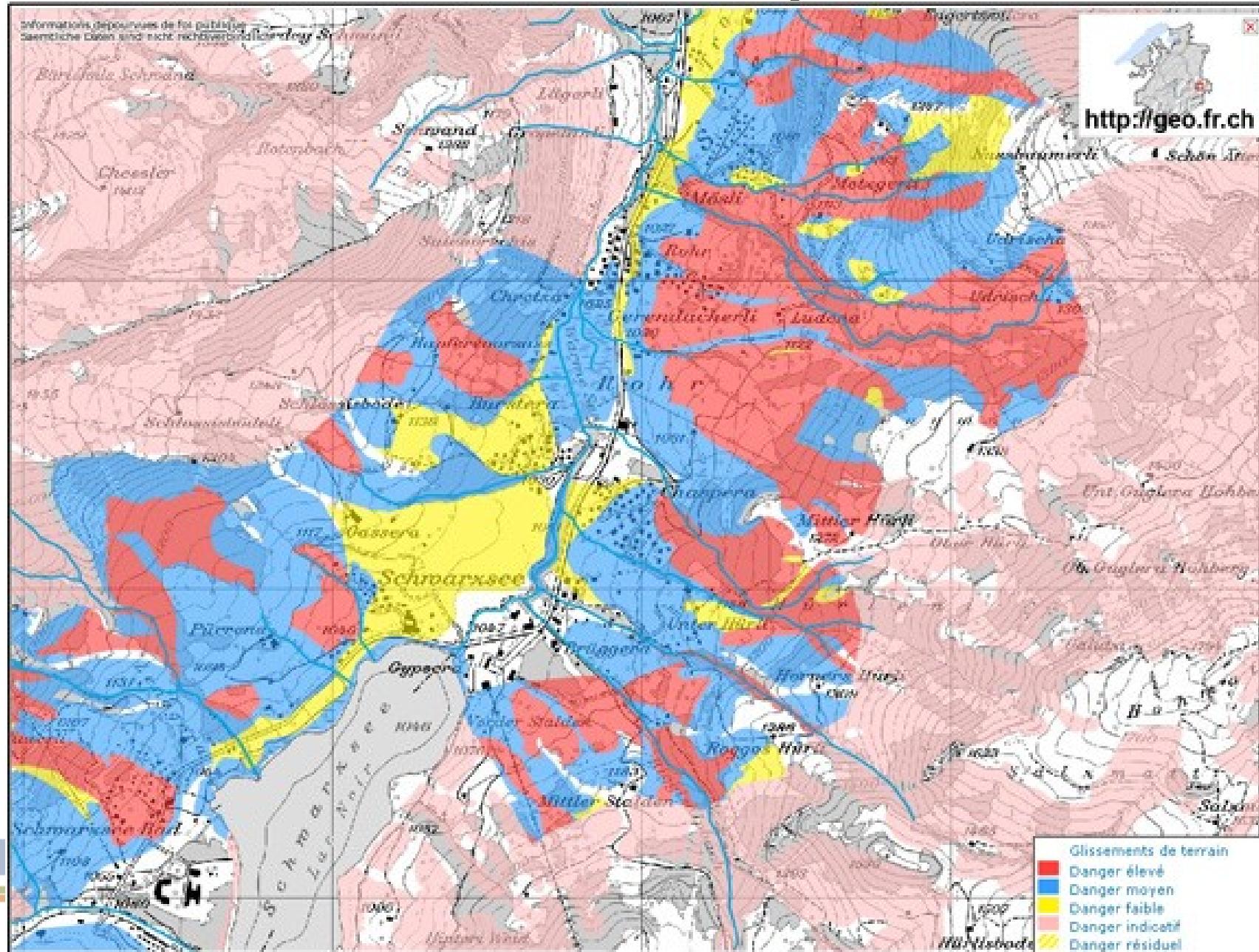
# GM: 2 approaches... or more

## Comprehensive map: map of phenomena (CH)



# GM: 2 approaches... or more

## Derivative thematic map: natural hazards



# GM: legend issues

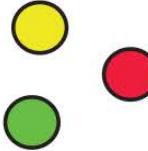
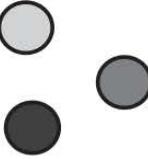
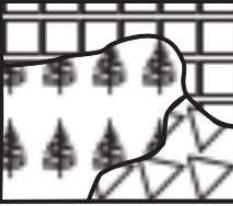
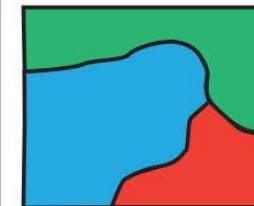
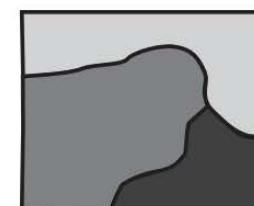
GM = interpreted, generalised and understandable picture of the mapped area. (Otto et al., 2011)

## Legend:

- is an essential component of the GM (St Onge, 1981)
- must be kept as simple as possible (Gustavsson, 2006)
- should be flexible (scale, area) (Verstappen, 1970)
- **has to enable the separation between descriptive (terrain) and interpretive (author) data**
  - > the reader can draw his own conclusions (or at least know what underlies the map maker's interpretation).

# GM: legend issues

All legends are based on basic visual elements.  
In some legends, letter codes are added to show  
the age of the landforms or the lithology.

	SIZE	SHAPE	TEXTURE	HUE	VALUE
POINT					
LINE					
AREA					

(Otto, 2006)

# GM: legend issues

## 2 general models

### **Landform Pattern Model**

More interpretive

Landforms are repetitive patterns, easily definable as "forms" (hills, moraines, channel,...).

### **Landform Element Model**

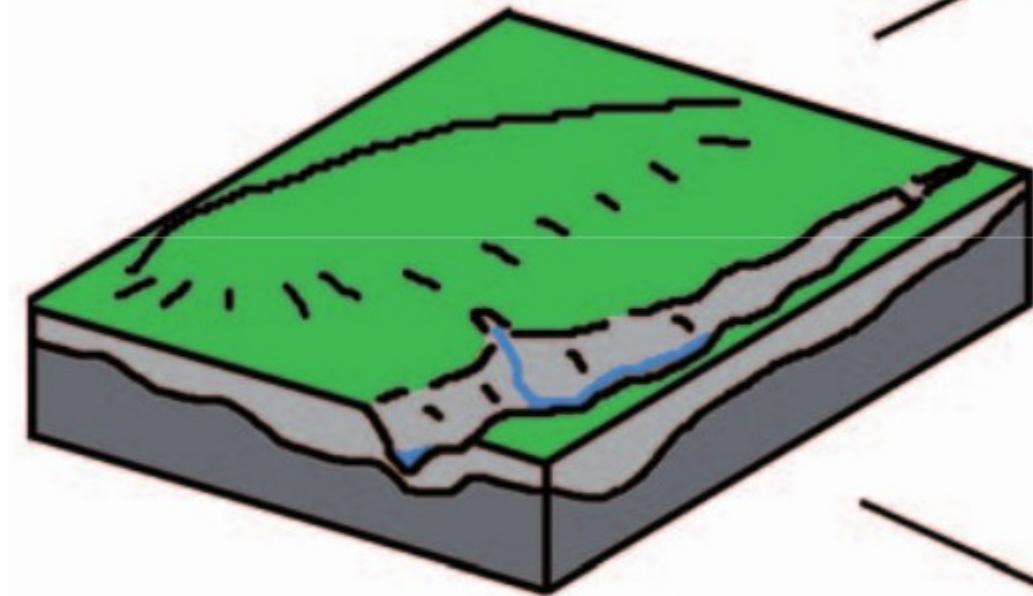
More descriptive

Landforms are described by geometric elements (slope, crest, plain) according to their morphology.

