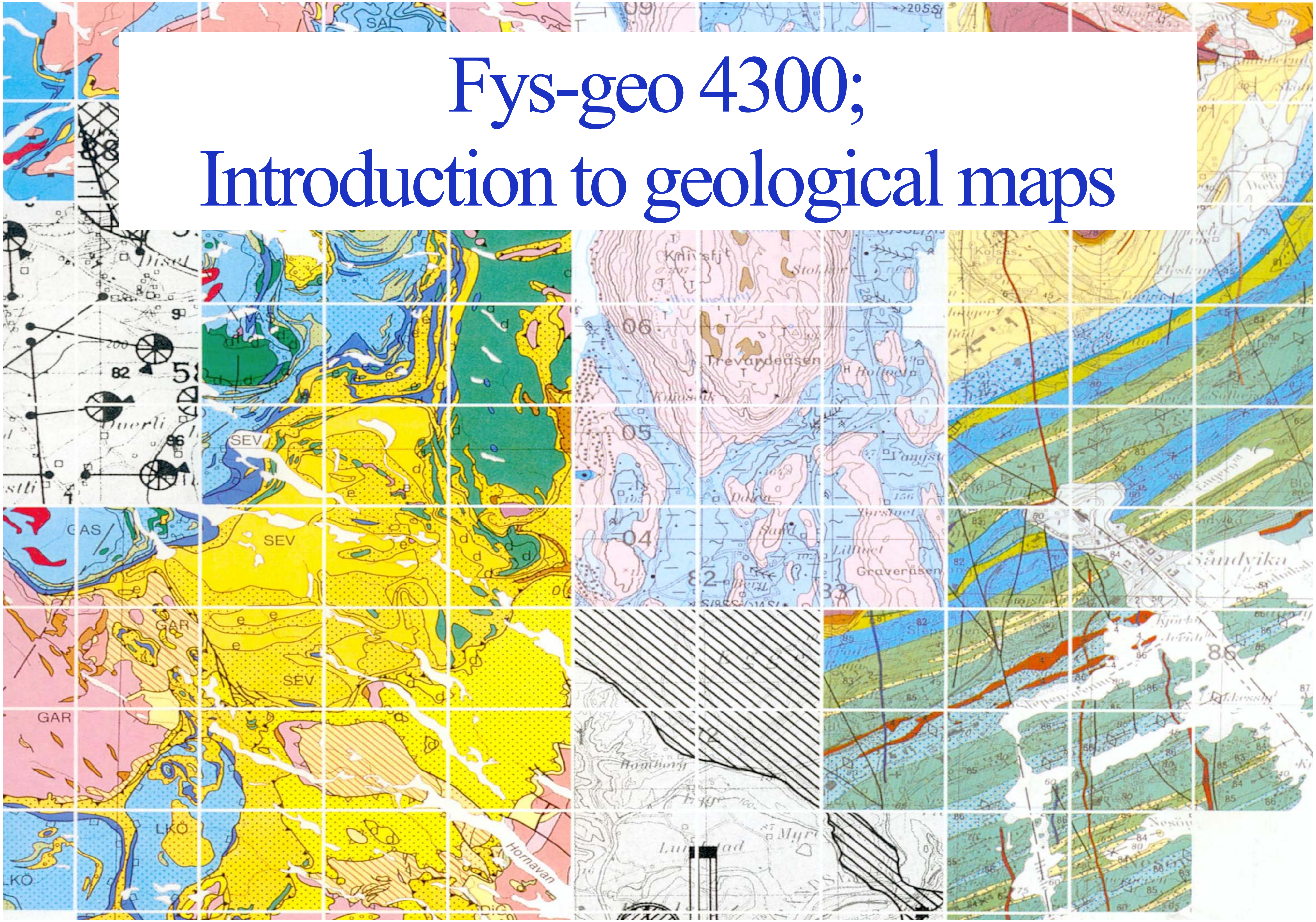
Fys-geo 4300;
Introduction to geological maps



Geological maps and their applications

- **Intro:**
  - **Geological maps are efficient tools to make geological information and data accessible for use by science, industry, individuals and the society.**
  - **Mapping and map presentations are consequently important tasks for geologists.**
  - **Here we shall learn some basics of map reading and presentation**

- **If a map is correct, and we have the ability to read it, it will provide important information regarding a number of phenomena depending on the type and focus of the map:**
  - **Distribution of hard and soft rocks, age/stratigraphy, structures, minerals and other resources, pollution, water, geotechnical aspects, targets for exploration etc.**
  - **We can deduce important elements in the geological evolutionary history from map-patterns.**

Topographic maps

- The base for most geological maps is a topographic map or some other representation of topography (aerial photographs, satellite images etc).
- In Norway topo-maps are made and distributed by Statens Kartverk (http:www.statkart.no/IPS/). Private companies, local authorities and other users may produce very detailed topo-maps for special purposes.
- Many parts of the country are mapped in greater detail, 1:5000 or in even greater detail. The country has the M-711 series at 1:50 000 as the main map series.
- The map projections is given in the legend for any serious topographic map
  - UTM Universal-Transvers-Mercator
  - WGS-84. Used for GPS positioning and navigation

Geological maps

- Geological surveys are commonly responsible for production and distribution of geological maps. In Norway this is Norges geologiske undersøkelse (http://www.ngu.no)
- NGU produces maps such as:
  - Bedrock (various scales)
  - Soft-rock (quaternary geology)
  - Geophysical (gravity, magnetics, conductivity etc).
  - Geochemical (distribution of elements of particular interest, Pb, Au, Hg etc.)
  - Hydrogeology and well data
  - Marine geology
  - Sand- and gravel resources
  - Industrial minerals
  - Ore minerals
  - Radioactivity
  - Other types of natural hazard (landslide etc.)
  - Lineament and fractures
  - Etc.

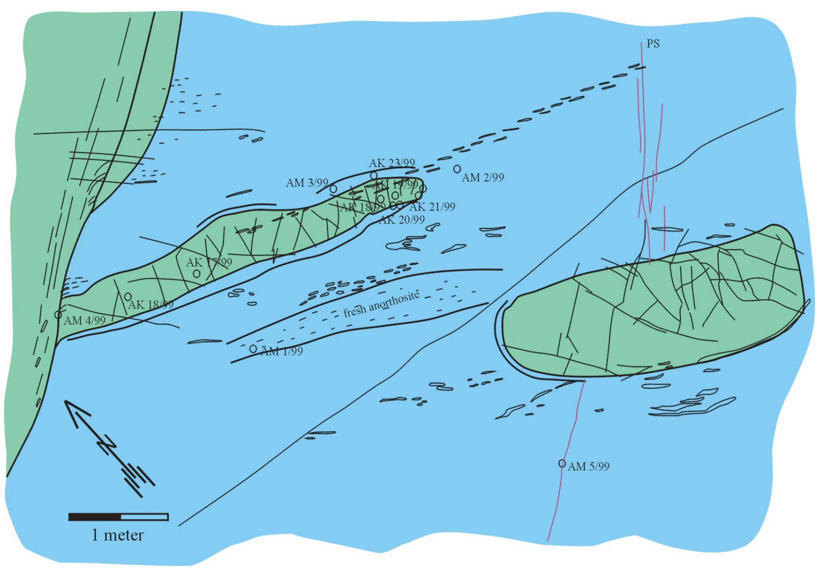
Bedrock maps

- Geological map of land and sea areas of northern Europe 1:4 mill
- Berggrunnskart ”NORGE MED HAVOMRÅDER” 1:3 mill.
- Berggrunnskart ”Norge” 1:1 mill.
- Regional geological maps 1:250 000 (completed).
- Some areas 1:50 000 (this series is discontinued and will only be completed for selected population centers).

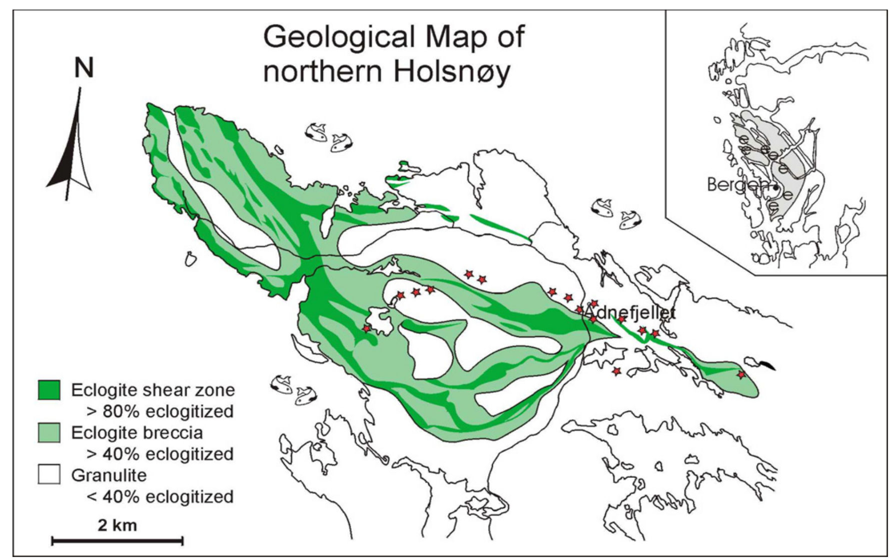
Other geo-maps

- Various geophysical total or anomaly potential field maps
- Similar scale maps of soft rocks/ geohazard/ groundwater etc.

- **Special maps for scientific and economical purposes.**
  - **Isopack maps and depth to basement or other specific levels (science, petroleum and other types of exploration)**
  - **Stratigraphy/age maps**
  - **Distribution of particular rocks or minerals (scientific or economical)**
  - **Structural geology map (science, exploration, planning, engineering etc)**
  - **Detailed problem-oriented maps (science, constructions etc). Such maps are equivalent of- and should be regarded to be of the same significance as laboratory experiment results in other sciences.**



Maps in large scale to illustrate specific phenomenon



Maps to show distribution of specific rocks and their relationship to surroundings, in this case the distribution of eclogitization.

How to make a geological map?

--not one simple answer, something like:

- Transfer the observations relevant for a particular purpose from nature into a system by which the planar or spacial distribution of different elements can be imaged.

  Mapping requires adequate knowledge about the problem in question, from being able to distinguish between ”black and white” rocks to be able to recognize and characterize more or less subtle differences, patterns and changes related to specific processes!

- Different methods for collection data.
  - Field observations directly transfered from nature to map/notes
  - Remote measurements from air, space, water

- Presentation in various formats f.ex by the use of geographical information systems (GIS).

What is the use of geo-maps?

