Structural Geology Laboratory

Lab Lecture 1: Geological "Attitude" and Orthographic Projections

Geological Geometry

- Most geological structures can be described geometrically with points, lines or planes, or some combination of these elements.
- Examples
  - Point: the projection of a fold hinge into a cross-section plane would be a point (i.e. intersection of a line with a plane).
  - Line: in 3D the hinge of a fold is a geometric line.
  - Plane: the contact between 2 undeformed sedimentary beds is a plane in 3D.

Geological Attitude

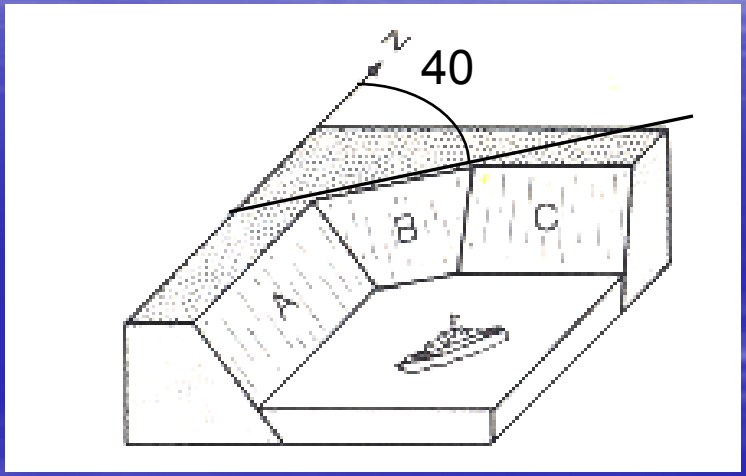
- Planes are described by strike and dip:
  - Strike: compass direction of the horizontal line in the structural plane.
  - Dip: inclination angle and quadrant direction in a compass direction perpendicular to strike.
  - Note: the “compass direction” refers to a geographic bearing or azimuth as measured by a magnetic compass (ex. N30E bearing, or 320 azimuth).

Strike Line Attitude

- Strike lines can be stated in one of two methods:
  - Quadrant: bearing (trend) direction as determined by an angle <= 90 relative to a North or South compass direction (N30E or S70W).
  - Azimuth: a trend direction as indicated by an angle 0-360 degrees with North at 0 (or 360), East at 90, South at 180, and West at 270.
- Note that N30E quadrant is the same as 030 azimuth, and S70W is equivalent to 250 azimuth.
- Since any line drawn on a map has 2 “ends”, by convention a north quadrant bearing is always used to denote the attitude. Therefore, a strike line is never reported as S70W (use N70E), or 250 (use 070).
- If a strike line is parallel to the North-South direction use N0E or N0W as a quadrant (both are equivalent), or 000 for azimuth.
- If a strike line is parallel to the East-West direction use N90E or N90W as a quadrant (both are equivalent), or 090 or 270 for azimuth.

Strike Line Attitude

- Assume that the planar cliff faces A, B, and C are fault surfaces:
  - A strike: N0E quadrant; 000 azimuth
  - B strike: N40E quadrant; 040 azimuth
  - C strike: N90E quadrant; 090 azimuth