# GM: legend issues

## 2 general models

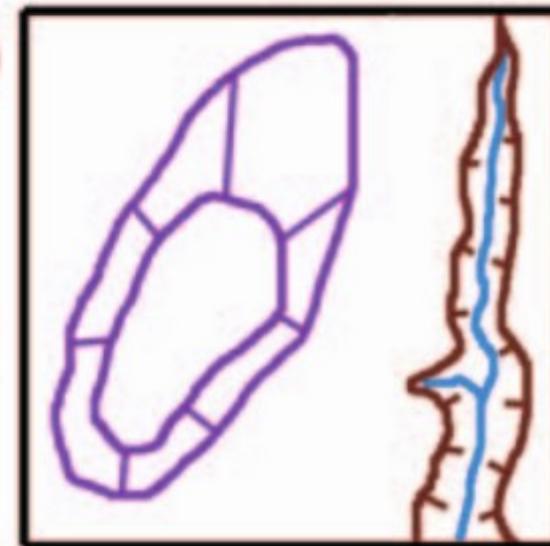
**Landform Pattern Model**



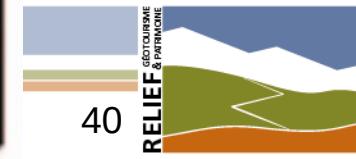
a



b

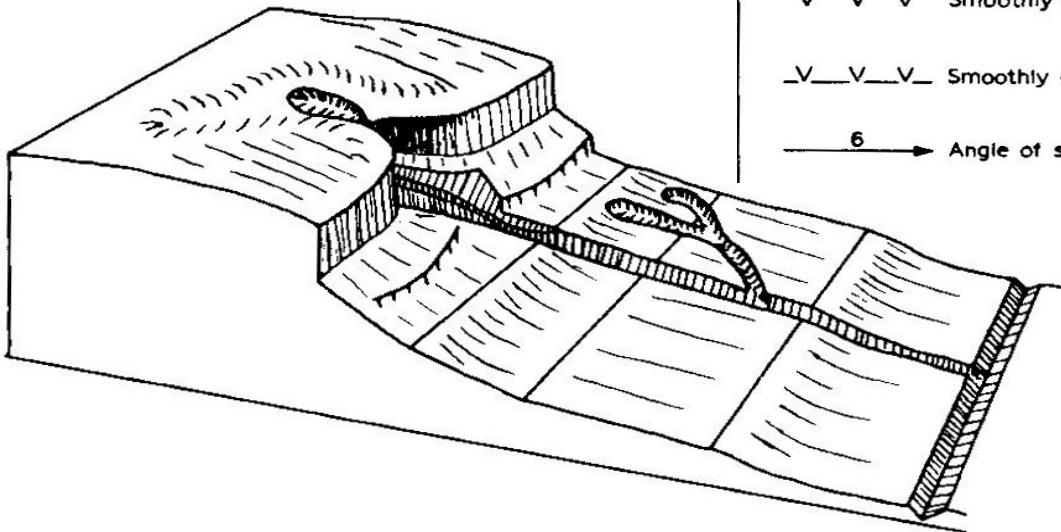


**Landform Element Model**



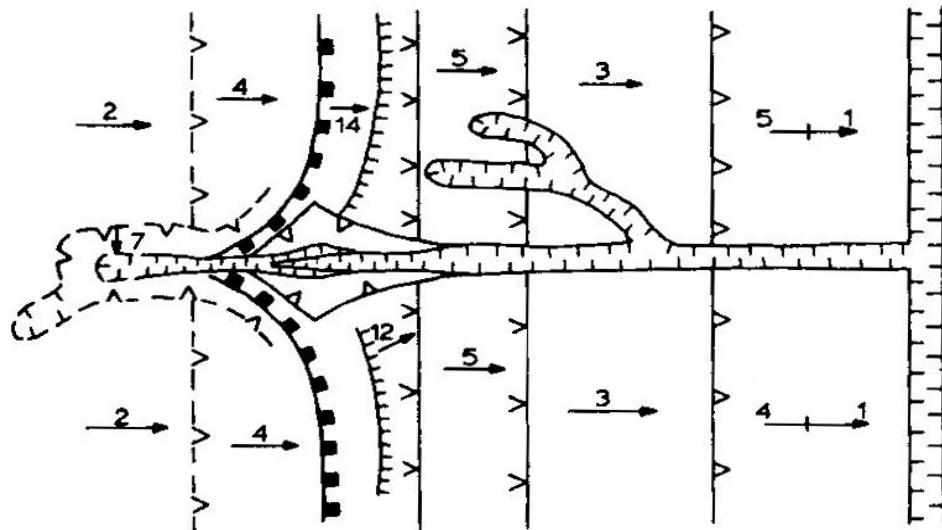
# GM: legend issues

## MORPHOLOGICAL MAPPING SYMBOLS



▽▽▽ Angular convex break of slope	██████ Cliffs (bedrock, 40° or more)
＼＼＼ Angular concave break of slope	Breaks of slope
~V~V~V~ Smoothly convex change of slope	TTTTT Changes of slope
＼＼＼ Smoothly concave change of slope	X Convex slope unit
6 → Angle of slope (degrees)	—+— Concave slope unit

Convex and concave too close together to allow the use of separate symbols



## Landform Element Model



# GM: legend issues

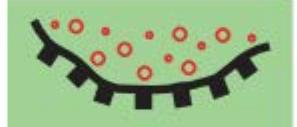
## But many legends

Because:

- Both models can be mixed.
- Focus can be on genesis, process, form, material.
- Legends are adapted according to the area (mountain, lowland, costal...) and the scale.

# GM: legend issues

(Otto, 2006)

Legend system	Landform		Emphasis
	Moraine Ridge	Fluvial Terrace	
IGU unified key (Demek et al., 1972)			morphogenesis
ITC (NL) (Verstappen & Zuidam, 1968)			process / genesis
GMK 25/100 (GER) (Barsch, 1978)			genesis
British Geomorphological Maps (Evans, 1990)			form / genesis
ARAG (NL) (DeGraaf et al, 1987)			genesis / surface material
IGUL (CH) (Schoeneich et al. 1998)			morphogenesis /landforms
Mapping system by Gustavsson (Gustavsson et al., 2006)			morphogenesis
BUWAL / BAFU (CH) (Kienholz, 1976)			process / landform

# GM: legend issues

**1<sup>st</sup> issue: universality**

# GM: legend issues

## IGU Unified Key (1968, published 1972)

An attempt to propose a unified GM legend for the whole world, with 353 landform symbols and 10 colors.

Unified Key maps are comprehensive: genesis, morphometry/graphy, age (altitude, slope classes, hydrography, lithology).

