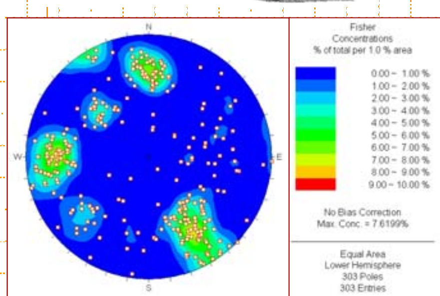
EOSC433:

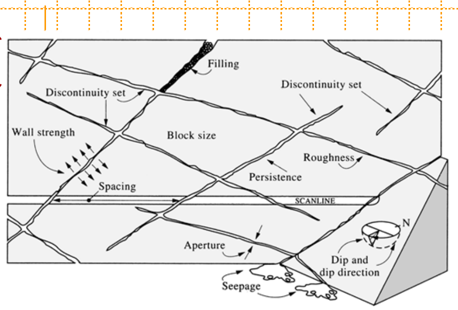
Geotechnical Engineering Practice & Design

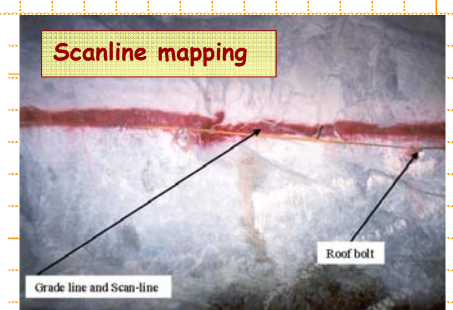


Supplementary Notes: Stereonets

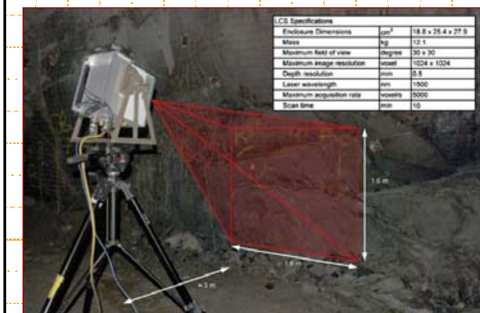
Discontinuity Mapping

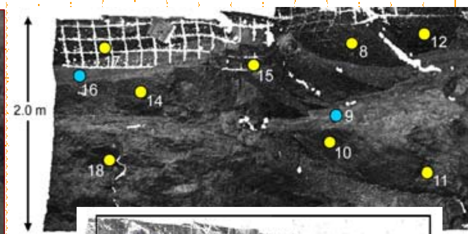
Hudson & Harrison (1997)

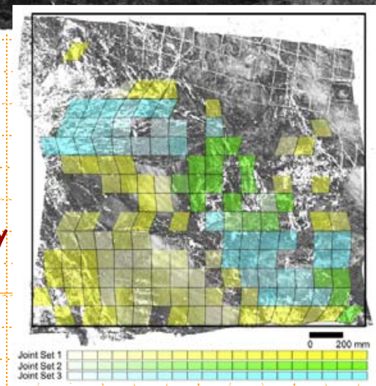




Discontinuity Mapping – Remote Sensing







Mah *et al.* (2013)

3-D laser imaging is an emerging tool for discontinuity mapping. Acquisition is performed at a safe distance, including for inaccessible areas. Millions of high accuracy 3D data points are acquired in Cartesian space, and processed efficiently by automatic algorithms, leading to robust estimates of joint dip and dip direction.