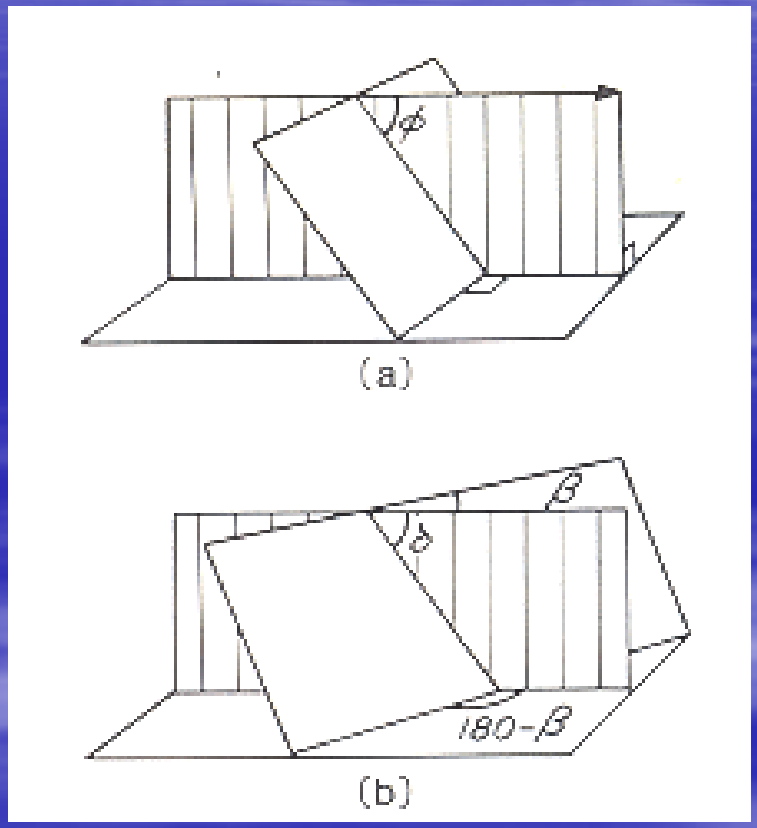


Dip Attitude

- The dip of a plane is defined as the angle of inclination of the plane measured in a vertical plane perpendicular to the strike line. The quadrant direction of the inclination must also be specified since there are 2 “sides” to a strike line.
- The above definition basically specifies a 2nd line perpendicular to the strike that lies within the structural plane. Any 2 non-parallel lines that lie within a plane uniquely determines the 3D orientation of the plane.
- Note that the dip angle is always the maximum angle of inclination in the plane. The inclination angle measured in any other direction is always less than the “true” dip. These lesser inclination angles are often referred to as “apparent” dips.

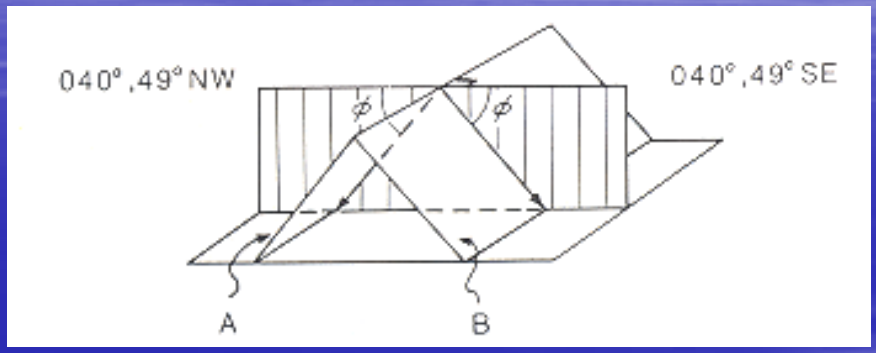
Dip Attitude continued

- True dip (Φ) angle in figure (a) is measured in the vertical plane (ruled plane) perpendicular to the strike of the structural plane (un-ruled).
- Apparent dip (δ) angle in figure (b) is measured in the vertical plane (ruled) that is at an angle (β) less than 90 degrees from the strike of the structural plane (un-ruled).
- In both cases of Φ & β the inclination angle is measured from the horizontal map surface down to the structural plane.
- In both (a) and (b) the intersection of the ruled plane with the structural plane defines a line (true dip or apparent dip line) that combined with the strike line uniquely defines the 3D orientation of the structural plane.



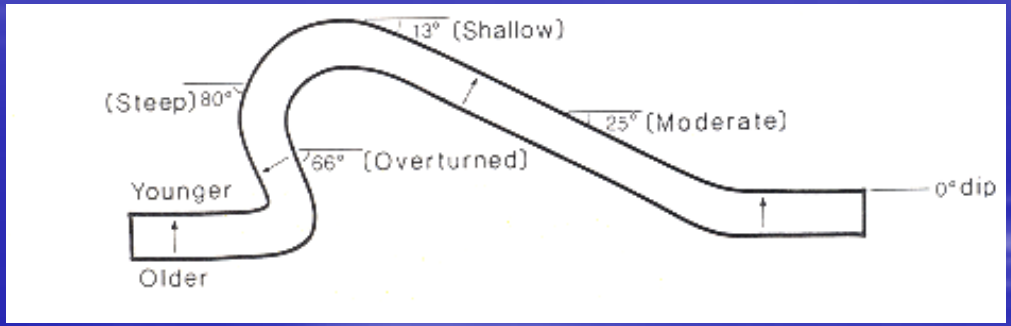
Dip Direction and Magnitude

- The dip angle magnitude must be combined with the dip direction quadrant
- The attitude of a plane should be written as {strike}, {dip angle} {dip quadrant}. In the adjacent diagram the 2 structural planes are:
  - A: 040, 49 NW
  - B: 040, 49 SE
- Note that if the dip quadrant is not listed the two different structural planes (A) and (B) would not be distinguished.