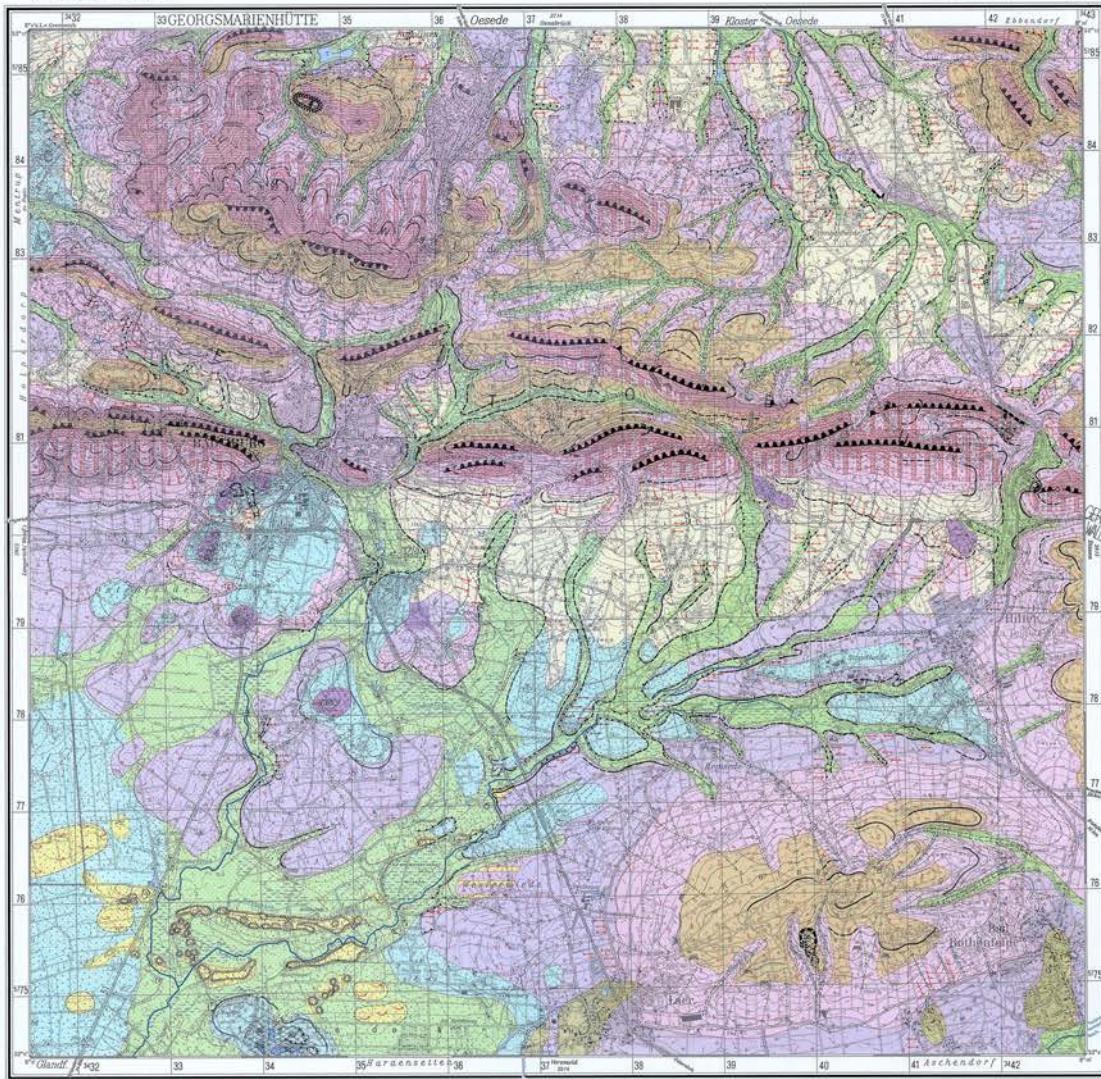
# GM: legend issues

**2<sup>nd</sup> issue: complexity / readability**

# GM: legend issues

Geomorphologische Karte 1:25 000 der Bundesrepublik Deutschland

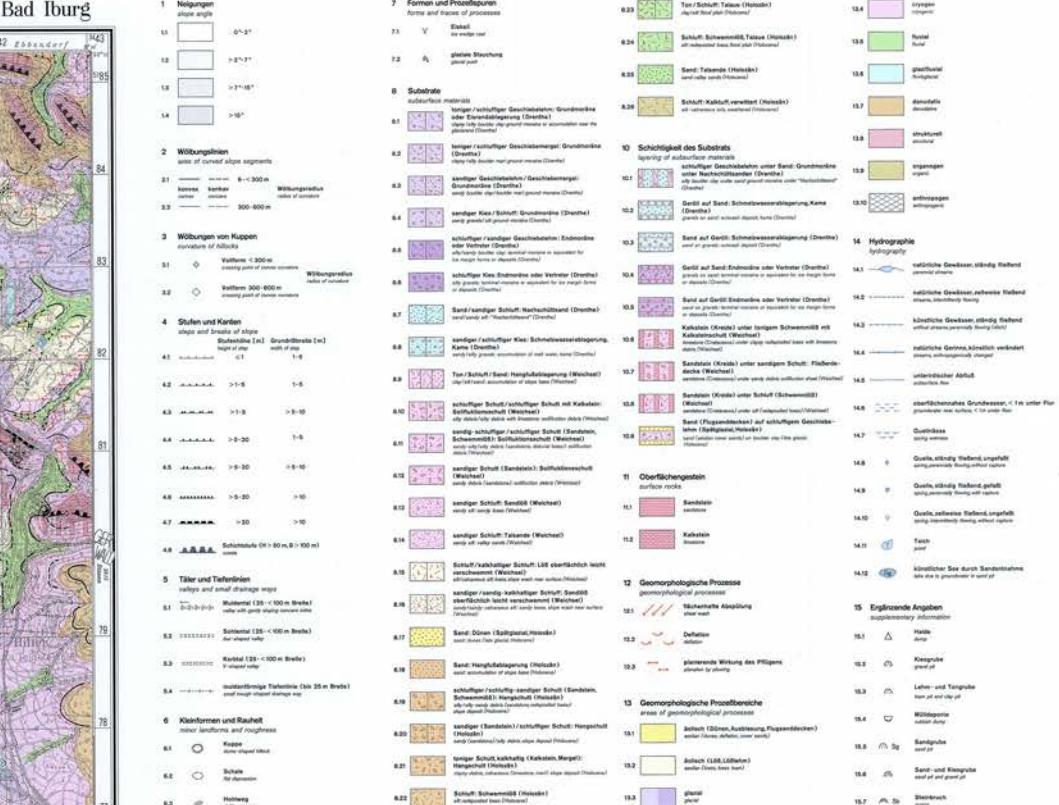
GMK 25 Blatt 6



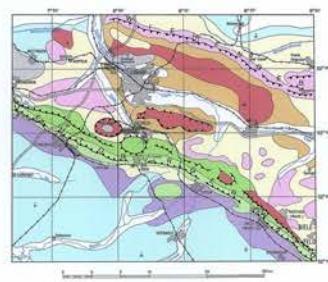
Geographisches Institut  
D. Borch, O. Fröhle, H. Lesser, H. Liedtke und G. Stöcklin  
als Mitglieder der Koordinationskommission des  
GMK-Schwerpunktprogramms der Deutschen Forschungsgemeinschaft (DFG)

Grundlage: Topographische Karte 1:25 000 Blatt 3814 Bad Iburg (Ausgabe 1979)  
Mit Genehmigung des Landesvermessungsamtes Niedersachsen  
Bearbeitet und gedruckt mit Unterstützung der Deutschen Forschungsgemeinschaft

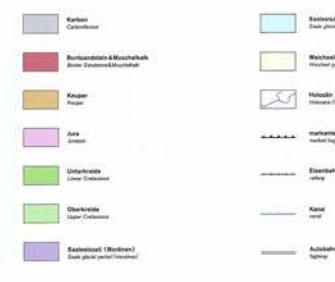
Aufnahme: J. August 1979  
Kartographie: A. Gertel im GMK-Schwerpunktprogramm  
Druck: Institut für Angewandte Geodäsie, Ingenieurtheorie Berlin  
Auslieferung: GeoCensus, Postfach 800 850, D-7000 Stuttgart 81



