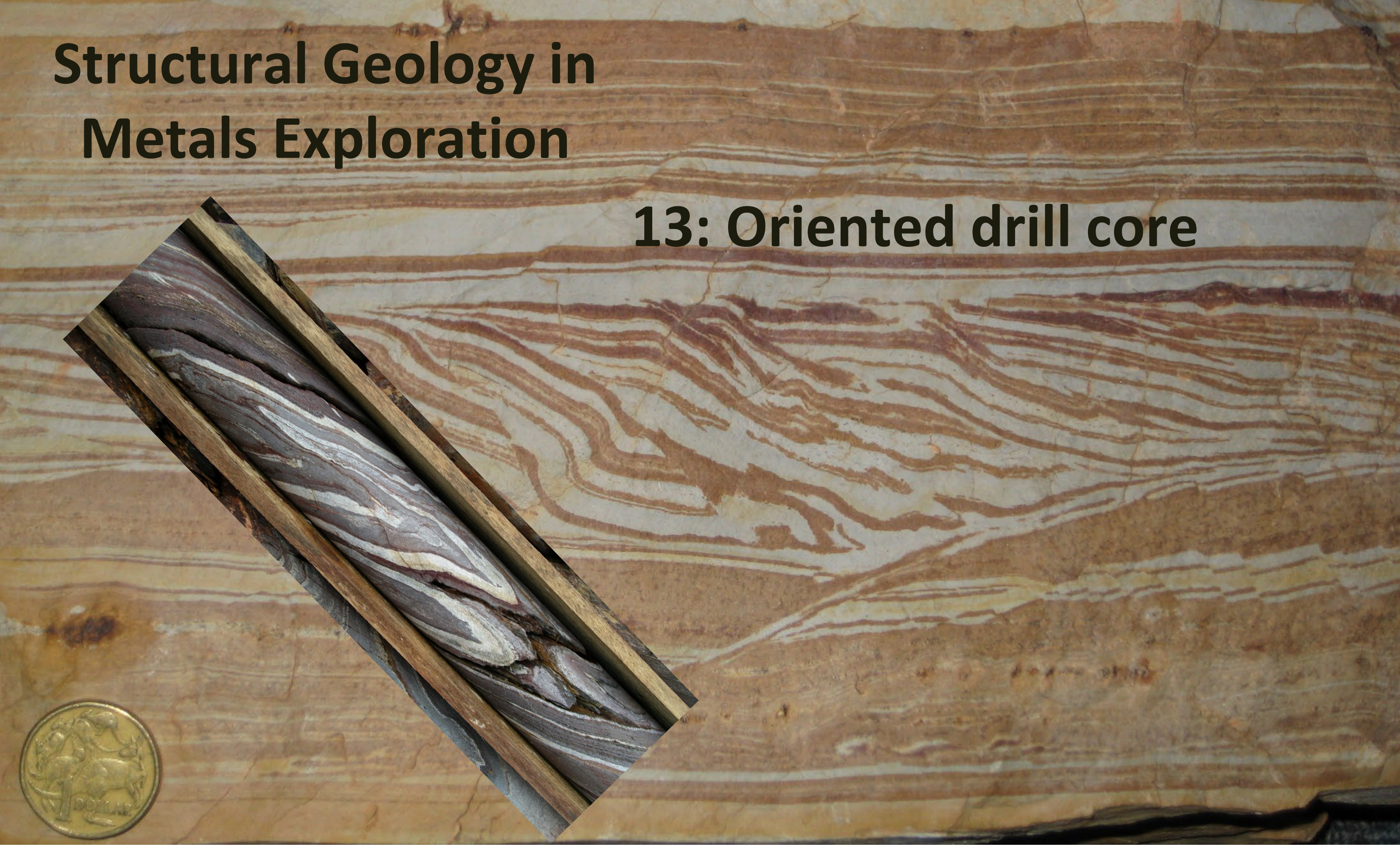
Structural Geology in Metals Exploration

13: Oriented drill core



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What is in this module?

This module covers aspects of oriented core procedures and the extraction and analysis of reliable structural data.

It is extracted from my more comprehensive downloadable manual at: https://www.holcombe.net.au/downloads/HCOVG_oriented_core_procedures.pdf

It includes:

1. An assessment of various core orienting methods
2. Marking-up core ready for measuring structural data
3. The need for ORI confidence scores and
4. The geometry of structures in oriented core
5. QA/QC procedures on data from oriented core
6. Classified plots and their interpretation

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Diamond drill rigs

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Wire-line core drilling

- Nested core barrels
- The core barrel lies inside 1-2 other rods

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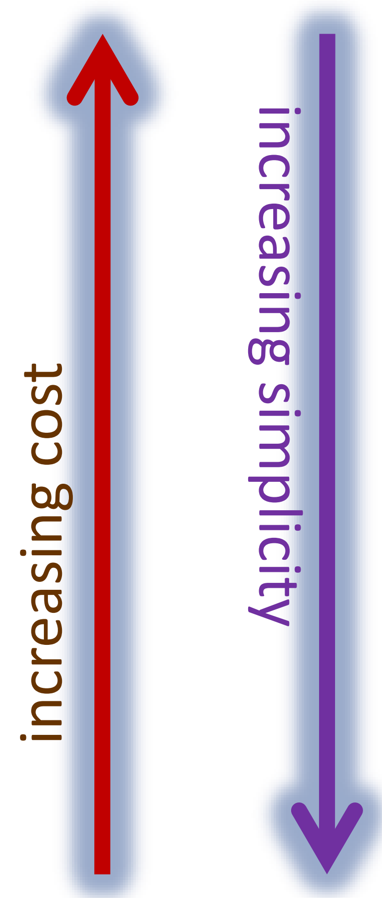
Core orienting methods

- Electronic
  - Reflex Ace (ACT)
    - can handle holes inclined up to 88°
- Camera + scribe
  - Christensen Hugel method
- Mechanical:
  - clay impression barrels
  - Ezi-Mark
  - ...
  - ...
  - spear



Reflex ACT

- Uses three accelerometers which electronically measure the Earth's gravitational field
- Every minute during the drilling process, the accelerometers sense the 'low side' of the core tube and records the position in the memory.
- The time at which the core was broken is recorded and the tool returned to the surface with the core.
- The tool uses the associated accelerometer information stored in its memory and guides the user to position the tool and the core so that the same 'low side' position is reproduced on the surface.
- That is, the tool is acting as an electronic plumb line.

