The Importance of Bedding [and Borehole] Orientation When Looking for Fractures*

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Abstract

It has been observed that joints are the dominant fracture type on formation image logs. These tensile fractures are likely to be open, especially if they are recent. (In order to avoid a genetic definition, joints will be defined here as those fractures which are close to perpendicular to bedding.) A good way to illustrate the manner in which joints dominate fractures in a given well is to remove the structural tilt from the fractures by rotation. In polar plots, most fractures will concentrate at the perimeter of the plot, to within 20 degrees of perpendicular and will be most concentrated at 90 degrees. In other words, most of the fractures qualify as joints. The degree of concentration of fractures toward the perimeter of the polar plot may vary by well, but this phenomenon is usually there. An interesting exercise is to observe fracture orientation in vertical wells with low dip. The fracture concentration will increase to about 70 degrees dip and fall off rapidly, with virtually no fractures with dip higher 80 degrees. This is because the chance of hitting a near-vertical fracture is very low, not because near-vertical fractures are not present.

It naturally follows that horizontal wells can greatly enhance the contribution of fractures to production, and not simply because they drill through more of the formation. As horizontal or high angle wells are drilled in more complex structures, it is natural to assume that borehole orientation is less of a factor. However, it is a good idea to plan a borehole trajectory with bedding orientation in mind, because, even in complex structures, fractures tend to be perpendicular to bedding. For instance, it would not be a wise idea to enter the zone of interest with the borehole near perpendicular to bedding; for this would be equivalent to drilling a vertical well into horizontal bedding.

The joint/fracture relationship can be exploited in ways other than simply avoiding drilling perpendicular into bedding. If one knows in advance that a particular fracture orientation might be encountered, the borehole trajectory can be modified to intercept the maximum number of fractures at the optimal position relative to bedding. Because the attitude of the objective zones to the borehole is as important as their positions in the borehole, geologists must take an increasing role in the planning and drilling of horizontal wells, because drilling concerns may sometimes conflict with geologic concerns.

References

Terzaghi, R.D., 1965, Sources of errors in joint surveys: Geotechnique, v. 15, p. 287−304.

Priest, S.D., 1993, Discontinuity analysis for rock engineering: London, Chapman and Hall, 965 p.

Griggs, D.T., and J.W. Handin, 1960, Observations of fracture and a hypothesis of earthquakes: GSA Memoir 79, p. 347-364.

Stearns, D.W., and M. Friedman, 1972, Reservoirs in fractured rock: Geologic exploration methods, *in* H.R. Gould, ed., Classification, Exploration Methods, and Case Histories: AAPG Memoir 16, p. 82-106.

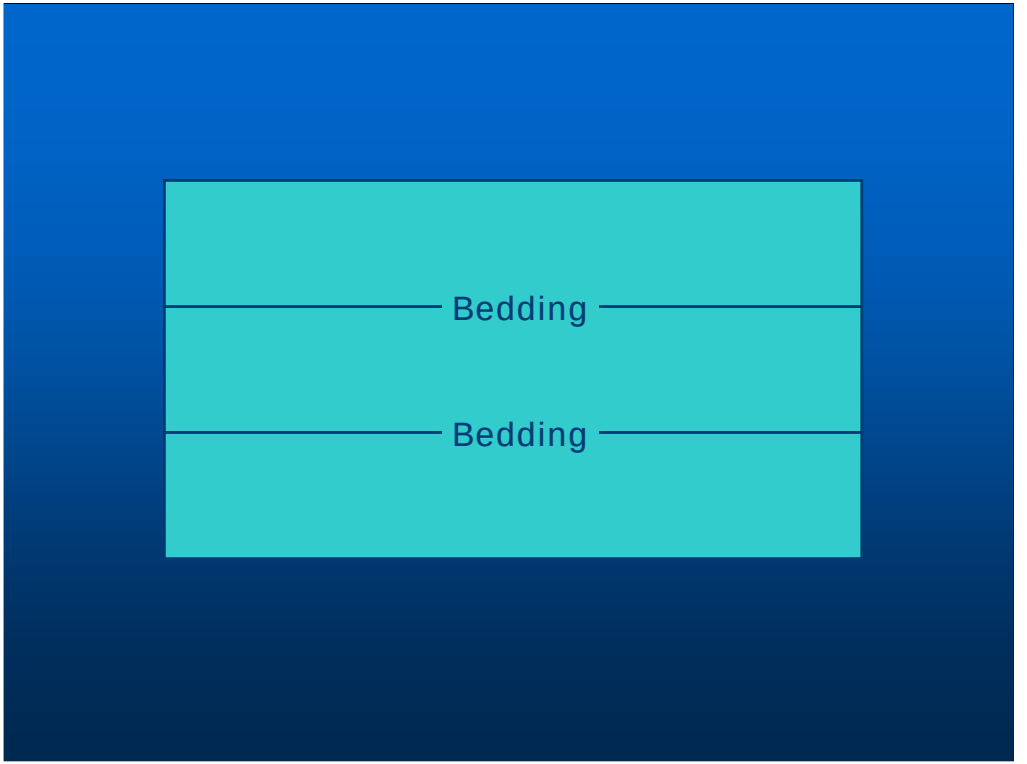
The Importance of Bedding [and Borehole] Orientation When Looking for Fractures