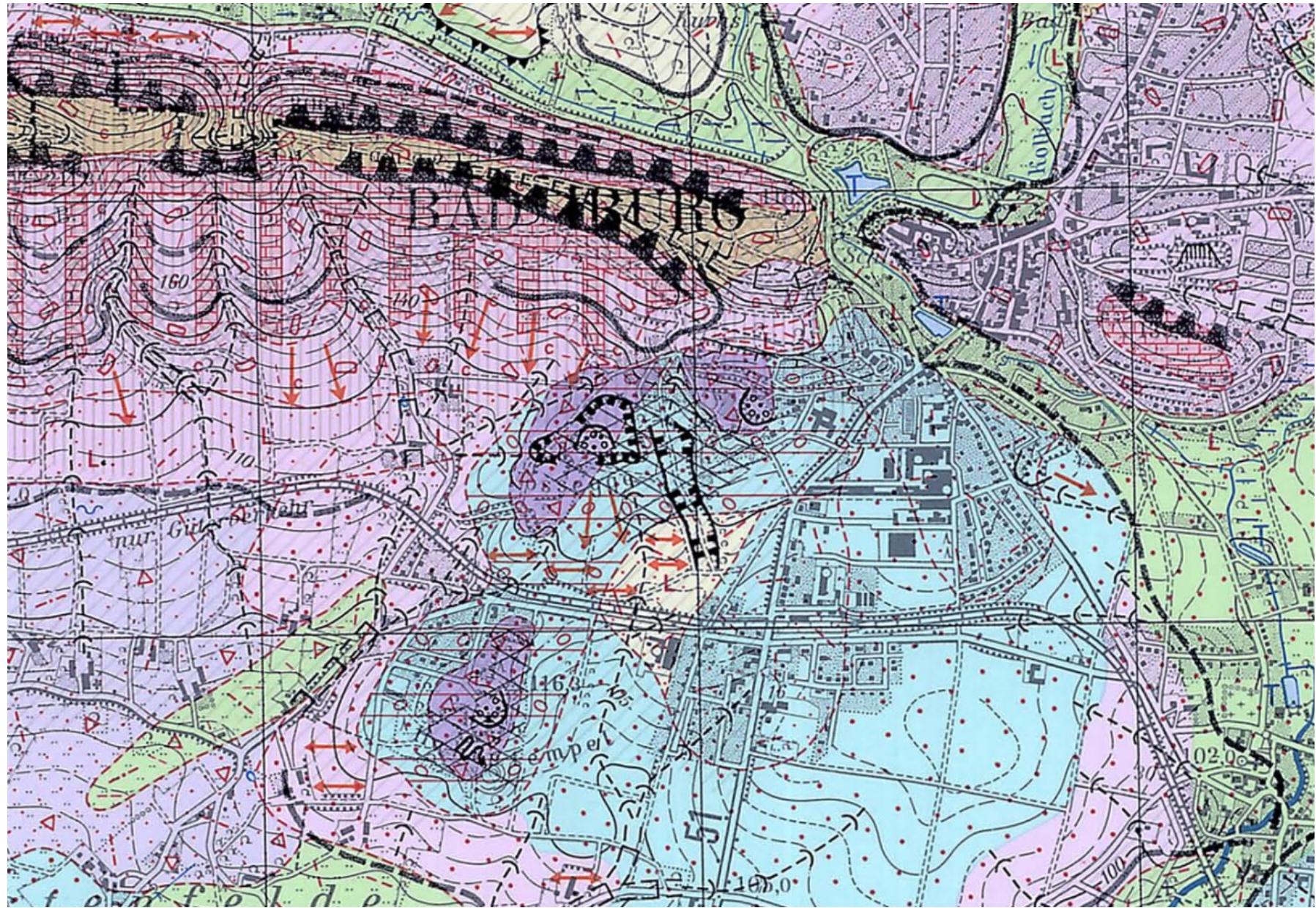
GEOLOGISCHE ÜBERSICHTSKARTE  
GEOLOGICAL MAP OF THE REGION



Als Quelle dienten die Geologischen Karten 1:25 000:  
Nr. 3712 (1970), Nr. 3712 (1984), Nr. 3714 (1982), Nr. 3716 (1984), Nr. 3812 (1984), Nr. 3814 (1982), Nr. 3815 (1985).



# GM: legend issues



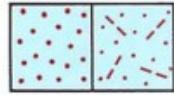
# GM: legend issues

8.6



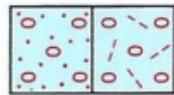
**schluffiger Kies:** Endmoräne oder Vertreter (Drenthe)  
silty gravels: terminal-moraine or equivalent for ice margin forms or deposits (Drenthe)

8.7



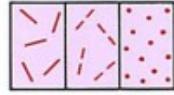
**Sand / sandiger Schluff:** Nachschütt sand (Drenthe)  
sand / sandy silt: "Nachschütt sand" (Drenthe)

8.8



**sandiger / schluffiger Kies:** Schmelzwasserablagerung, Kame (Drenthe)  
sandy / silty gravels: accumulation of melt water, kame (Drenthe)

8.9



**Ton / Schluff / Sand:** Hangfußablagerung (Weichsel)  
clay / silt / sand: accumulation of slope base (Weichsel)

## 12 Geomorphologische Prozesse geomorphological processes



**12.1** flächenhafte Abspülung  
sheet wash



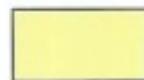
**12.2** Deflation  
deflation



**12.3** planierende Wirkung des Pflügens  
planation by plowing

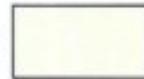
## 13 Geomorphologische Prozeßbereiche areas of geomorphological processes

