# Methods of Structural Geology

# 1. Cross sections



## 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 & $CO_2$-sequestration



## 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.

## 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



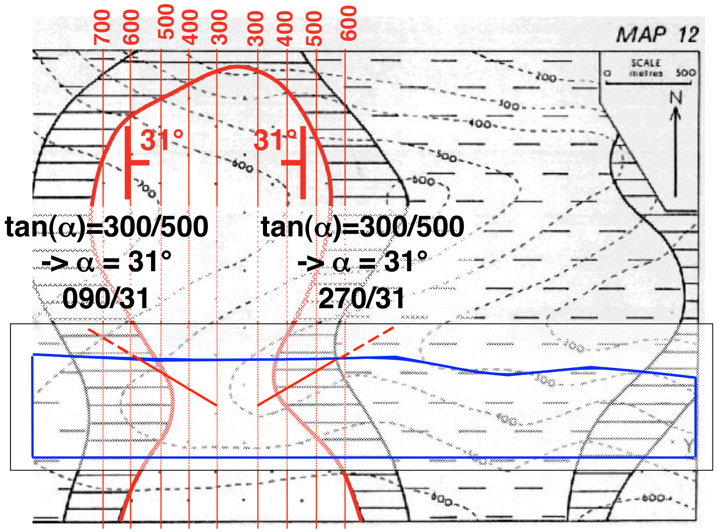
## Lecture 1. Cross sections

- 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?

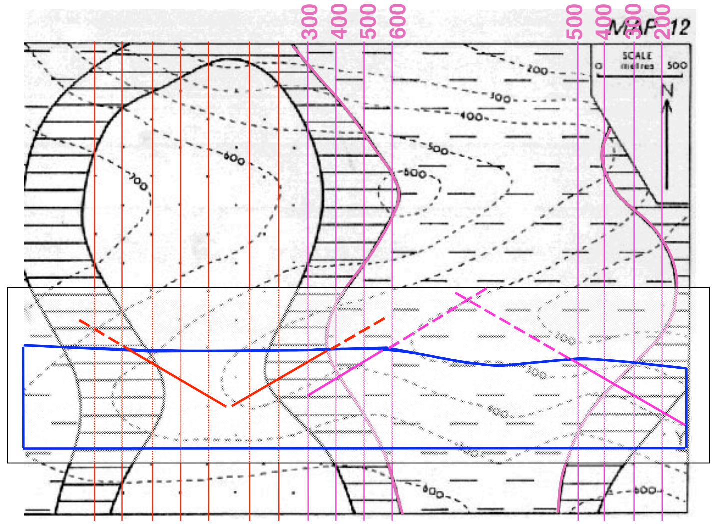


## This lecture

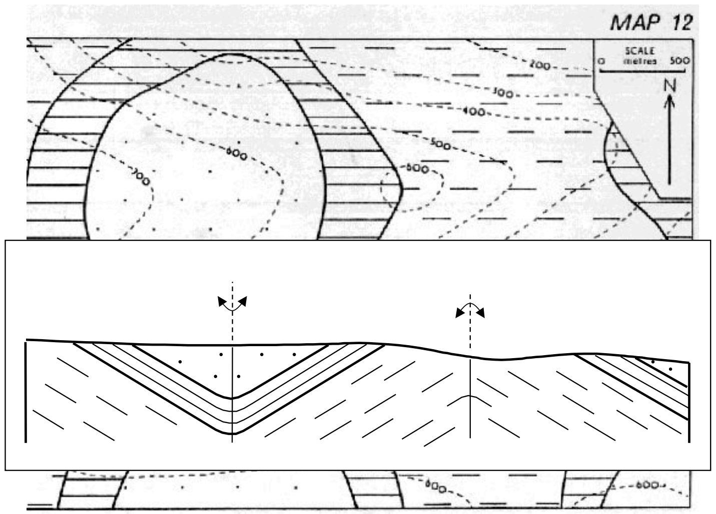
- Some basic techniques
- Using a geological map with structure contours (lecture K&P)
- Using data along a surface line ± drill core
  - Assuming layers have constant width
  - Dip domain method
    - Chevron folds (Knickfalten) with straight hinges
  - Circular arcs method
    - Cylindrical folds with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