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QA/QC aspects of Reflex ACT

- Theoretically the precision and accuracy should be very high
- Errors are difficult to detect at the measurement stage because the method leaves no visible trace
- Errors can be detected at the core reassembly and mark-up stage by sequential orientation bottom marks being unaligned
- In early versions of the instrument the main cause of error seemed to be related to the timing procedures. The newer versions with electronic guidance and automatic download should produce fewer errors

- As with all methods, one potential source of error that requires QC vigilance is the fabrication of the result by the logger

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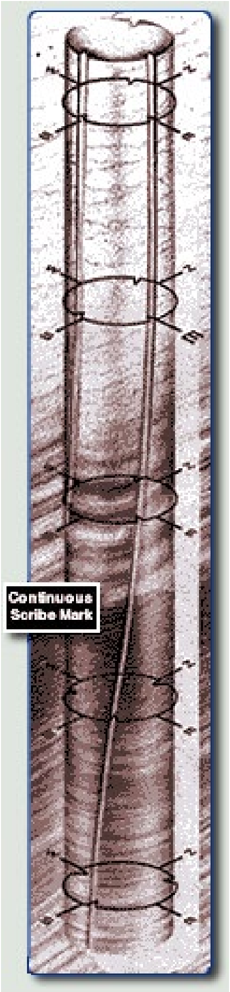
Christensen Hugel method

- Core assembly that scribes the core as it is drilled
- Camera photographs the core and scribe



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Clay impression barrel

- Special inner barrel containing lead weights is lowered down hole
  - weights rotate and define bottom of the barrel
- Clay protrudes between drill bit and is pushed onto the top of the rock below
- The barrel is retrieved and the next run of core is drilled and extracted
- After extraction the clay impression is aligned with the top end of the core

Ezi-Mark

- Forms part of the drilling assembly
  - ∴ no interruption of the drilling cycle
- Can be used in up or down holes

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Spear orientation tool

- Lowered down the hole and marks the top of the NEXT run of core
- mark should lie close to the bottom of the core tube

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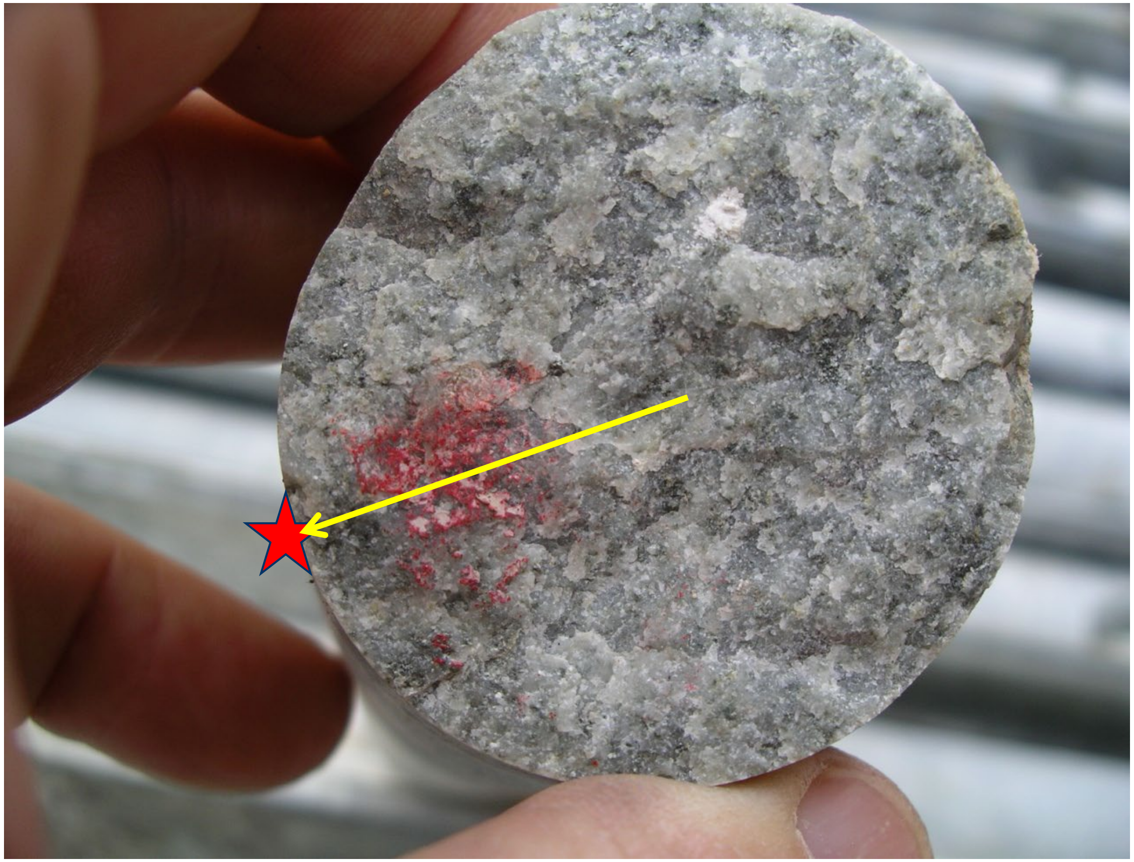
Bottom mark from spear

- Ideally the bottom point of the core lies along the line joining the centre of the core through the spear mark

- only works in tilted drillholes
  - <~75°



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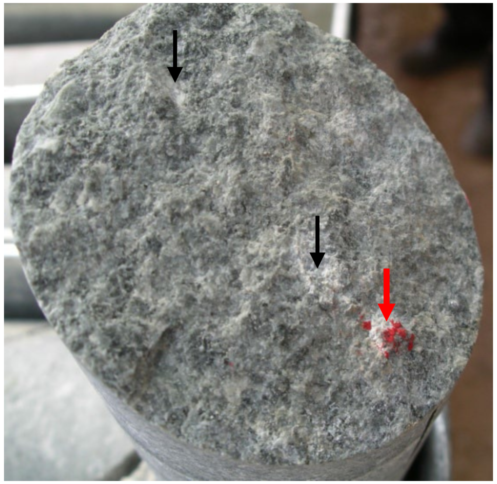
QA/QC aspects of spear

- Despite its simplicity the spear **can** give reliable orientations provided that the driller
  - is experienced with the tool
  - takes care to ensure that the final drop of the tool is at a low enough speed that it does not bounce of the sidewalls
  - stops the tool at the point where it just touches the top of the next core run
    - the tool should not show bounce or chatter marks
- A spear is commonly used to provide a check on other methods that don’t leave a visible mark on the core

Chatter marks across the face of the core caused by dropping the tool too fast



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Core reassembly

- Core is reassembled by docking as many continuous sections as possible
- Stop either when a natural non-dockable break occurs or you exceed some arbitrary number of continuous core runs
- Best done under controlled conditions, not at the drill rig