Discontinuity Mapping

DISCONTINUITY SURVEY DATA SHEET

GENERAL INFORMATION

Location [ ] Station / Hole No. [ ] Date: Day [ ] Month [ ] Year [ ] Inspector [ ] Discontinuity data sheet no. [ ] of [ ]

NATURE AND ORIENTATION OF DISCONTINUITY

Chainage or Depth	Type	Dip	Dip Direction	Persistence	Termination	Aperture/ Width	Nature of Filling	Strength of Filling	Surface Roughness	Surface Shape	Waviness Wavelength	Waviness Amplitude	JRC	Water Flow	Spacing	Remarks

Type
0. Fault zone
1. Fault
2. Joint
3. Cleavage
4. Schistosity
5. Shear
6. Fissure
7. Tension Crack
8. Foliation
9. Bedding

Persistence
1. Very low persistence <1 m
2. Low persistence 1-3 m
3. Medium persistence 3-10 m
4. High persistence 10-20 m
5. Very high persistence >20 m

Aperture/width
1. Very tight (<0.1 mm)
2. Tight (0.1-0.25 mm)
3. Partly open (0.25-0.5 mm)
4. Open (0.5-2.5 mm)
5. Moderately wide (2.5-10 mm)
6. Wide (>10 mm)
7. Very wide (1-10 cm)
8. Extremely wide (10-100 cm)
9. Cavernous (>1 m)

Nature of filling
1. Clean
2. Surface staining
3. Non-cohesive
4. Inactive clay or clay matrix
5. Swelling clay or clay matrix
6. Cemented
7. Chlorite, talc or gypsum
8. Other - specify

Compressive strength of infilling (MPa)
S1 Very soft clay <0.025
S2 Soft clay 0.025-0.05
S3 Firm clay 0.05-0.10
S4 Stiff clay 0.10-0.25
S5 Very stiff clay 0.25-0.50
S6 Hard clay >0.50
R0 Extremely weak rock 0.25-1.0
R1 Very weak rock 1.0-5.0
R2 Weak rock 5.0-25
R3 Medium strong rock 25-50
R4 Strong rock 50-100
R5 Very strong rock 100-250
R6 Extremely strong rock >250

Water flow (open)
0. The water flow along it does not appear possible.
1. The discontinuity is dry with no evidence of water flow.
2. The discontinuity is dry but shows evidence of water flow, i.e. rust staining, etc.
3. The discontinuity is damp but no free water is present.
4. The discontinuity shows seepage, occasional drops of water, but no continuous flow.
5. The discontinuity shows a continuous flow of water (Estimate 1/mm and describe pressure, i.e. low medium, high).

Water flow (filled)
6. The filling materials are heavily consolidated and dry; significant flow appears unlikely due to very low permeability.
7. The filling materials are damp, but no free water is present.
8. The filling materials are wet; occasional drops of water.
9. The filling materials show signs of outwash, continuos flow of water (estimate litres/minute).
10. The filling materials are washed out locally; considerable water flow along out-wash channels (estimate litres/minute and describe pressure, i.e. low, medium, high).

Termination
0. Neither end visible
1. One end visible
2. Both ends visible

Surface shape
1. Stepped
2. Undulating
3. Planar

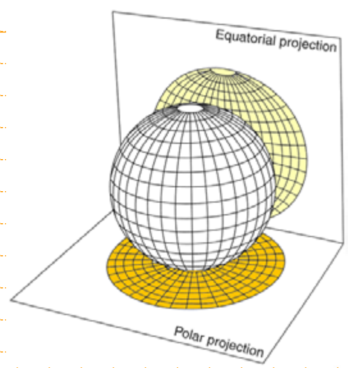
Surface roughness
1. Rough
2. Smooth
3. Polished
4. Slickensided

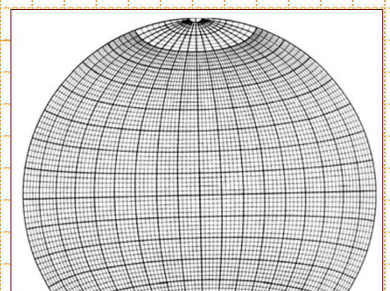
Spacing
1. Extremely close spacing <20 mm
2. Very close spacing 20 - 60 mm
3. Close spacing 60 - 200 mm
4. Moderate spacing 200 - 600 mm
5. Wide spacing 600 - 2000 mm
6. Very wide spacing 2000 - 6000 mm
7. Extremely wide spacing >6000 mm

Wyllie & Mah (2004)

Stereographic Projection

Stereographic projection allows 3-D orientation data to be represented and analyzed in 2-D. This projection consists of a reference sphere in which its equatorial plane is horizontal, and its orientation fixed relative to north. The equatorial projection is the one generally favoured for plotting and analyzing discontinuity data.