Dip Magnitude Descriptions

- Use the following terms to qualitatively describe true dip:
  - Horizontal: 0
  - Shallow: 1-20
  - Moderate: 21-50
  - Steep: 51-89
  - Vertical: 90
- Note that overturned beds should be identified when recorded:
  - 023, 66 SE OT
- The above “OT” is shorthand for overturned.



Strike & Dip Formats

- Traditional Strike and Dip formats:
  - Quadrant:
    - N50W, 78NE {the “N” in “NE” is not necessary}
    - N90E, 50S {“S” means the dip direction is due south}
    - N90W, 33N {“N” indicates due North dip direction}
    - N70W, 90 {Vertical dips have no quadrant direction}
  - Azimuth:
    - 310, 78NE
    - 090, 50S
    - 270, 33N
    - 290, 90

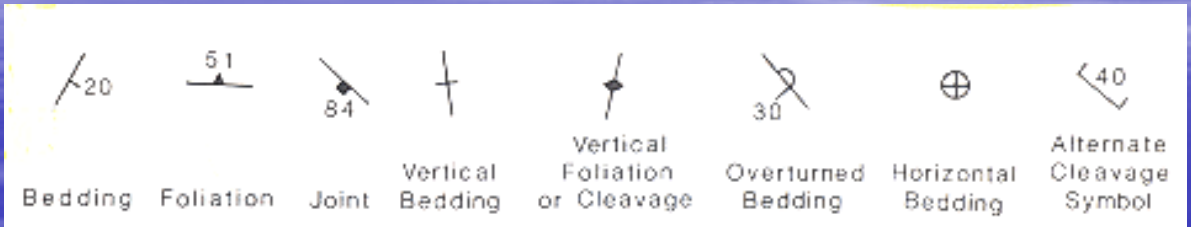
Non-Traditional Strike & Dip Formats

- Right-Hand Rule: this is used to condense strike & dip to pure numbers so that computer applications can more easily assimilate the attitude. The strike is listed as an azimuth direction such that if viewed in the azimuth direction the true dip would be inclined to the right. This means that a strike azimuth could be to a southern quadrant:
- Conversion examples:
  - N 40 E, 67 SE = 040 67
  - N 40 E, 67 NW = 220 67
  - N 40 W, 67 NE = 320 67
  - N 40 W, 67 SW = 140 67

Non-traditional Strike & Dip Formats

- Dip and Dip-azimuth: this is similar to the right-hand rule in that it reduces the strike & dip to pure numbers. The format is written {true dip angle}, {true dip direction azimuth}. Since the strike is always defined as being perpendicular to the dip azimuth it is always implicit in this format.
- Examples:
  - N50E, 35SE = 35, 140
  - N50E, 35NW = 35, 310
  - N30W, 70NE = 70, 060
  - N30W, 70SW = 70, 240
- Note that the above Dip and Dip-azimuth attitudes are written as a plunge & trend of a line attitude because the true dip direction is a linear geometry.

Map Symbols for Strike & Dip

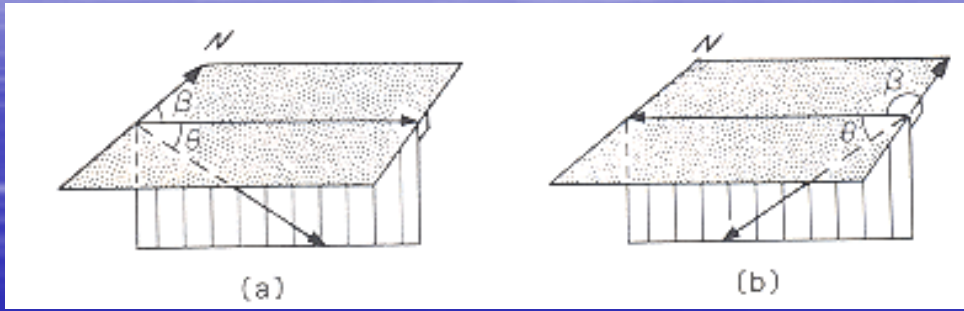


- The long dimension of the symbol indicates the trend of the strike. The “tic” mark or “arrow” perpendicular to the strike line indicates the dip quadrant direction. The number indicates the dip angle amount.
- For vertical attitudes the dip direction indicator points in both directions perpendicular to strike and there is no number next to the symbol.
- For Horizontal attitudes a circular symbol indicates that there is no definable strike, and that the dip is 0.