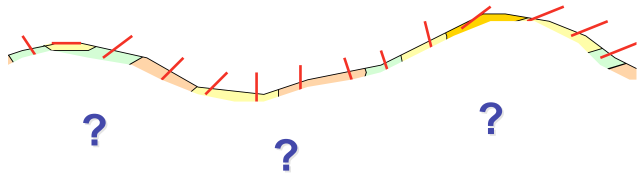


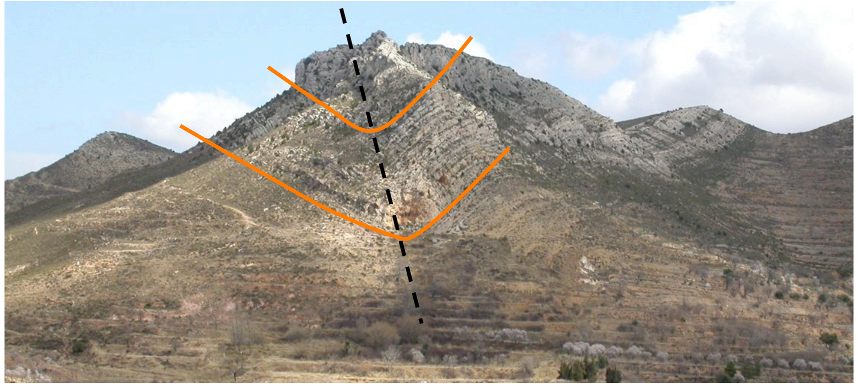



## Profiles from a line section

- Often data are available along a section only
  - River bed or gorge
  - Cleared strip



# Example of field data to determine fold type

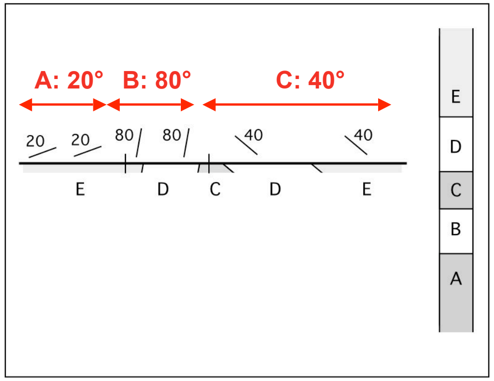


**Very low grade rocks: ductile deformation absent**
**→ Folding by flexural slip**
**→ Sharp hinge: Kink or chevron folds**



# A profile line with some data

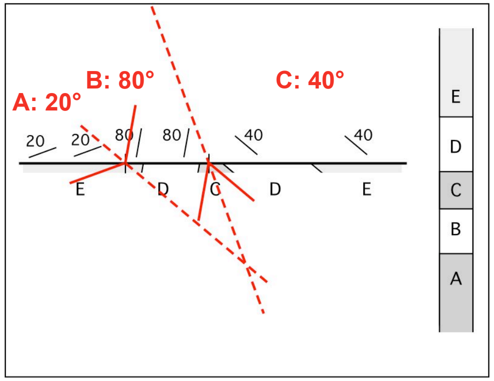
- **We know**
  - **Orientations**
  - **Stratigraphy**
  - **Fold type?**
- **Assumption**
  - **Chevron fold**
  - **Fold panels or domains**
  - **Axial plane bisects limbs in middle**






# A profile line with some data

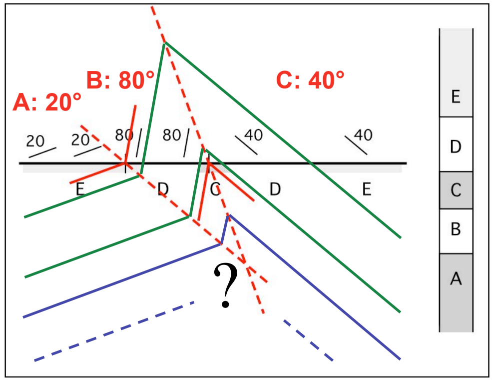
- **Construct axial planes**
- **Between domain A and B : 40° to E**
- **Between domain B and C: 70° to E**





