Geology and Geophysics 612: Structural Geology Section

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Class Themes

The crust of the earth is deformed at many scales, locations, and times; this deformation produces identifiable structures in the crust such as fractures and folds. An appreciation of earth structures has both enormous practical value and profound intellectual implications for how we view this planet. This class deals with ways to recognize and characterize major structures in the earth's crust and ways to gain insight into how these structures form. The thrust of the structural geology lectures will be to introduce you to how the earth's crust can be viewed as a mechanical system. Owing to time constraints, the class will focus on macroscopic structures; we will not deal with the microscopic aspects of structural geology.

Our ability to understand geologic structures depends in large part on how we perceive them. Few geologic structures form by trivially simple processes, but depending on how we view geologic structures, they can appear horribly complicated or amenable to understanding; perspective is critically important. You do will do an exercise to introduce you to a graphical method for viewing the geometry of geologic structures such that the underlying essential forms emerge clearly.

An undercurrent of the lectures is the usefulness of integrated knowledge. We can think of unrelated pieces of knowledge as unconnected nodes of a net. A cut-up net is not very useful for catching fish. However, if the nodes of a net are connected, a net is a wonderful device for catching fish. It is also light, strong, and flexible. The outstanding feature of a net that makes it so useful then is the connection of the nodes. Similarly, concepts are vastly more powerful when they are connected rather than isolated. The knowledge connection process is not easy to master, but it is a key part of thinking, problem recognition, and problem solution. For these reasons, integrating pieces of knowledge can be very satisfying. Synergistic links in structural geology are forged between disciplines (e.g., , mathematics, and physics) and between observations made at different scales.

Introduction/Philosophy/Science

Science

- Possession of knowledge as distinguished from ignorance or misunderstanding;
- Knowledge attained through study and practice
- Knowledge covering general truths or the operation of general laws especially as obtained and tested through the scientific method

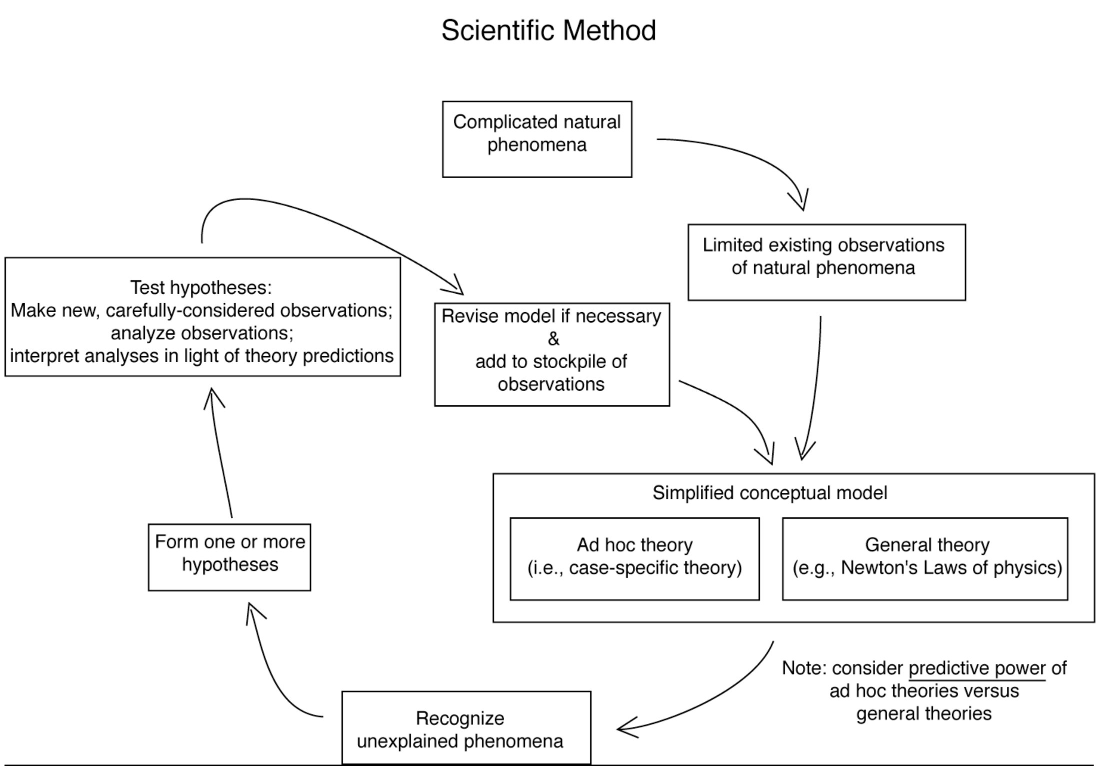
Scientific Method

Principles and procedures for the *systematic* pursuit of knowledge involving the *recognition and formulation of a problem, the collection of data through observation and experiment, and the formulation and testing of hypotheses.*

Concepts vs. vocabulary; critical thinking vs. cookbooks; fundamentals vs. fashion

Quantitative predictions (Where, when, how big?)