Attitudes of Geological Lines

- Linear geological structures include:
  - Mineral lineations
  - Fold hinges
  - Slickensides
  - Intersection of 2 planes
  - Stretched pebbles
  - Flute casts

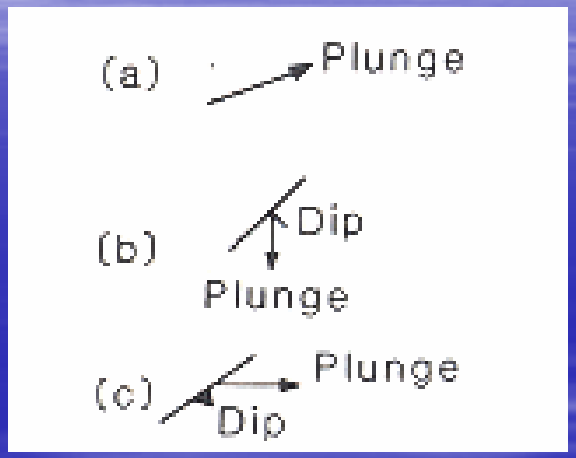
Plunge & Bearing



- The attitude of a linear structure is specified by a plunge and bearing (also known as trend).
- The plunge angle is angle of inclination of the line (θ) measured in the vertical plane (ruled) that contains the line (inclined arrow). The angle of inclination is measured from the horizontal map surface (stippled plane) down to the structural line (inclined arrow).
- The projection of the vertical plane (ruled) that contains the line (inclined arrow) to the horizontal map surface defines the compass direction (β) of the bearing (arrow in the stippled plane).
- If θ=40 in (a) and (b) the attitude of the structural line in (a) and (b) would be:
  - (a) 40, 090
  - (b) 40, 270