- Local and regional planning purposes
- The discovery, extraction and use of natural resources on which any high-tech society is based
- Traffic/communication and construction purposes
- Environmental surveillance (GRID- Arendal, http://www.grida.no/)
- Preventive medical purposes (geographic anomalies in the distribution of diseases)

For our purpose:

Research in geosciences with the aim to improve the physical understanding of how geological processes- and eventually how the earth works.

Geological processes and their map expressions

- Geological map patterns reflect the geological processes that have affected an area over time, either by:

  the primary formation of specific rock types (sediments of magmatic rocks) in specific time periods

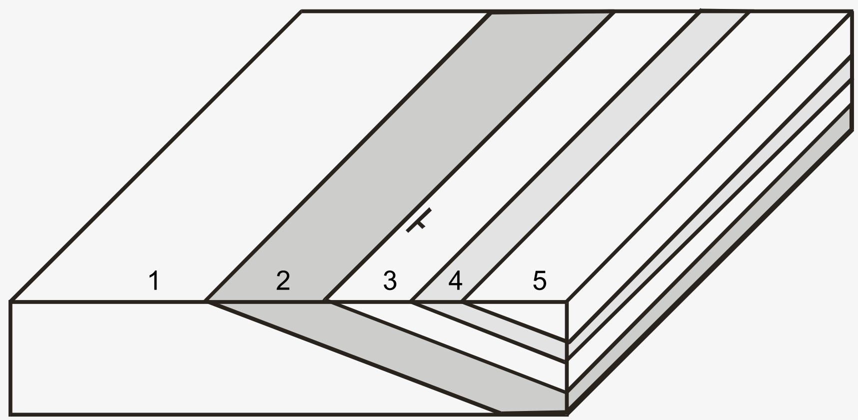
  or

  by secondary modifications of the rocks already present.

- Secondary processes can be penetrative to an extent that primary features can be completely obliterated, f.ex. by partial to complete melting and/or deformation. Mapping and exact record of transitions between different states of alteration may be particularly useful to map in order to understand important geological processes.

SOME BASICS: Primary layering

- Sedimentary and magmatic processes.
  - Sedimentary and volcanic layering in supracrustal rocks.
  - Sub-horizontal, (grain-size/composition) controlled by gravity and transport medium.
  - Youngs upward if undisturbed the principle of *superposition.*



In a normal stratigraphic succession the strata youngs upward. In a tilted one they young in the direction of dip.

Plutonic rocks

- **Planar structures in magmatic rocks crystallized at depth may have different forms and widely different primary orientations. (parallel, cross-cutting, oblique with respect to envelope).**

- **In larger plutons, particularly of gabbroic (px, ol, plag) to ultramafic composition (ol, px) is primary layering formed by accumulation of crystals by the sinking or buoyant rise to accumulate in specific sub-horizontal or draping layers in the magma chamber, a common feature. Such layering can be used to determine the original way-up or down in the chamber.**

ol - olivine [$(Mg,Fe)_2SiO_4$],

px - pyroxene [$(Ca,Na)(Mg,Fe,Al,Ti)(Si,Al)_2O_6$]

plag- plagioclase [$(Na,Ca)(Si,Al)_4O_8$]

Metamorphism and deformation.

- Primary structures are commonly re-oriented during tectonic events, and new planar structures may form by transposition- or by formation of entirely new planar structures.
- Such structures may be fractures (faults, joints and fissures) related to irreversible brittle phenomenon and most commonly formed at shallow depth. Both recti- and curve-planar fractures are common.
- Deeper level, higher temperature and commonly slower, but more continuous flow produce secondary planar structural elements in rocks even if they start out as homogenous bodies.
- Secondary structures formed by deformation and metamorphism are sometimes mistakenly identifed as primary structures.

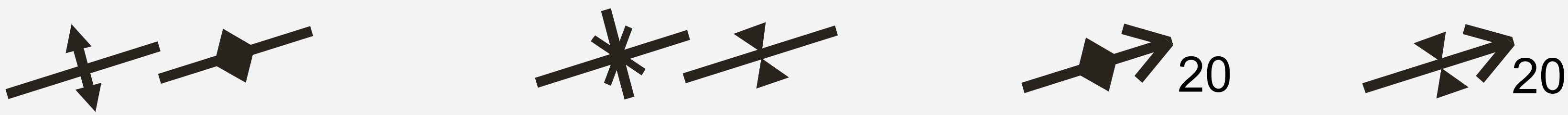
Bedding planes, surfaces, strike and dip, thicknesses, cross-sections

I. Common map symbols

Strike and dip of planar structures

Dipping | vertical | horizontal | inverted

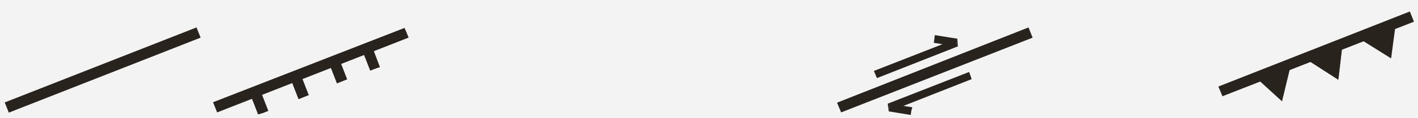
Folds



antiforms | synforms | antiforms | synforms

plunging

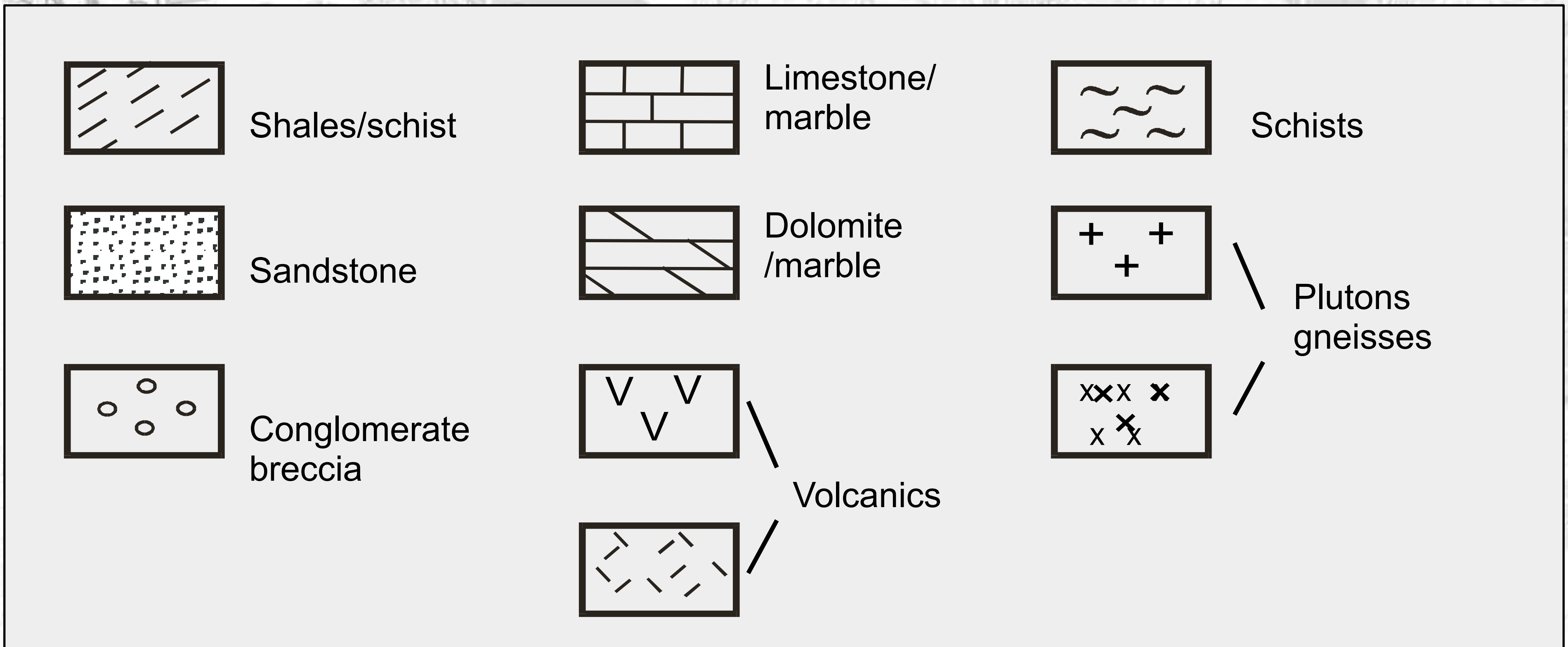
Faults



Fault (down-throw in dir. lines) | Relative movement | Thrust saw-tooth towards hanging-wall