Fig. 1.1



Mechanistic Approach to Structural Geology

Topic	Definition	Application to structural geology
Descriptive geometry	The representation of the spatial relationships of points lines and planes by means of projections	Used to describe the geometry of deformed or undeformed bodies. Relies on good field work (e.g., preparation of geologic maps)
Kinematics	The study of the position of bodies through time without regard to the causative forces	Used to describe how a body changes shape and/or position through time
Mechanics	The study of forces and their effects on bodies, and in particular how bodies deform in response to forces	Used to understand and predict how bodies deform

Geometry of lines and planes

Lines

- Trend: Bearing of the projection of a line into the horizontal plane
- Plunge: Inclination of a line below the horizontal plane

Planes

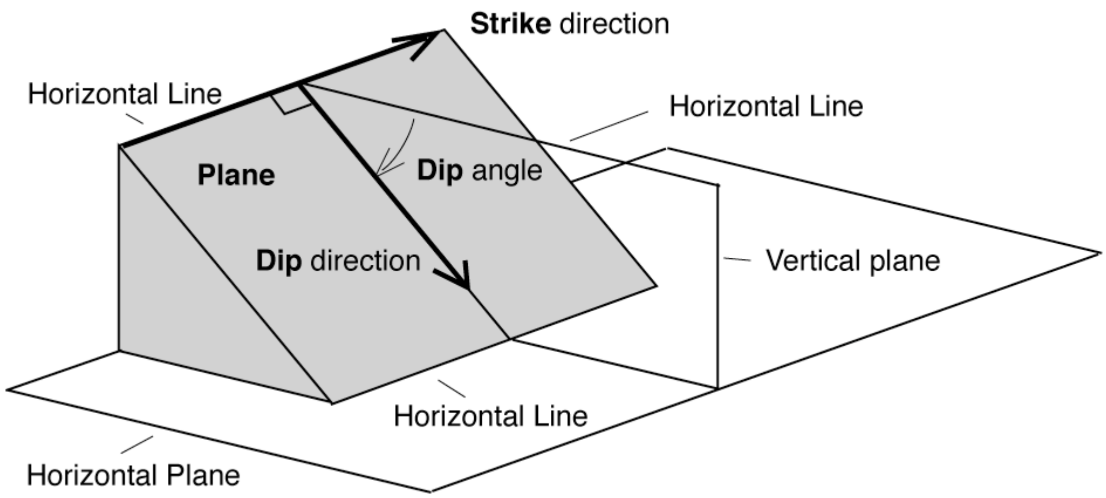
- Strike: Bearing of a horizontal line contained in a plane/
  Bearing of a line connecting two points of equal elevation in a plane
- Dip: Inclination of a plane below the horizontal plane/
  The maximum inclination of any line contained in a plane