by Charles R. Berg and Andrew C. Newson

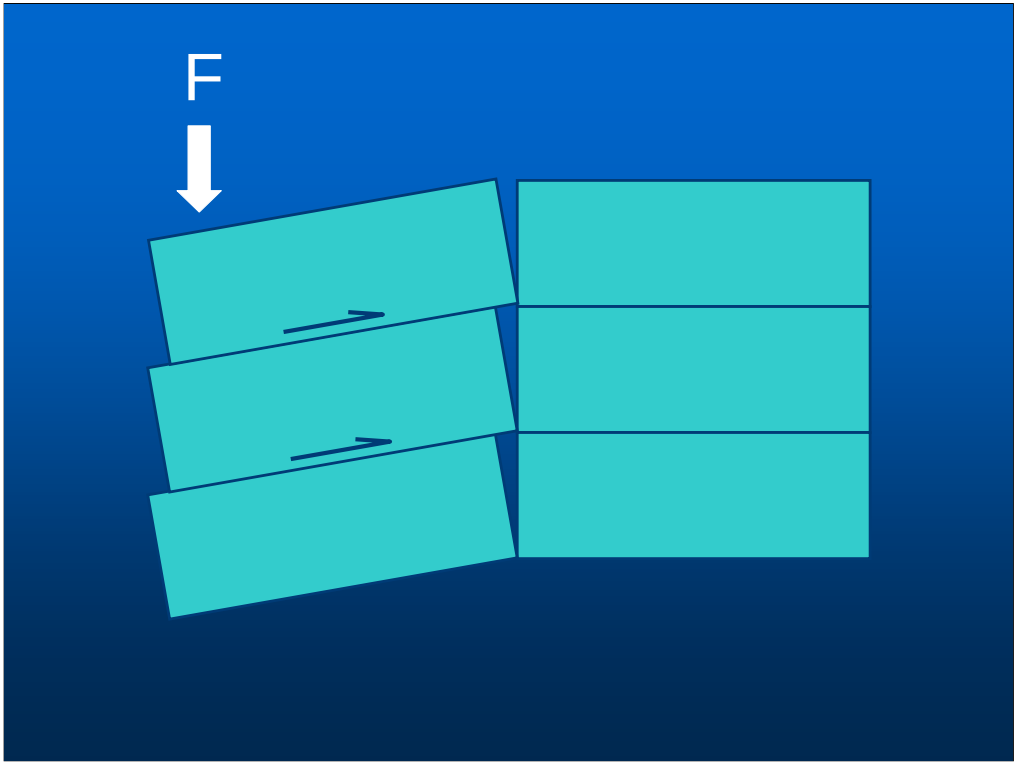
- Bedding Orientation—Joints
  - The Relationship between Joints and Bedding
  - Removal of Structural Tilt
- Borehole Orientation—the Shadow Zone
  - Basic Relationship (Terzaghi, 1965)
  - Approximation
  - 2D Plots of Angle Between the Borehole and Fracture planes
    - Relative Amplitude
    - Introducing Attenuation (1 minus Relative Amplitude)
    - Correcting for Bias (Priest, 1993)
- Examples
  - Horizontal Well Across Anticline
  - Highly Deviated Well with Borehole Perpendicular to Dip
  - Cardium Fractured Sand