Preliminary core mark-up

- A preliminary BOH line is extrapolated from the first bottom-of-core (ORI) mark along the continuously docked core
  - do this with pencil
- When the next core ORI mark is met record the mismatch, if any. Record the mismatch as mm left or right of the initial BOH line (looking down-core)
  - The amount of angular 'spin' that this mismatch represents depends on the core diameter. For HQ core, 5.5mm represents 10° of rotation (spin) from the previous mark
  - The amount of spin that can be tolerated depends on company protocols for the type and complexity of the deposit
  - In complex terranes it should be no more than ~10-15°
- Continue drawing the initial orientation line through subsequent dockable runs of core, recording the spin as each new driller's BOH mark is met
- Stop when a natural non-dockable break occurs or you exceed an arbitrary number of continuous core runs (e.g. ten)

- (The range of core spin should be transmitted back to the driller as part of the QA/QC process)

Left	initial	Right
	0	
-2		
		3

Range: 5

Mode: 0

Mean: 0.3

No. excluded: 0

BOH score: 3

NB: These procedures vary widely from one operation to another

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Final core mark-up

- Examine the array of recorded 'spins' for a natural cluster and estimate the mode (the central value of the cluster)
- Eliminate outliers from the following calculation (including the zero value of the initial BOH mark if required). Outliers will be those with a spin >10° (say) from the mode.
- Calculate a mean value for the remainder. This will be a number of mm left or right (+ve or –ve) of the initial BOH line.
- Identify the point on the core that corresponds to this mean and draw in the final BOH line
  - Mark arrows on this line pointing down-hole
  - If the ORI confidence score (see next) is only 1 then use a dashed line. Use a solid line for all other oriented sections of core. Do not mark any section of the core that is unoriented
- Mark a separate cutting line (in a different colour) (if required).

Mark	Right	initial	Left
1		0	
2			-2
3	3		

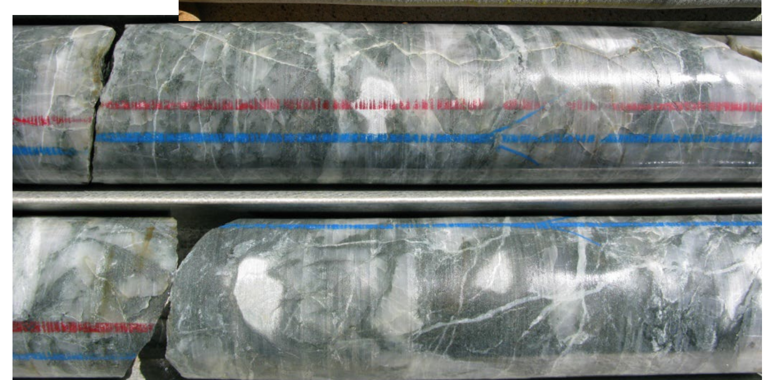
Range: 5

Mode: 0

Mean: 0.3

No. excluded: 0

BOH score: 3



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ORI Confidence Score

- Examine the array of recorded ‘spins’ for a natural cluster and estimate the mode
- Eliminate outliers from the following calculation (including the zero value of the initial BOH mark if required). Outliers will be those with a spin >10° (say) from the mode.
- Calculate a mean value for the remainder. This will be a number of mm left or right of the initial BOH line.
- Assign an ORI Confidence Score between 1-5
  - Assign a score of 1 if there is no clear mode
    - top example
  - Otherwise, count the number of docked full runs of core in the set up to a maximum score of 5, then subtract 1 for each outlier in the set
    - bottom example (with one outlier)
  - Single runs of core that can’t be docked to adjacent runs will automatically have a score of 1
- This confidence score is assigned to all structural data within the scored interval

Mark	Right	zero	Left
1		0	
2			-12
3	3		
4			-4
5	2		
6			-11

Range: 15
Mode: none
Mean: -3.5
No. excluded: 0
BOH score: 1

Mark	Right	zero	Left
1		0	
2			-2
3			-6
4	8		
5			-7
6			-5

Range: 15
Mode: ~-6
Mean: -4
No. excluded: 1
BOH score: 4

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Oriented core types

- Unoriented core
  - uncontrolled core rotation
- Partially oriented core
  - No overt BOH procedure but some known aspect of the local geology allows the core to be oriented
    - commonly produces two ambiguous answers
- Fully oriented core
  - one of a suite of tools has been used to identify the geographic bottom line along the core

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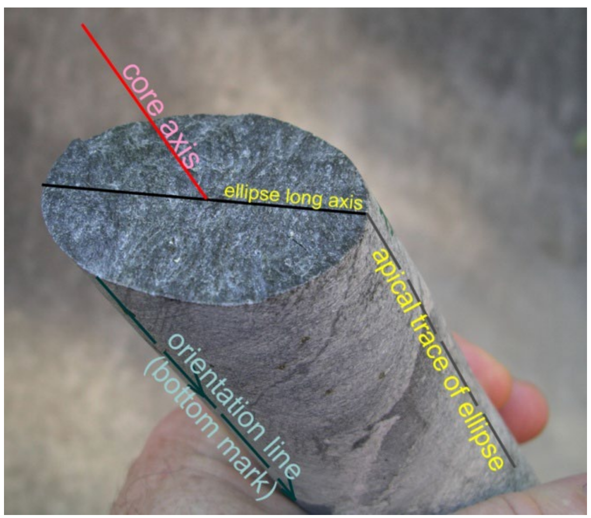
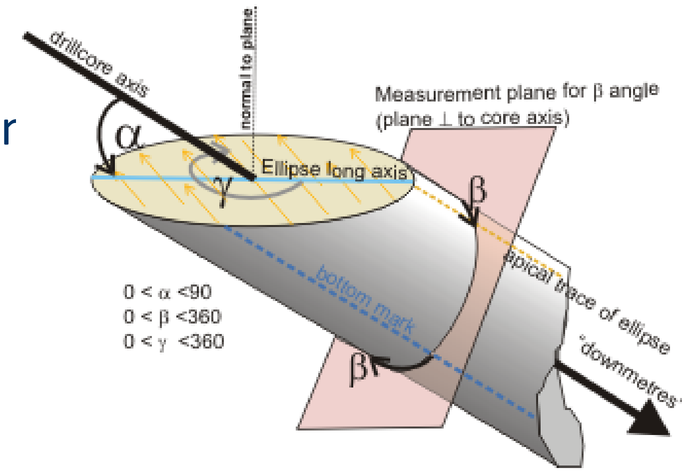
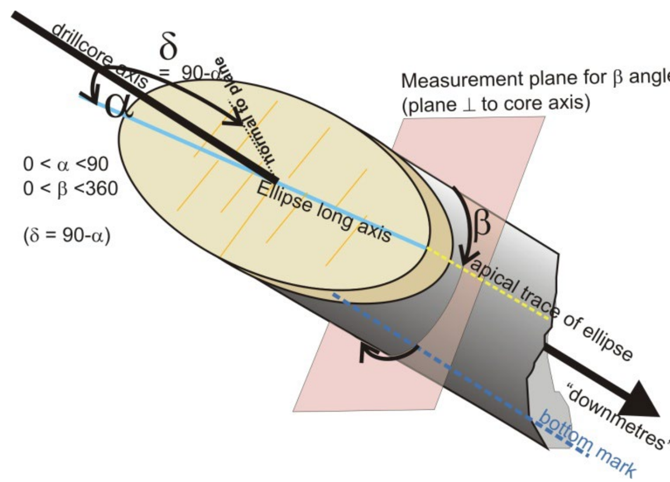
Drillcore conventions