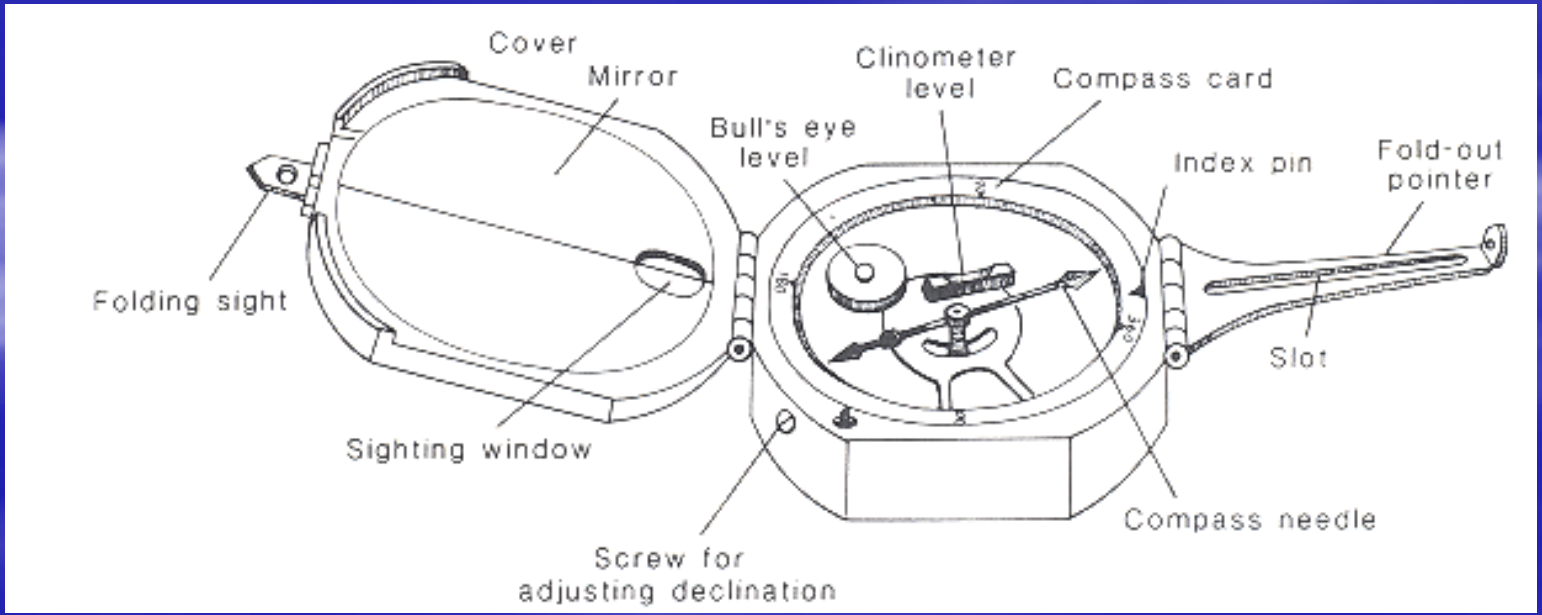
Linear Structure Map Symbols

- The long dimension of a linear map symbol indicates the trend of the structure in the direction of the arrowhead. The number next to the arrowhead is the plunge amount.
- The format for recording linear attitudes is: {plunge angle}, {trend, azimuth or quadrant}
- Examples:
  - 12, S30W
  - 12, 210
  - 0, N20E {will be a double-headed arrow}
  - 90, N/A {vertical plunge means that the trend is undefined}
- Lineations are often combined with a planar structure symbols (b) and (c) if they are contained within the surface.



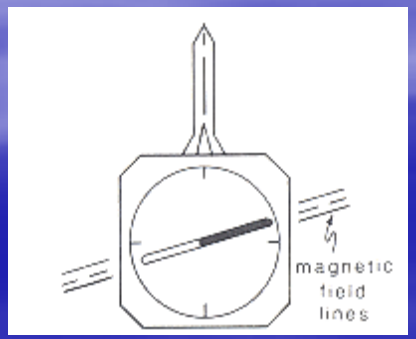
Measurement of Strike & Dip

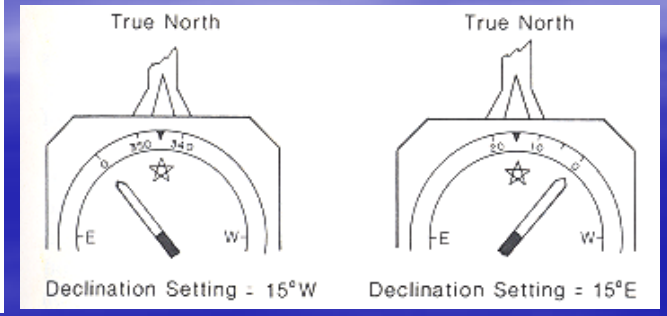
- Measurement of strike and dip in the field is usually done with a pocket transit
- Strike is measured with the compass component
- Dip is measured with the clinometer

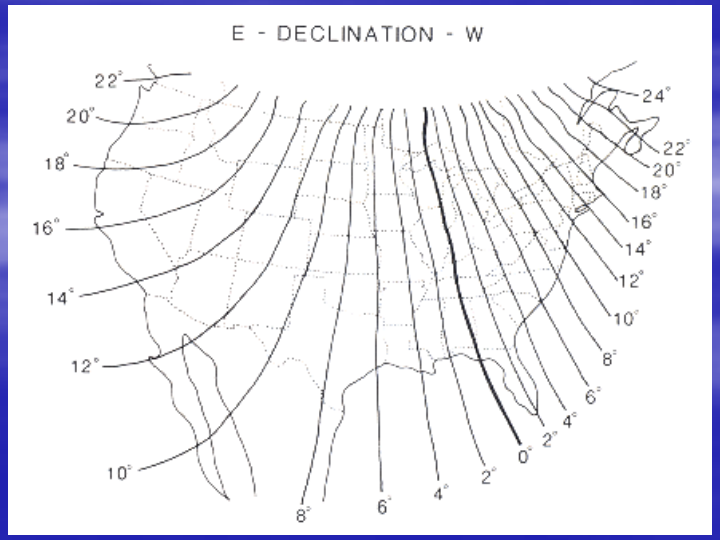


Compass Component of Pocket Transit

- Compass direction (azimuth or bearing) is indicated by the alignment of the magnetic needle relative to the sighting arm
- Azimuth or bearing must be corrected for magnetic declination