Joints

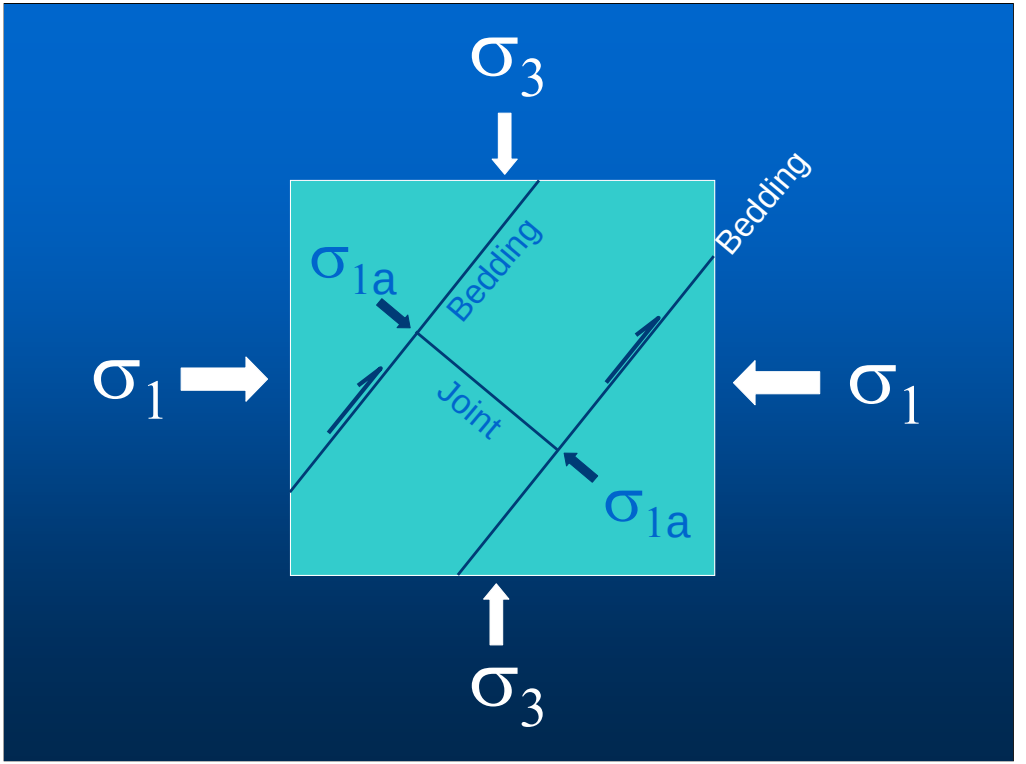
- Definitions of the term “joints”
  1. Fractures sub-perpendicular to bedding
  2. Fractures that terminate at bed boundaries
  3. Fractures in which no appreciable movement has occurred
  4. Tensional fractures
- In this study, because the last three criteria are usually unknown, the only workable definition is the first.



Notes by Presenter: Three slabs of rock, no confining pressure.

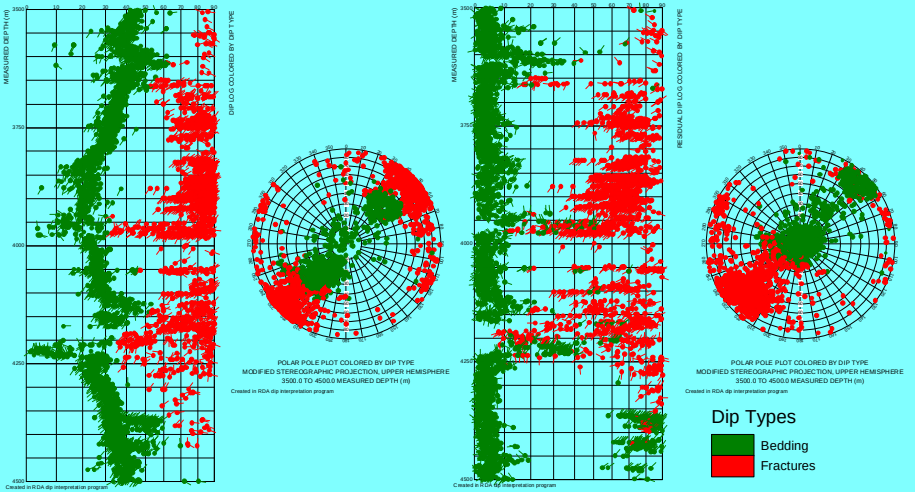


Notes by Presenter: Large force applied at the end of block will break the slabs with near-vertical breaks and slippage between slabs. In rocks, where the bending is occurring over a large area, there would probably be many small breaks.