Pole to a plane

- A line that is normal to a plane

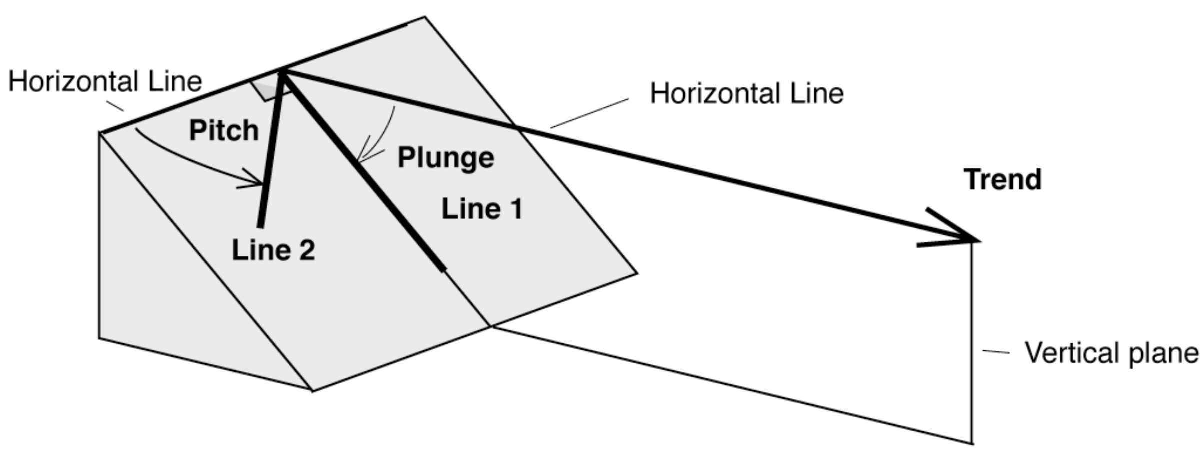
ORIENTATION OF LINES AND PLANES

PLANES



Right hand rule for strike and dip directions: If thumb on right hand points in the direction of strike the fingers on the right hand should point in the direction of dip

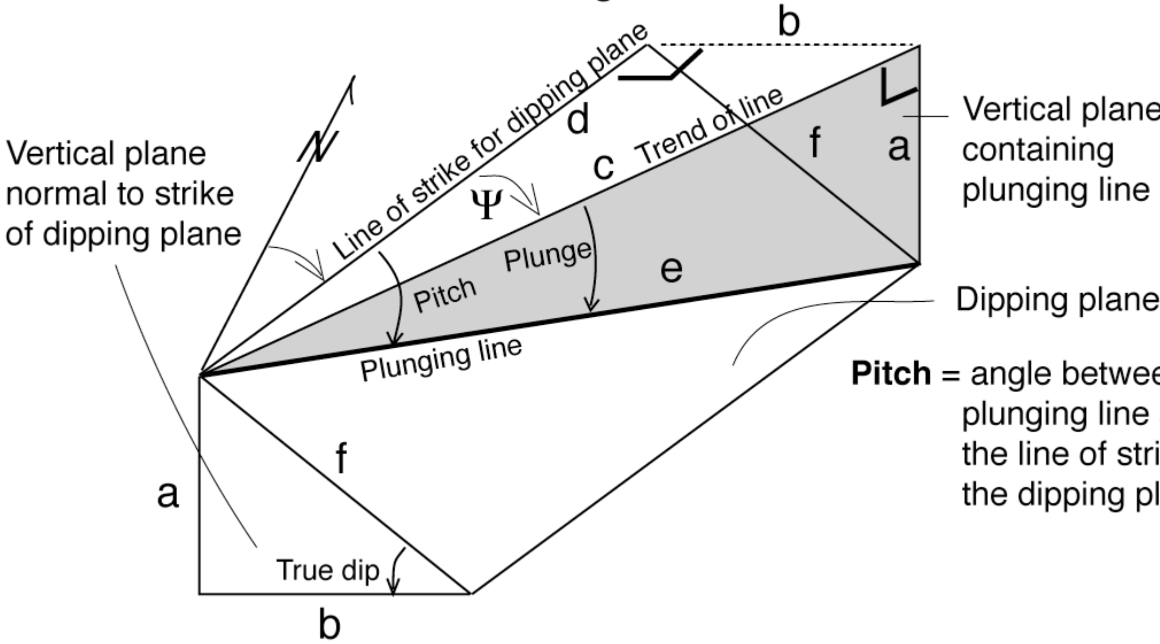
LINES



Need to define orientation of plane for the pitch (rake) to have meaning

The POLE to a plane is a line that is perpendicular to the plane.
The trend of the pole is opposite the direction a plane dips.
The plunge of a pole and the dip of a plane sum to 90°.

Trend, Plunge, & Pitch



Pitch = angle between plunging line and the line of strike for the dipping plane

	plunge (ϕ)	pitch (Ω)	dip (δ)	Ψ
sin	$\frac{a}{e}$	$\frac{f}{e}$	$\frac{a}{f}$	$\frac{b}{c}$
cos	$\frac{c}{e}$	$\frac{d}{e}$	$\frac{b}{f}$	$\frac{d}{c}$
tan	$\frac{a}{c}$	$\frac{f}{d}$	$\frac{a}{b}$	$\frac{b}{d}$

(1) Trend = θ = strike + Ψ = strike + $\cos^{-1}$ (d/c) = strike + $\cos^{-1}\{(\cos \Omega)/(\cos \phi)\}$