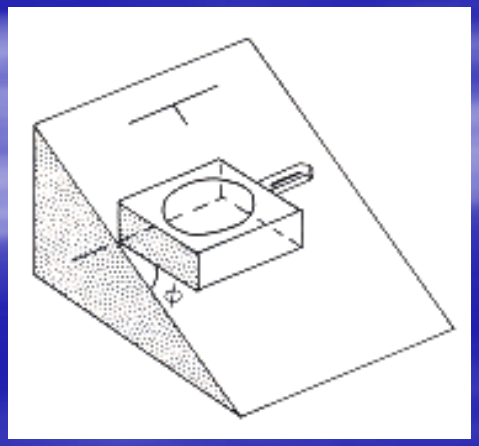


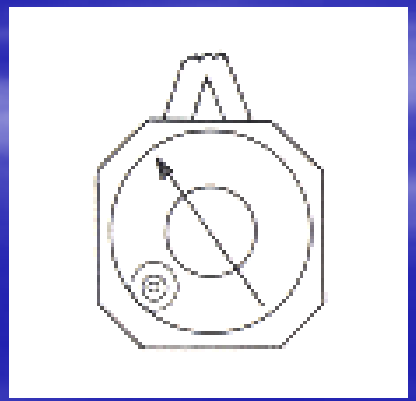




Measurement of Strike with the Pocket Transit

- The straight-edge side of the pocket transit should be in contact with the geological planar surface while the bubble level is centered. The azimuth pointed to by the sighting arm is indicated on the azimuth ring by the north end of the magnetic needle.



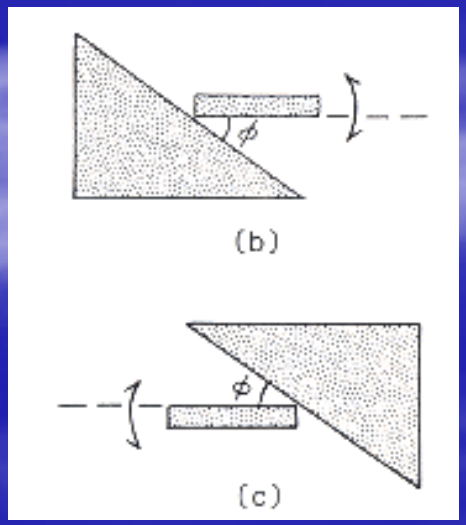


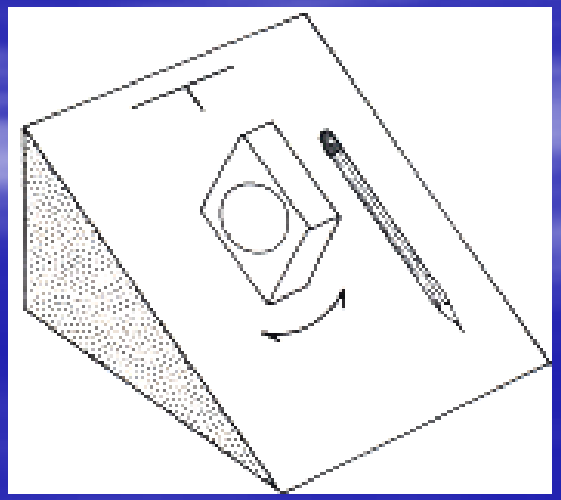
Other Strike Measurement Methods

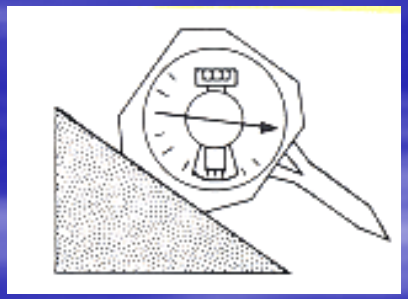
- The strike line is the intersection of a horizontal plane with a geological plane, therefore, the straight shoreline formed by calm water along a bedding plane would be a strike line.
- On a topographic map if a planar contact is exposed at two different points that have the same elevation the strike line is the line between those 2 points.
- Because structural contours are by definition lines of equal elevation the trend of a structure contour is the strike of the surface at that point.

