Indian Institute of Technology, Kanpur

Department of Earth Sciences

ESO213A: Fundamentals of Earth Sciences

Lecture 15. Deformation of Rocks - I

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Aims of this lecture

- Do the rocks deform?
- The subjects “Structural Geology”; “Tectonics” and “Geodynamics”
- Concepts of Scale, Continuity and Homogeneity

Reference:
Chapter 7, Grotzinger_Jordan’s Book

Do the rocks deform?

We use the term “Rock Solid”… but rocks indeed deform mostly because of the tectonic forces acting on them in presence of various magnitude of pressure and temperature

Photograph: Santanu Misra

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Do the rocks deform?

- YES, Rocks do fracture and flow under force and produce various structures which are very important to understand the mechanics of earth globally or locally.

- The sub-discipline under which Geologists study the deformation of rocks are

  Structural Geology

  Tectonics, and

  Geodymanics

What is Structural Geology?

Structural Geology is commonly used together with **Tectonics** and **Geodynamics**

struere *(latin)*	: **build**
tektos *(greek)*	: **builder**
dunamis *(greek)*	: **power, force**

The subject concerns in general with the shape (geometry), displacements (kinematics) and forces (mechanics) in Earth and Planetary bodies

Structural Geology / Tectonics / Geodynamics

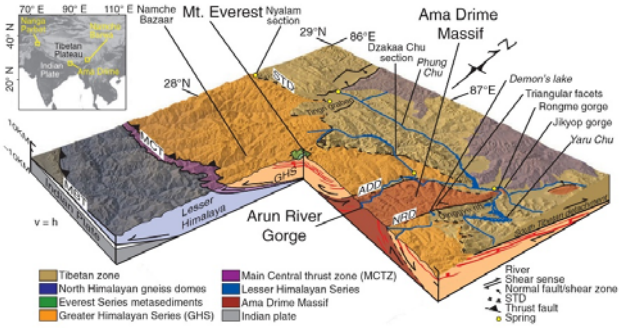
- **Structural Geology** characterizes the deformation structures, displacements (kinematics), and forces that produced the deformation (dynamics). A field-based discipline, structural geology operates at scales ranging from 100 microns to 100 meters (i.e. grain to outcrop).

  Tools: Field-study, Rock Deformation, Analogue experiments, Numerical models.

Structural Geology / Tectonics / Geodynamics

- **Tectonics** picturizes the geological scenario (maps, cross sections, 3D presentations etc.) of deformation together with information from petrology, stratigraphy and geophysics. Tectonics operates at scales ranging from 100 m to 1000 km, mostly confined on the movement of the plates and their mutual-interactions (continental rifting and basins formation, subduction, collisional processes and mountain building processes etc.).

  Tools: Field-study, Analogue experiments, Numerical models.

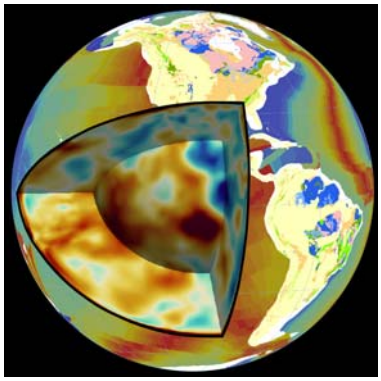


GSA Guest Blog, M. J. Jessup, 2013

Structural Geology / Tectonics / Geodynamics

- **Geodynamics** discusses about the forces and processes drive the plate tectonics, and deformation of materials inside the earth (mantle convection, plumes etc.). The study of Geodynamics operates at scales > 100 km.

  Tools: Analogue experiments, Numerical Models



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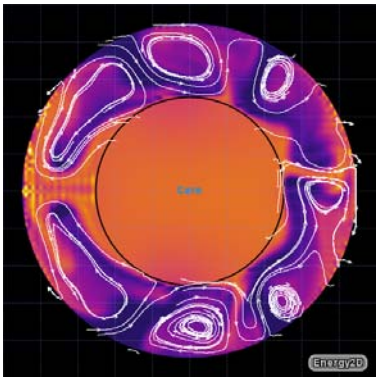

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A few things to remember

SCALE

CONTINUOUS
DISCONTINUOUS

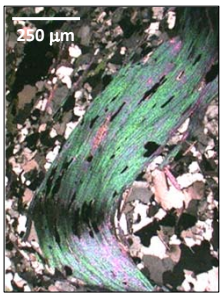
HOMOGENEOUS
HETEROGENEOUS

ISOTROPIC
ANISOTROPIC

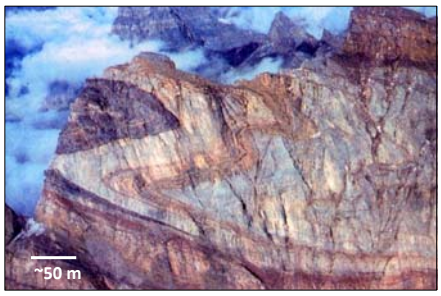
Scale

- There are classically three scales of investigation: ***microscopic***, ***mesoscopic***, and ***macroscopic***
  - **Microscopic** scale pertains to any structure so small ($<10^{-2}$ m) that it requires to be examined with an optical or electron microscope. [*microscopic scale*]
  - **Mesoscopic** scale pertains to any structure that can be observed without the aid of the microscope on a hand specimen or a single outcrop (10^{-2} to 10^{2} m). [*outcrop scale*]
  - **Macroscopic** scale pertains to structures that are too large ($>10^{2}$ m) to be completely exposed in one outcrop, which implies the interpretative step of reconstructing the structure from data collected at a number of outcrops. [*field/regional scale*]