(2) Trend = θ = strike + Ψ = strike + $\tan^{-1}$ (b/d) = strike + $\tan^{-1}\{(\cos \delta)(\tan\Omega)\}$

(3) Plunge = ϕ = $\sin^{-1}$ (a/e) = $\sin^{-1}$ $\{(\sin \delta)(\sin\Omega)\}$

(4) Pitch = Ω = $\sin^{-1}$ (f/e) = $\sin^{-1}$ $\{(\sin\phi) / (\sin \delta)\}$

Geologic Conventions for Measuring Orientations

Compass Bearings

By quadrant (relative to north or south). The angle does not exceed 90°

By 360° azimuth (0° - 360°)

Examples

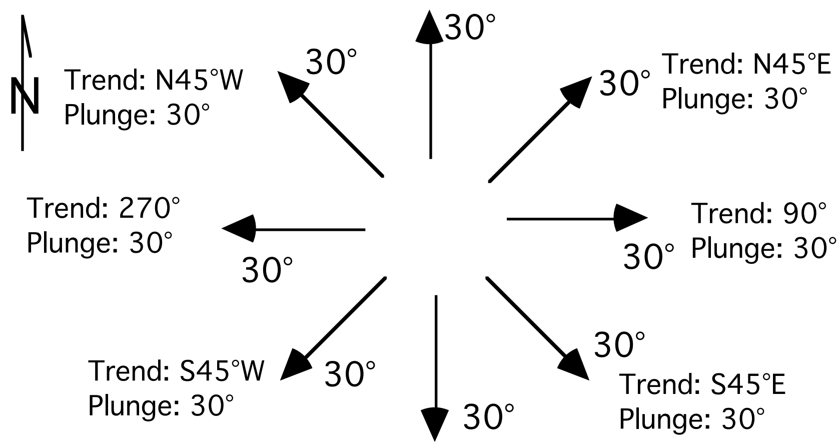
N0°E	N45°E	N90°E	S45°E	S0°E	S45°W	S90°W	N45°W
0°	45°	90°	135°	180°	225°	270°	315°

Lines

Trend: A compass bearing

Plunge: An inclination below horizontal

Examples: The lines below all plunge at 30°. Their trends vary according to the table above

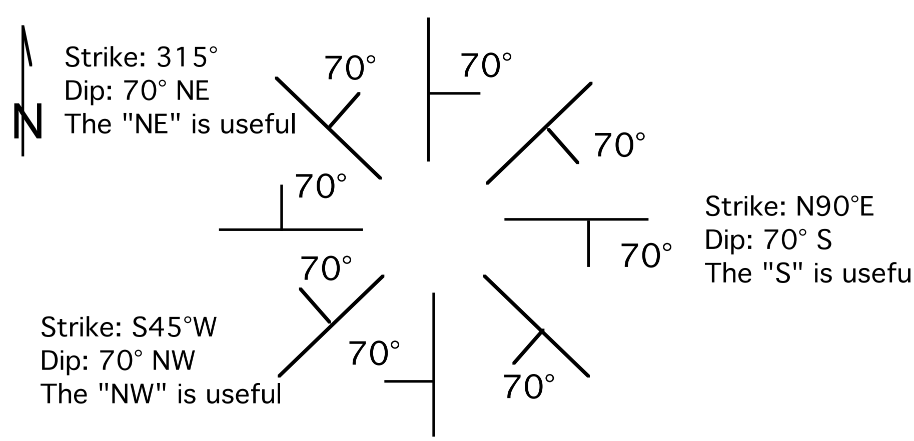


Planes

Strike: A compass bearing along a horizontal line in a plane

Dip: An inclination below horizontal

Examples: The planes below all dip at 70°. Their strikes vary according to the table above



<u>Key steps in a geometric analysis</u>

- Establish location, size, orientation, shape of individual elements
- Establish relative positions and orientations of a collection of elements

<u>Key steps in a kinematic analysis</u>

- Establish sequence of deformational events
- Establish (or infer) initial, intermediate, and final geometry of bodies (e.g., undeformed and deformed states; initial and final positions, etc)

<u>Key steps in a mechanical analysis</u>

- Conceptual model
- Establish boundary conditions (e.g., pressure on boundary conditions)
- Set governing equation (reflect rheology of material)
- Find general solution of governing equation
- Solve governing equation to fit boundary conditions
- Compare with field observations