- core axis (plunge vs ‘dip’)
- plane ellipse
- down-metres/down-hole directior
- apical trace
- measurement plane
- α,β,γ,δ angles







- conventions becoming standardised – but still can vary

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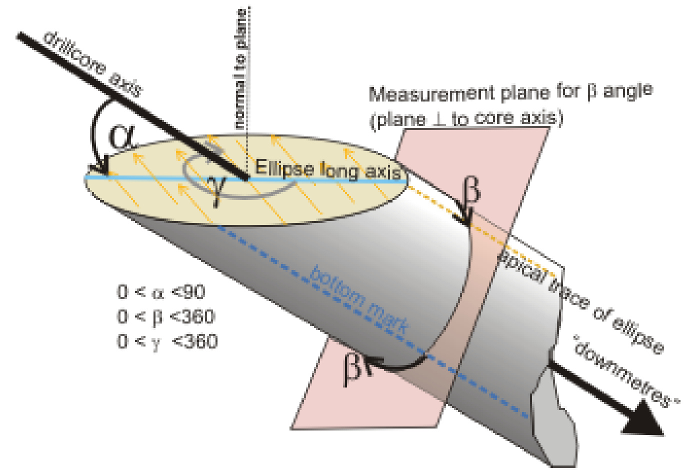
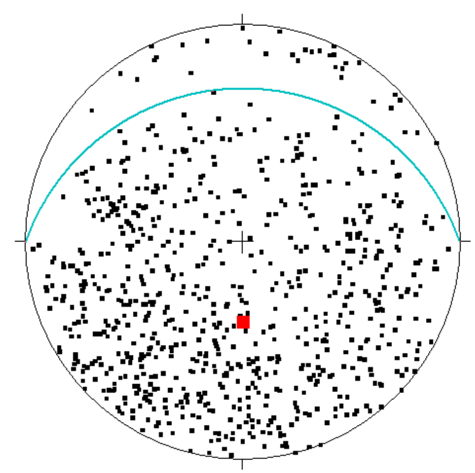
Measurement of planes

- Alpha – acute angle (<90°) between core axis and ellipse long axis
- Beta – 360° **clockwise** angle from 'bottom mark' to the **bottom** of the ellipse (**looking 'downmetres'**)
  - record 360, not zero, if the bottom of ellipse coincides with the bottom mark
  - If the alpha angle is 90° then the beta angle can be anything
    - record it as 360 rather than zero
- If the core is vertical then the alpha angle is the complement of the true dip – but the beta angle cannot be measured
- Major bias error: not measuring planes parallel to core (i.e. very small alpha angle)
  - Have seen situations where systematic avoidance of low α-angle planes has concealed the presence of folding and led to major overestimation of resource
  - recognised by the presence of a great circle 'data'gap





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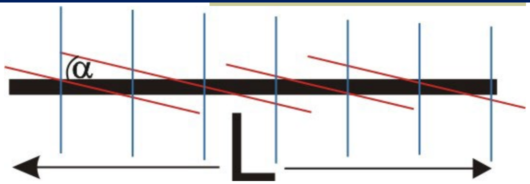
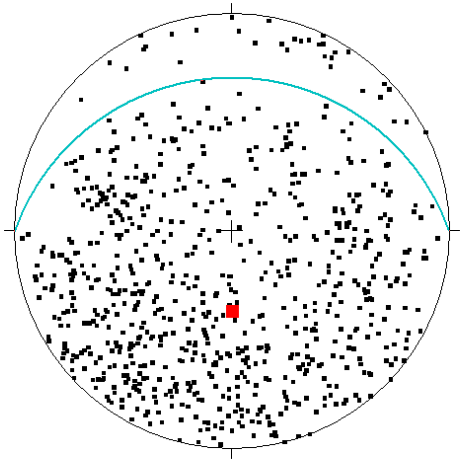
The ‘data gap’

- Terzagghi bias
  - the apparent frequency of planes along a linear traverse is a function of the alpha angle
  - produces a great circle void perpendicular to the drill hole in stereonet projections
  - is a critical statistical bias problem with spaced planar features (joints, veins)
  - should not be critical with penetrative fabrics such as cleavage and fine bedding laminae
    - but because such planes do not have clear ellipses, they tend to be avoided during routine structural measurements ‘
    - conceals the presence of folding
    - leads to resource overestimation





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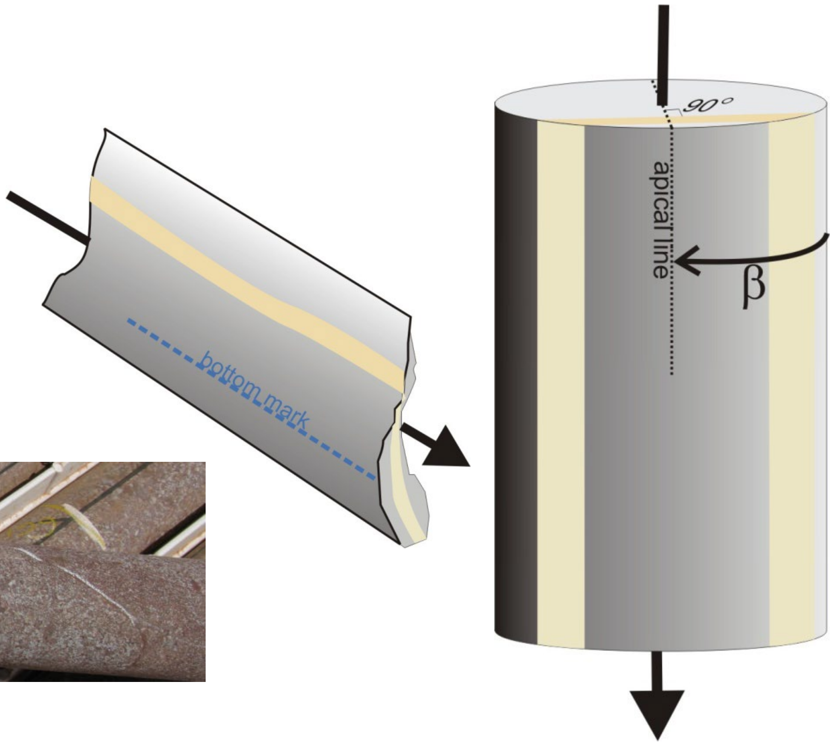
Planes parallel to core

- Alpha angle <5°
  - can be estimated with low error
- No clear ellipse so the apical line has to be constructed manually in order to measure beta angle
- Procedure:

1. Identify an imaginary plane that is perpendicular to the observed planar feature and passes through the core axis
2. The possible apical lines are where this imaginery plane intersects the surface of the core.