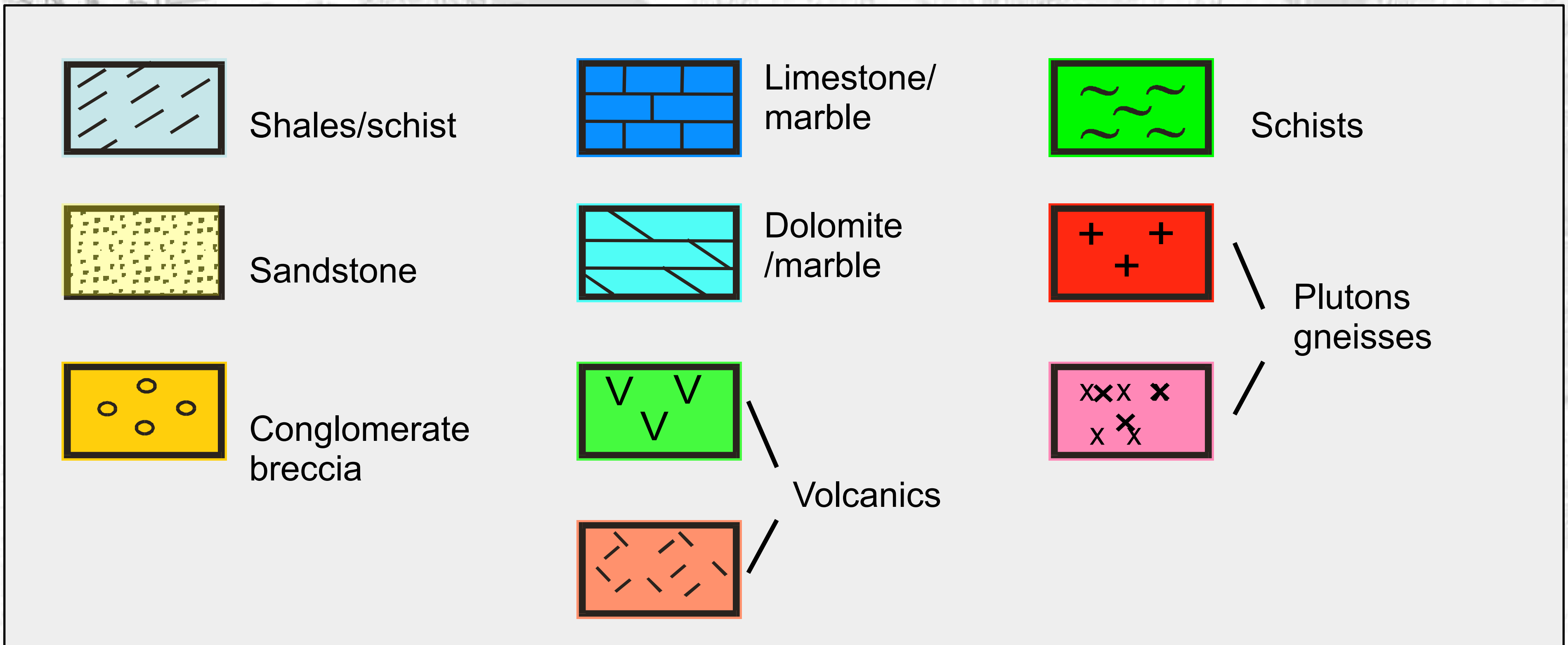
II. Common map symbols

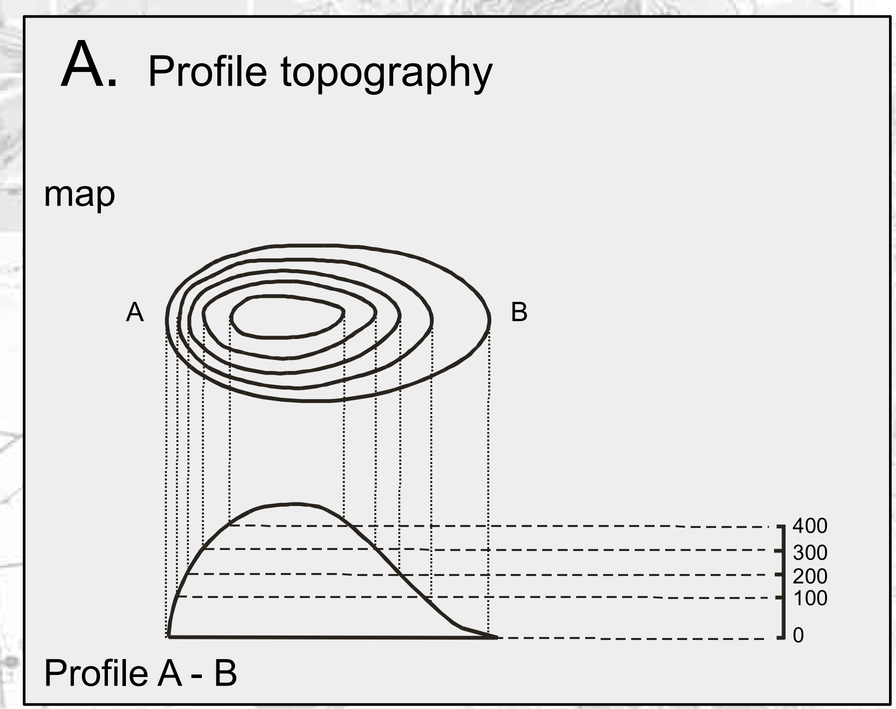
Common symbols for lithologies. NB, no rule!



II. Common map colours

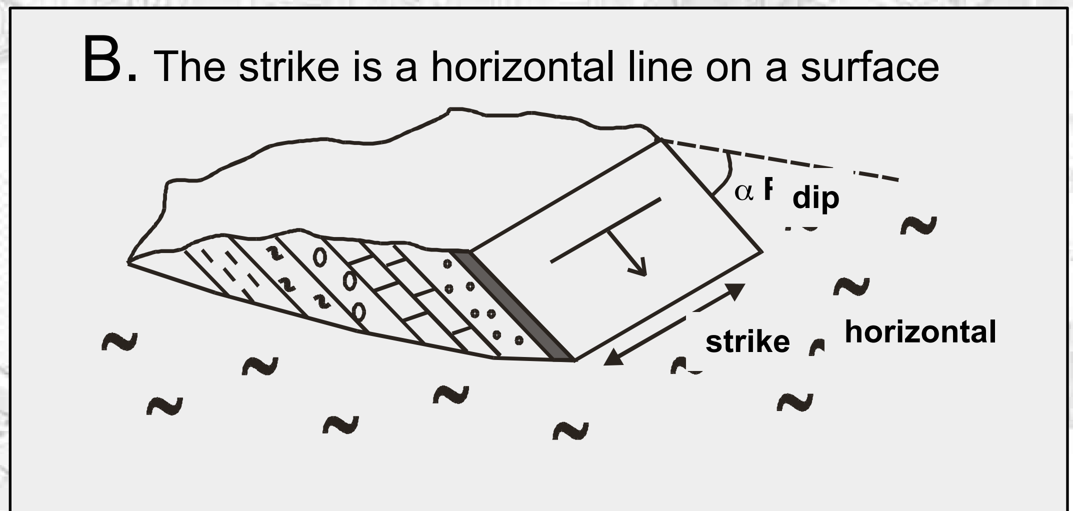
Common symbols for lithologies. NB, no rules!



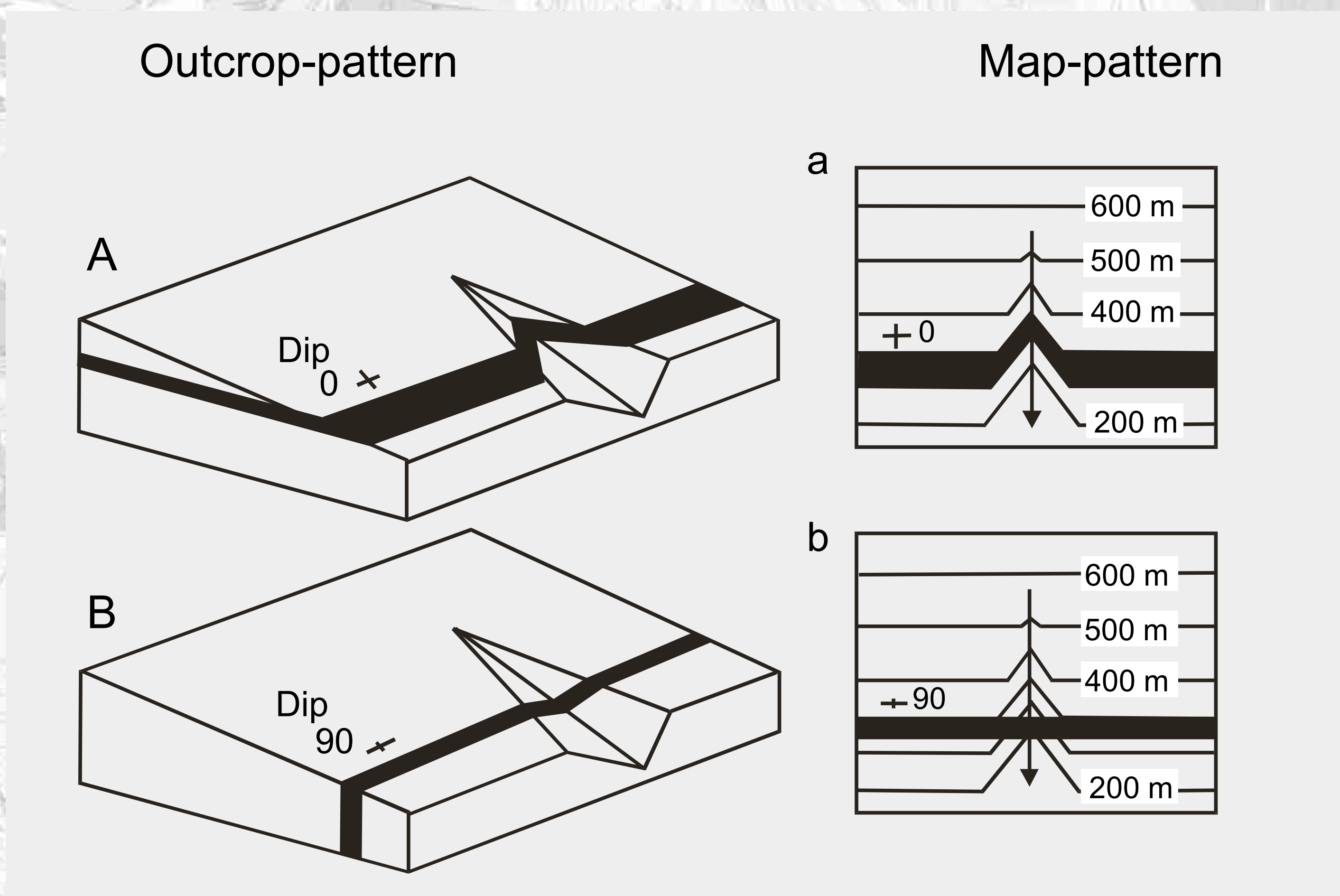


Remember to compare the scales used in maps/cross-sections you analyze/make, and to use same vertical and horizontal scale. Otherwise all dips and thicknesses will be exaggerated and all thickness.

In seismic reflection profiles the vertical scale commonly varies from travel-time to depth converted scales of various quality.



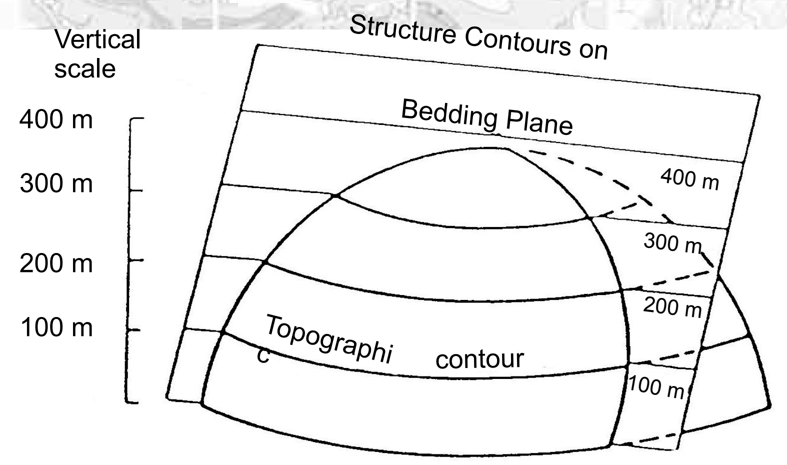
Map-patterns of layers of equal thickness cutting a sloping (≈ 15°) hill-side.