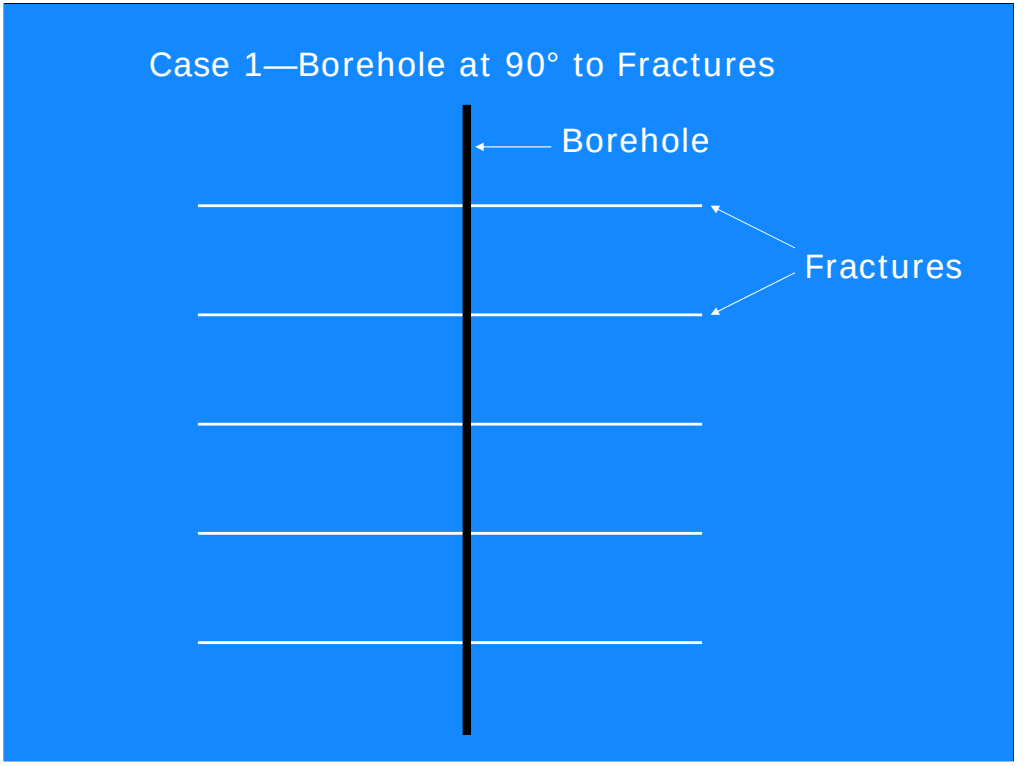
Notes by Presenter: Possible origin of joints. The "regional" stress pattern cannot be transmitted to the beds a of slippage on the bed boundaries. The vertical tensional fractures would be type 1 and 2 (Griggs and Handin, 1960, in Stearns and Friedman, 1972).