3.1



**äolisch (Dünen, Ausblasung, Flugsanddecken)**  
aeolian (dunes, deflation, cover sands.)

3.2



**äolisch (LöB, LöBlehm)**  
aeolian (loess, loess loam)

3.3



**glazial**  
glacial

13.4



**cryogen**  
cryogenic

13.5



**fluvial**  
fluvial

13.6



**glazifluvial**  
fluvioglacial

13.7



**denudativ**  
denudative

13.8



**strukturell**  
structural

13.9



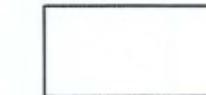
**organogen**  
organic

13.10



**anthropogen**  
anthropogenic

## 1 Neigungen slope angle



$0^\circ - 2^\circ$



$> 2^\circ - 7^\circ$



$> 7^\circ - 15^\circ$

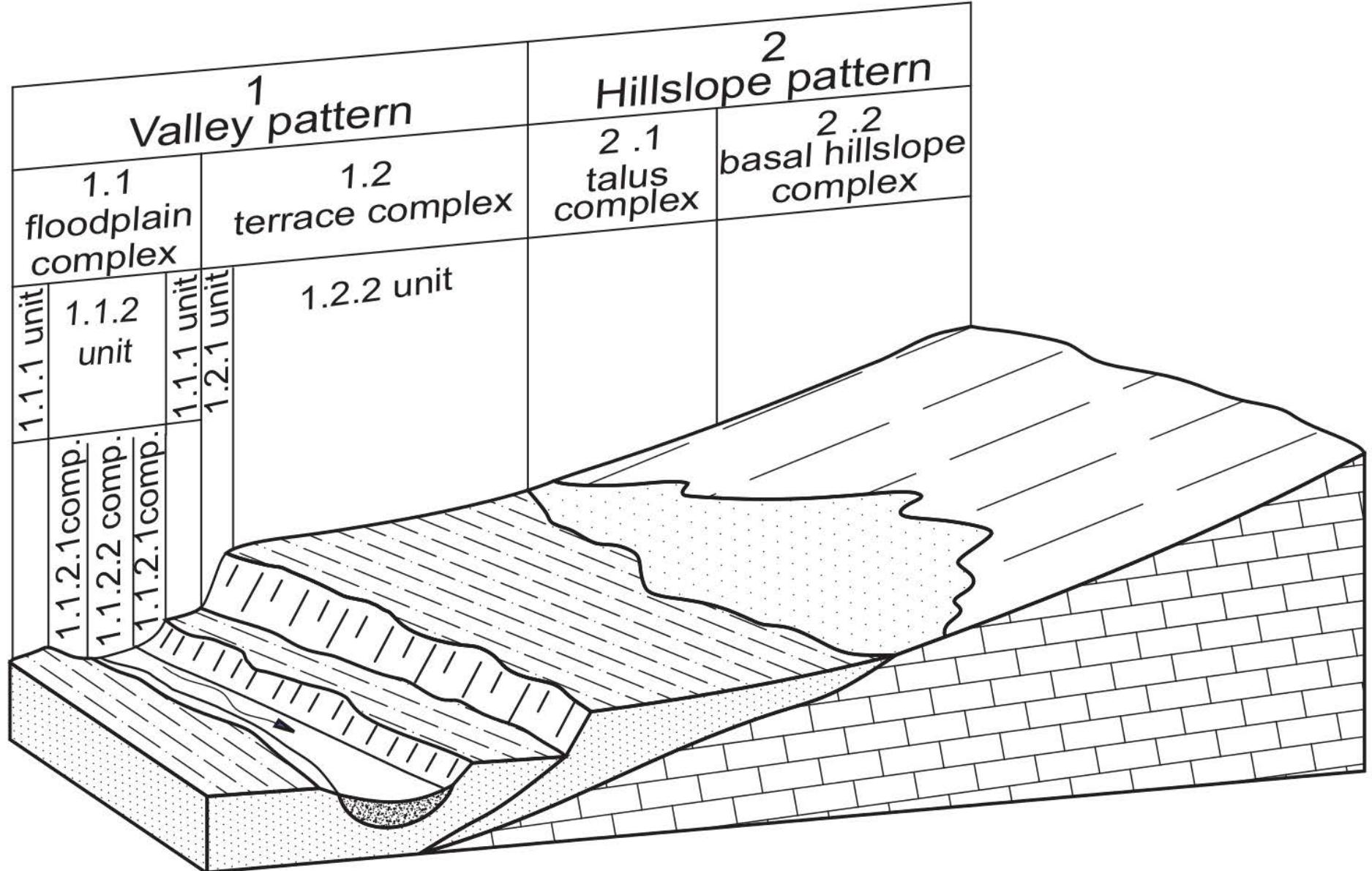


$> 15^\circ$

# GM: legend issues

## 3<sup>rd</sup> issue: scale

# GM: legend issues

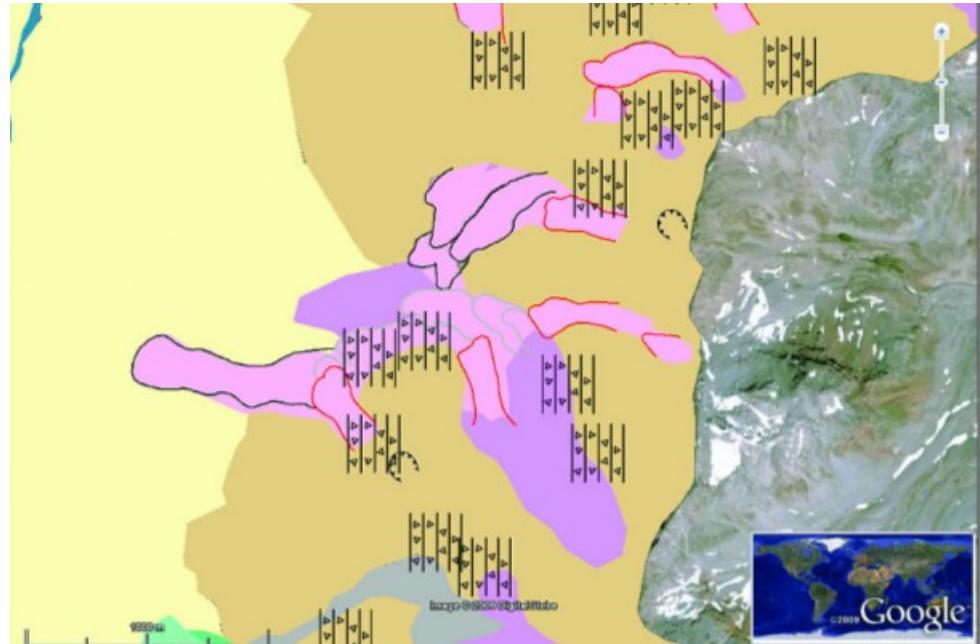
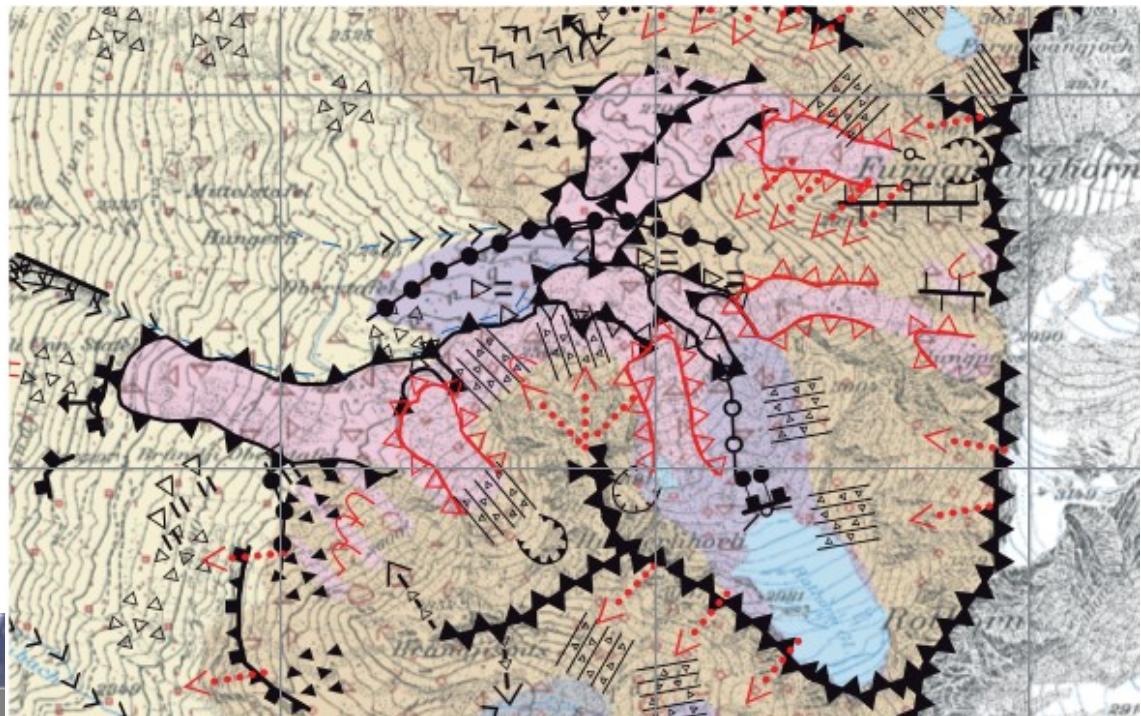
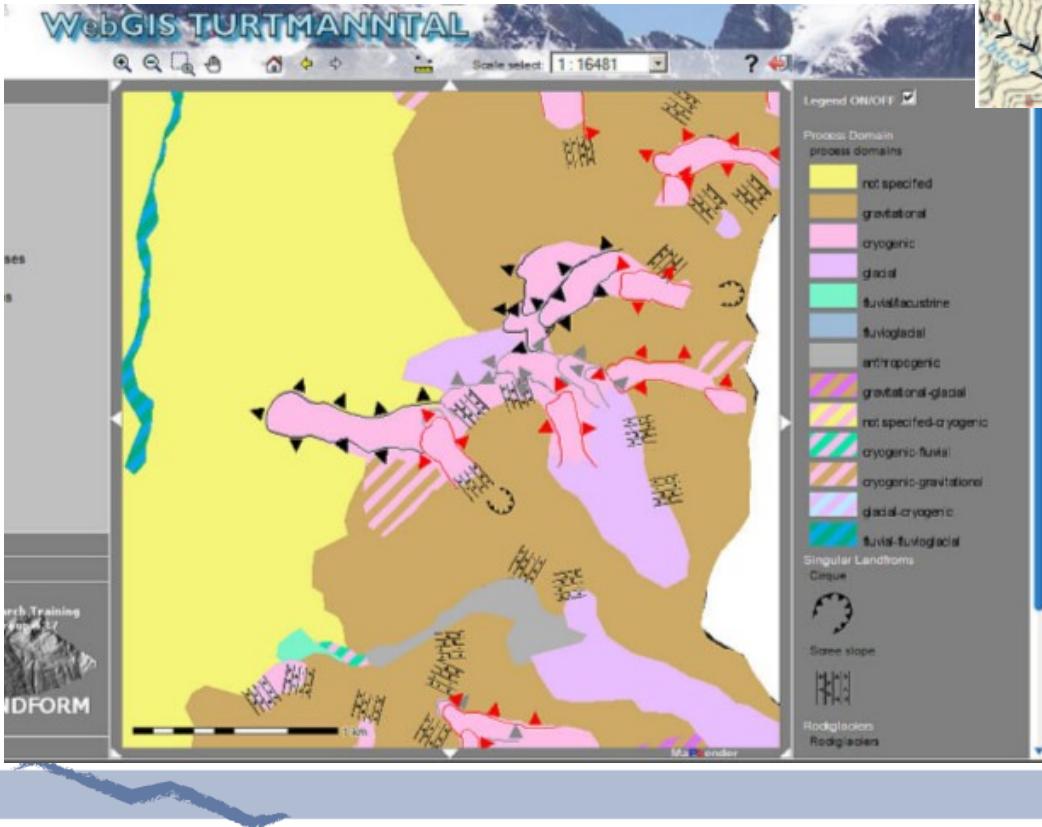