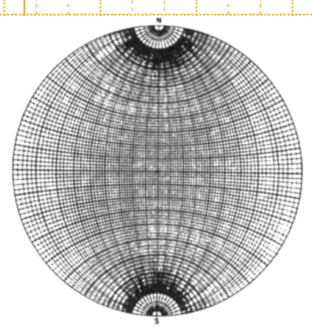


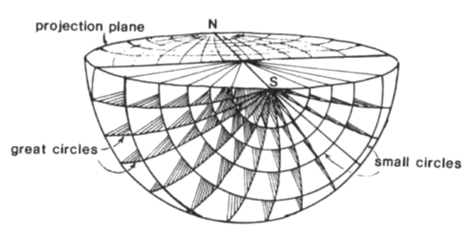
The most common Equatorial projection is the "equal area" stereonet (aka Schmidt or Lambert stereonet).

Stereographic Projection

Equal-area stereonets are used in structural geology because they present no statistical bias when large numbers of data are plotted. On the equal-area net area is preserved so, for example, each 2 degrees polygon on the net has the same area.

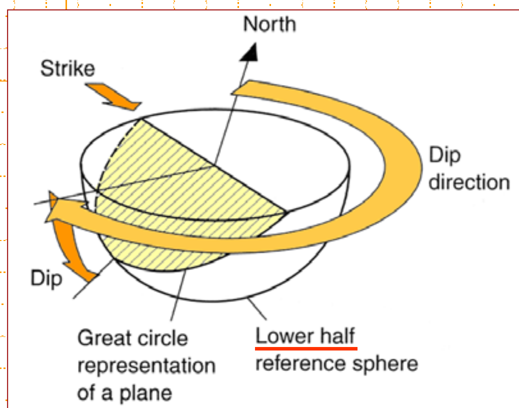
In structural geology the stereonet is assumed to be a lower-hemisphere projection since all structural elements are defined to be inclined below the horizontal.

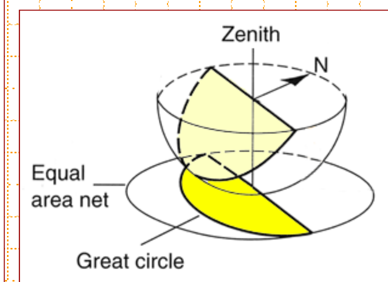




Stereographic Projection

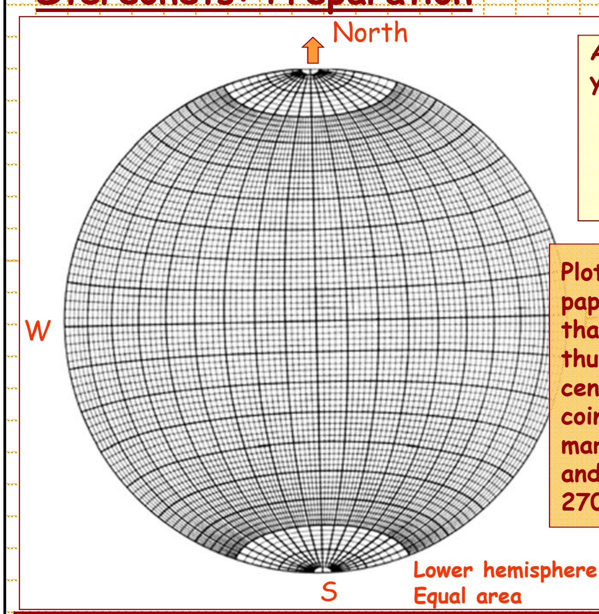
For a plane (e.g. a discontinuity surface), its intersection with the lower half of the reference sphere defines a unique line on the stereonet (in the shape of a circular arc called a "great circle". To plot the great circle, the dip direction and dip must be known.