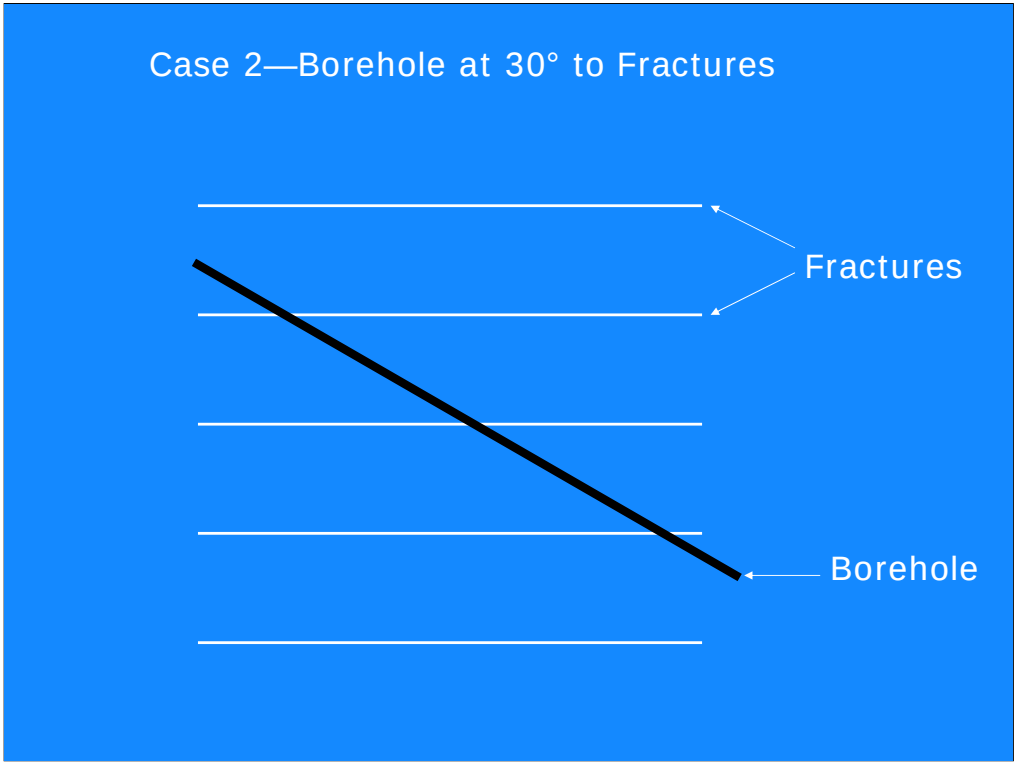
Removal of Structural Tilt by Rotation

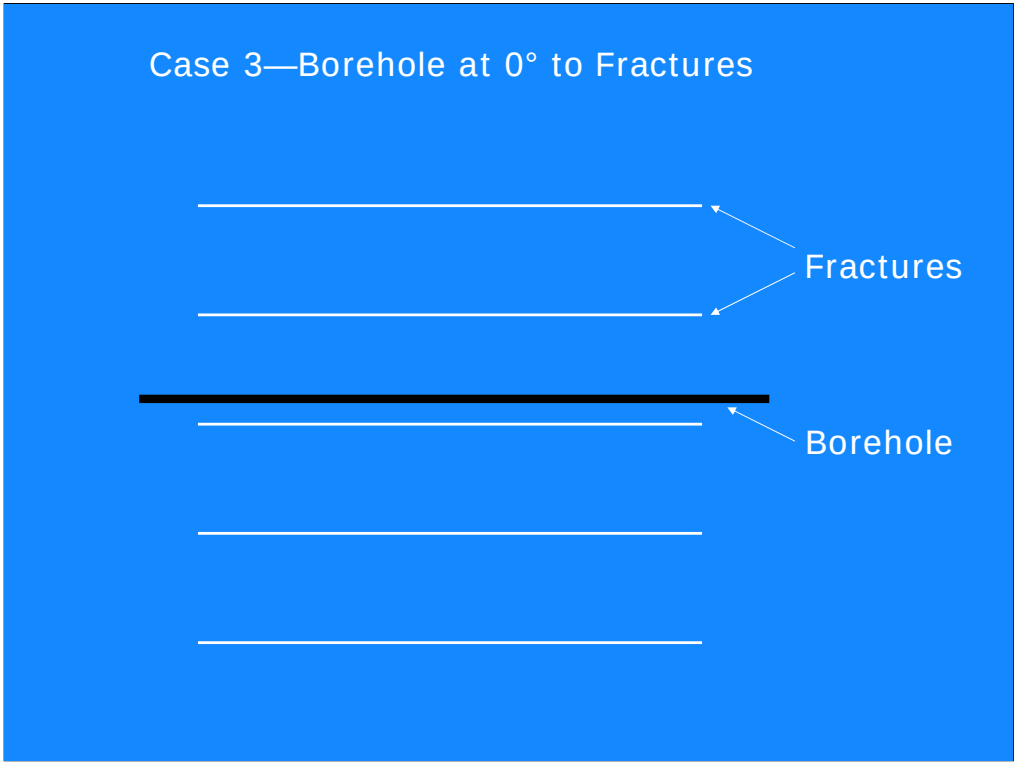


True Dips