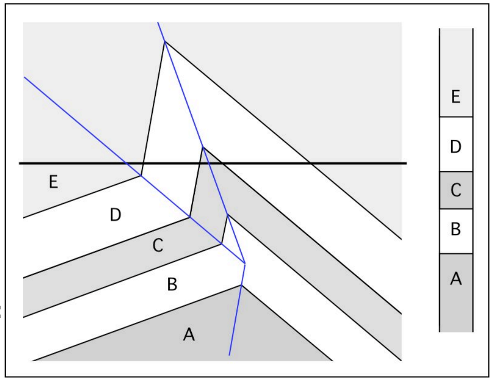

# A profile line with some data

- **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

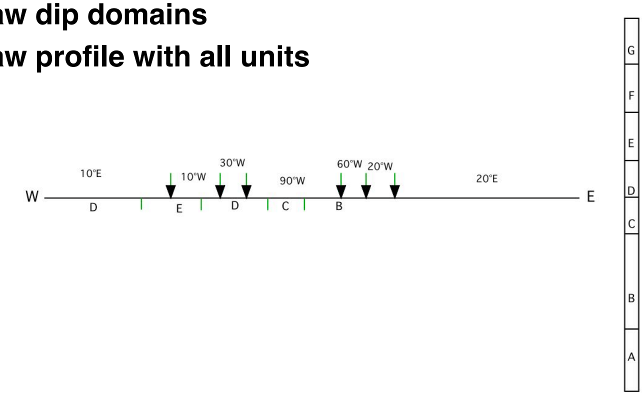
- **Where two axial planes meet, a fold panel disappears (B)**
- **The two adjacent panels now become neighbours:**
  - **One fold**
- **Determine axial plane between A & C: 80° to W**