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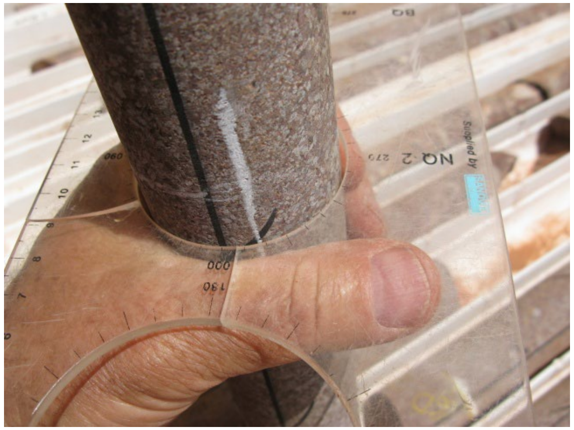
Planes near-parallel to core

1. Identify an imaginary plane that is perpendicular to the observed planar feature and passes through the core axis
2. The possible apical lines are where this imaginery plane intersects the surface of the core.

3. identify opposite ends of a line on the bedding and perpendicular to the core axis
4. Measure the angle between them with a beta-angle protractor
5. Bisect the angle to mark an initial apical line
    1. If the α-angle is zero then this is the true apical line for measuring beta
    2. If the α-angle is non-zero then decide on which side of the core the lower end of the ellipse would likely terminate
    3. Transfer the initial apical line to the opposite side of the core if the inferred ellipse bottom is on that side



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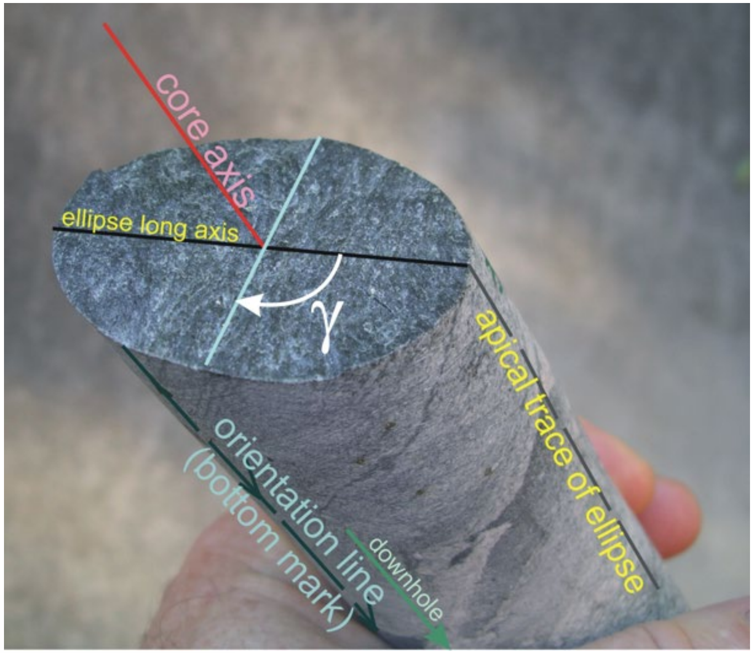
Measurement of Lines

- Two types of line
  1. lineations lying within a clearly defined plane
  2. discrete lines
     - such as fold hinges



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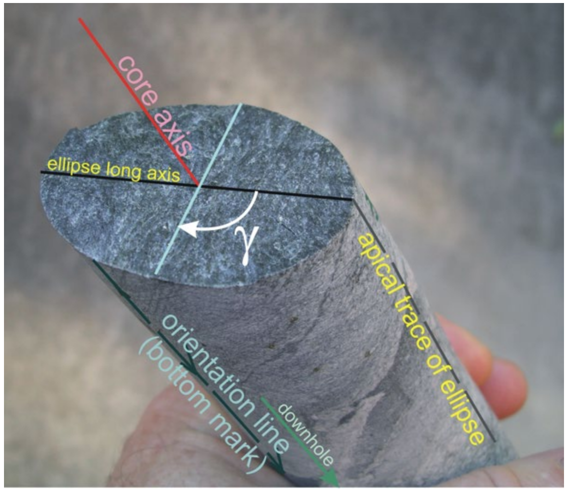
Lines lying within a plane

- Measure alpha and beta of plane
- Measure angle (gamma) within the plane between the long axis of the plane ellipse and the line
- Various conventions in use for γ*:



* Other names used for γ: epsilon, delta

- 360° clockwise angle from bottom of ellipse (allows polar lines such as current directions to be plotted)
- ±180° angle from bottom of ellipse
- conventions that use the short axis of the ellipse as the starting reference line are not recommended
  - starting end for vector lines is ambiguous

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Discrete lines in core

- If the line passes through the centre of the core then it can be oriented by measuring alpha and beta angles as for planes
  - the downmetres end of the line is equivalent to the downmetres end of the ellipse axis
- If the line does not pass through the centre of the core:
  - mark the two ends of the line
  - use these marks to guide locating the ends of the parallel line that **would** pass through the centre of the core
    - method is approximate, but errors should be less than 10°
- Alternatively: use a ‘rocket launcher’ or bucket of sand and measure manually
  - Precision is generally lower than other methods

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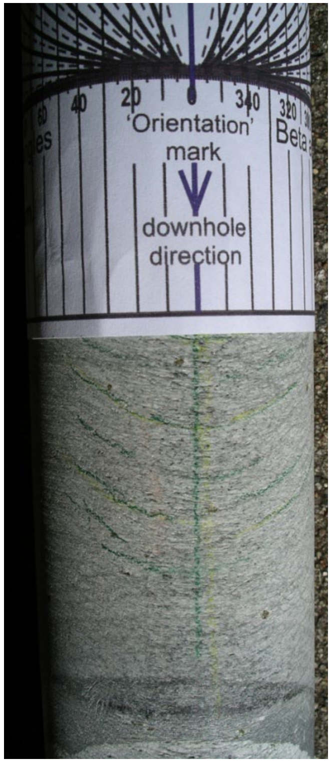
Partly oriented core