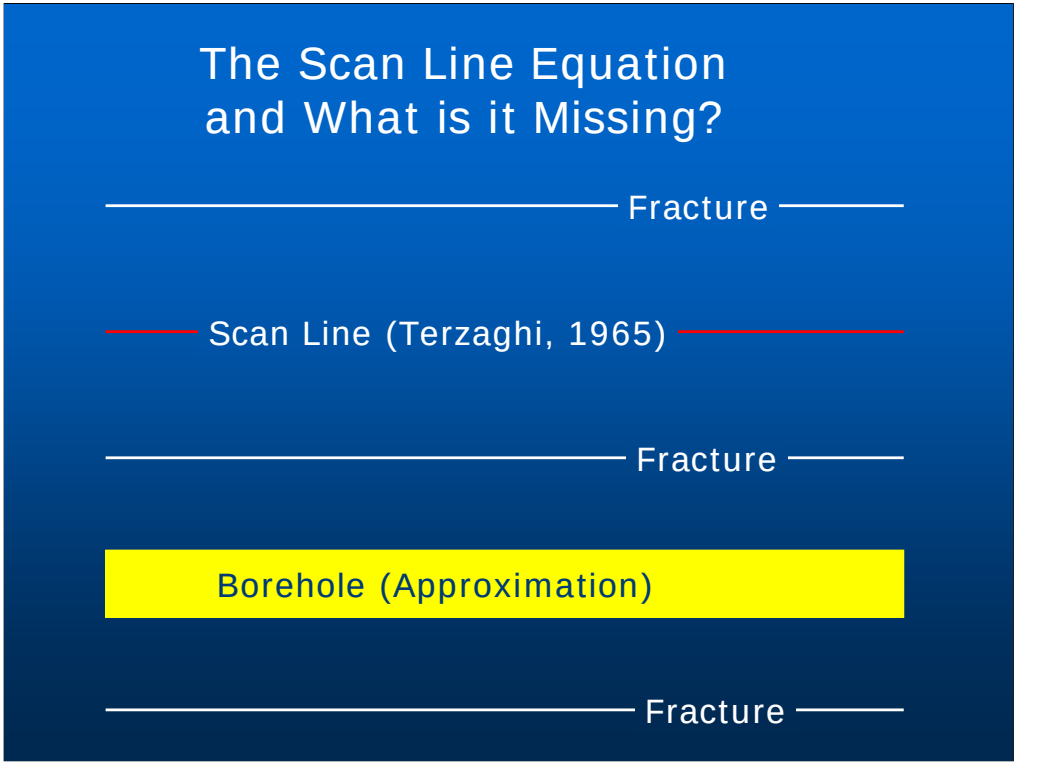
Residual Dips

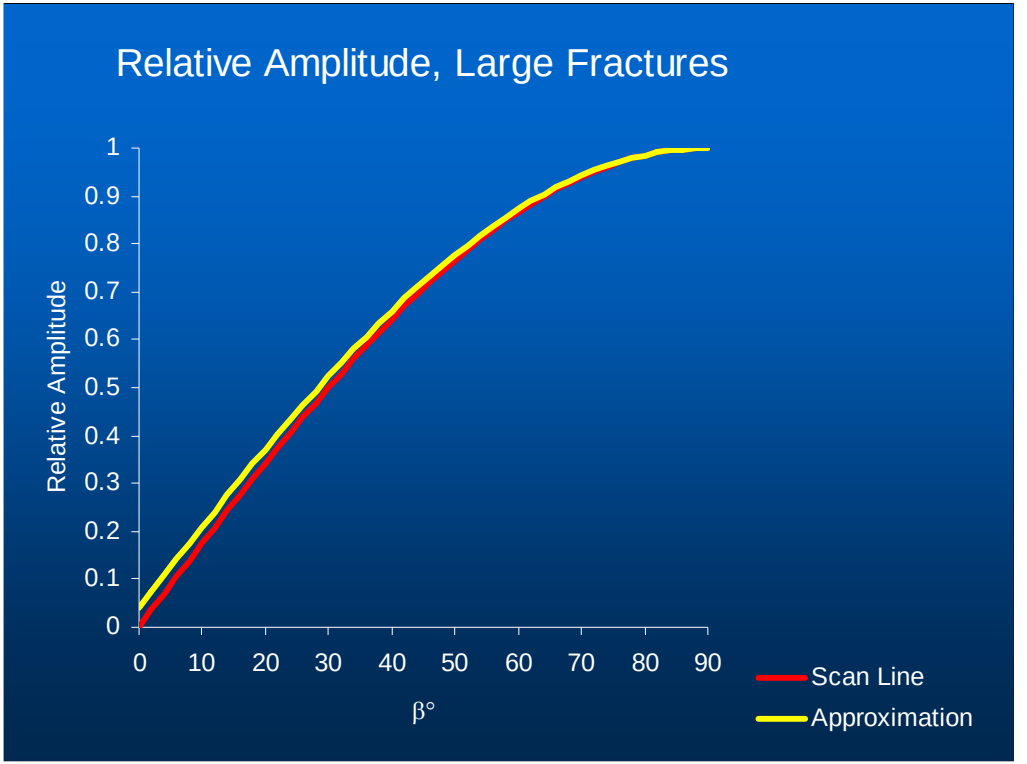

Case 1—Borehole at 90° to Fractures
Borehole
Fractures