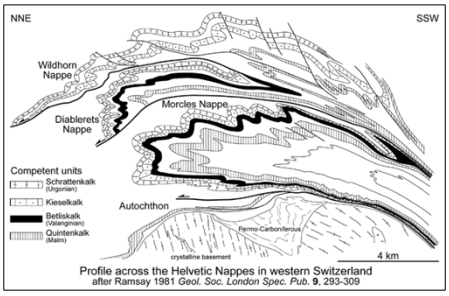
Scale



Folded biotite
microscope



Morcles Nappe (Dent de Morcles)
outcrop

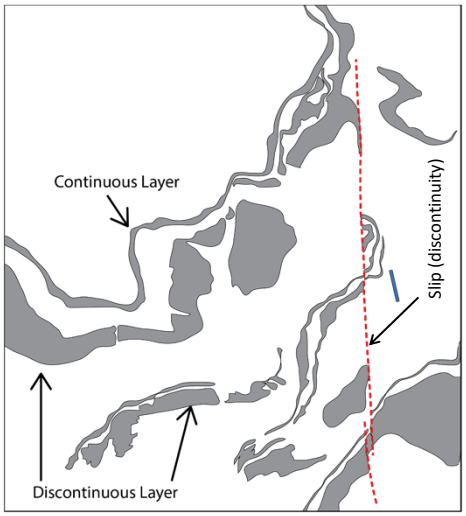


Morcles Nappe (Dent de Morcles)
field map

- The concept of scale is very important in structural geology. One must be constantly aware of the relationships between structures at all scales, and intellectually jump from one scale observation to another to solve the geometrical problems met in the field.

Continuous-Discontinuous

Continuous-Discontinuous



Basics of Ho-/He-/Iso-/Aniso-

- **Homogeneous Materials:**
  The term homogeneous is understood as “of uniform composition throughout” or “material composition and properties are independent of position.”

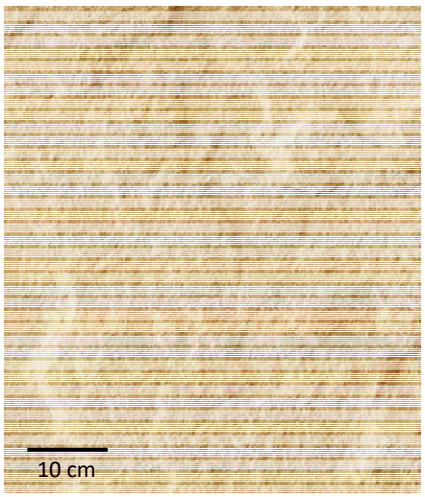
- **Heterogeneous Materials:**
  The term heterogeneous is understood as “of non-uniform composition throughout” or “material composition and properties varies with position. ”

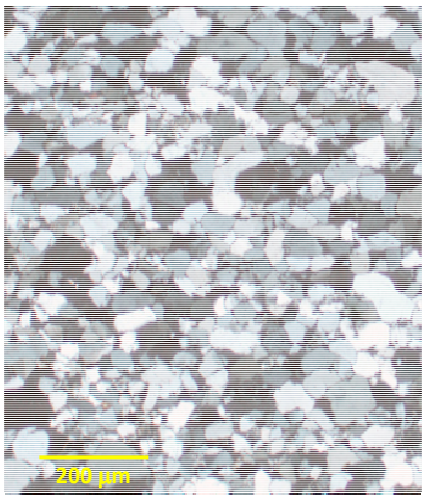
- **Isotropic Materials:**
  An isotropic material is one in which the physical properties are equal in all directions. In other words, material properties are independent of the direction in which they are measured.

- **Anisotropic Materials:**
  An anisotropic material is one in which the mechanical properties are not equal in all directions. In other words, material properties varies with the direction in which they are measured.

Note: The definitions above are absolutely **scale dependent**. For example, Layered and foliated rocks are statistically homogeneous, anisotropic materials if the scale of the layering or fabric is small relative to the scale of deformation.

Homogeneous-Heterogeneous





A sandstone in mesoscale is visually ***homogeneous***, but ***heterogeneous*** in microscale

Isotropic-Anisotropic

The granite in the left is ***isotropic*** in this scale, but the gneiss in the left is layered and ***anisotropic*** (across the layering).

Summary

Am I looking at a deformed rock?

What is the scale of the structure I am looking at….

Is the rock and deformation, homogeneous or heterogeneous?

Is the rock isotropic or anisotropic?

Next Lecture

In this lecture we learnt the basics of how to look and observe the deformed rocks.

In the next lecture we shall further investigate this topic and try to classify the different ways to interpret the deformation features.