# GM: legend issues

**4<sup>th</sup> issue: interoperability, structure**

# GM: legend issues

(Otto, 2006)



# GM: legend issues

## Exercice: comparison between 4 legends

- Swiss legend
- RCP77 (France)
- GMK25 (Germany)
- IGUL legend

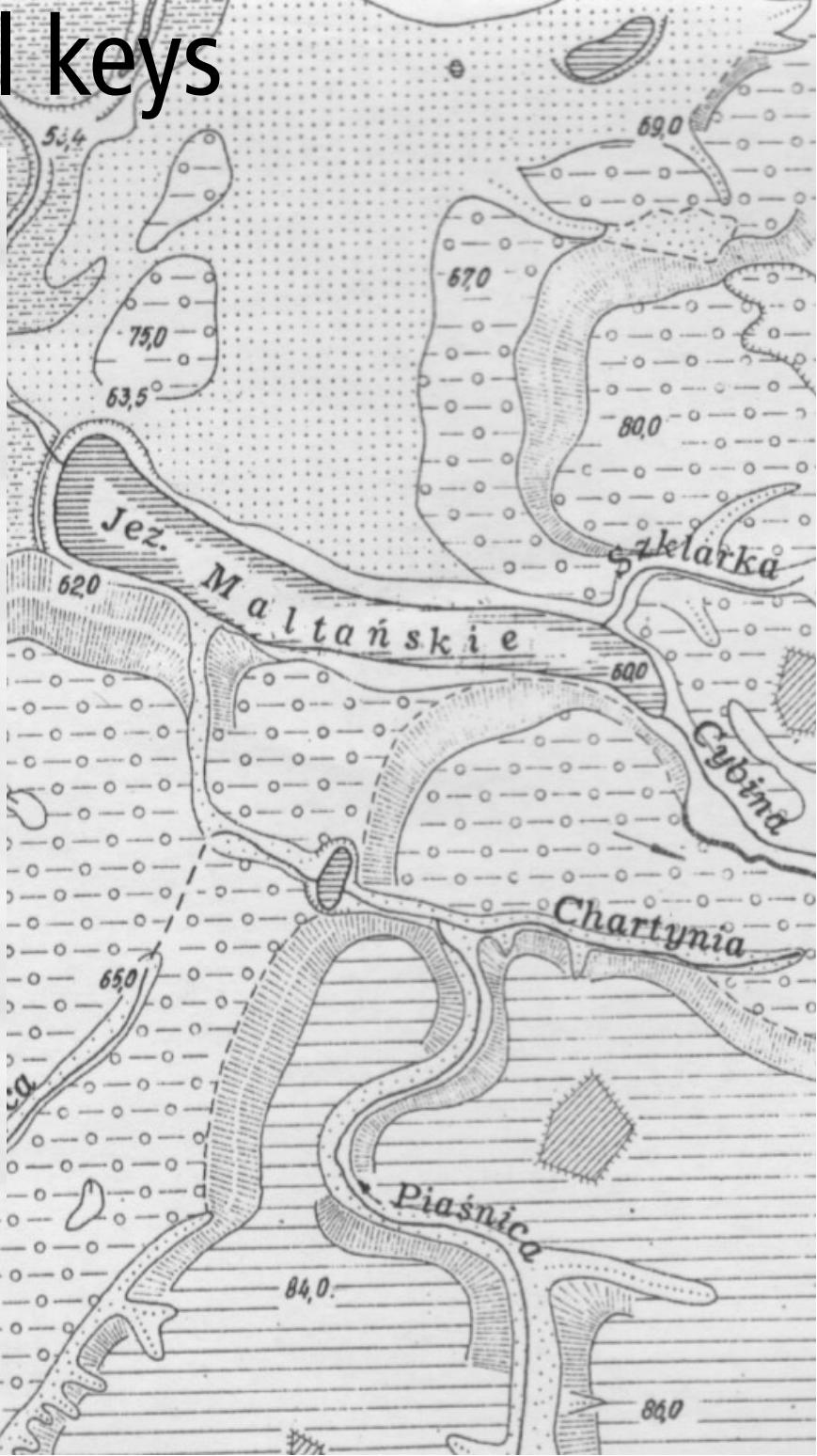
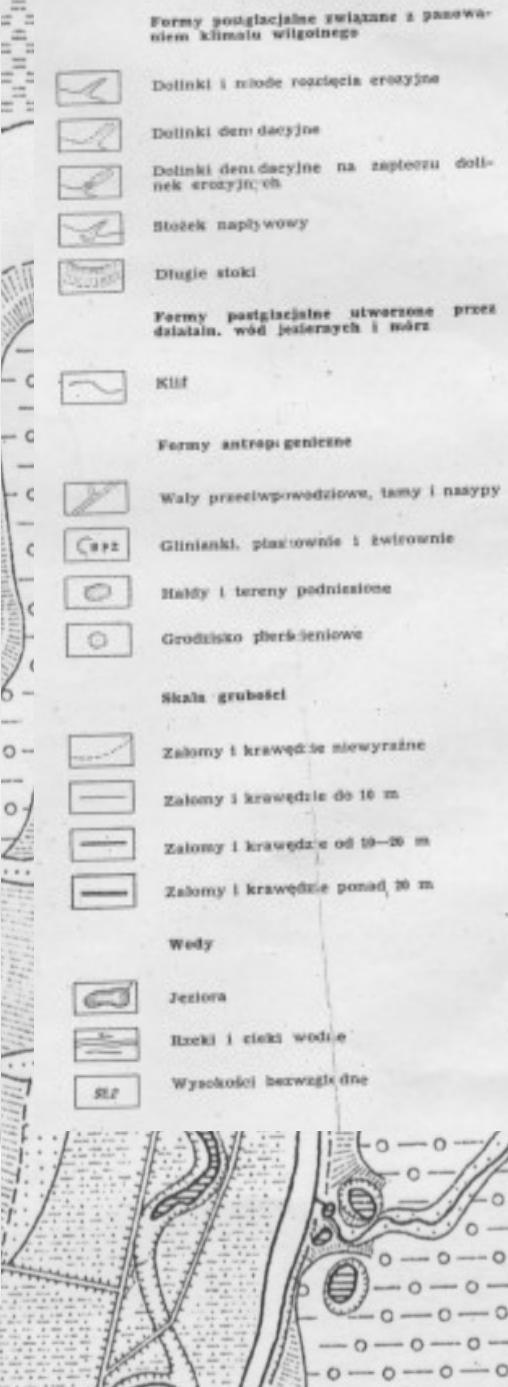
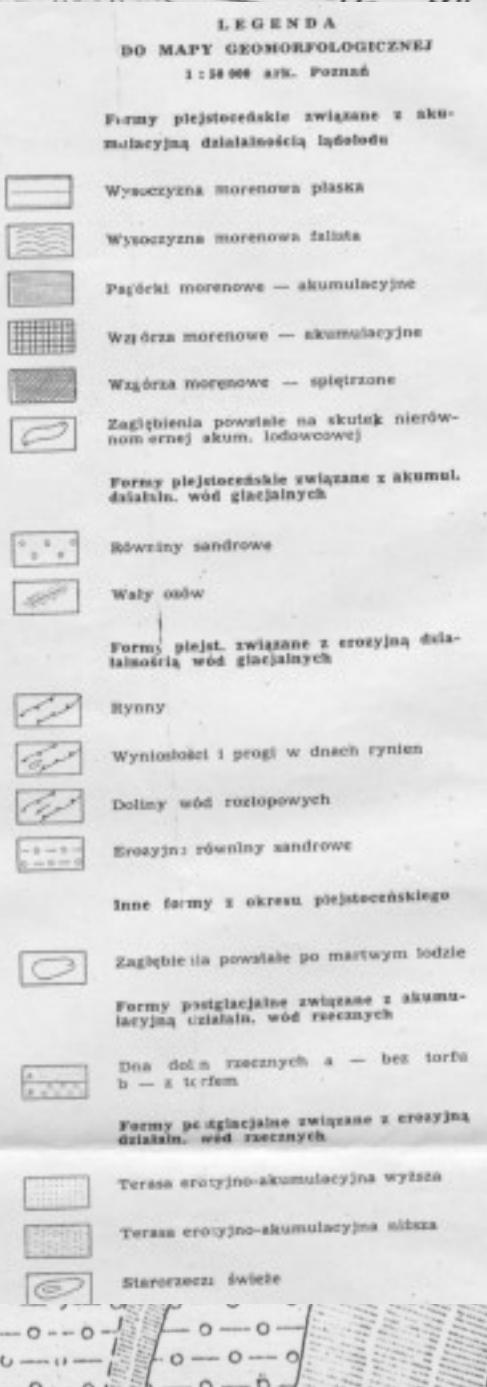
# GM: legend issues