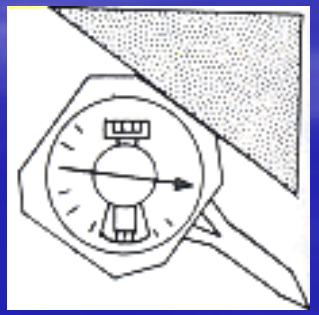
Measurement of the True Dip Angle

- The true dip angle (φ) is measured perpendicular to the trend of strike with the clinometer level.
- The true dip angle is also the maximum angle of inclination.







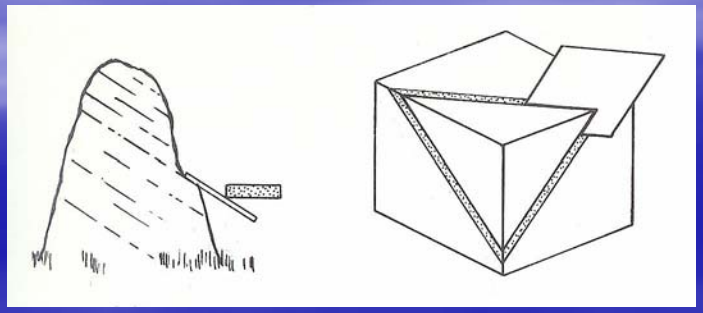


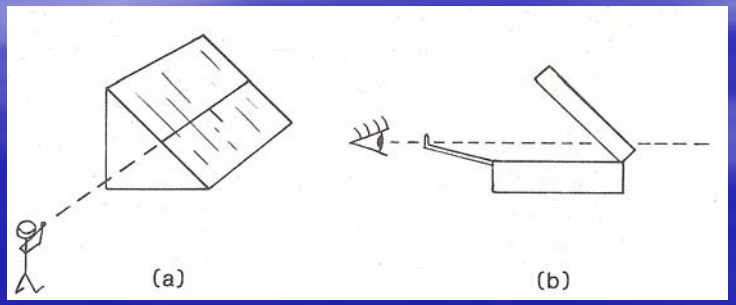
Dip Measurement “Tricks”

- For planes that dip < 12 degrees the bottom ring of the pocket transit will interfere with the strike measurements. Drip water on the surface- the drops will run directly down the true dip. The trend perpendicular to this direction is the strike. The clinometer reading parallel to this direction is the true dip angle.

Strike Measurement "Tricks"

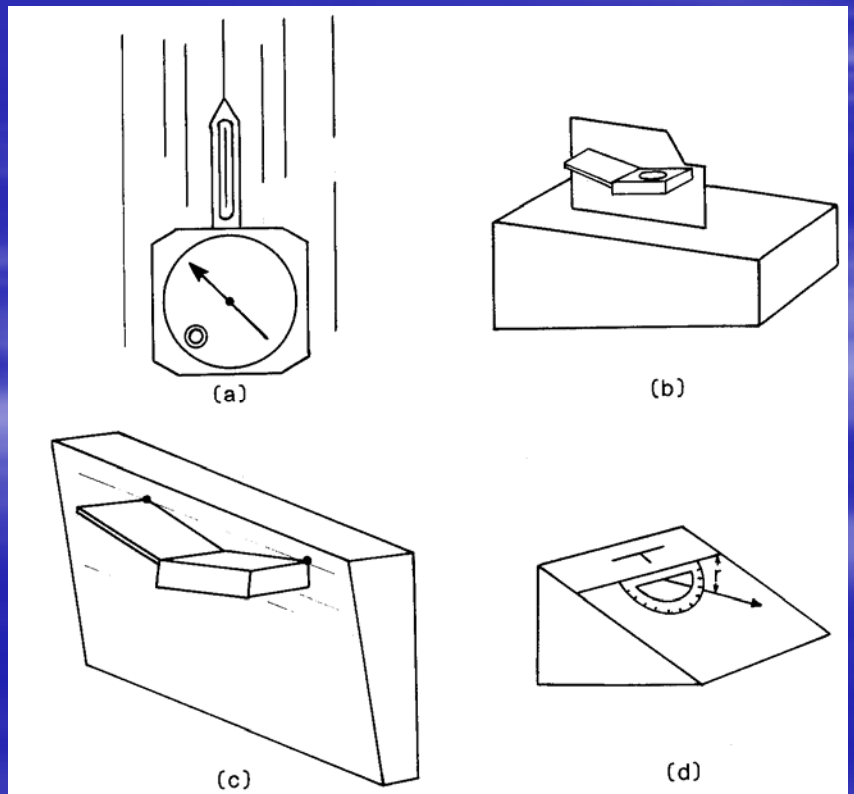
- A flat clipboard or similar device may be used to extend the bedding plane to make it easy to measure the strike.
- Remember that any 2 points of equal elevation that lie on the bedding plane will define the strike.
- The pocket transit can be configured to shoot an azimuth at eye-level if required.