Wyllie & Mah (2004)

Stereonets: Preparation



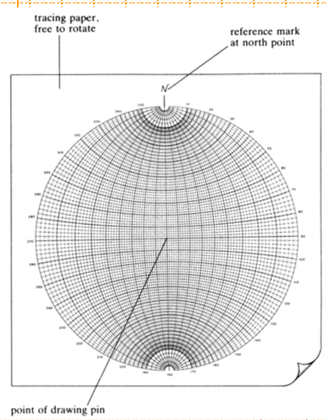
Always begin by labelling your stereonet!!

- North, south, east, west
- Lower/upper hemisphere
- Equal area/equal angle

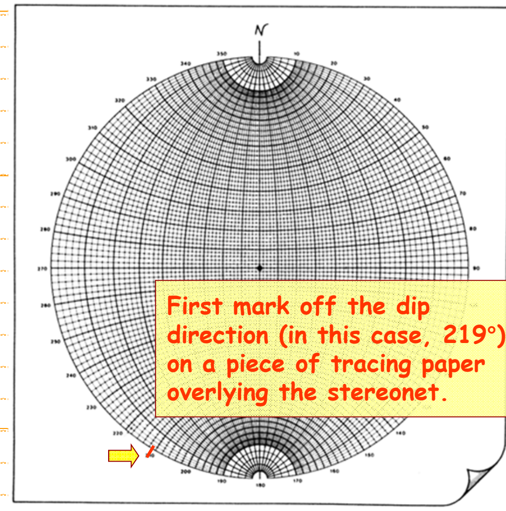
Plotting is done on transparent paper laid over the stereonet that can be rotated around a thumb tack poking up at the center of the net. A tick mark coinciding with the 0 degree mark is labeled N, with E, S and W marked at 90, 180 and 270 degrees, respectively.

Stereonets: Plotting a Plane (Dip Direction)

Example:
68/219° (dip/dip direction)



Priest (1985)



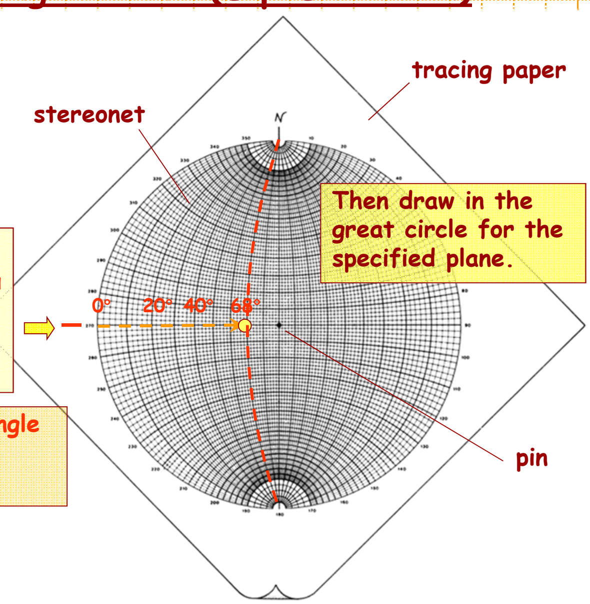
First mark off the dip direction (in this case, 219°) on a piece of tracing paper overlying the stereonet.

Stereonets: Plotting a Plane (Dip Direction)

Example:
68/219° (dip/dip direction)

Rotate the tracing paper until the mark you made is lying on the east-west diameter of the stereonet.

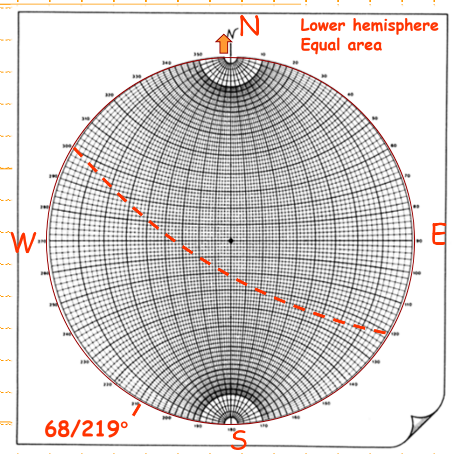
Count off the dip angle and mark it on the tracing paper.