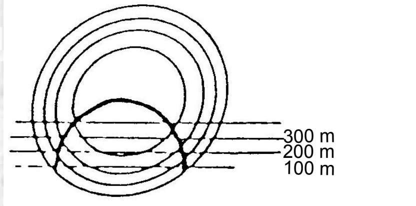
The "V-rule": The dip of strata is upward- into the valley if the V closes upward, and down the valley if the V-closes downward.

Determination of strike and dip with strike-lines

Relationship between strike lines and contour intervals.

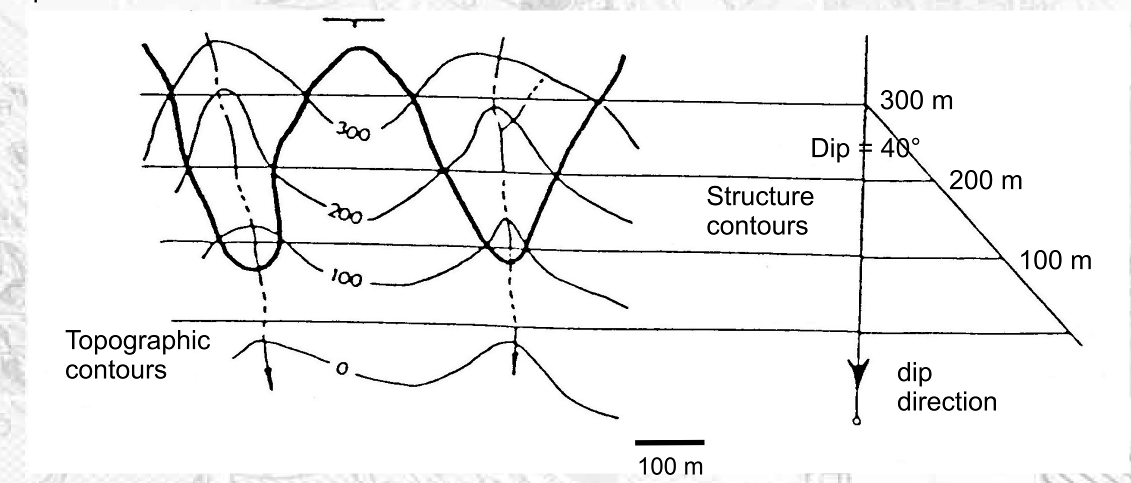


Map-pattern of the same



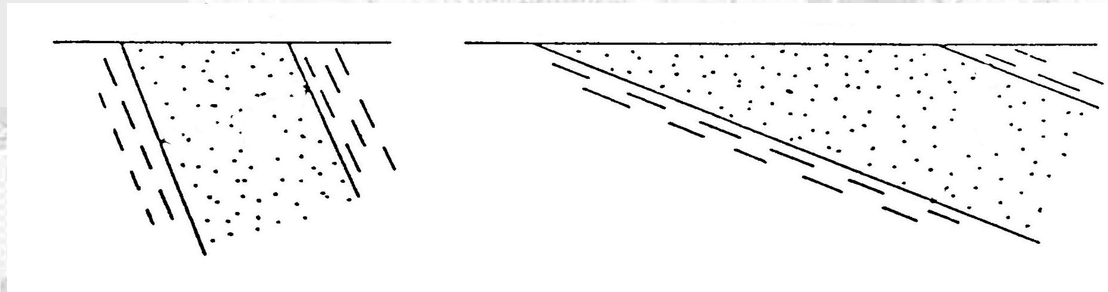
Map pattern of a layer with constant dip. Structur contour lines constructed for each countour interval, in this case 100 m.

Map

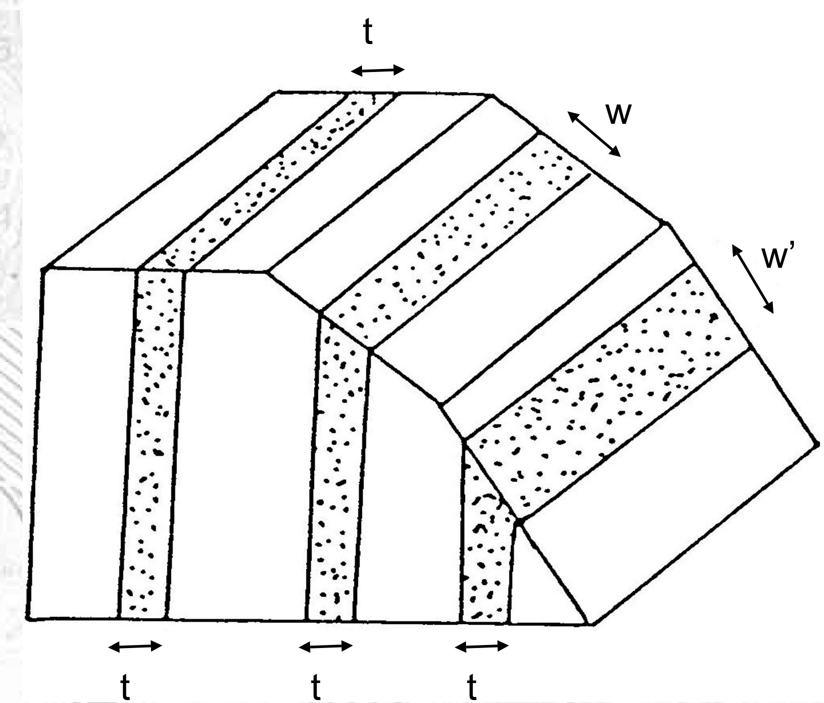


Width of outcrop

The outcrop width of a layer will depend on :
- -Real thickness
- -Dip and dip direction
- -Topography



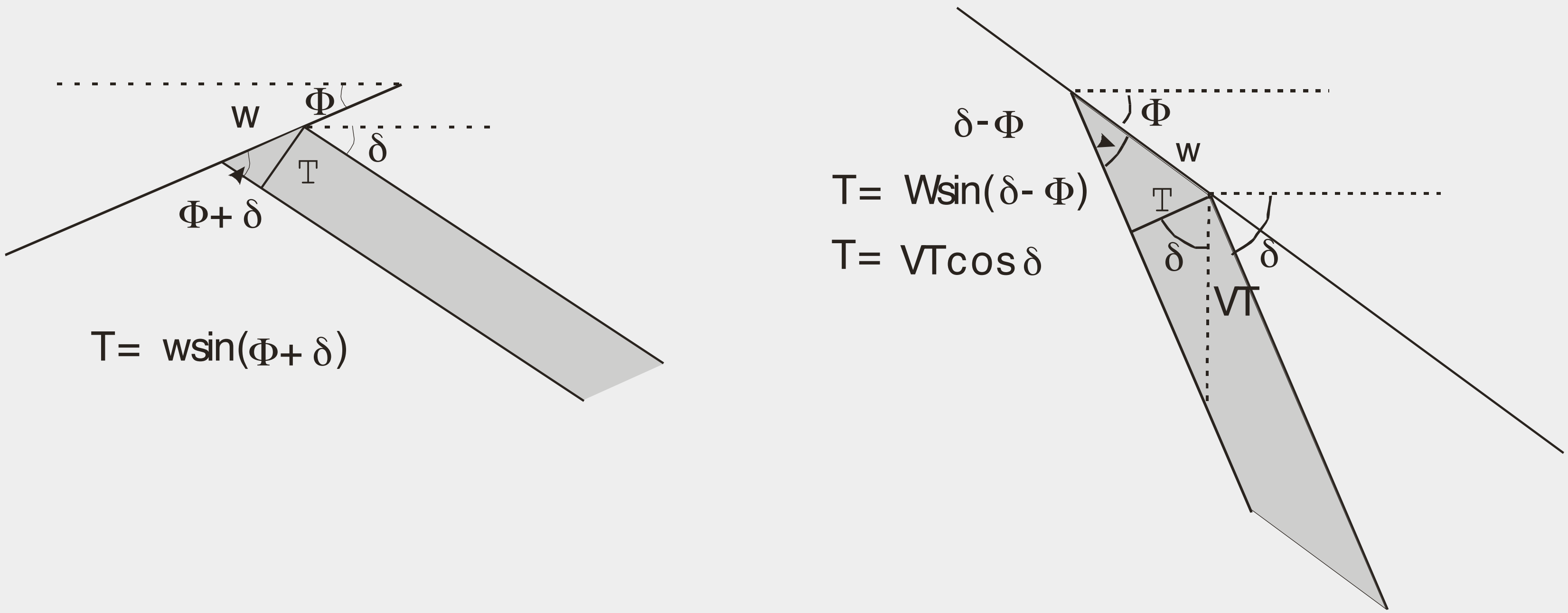
t = layer-normal thickness
w = width of outcrop



Detrmination of layer-normal thickness

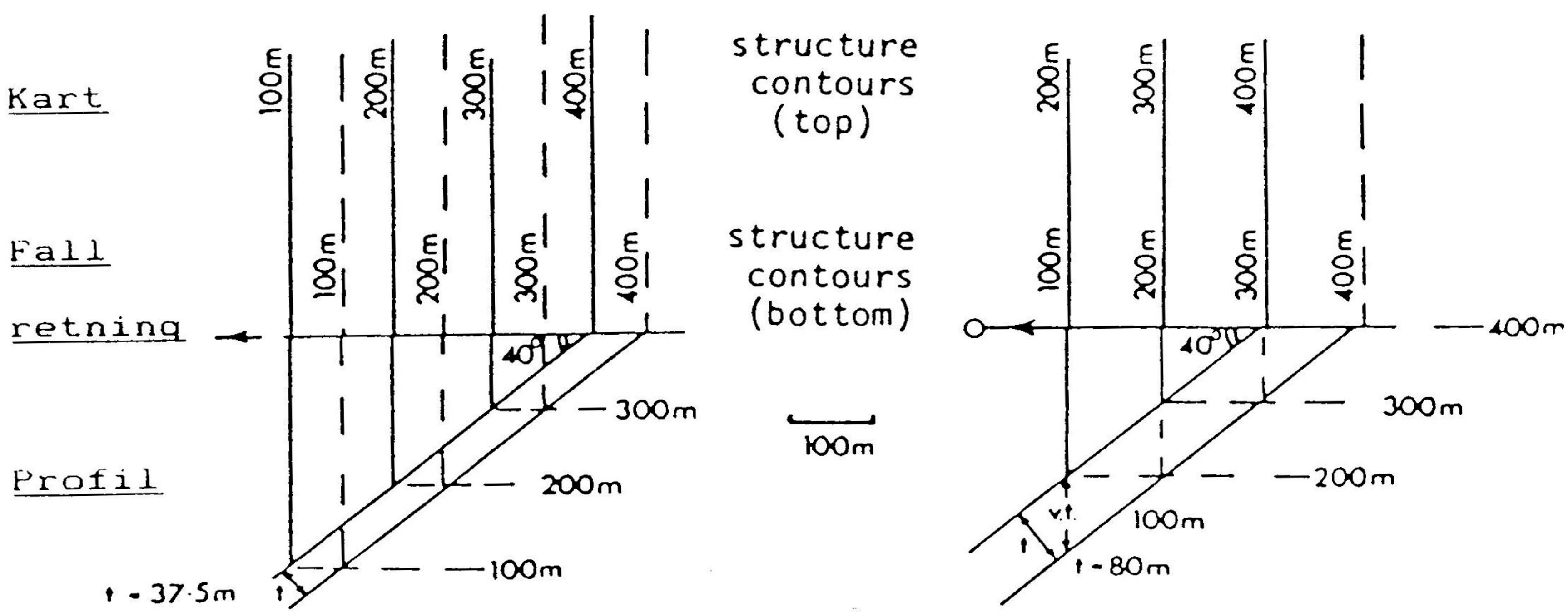
1) From width of of outcrop measured normal to the strike or from the vertical thickness
2) From the strike-lines (structure-contour lines).