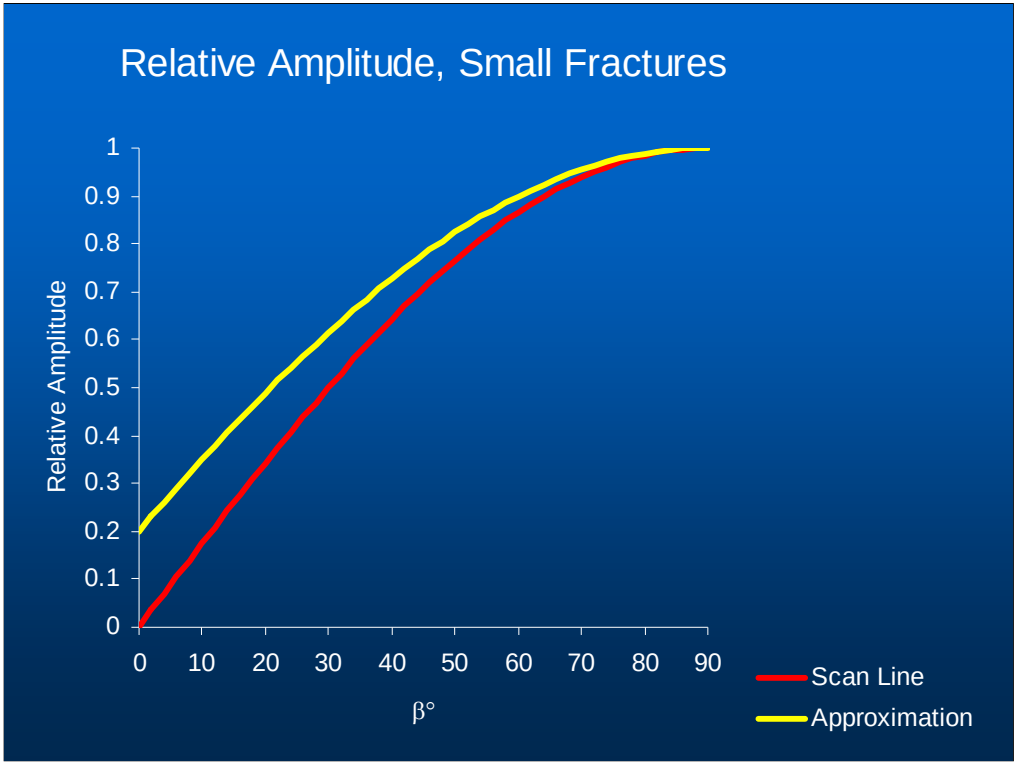

Case 2—Borehole at 30° to Fractures
Fractures
Borehole

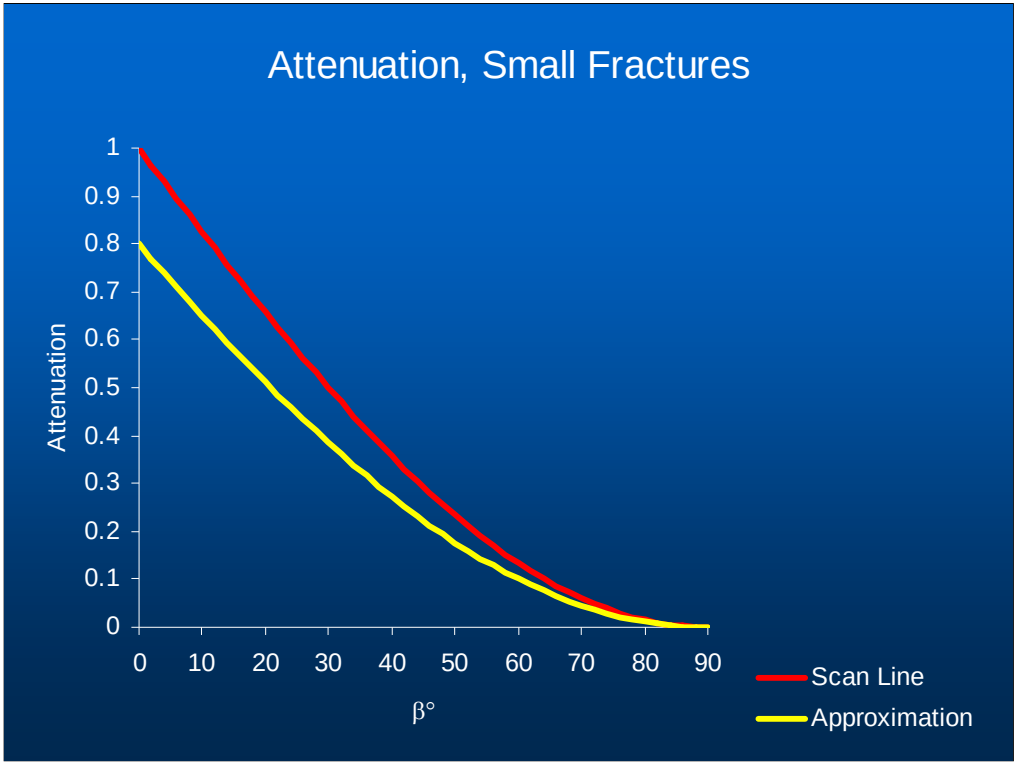