Measurement of Lineations with a Pocket Transit

- The sighting arm of the pocket transit should be aligned with the down-plunge direction of the lineation.
- Clipboards or the side of the pocket transit may be used as long as they are aligned with the lineation and are vertical.
- A rake angle is more accurate when the surface containing the lineation is steeply inclined.



Rake Angle Measurement

- The lineation must lie on a planar surface (i.e. bedding, foliation, etc.) and the strike and dip of the planar surface must be measured first.
- A protractor is then used to measure the angle from the strike line down to the lineation line.
- The rake angle is measured from a specific end of the strike line so that "end" must be recorded with the rake angle (ex. 35NE on a N60E, 76SE bedding plane)
- The stereonet is used to extract the plunge and bearing from the rake angle data.

Locating Map Points with a Pocket Transit

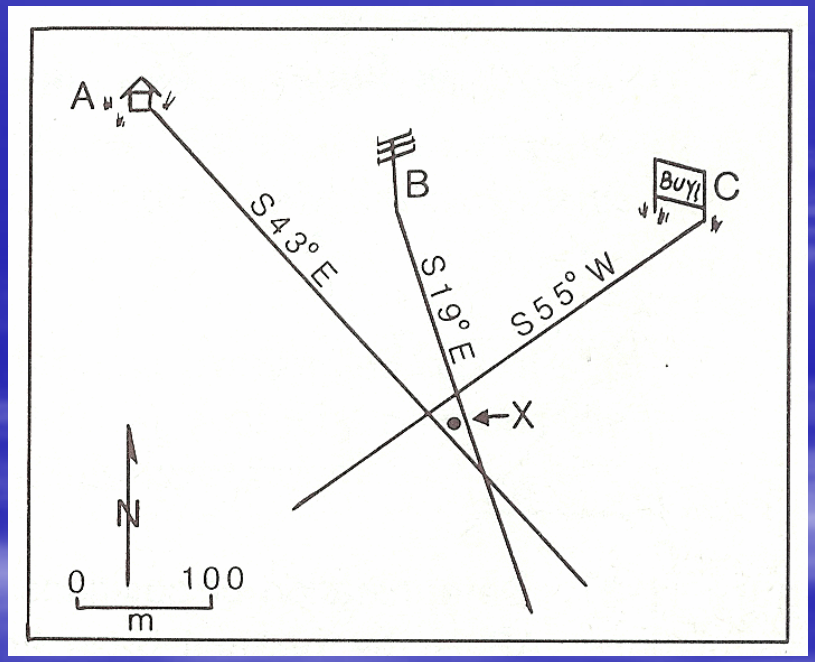
- Pace and Compass Traverse
- Triangulation
- Base line

Pace and Compass Traverse

- When mapping in an area without an adequate topographic base map the pace and compass method is used.
- While traveling from outcrop-to-outcrop the distance and travel direction bearing are recorded. Distance is measured by pacing or with a tape.
- A closed traverse is preferred because an error-analysis may be conducted.

Triangulation

- Triangulation is used when you are located at an unknown point while using a topographic base map. If 3 landmarks are observed that also are on the topographic map the position may be triangulated:
  - Sight the azimuth to each landmark, and plot the reverse azimuth on the map starting at the landmark map position.
  - Where the 3 back-azimuth lines intersect on the map determines the position.
  - There is always some error in measurements so the intersection forms a “error triangle”.



Baseline

- A baseline can be established to survey in points that cannot be accessed easily