T = layer-normal thickness
V^T = Vertical thickness
W = outcrop width
δ = dip
ϕ = slope of topgraphy normal to the layering

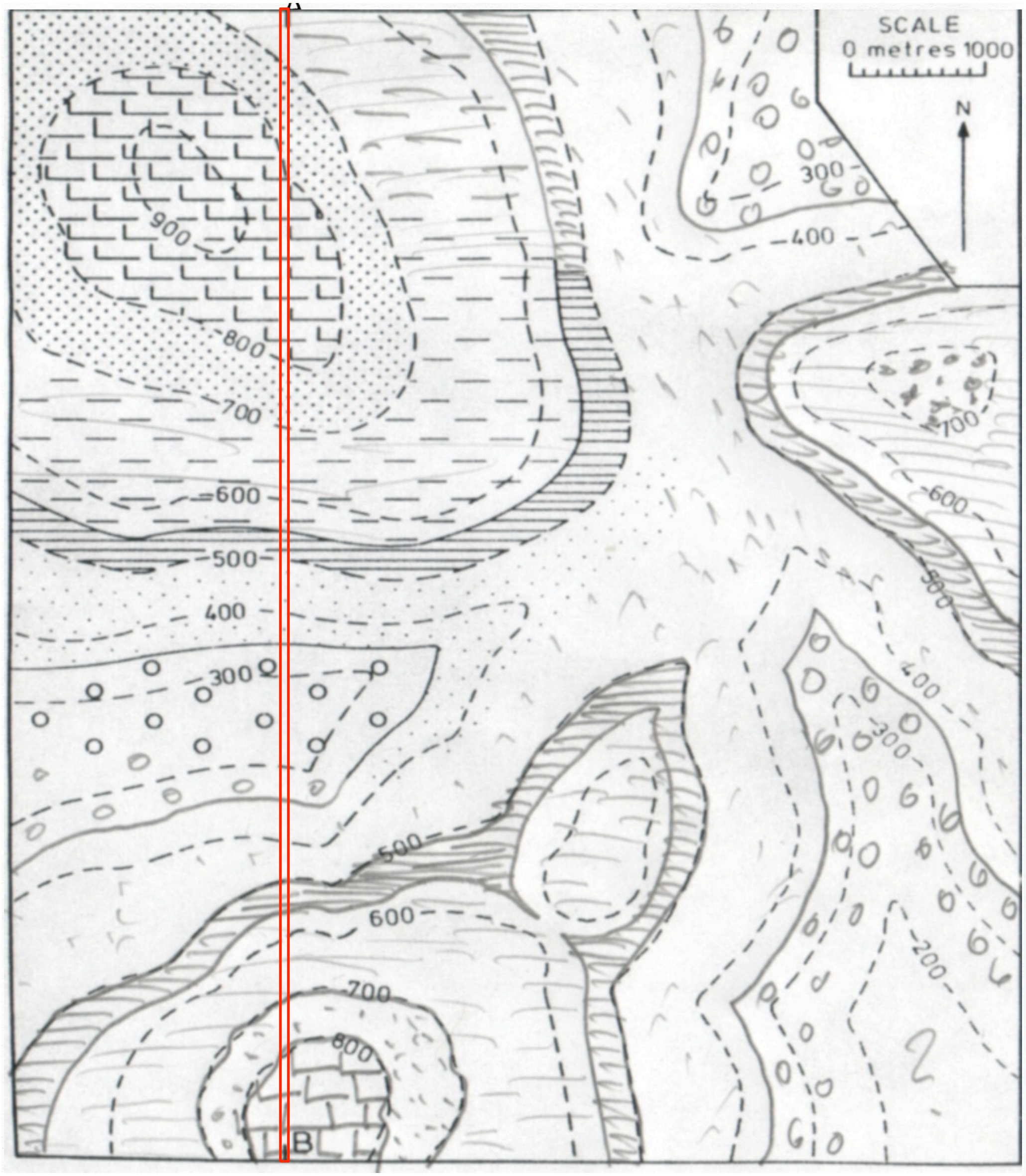


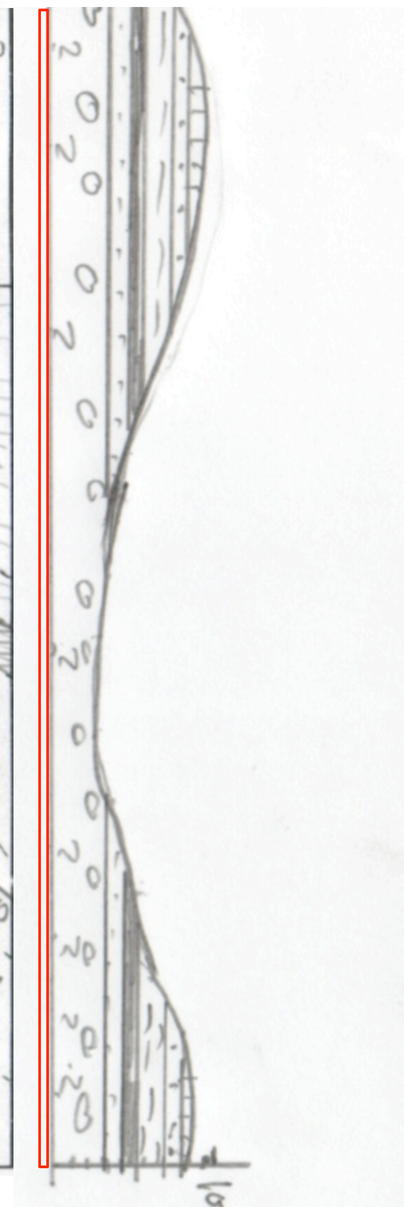
Determination of thickness directly from cross-sections

1) From width of outcrop measured normal to the strike or from the vertical thickness
2) By strike lines (structur contours).



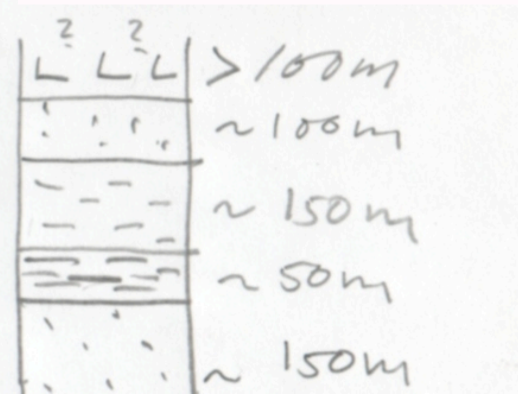
Two simple maps in honor of those who have never seen one!



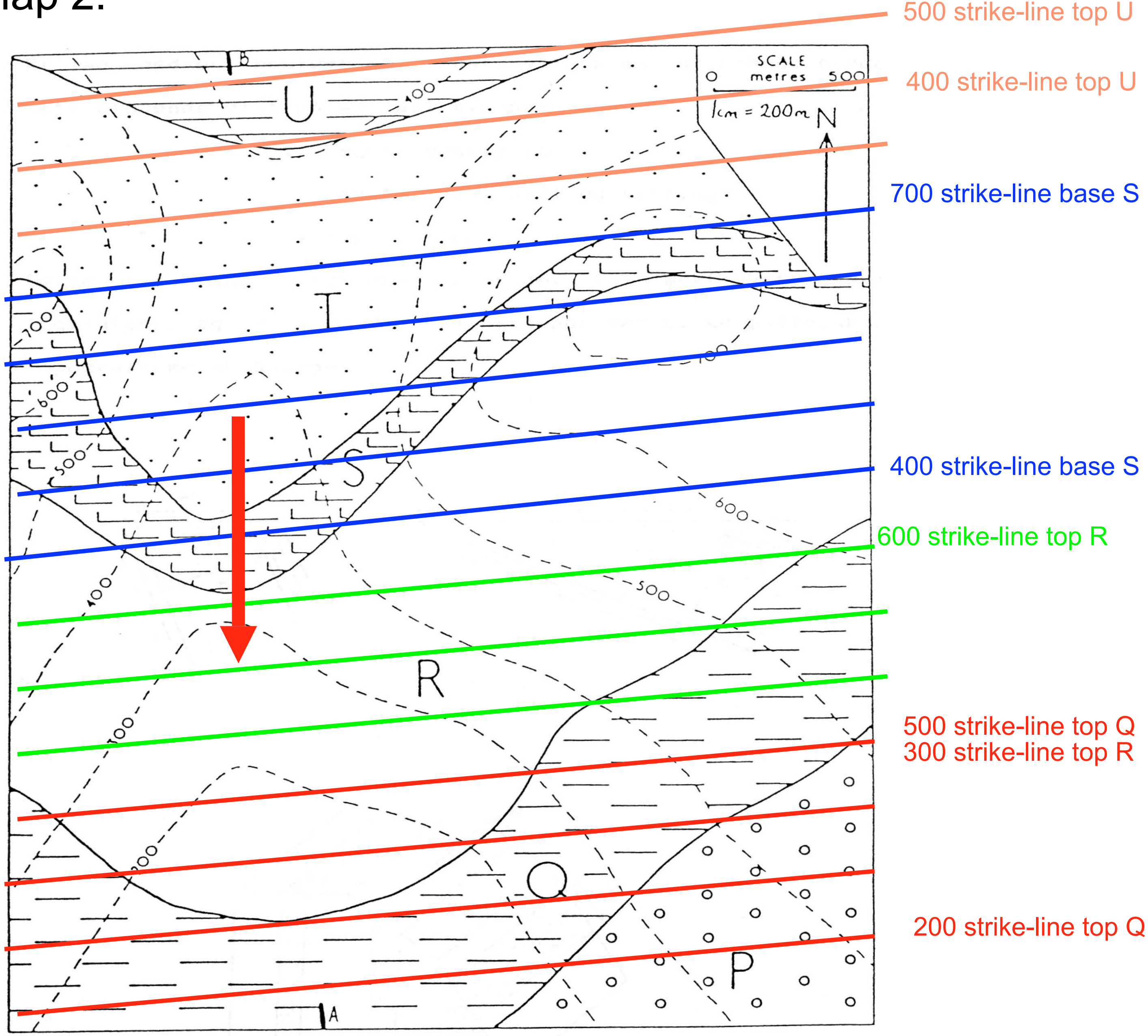


The boundaries between different sedimentary layers have been mapped in one area.