## Exercise: comparison between 4 legends

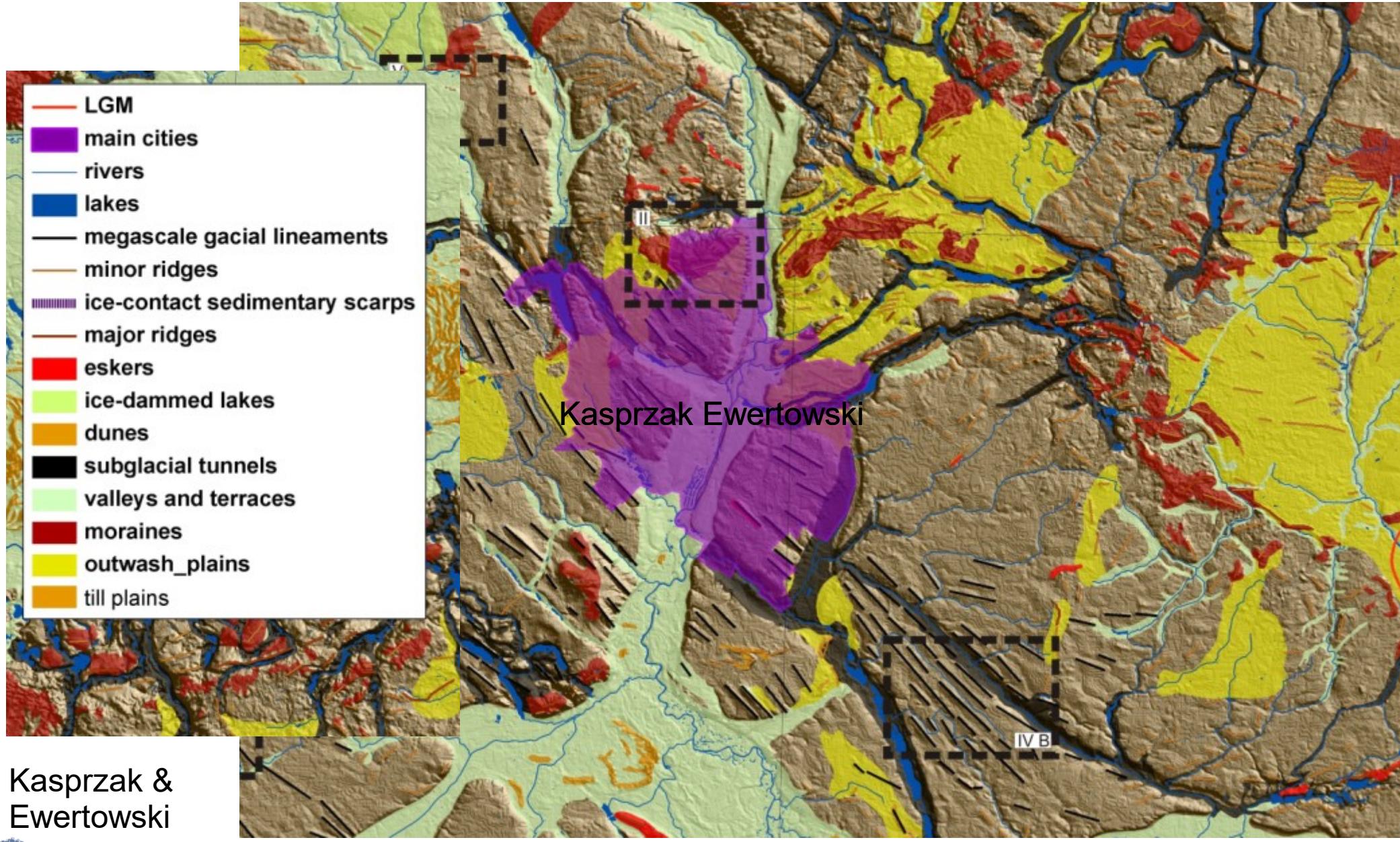
All follow Landform Pattern Model, with some items from Landform Element Model.