- If a pervasive fabric with a known, relatively constant, orientation exists then the apical angle of this fabric can be used a reference line instead of an actual bottom mark
- The alpha/beta angles of both the known and unknown planes are measured
- Only part of the orientation of the known fabric need be known accurately to be used
  - e.g.: the dip, the strike, or the orientation of fold axes if it is folded



- Cleavage of known orientation cutting bedding of unknown orientation
- This cleavage can be used to orient the bedding

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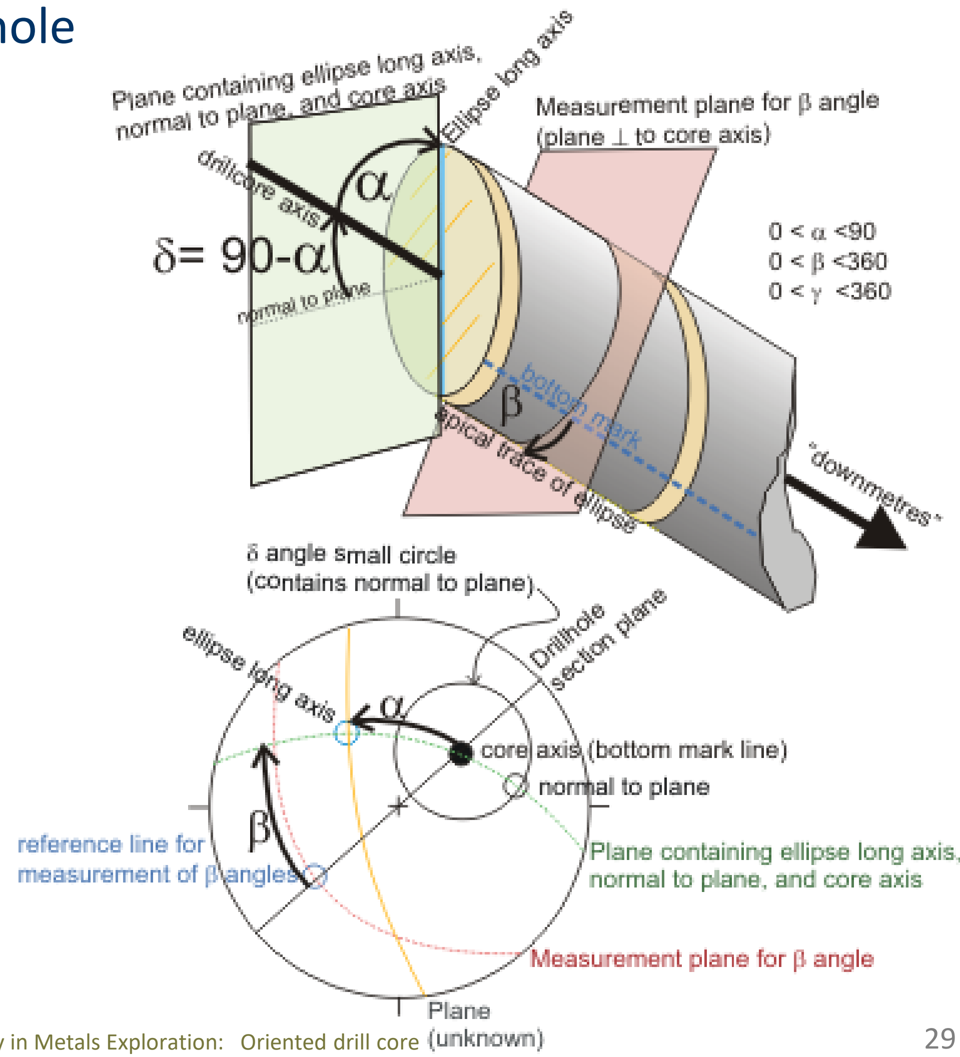
Processing orientation angles

- Requires knowledge of the drillhole orientation
- Manual conversion
  - stereographic projection
- Software conversion
  - 3D mine/exploration packages
  - DIPS
  - GeoCalculator
  - ...



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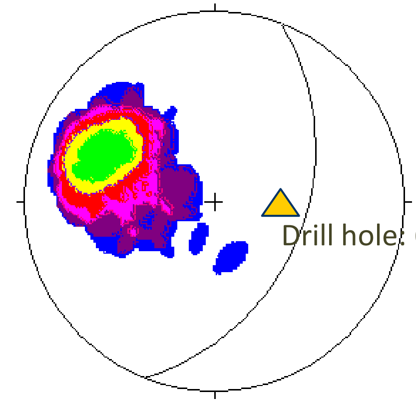
QA/QC of oriented core

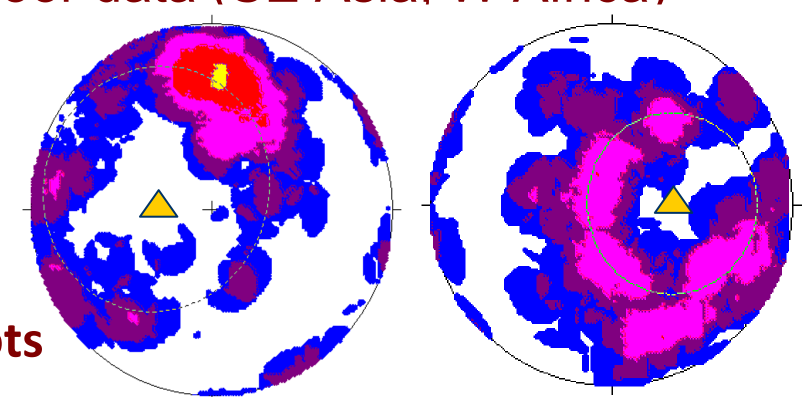
- Poor core orientation results in small-circle spread of poles to planes of constant orientation
  - The target surface in each of these real examples was a constantly oriented plane
  - Never trust data from planes where the poles define a small circle around the drillhole orientation

You should never be able to determine the orientation of a drillhole from structural data plots

Good data (Russia)



Poor data (SE Asia; W Africa)