1) What is the strike and dip of the layers?
2) Complete the map assuming the layers have constant orientation across the map area
3) Construct a cross-Section along A-B.
4) What is the stratigraphic (layer normal) thickness of each layers?
5) Make a stratigraphic column showing the stratigraphic thicknesses.



Map 2.



The boundaries between the layers P, Q, R, S, T, & U have been mapped. The bedding planes truncate the contour lines.

1) Use the V-rule to determine the general dip direction.
2) Construct strike lines for each of the bedding planes shown on the map. Find the exact strike and dip.
3) Make a cross-section along A-B.
4) What are the vertical and stratigraphic thicknesses.

SOME EXAMPLES

1) Map-distribution of sedimentary facies

We can deduce a lot about the geological history from the map-pattern only.

2) Map with fold

Folds can create very complex interference patterns between layers and topography even with relatively simple fold-geometries. Common

presence non-planar and/or non-cylindrical folds adds complication.

3) Map with fault

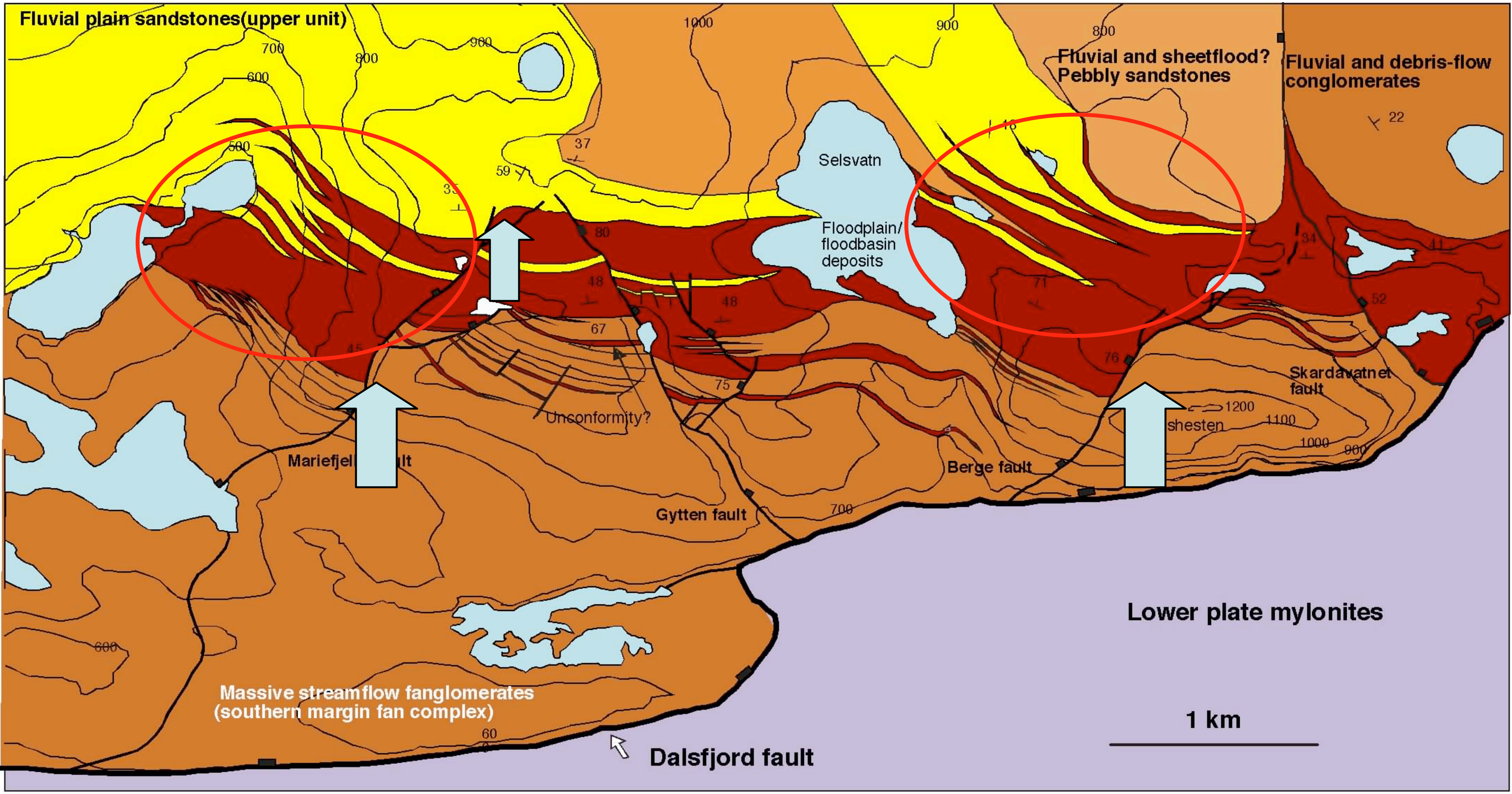
Remember: you can normally never determine the real displacement vector on a fault from the map-pattern alone.

4) Special maps with structure, lithology and alteration

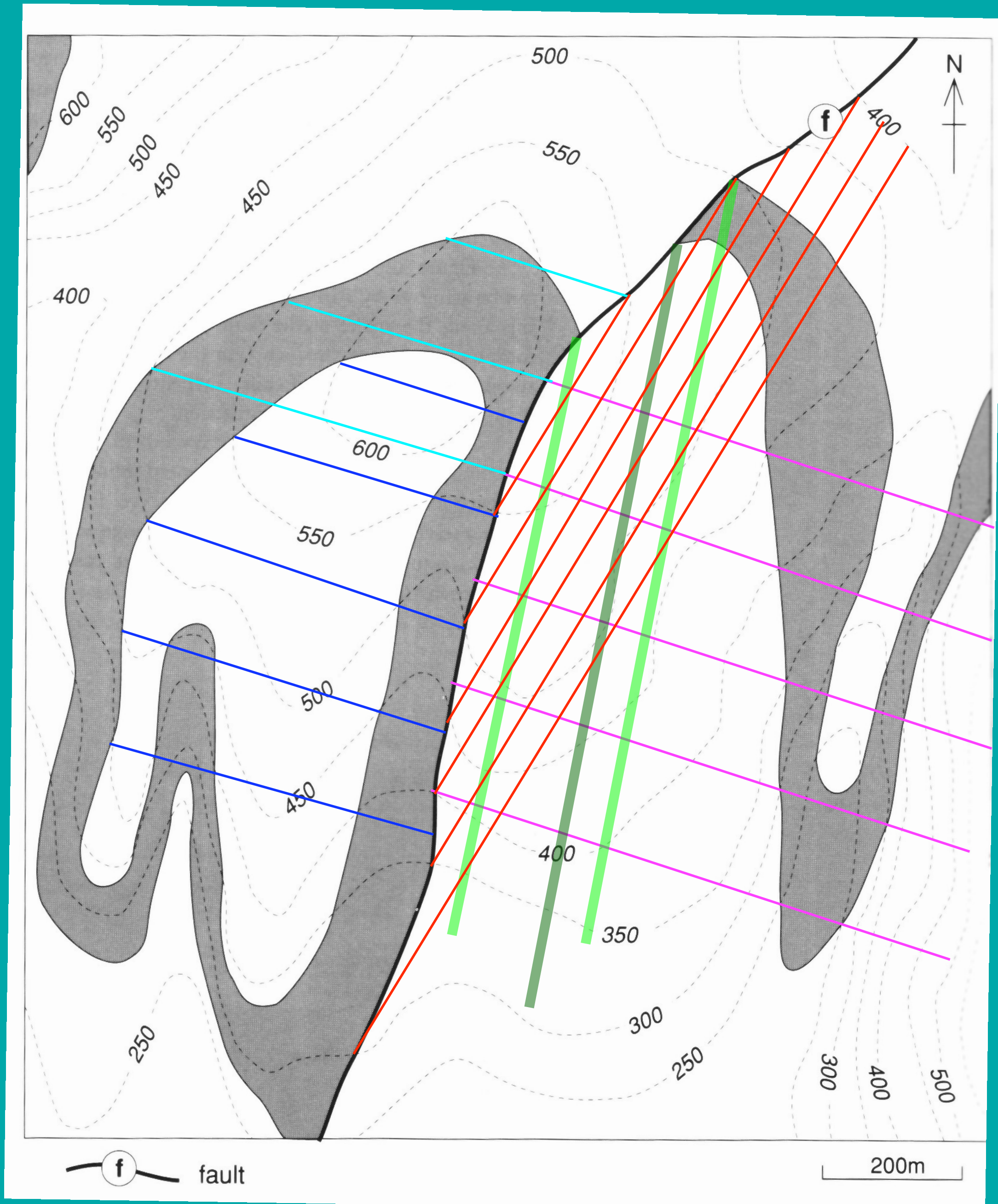
There are countless possibilities for special maps from regional to the scale of individual thin-sections and mineral