Then draw in the great circle for the specified plane.

Stereonets: Plotting a Plane (Dip Direction)

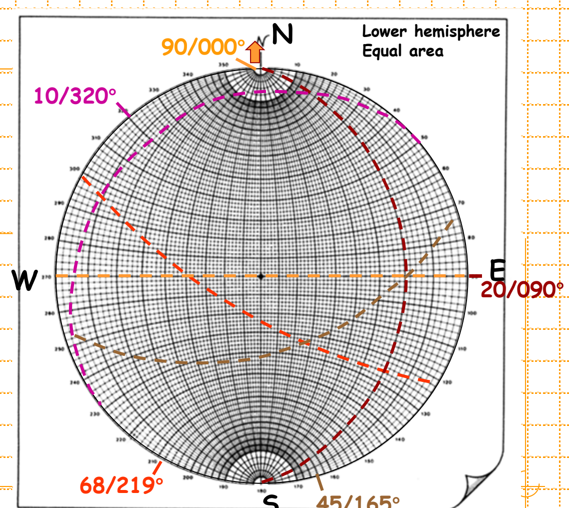
Example:
68/219° (dip/dip direction)



Your tracing paper should now look as follows:

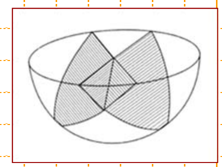
Stereonets: Plotting a Plane (Dip Direction)

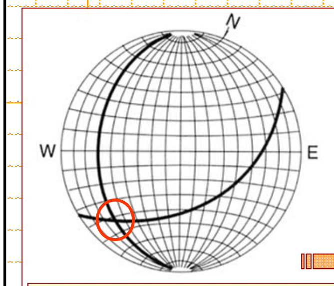
Now try adding:
20/090° (dip/dip direction)
45/165°
90/000°
10/320°



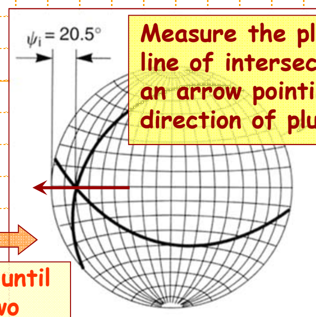
Intersecting Planes

When two planes intersect they define a line, which is common to both planes. The trend and plunge of this line can be read directly off the stereonet.

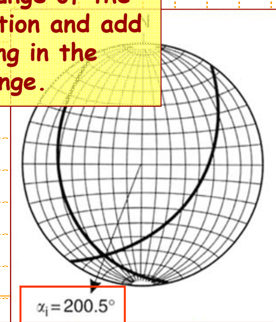




Rotate the tracing paper until the intersection of the two planes lies on the east-west diameter of the stereonet.



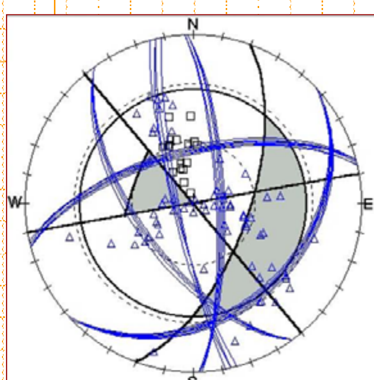
Measure the plunge of the line of intersection and add an arrow pointing in the direction of plunge.

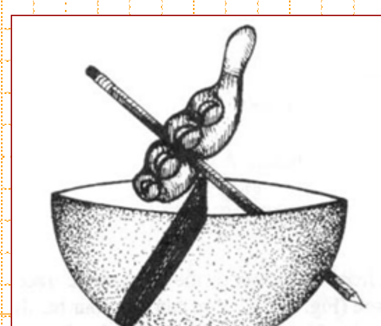


Rotate the tracing paper back to North, and measure the trend of the line.

