Methods of Structural Geology

1. Cross sections

Structural geological research

- Field-based research
  - Reconstruct the history and architecture of deformed rocks
    - Mountain belts, e.g. the Alps
    - Basin tectonics, e.g. for finding oil
- Theory-based research
  - How do structures form?
  - How do rocks deform?
    - Laboratory experiments of folding or faulting
    - Numerical modelling

Methods in structural geology

- Mapping structures in the field
  - Recording folds, cleavages, lineations, etc
    - Shape and character
    - Location
    - Orientation
- Thin-section analysis (→Kristallingeologie)
- Analysis
  - Developing 2 or 3D models (GIS)
  - Plotting data in graphs and stereonets
  - Analyse strain, stress, etc.

What is “Structural Geology”?

- The description and interpretation of structures in rocks
- that result from deformation
  - Changes in shape of rock volumes
    - (μm-km scale)
- Why?
  - Fundamental understanding of our planet(s)
  - Exploration (hydrocarbons, ore, etc.)
  - Nuclear waste disposal & CO₂-sequestration
This course

- Constructing cross-sections

- Strain analysis
  - Fry method, Centre-to-centre method, ...
  - Using stretch and rotation of lines & planes
    - Mohr circle for strain!

- Brittle deformation
  - Analysis of fault & slip measurements

Practical info

- During this course you will need
  - Drawing materials: pencils, etc.
  - Paper (plain, mm-grid, transparent)
  - Ruler & compass
  - Calculator
  - Stereonet + thumb tacks

- PDF's of the lecture will be posted on:
  - http://www.structural-geology.info

- There will be one written exam: February 10, 2009

Lecture 1. Cross sections

- To make a cross section through a structure we need field data (& drill core data, seismic, etc.)
  - Orientation data
    - Sedimentary bedding
    - Faults
    - Fold axes and axial planes
  - Stratigraphical (lithological) column
  - Type of structures
    - Parallel folds or similar folds?
    - Thin- or thick-skinned tectonics?

This lecture

- Some basic techniques
- Using a geological map with structure contours (lecture K&P)
- Using data along a surface line ± drill core
  - Assuming layers have constant width
  - Dip domain method
    - Chevron folds \textit{(Knickfalten)} with straight hinges
  - Circular arcs method
    - Cylindrical folds with curved hinges
Profiles from a line section

- Often data are available along a section only
  - River bed or gorge
  - Cleared strip
Example of field data to determine fold type

- Very low grade rocks: ductile deformation absent
  - Folding by flexural slip
  - Sharp hinge: Kink or chevron folds

A profile line with some data

- We know
  - Orientations
  - Stratigraphy
  - Fold type?

- Assumption
  - Chevron fold
  - Fold panels or domains
  - Axial plane bisects limbs in middle

A profile line with some data

- Construct axial planes
- Between domain A and B: 40° to E
- Between domain B and C: 70° to E

A profile line with some data

- Now fill in unit boundaries with constant dip in each domain
- With stratigraphic column we can extend further down
- But how to deal with crossing axial planes?
A profile line with some data

- Where two axial planes meet, a fold panel disappears (B)
- The two adjacent panels now become neighbours:
  - One fold
- Determine axial plane between A & C: 80° to W

Exercise

- An EW-profile
- Draw dip domains
- Draw profile with all units

Dip domains
Parallel folds with curved hinges

- Folds do not always have sharp hinges and straight limbs (chevron folds)
- The may have smoothly curving hinges

Circular arc method

- Dip domain method cannot be used for smoothly curved layers
- Instead: circular arc method

Segments of fold form portions of circular arcs

Rays of the circles are perpendicular to the beds

Finding the arc segments

- Profile with
  - 3 dip measurements
  - One lithological boundary A-B

Find centres of arcs

- Construct rays perpendicular to dip measurements
- Intersections of rays define centres of arcs
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- Construct rays perpendicular to dip measurements
- Intersections of rays define centres of arcs

Draw arcs for layer boundary A-B

- For each arc centre, find the arc for layer boundary A-B

Your profile is ready

- To maintain constant bed thickness, cusps always form in the core of a fold
- This is an artefact of the method

Cusps in core of fold
A profile with dip data and stratigraphy

- Both dip data and stratigraphy are known
- Contact AB on the left should link up with contact BA on right

Interpolation with linear domain - step 1

- Extend the two dips with straight lines to find point X

Problems when not enough dip data

- The two arcs with the same centre do not match
- We apparently lack dip data between the two measurements
- We need to interpolate the best we can

Interpolation with linear domain - step 2

- Find point Y on longest section (PX), such that
- Length XY equals XQ
Interpolation with linear domain - step 3

- Draw lines perpendicular to dip at P and Q, which meet at point R
- The perpendicular to dip at Y and the bisector of YX and QX meet on line QR at point Z

Logically it follows that length YZ = length QZ

Exercise

- The profile shows two lithological units and some layer orientations at the lithological boundary
- Draw a profile using the circular arc method
  - You will have to add one interpolated straight section
- Draw layers every 1-2 cm
  - Extend profile both downwards and upwards

Exercise

Draw profiles for this section
- One with the dip domain method
- One with the circular arc method

Fig. 7.57. Cross section through the Burma No. 1 and 2 wells. Short lines are surface dips. Letters A–G are marker horizons seen at the locations of dip measurements that can be correlated. Arrows point to locations where markers can be identified in outcrop but the dip cannot be measured. The dips in the wells are from oriented cores