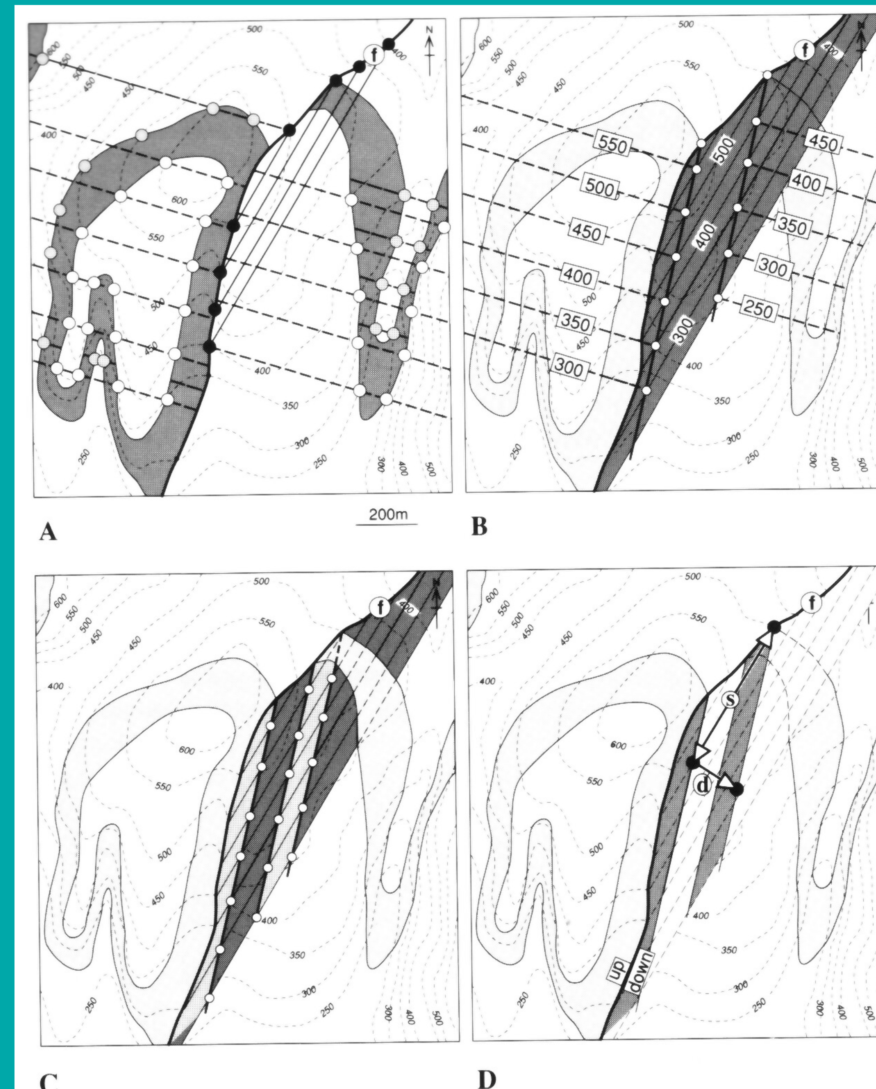
A map showing distribution of interpreted sedimentary depositional environments in a Devonian sedimentary basin, western Norway

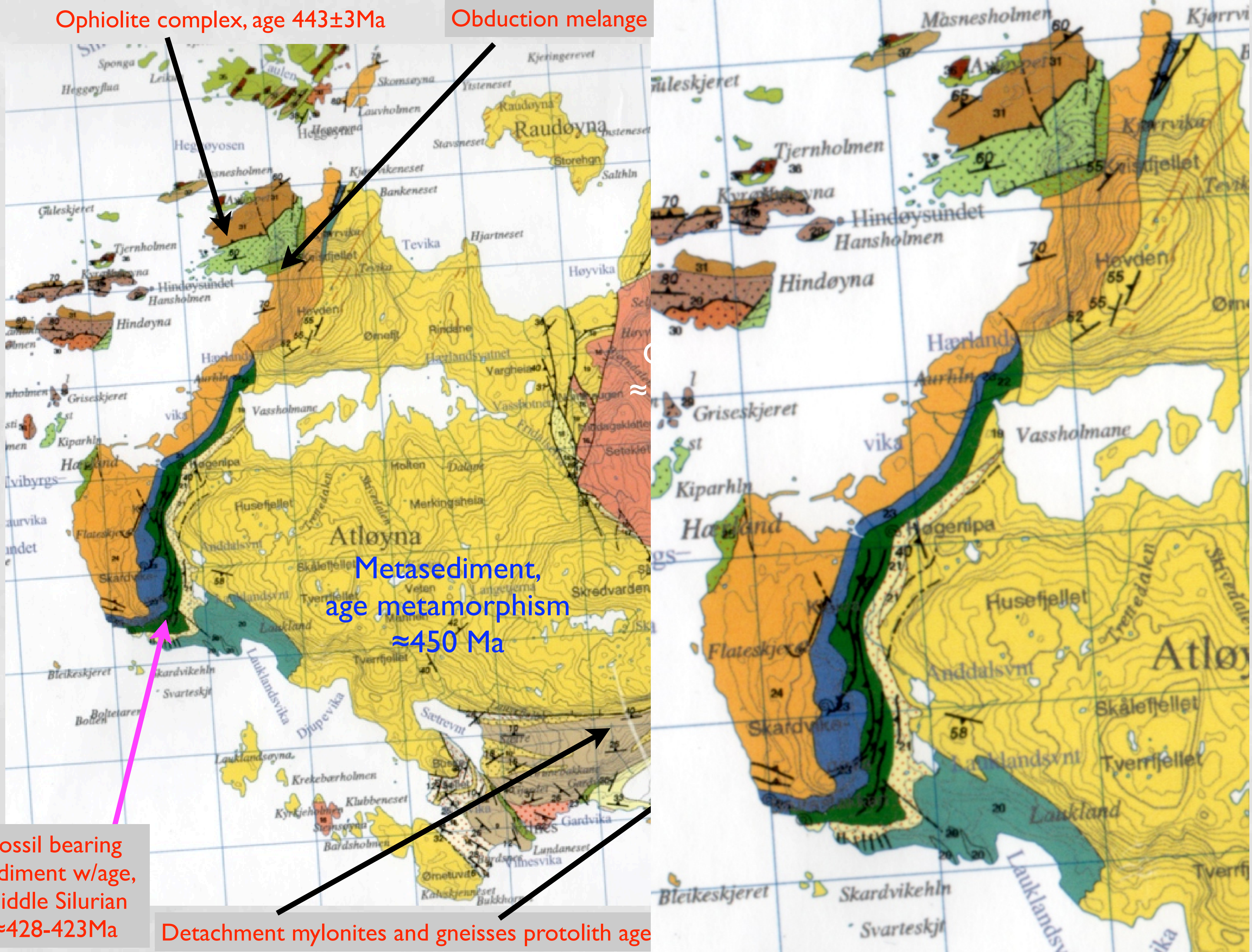
Mostly N-dipping strata (ca 35 to 71°)



Faulted layer of interest Analyzed by strike-line construction.