Pole Plots

In many situations it is more convenient to plot the pole of a plane rather than the great circle. The pole represents the line that is perpendicular to the plane. Since the intersection of a line with the lower hemisphere is a point, the pole will always plot as a point, and will always have an attitude measured as a plunge and bearing.

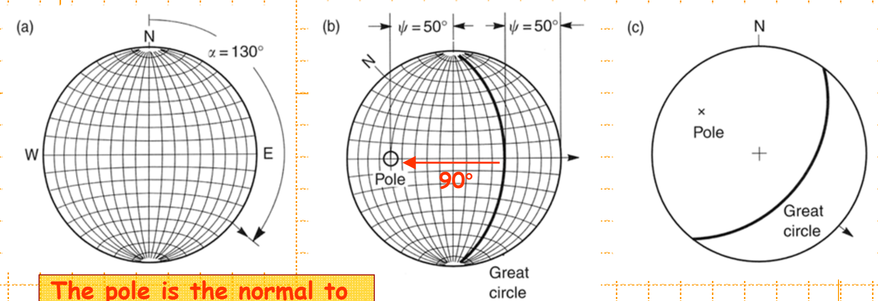




A pole perpendicular to a plane surface intersects the outer bowl as a point.

Stereonets: Plotting a Pole

The pole (or normal vector) of a plane allows the plane to be represented on the stereonet as a single point. Pole plots are a convenient way to examine the orientation of a large number of discontinuities, such as that measured during a discontinuity scanline survey.



Wyllie & Mah (2004)

The pole is the normal to the plane (i.e. the vector that is perpendicular to the plane).

When the tracing paper is rotated so that the dip direction is aligned with the east-west diameter, the pole is plotted 90° from the edge of the Great Circle.

Stereonets: Plotting a Pole

Try plotting the poles to our earlier example planes:

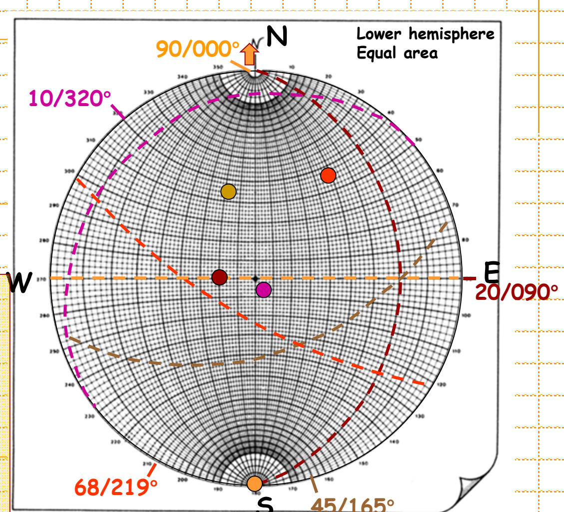
68/219° (dip/dip direction)

20/090°

45/165°

90/000°

10/320°



As a guide in helping you visualize poles, planes with a shallow dip will have poles that plot near the centre, and planes that are steeply dipping will have poles that plot near the circumference of the stereonet.

Stereonets: YouTube

Check out all of the exhilarating stereonet action on YouTube:

Setting up a stereonet:

http://www.youtube.com/watch?v=kCvqSsgyCS8

Plotting a plane:

http://www.youtube.com/watch?v=BBJndEjCINw

Plotting a pole:

http://www.youtube.com/watch?v=xspWJkDQVYw

Lecture References

Hudson, JA & Harrison, JP (1997). Engineering Rock Mechanics – An Introduction to the Principles . Elsevier Science: Oxford.

Mah, J, Samson, C, McKinnon, SD & Thibodeau, D (2013). 3D laser imaging for surface roughness analysis. *International Journal of Rock Mechanics & Mining Sciences* 58: 111-117

Priest, SD (1985). Hemispherical Projection Methods in Rock Mechanics. George Allen & Unwin: London.

Wyllie, DC & Mah, CW (2004). Rock Slope Engineering (4th edition). Spon Press: London.