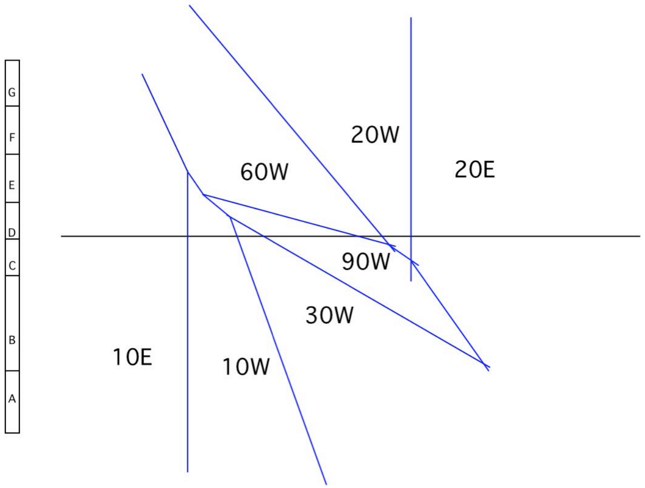

# Exercise

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

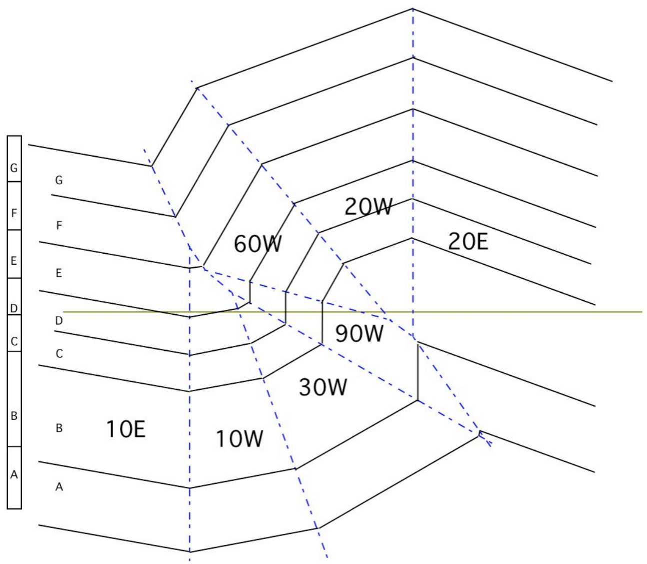





# Dip domains

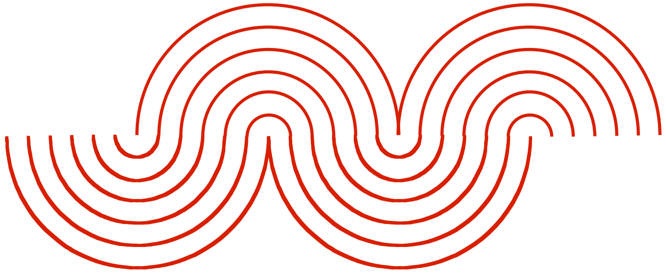




## Parallel folds with curved hinges

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



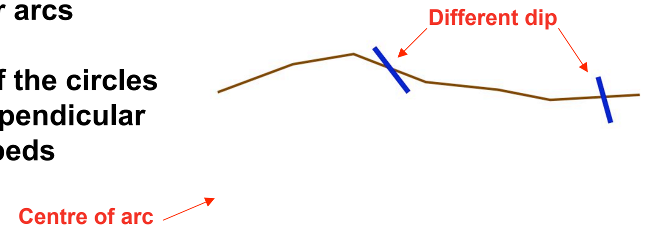


## Circular arc method

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

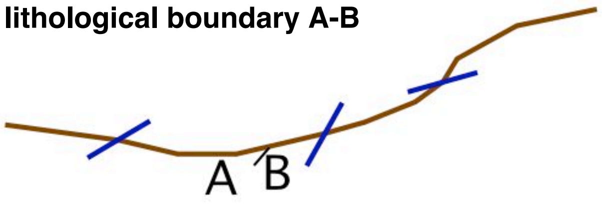
Segments of fold form portions of circular arcs