- Swiss legend: focus on dynamic, aimed for land management (hazard maps).
- RCP77 (France): focus on landforms and morphogenesis.
- GMK25 (Germany): focus on morphography (detail) and morphogenesis (general).
- IGUL legend: focus on landforms and morphogenesis, secondly on dynamic.

# GM: legend issues – local keys



# GM: legend issues – local keys



Kasprzak &  
Ewertowski

# GM: legend issues – local keys

## Formy występujące na obszarze młodszego zlodowacenia (bałtyckie)

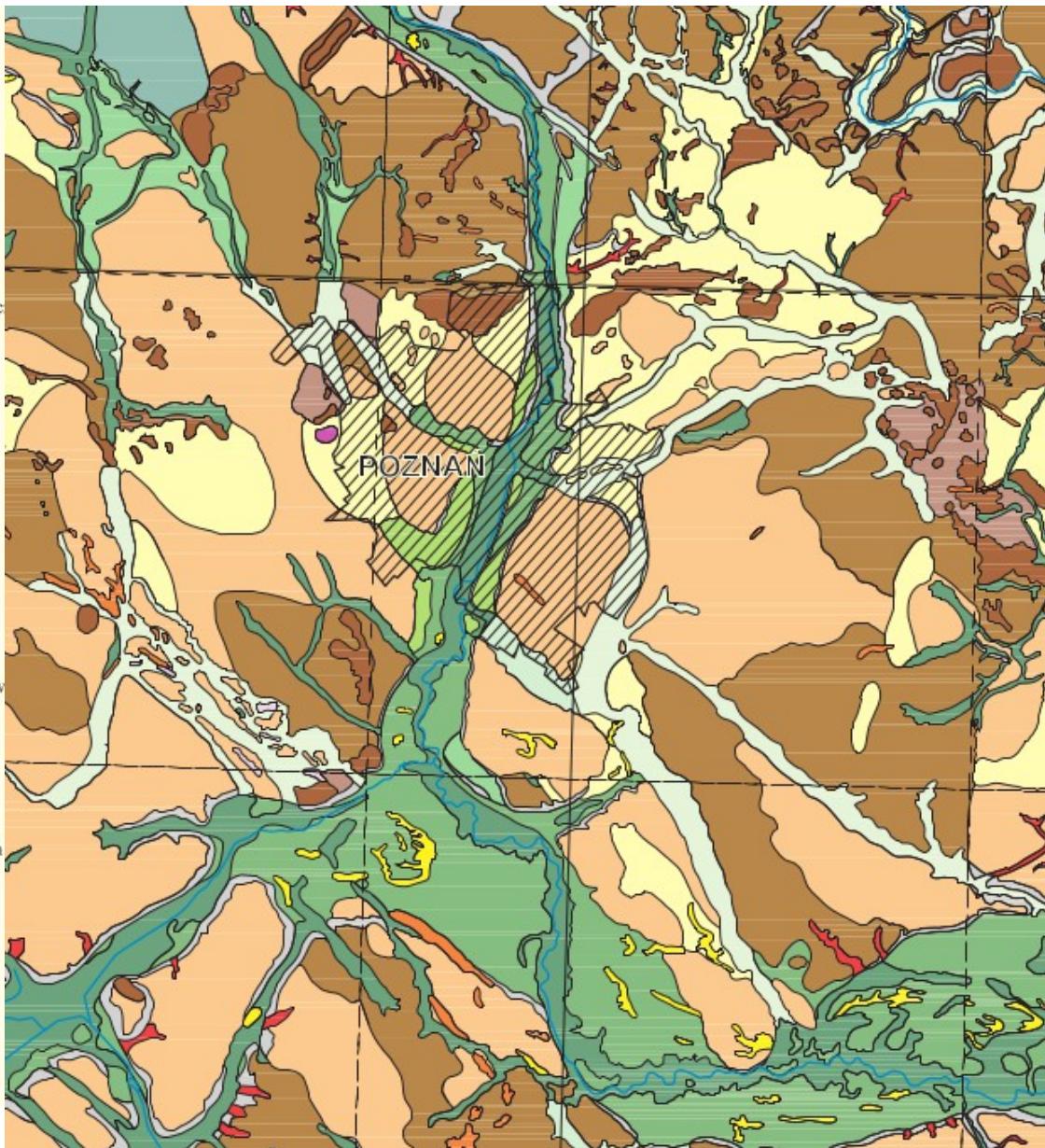
	wysoczyzna morenowa płaska zl. bałtyckiego
	wysoczyzna morenowa falista
	wysoczyzna morenowa pagórkowata poch. akum.
	wysoczyzna morenowa pagórkowata poch. eroz. lub eroz.-akum.
	strefa pagórków moreny czołowej o drobnym rytmie
	strefa pagórków moreny czołowej o większym rytmie
	pagórki morenowe odosobnione
	równiny sandrowe
	pagórki kemowe
	wały ozowe
	równiny zastoiskowe
	rynna o dnie płaskim
	rynna o dnie pagórkowatym
	wytopiska występujące zespołowo
	wytopiska pojedyncze
	pagórki ostańcowe
	wały morenowe typu ostańcowego
	stopnie terasowe, krawędzie, załomy, zbocza dolinne
	pagórki wydmowe

	terasa zalewowa, denna, dna basenów
	terasa środkowa, wydmowa
	terasy wysokie, niższa
	terasy wysokie, wyższa
	drobne doliny i parowy roczinające wysoc.
	zasięg zlodowacenia bałtyckiego

## Formy występujące na obszarze starszego zlodowacenia (środkowopolskiego)

	wierzchowina Gór Kocich
	wysoczyzna morenowa płaska zl. środkow.
	równiny denudacji peryglacialnej
	stoki i zbocza
	równiny akum. peryglacialnej w kotlinach

- arkusze mapy w skali 1:100 000
- sieć rzeczna
- wybrane miasta



Karczewski et al.

# GM: references

- Demek, J., Embleton, C., Gellert, J.-F., & Verstappen, H. T. (Éd.). (1972). Manual of detailed geomorphological mapping. Prague: Academia.
- Smith, M. J., Paron, P., & Griffiths, J. S. (Éd.). (2011). Geomorphological mapping. Methods and applications. Amsterdam: Elsevier.

## Review and comparisons between legend:

Gilewska, S. (1967). Different methods of showing the relief on the detailed geomorphological maps. *Zeitschrift für Geomorphologie*, 11, 481–490.

Gustavsson, M., Kolstrup, E., & Seijmonsbergen, A. C. (2006). A new symbol-and-GIS based detailed geomorphological mapping system. Renewal of a scientific discipline for understanding landscape development. *Geomorphology*, 77(1), 90–111.

Salomé, A. I., Van Dorsser, H. J., & Rieff, P. L. (1982). A comparison of geomorphological mapping systems. *ITC Journal*, 3, 272–274.

Schoeneich, P. (1993). Comparaison des systèmes de légende français, allemand et suisse. *Cartographie géomorphologique-Cartographie des risques*, 15–24.