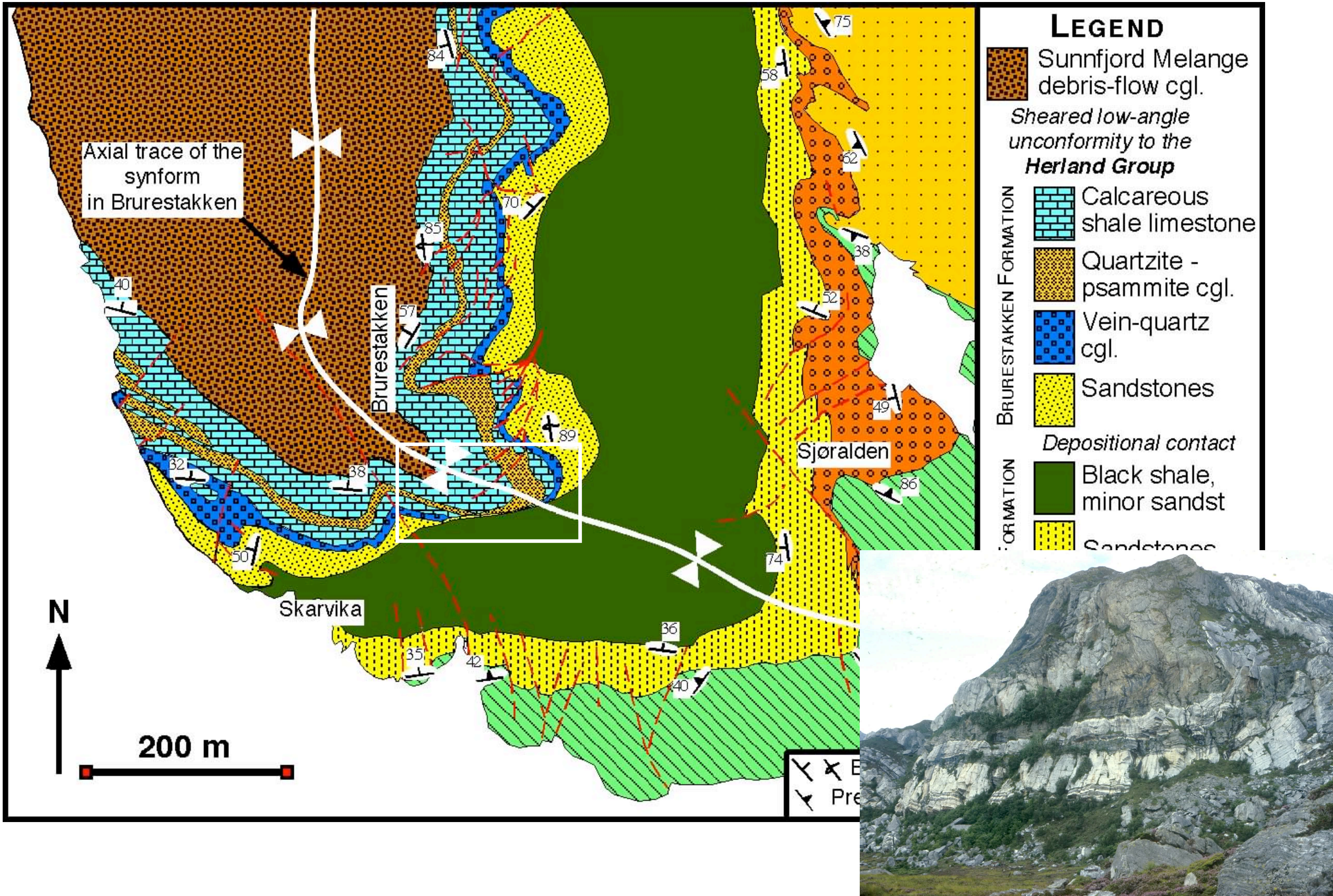




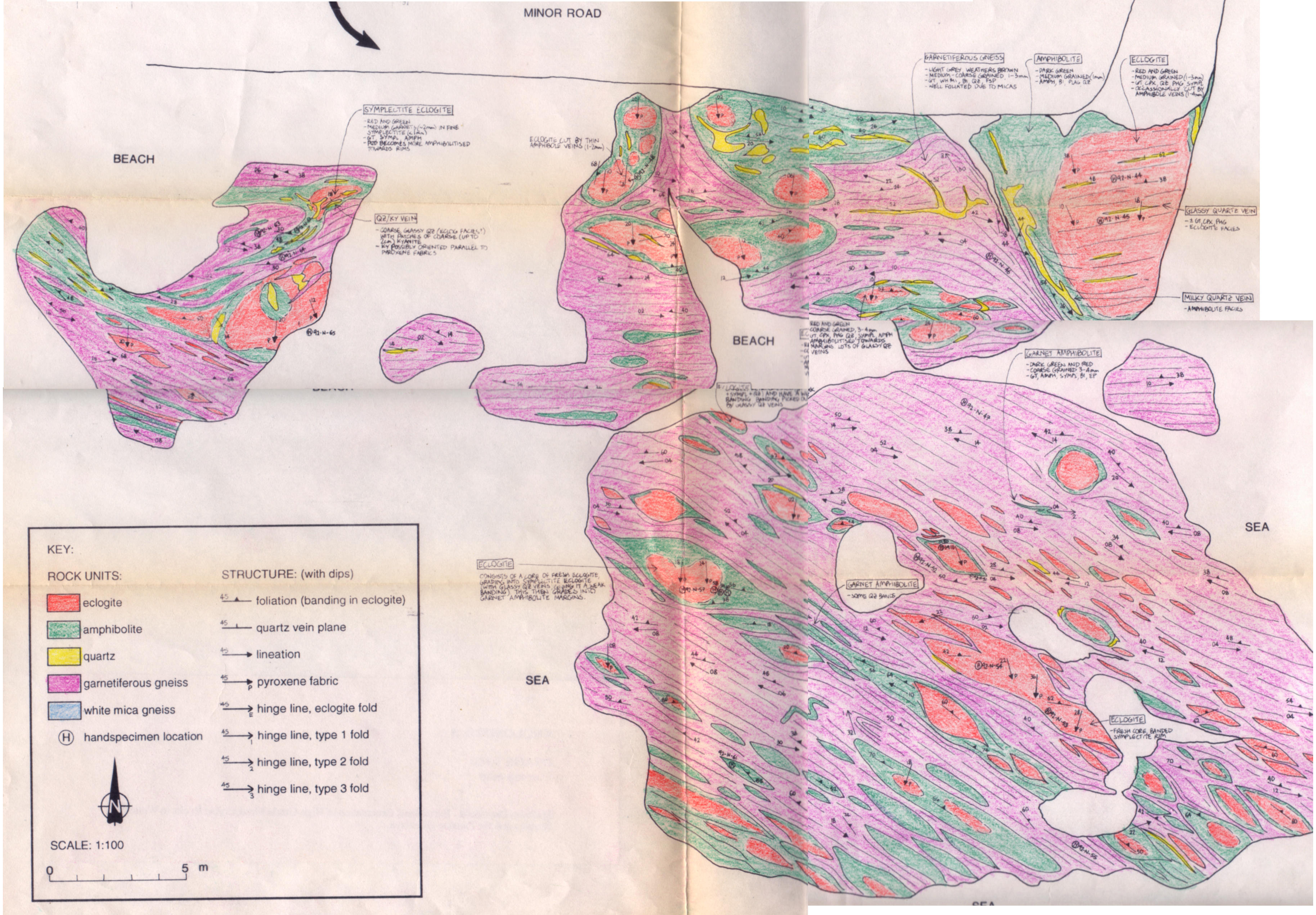


Ophiolite complex, age 443±3Ma
Obduction melange
Metasediment,
age metamorphism
≈450 Ma
Fossil bearing
sediment w/age,
Middle Silurian
≈428-423Ma
Detachment mylonites and gneisses protolith age
Raudøyna
Atløyna
Hindøyna
Tjernholmen
Hindøysundet
Hansholmen
Vassholmane
Husefjellet
Skålefjellet
Tverrfjellet
Laukland
Lauklandsvika
Bleikeskjeret
Skardvikehln
Griseskjeret
Kiparhln
Tevika
Hjartneset
Høyvika
Djupevika
Krekebærholmen
Klubbeneset
Landaneset
Måsnesholmen
Flateskjer

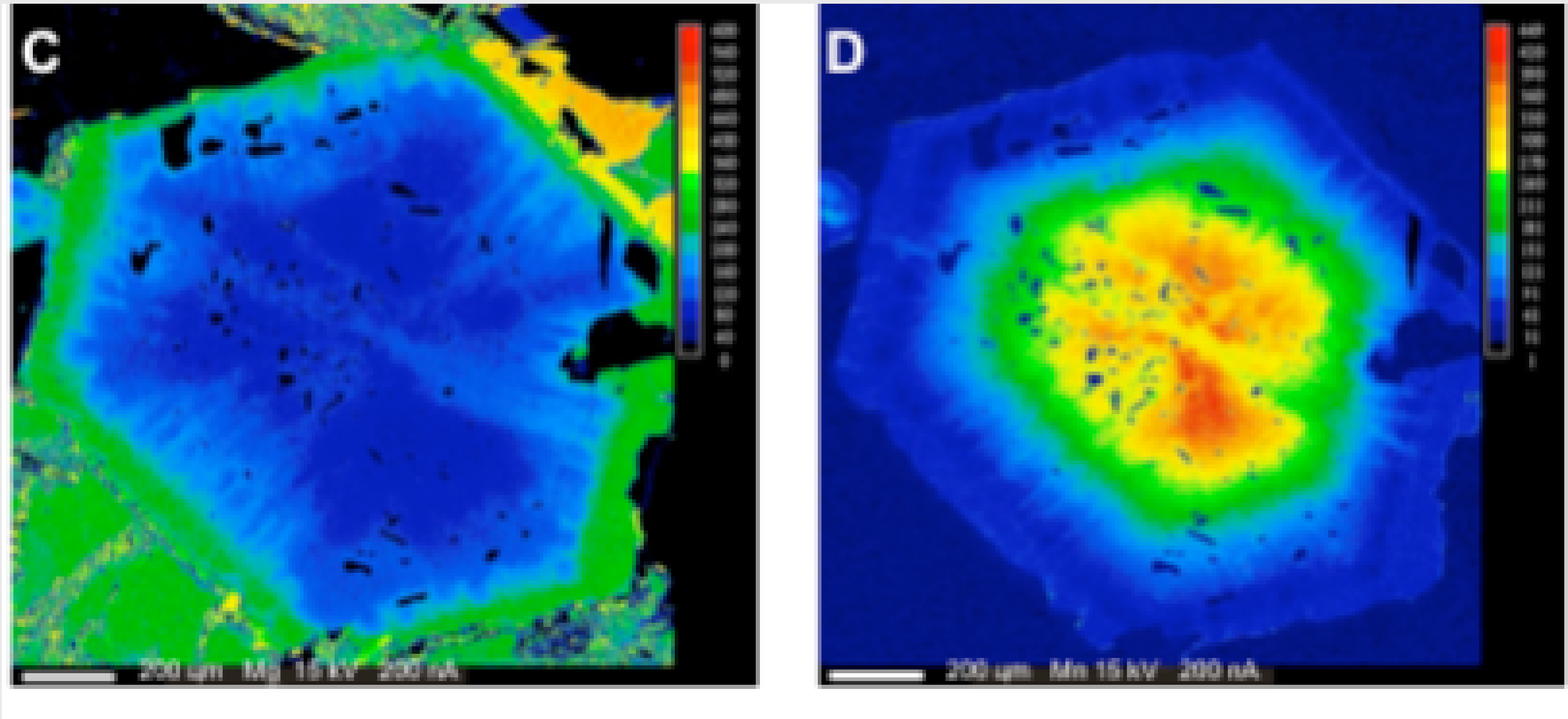
Folds, strike lines must not truncate the layers, are often curvilinear



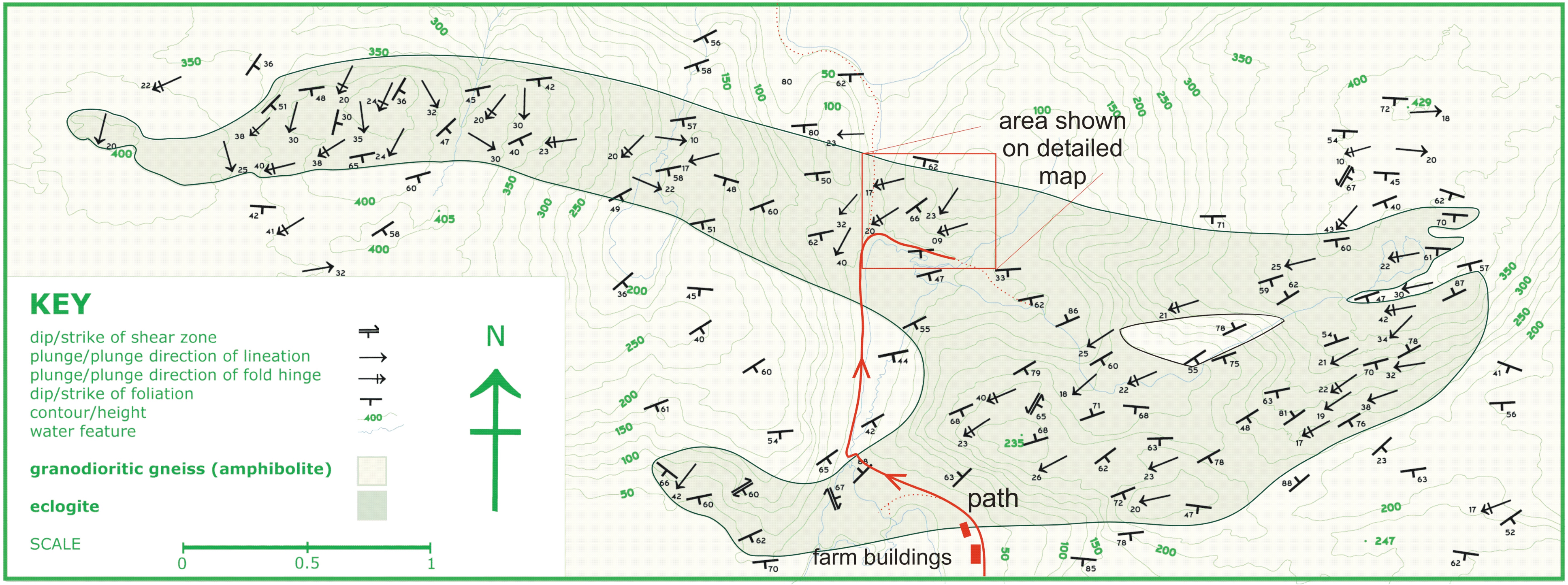
Detailed map of an eclogite body with internal structures and zones of veining and alterations (unpublished M. Dransfield 1994)



Element map in garnet crystals
Mg and Mn



How can we explain and quantify the observed element distributions ?



Internal structure of a rock-body of special interest