Rays of the circles are perpendicular to the beds



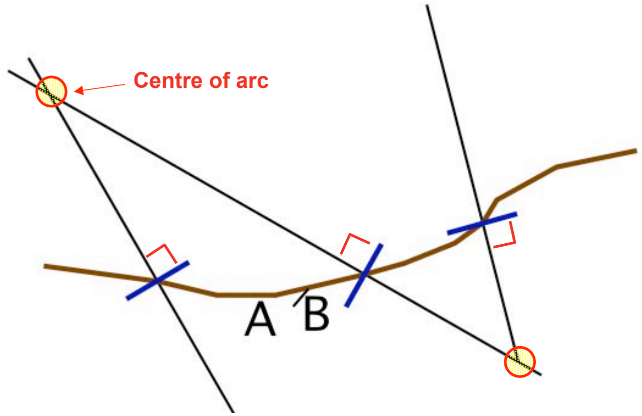

## Finding the arc segments

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



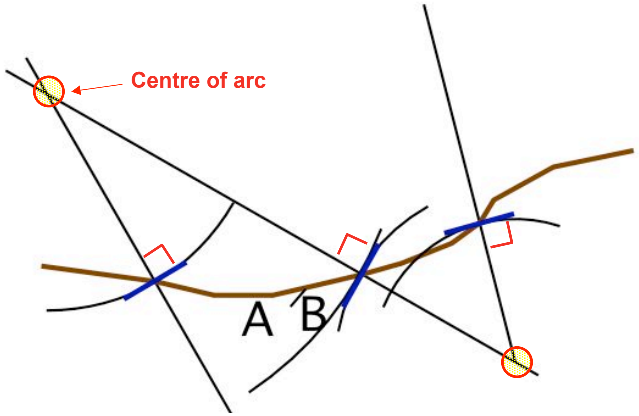



## Find centres of arcs




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

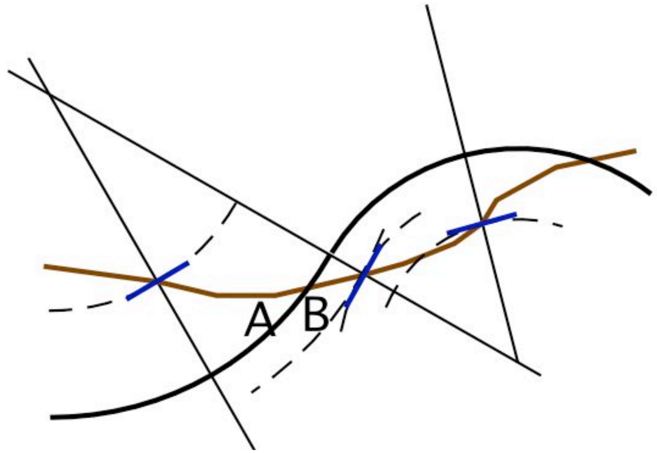
## Find centres of arcs




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



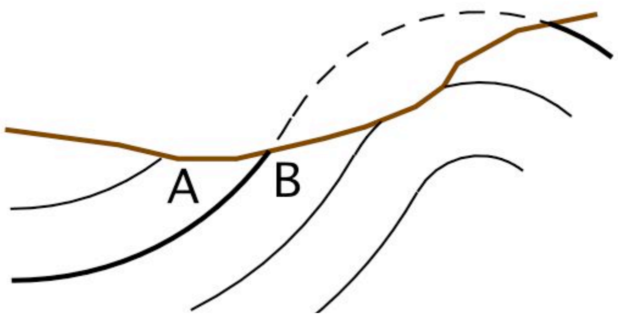
## Draw arcs for layer boundary A-B




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

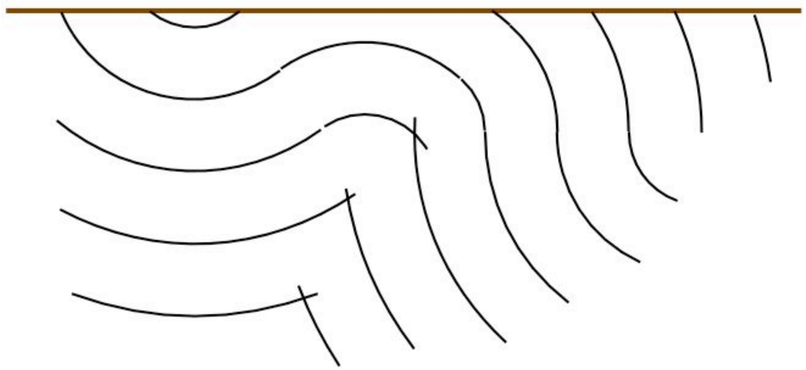


## Your profile is ready



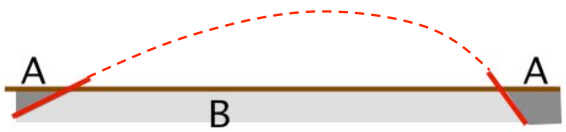



## Cusps in core of fold



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

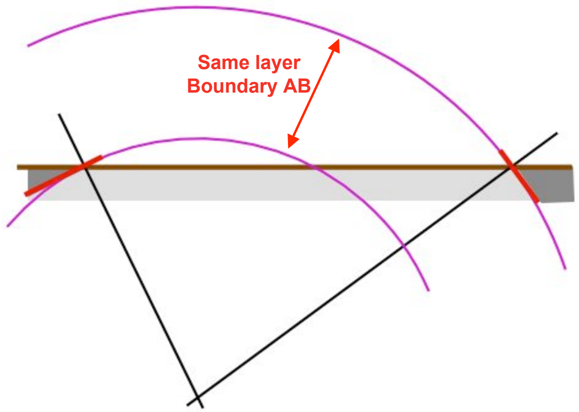
## A profile with dip data and stratigraphy