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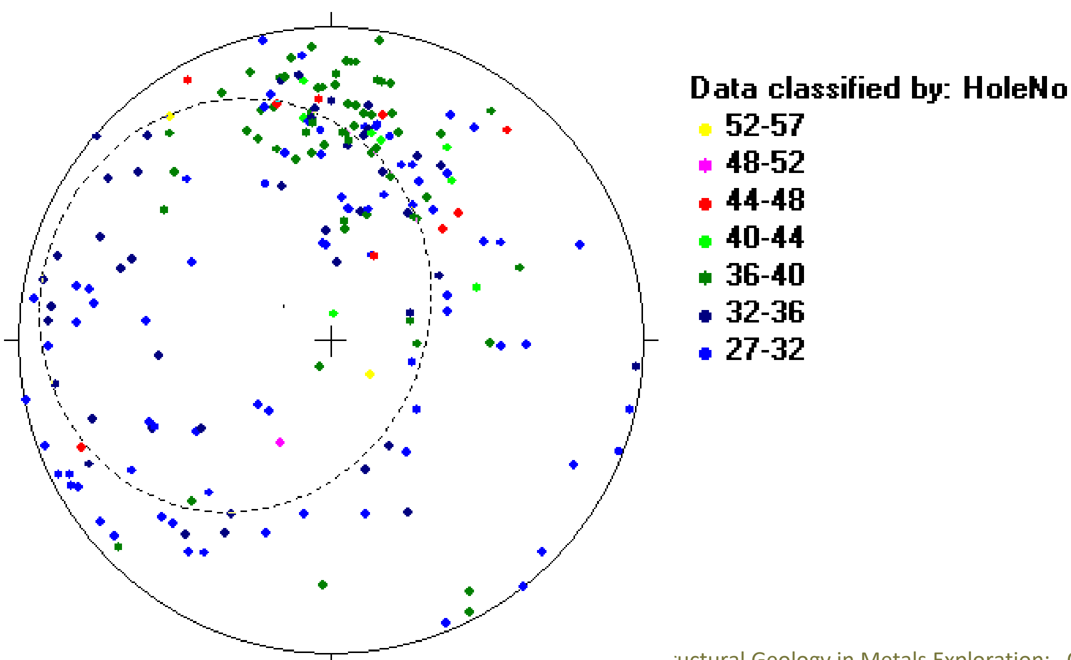
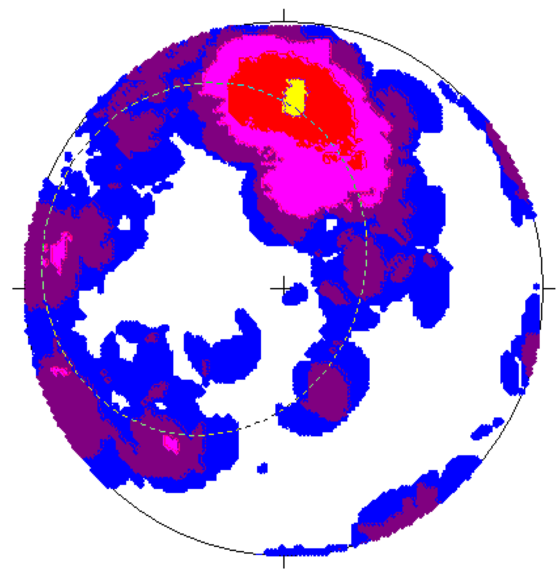
Classification plots

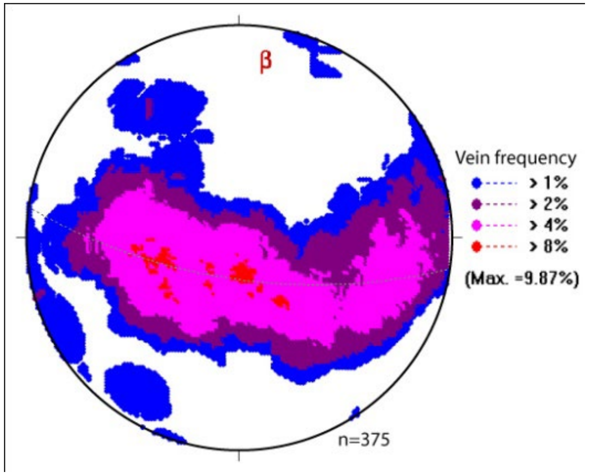
- Data is coloured by an associated numeric or text value
- Example: orientation data coloured by drillhole number
  - In this case, it was used to determine which drillholes produced the ‘bad’ data
    - All data from drillholes 32 to 36 had to be discarded





Classified numeric plot example…

- If the associated data is numeric (i.e. not just a text value) then that associated data can be contoured separately
  - The procedure was originally developed in GEOrient to handle sonic velocities in petrophysical measurements
- The example shown in the next two pages is an analysis of drillcore quartz vein data from a gold project in Laos. The vein orientations were distributed around a common axis, typical of conjugate veins, with a predominance of either steeply dipping or shallowly dipping vein sets.
  - Vein orientation and thickness had been recorded as well as the gold assay value in each metre of core. In the analysis, that assay value was assigned to any vein within that metre interval.
    - A bit of a dubious assumption, but the veins tended not to occur in swarms, and were widely spaced



Vein orientation frequency

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Classified numeric plot example

- Plots showing both mean and cumulative values within each 1% area of the orientation plot.
- Vein orientations contoured by:

  Cumulative values:

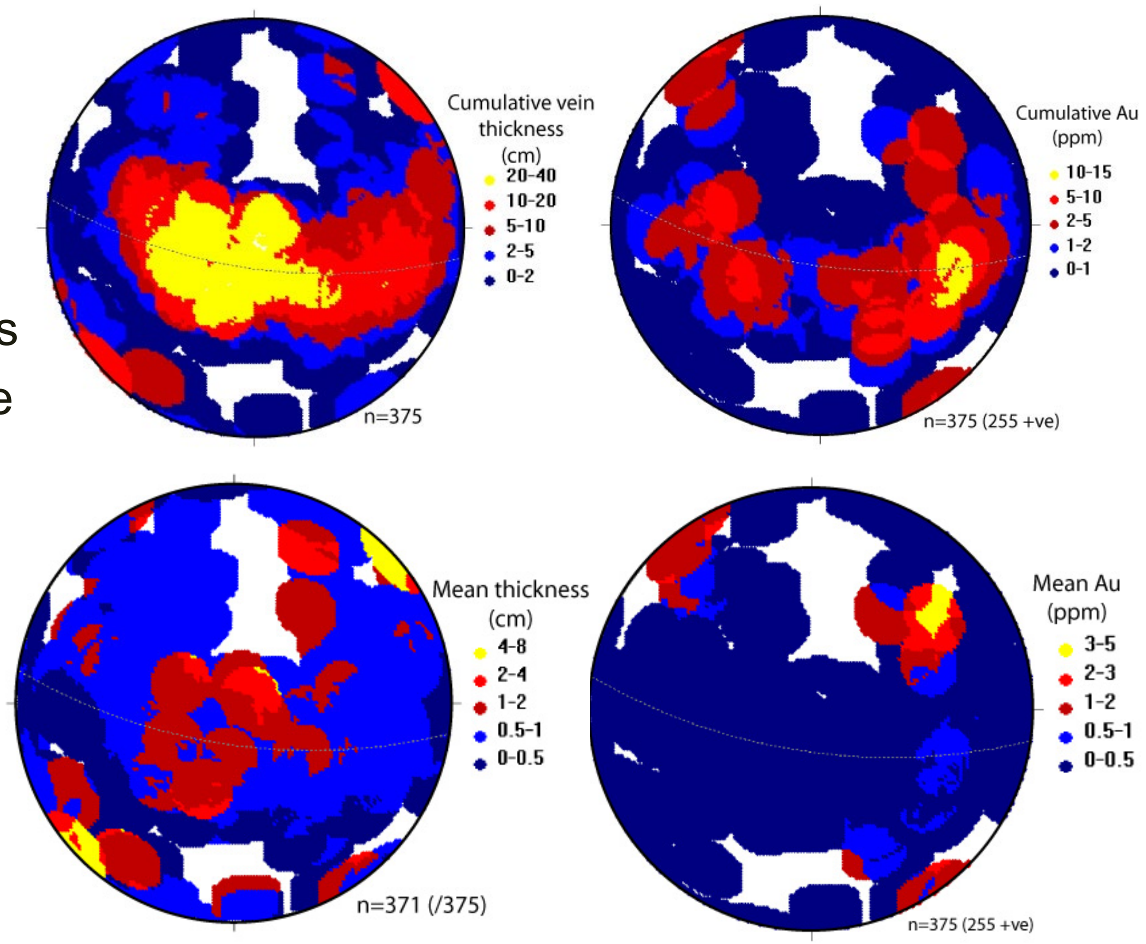
  (a) cumulative thickness

  (b) cumulative Au grade

  Means:

  (a) Thickness

  (b) Assay value



See next page for analysis…

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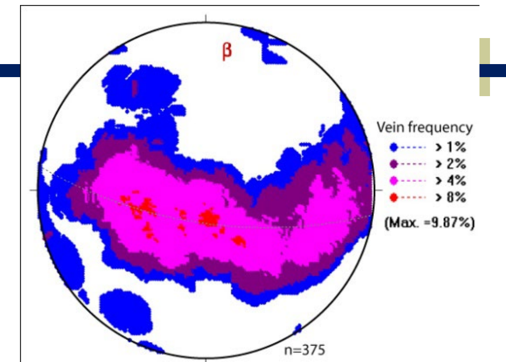
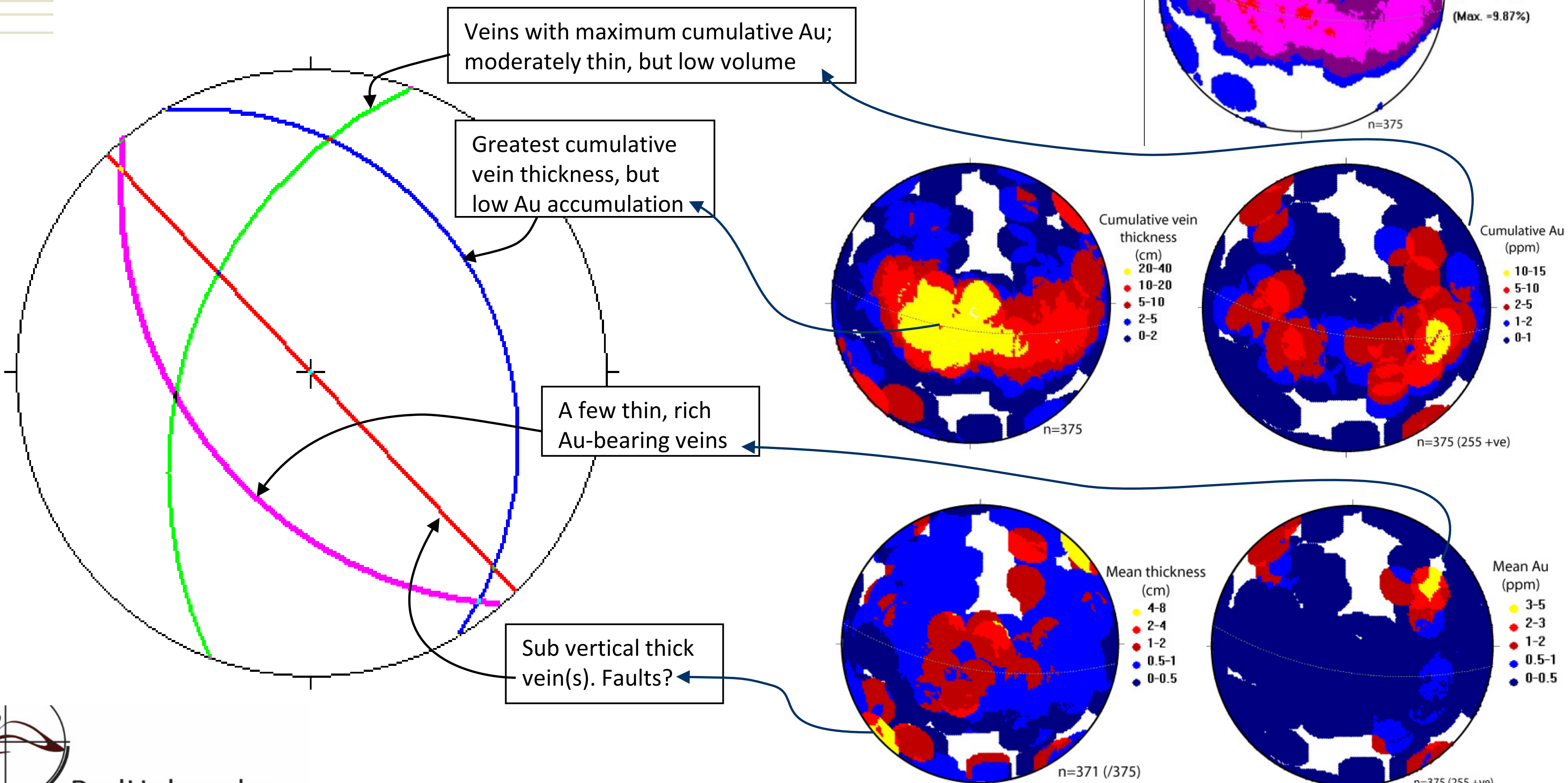
Classified numeric plot interpretation

- Different plots tell us different things…





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