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



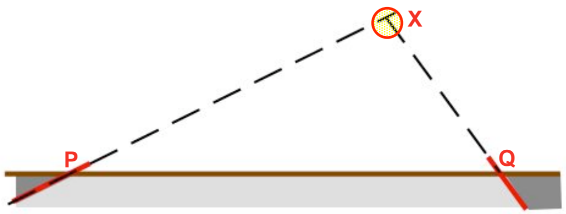
## Problems when not enough dip data




- 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



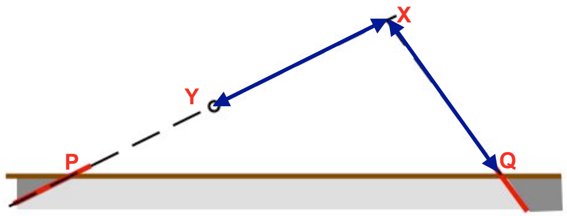
## Interpolation with linear domain - step 1




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

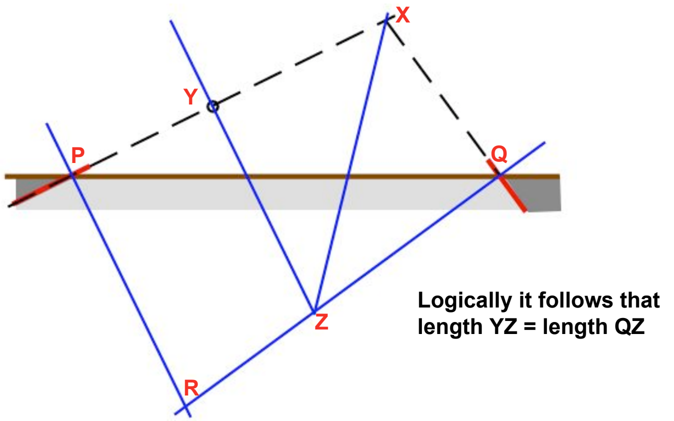


## Interpolation with linear domain - step 2




- Find point Y on longest section (PX), such that
- Length XY equals XQ

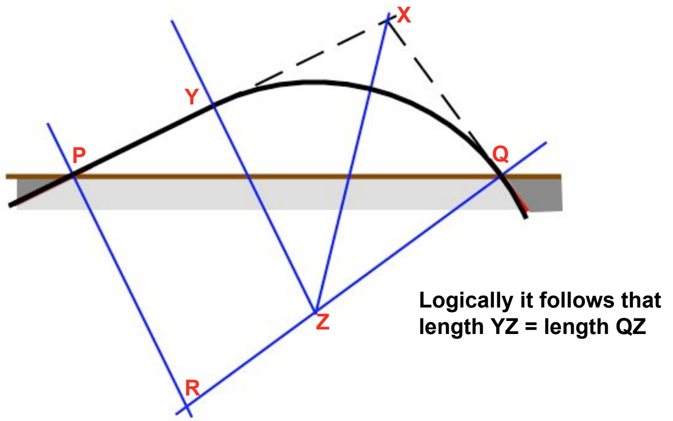
## Interpolation with linear domain - step 3




- 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



## Interpolation with linear domain - step 4




- Draw the arc with centre Z for the section from points Q to Y
- Insert a straight section from points P to Y



## 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

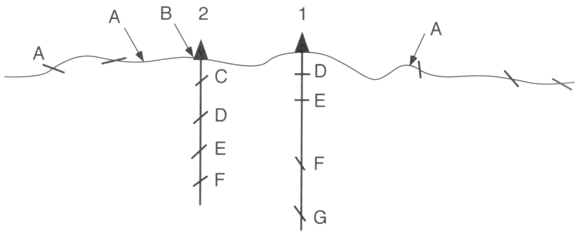



**Fig. 7.57.** Cross section through the Burma No. 1 and 2 wells. *Short lines* are surface dips. Letters *A–G* are marker horizons seen at the locations of dip measurements that can be correlated. *Arrows* point to locations where markers can be identified in outcrop but the dip cannot be measured.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