Case 3—Borehole at 0° to Fractures
Fractures
Borehole

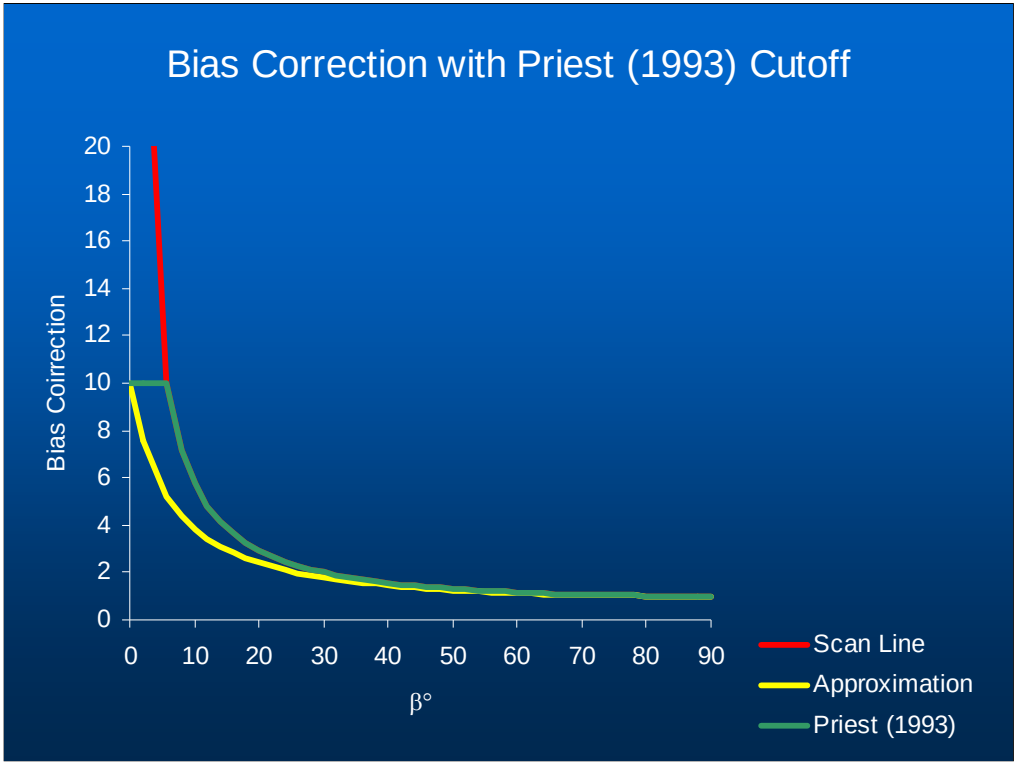
The Scan Line Equation and What is it Missing?

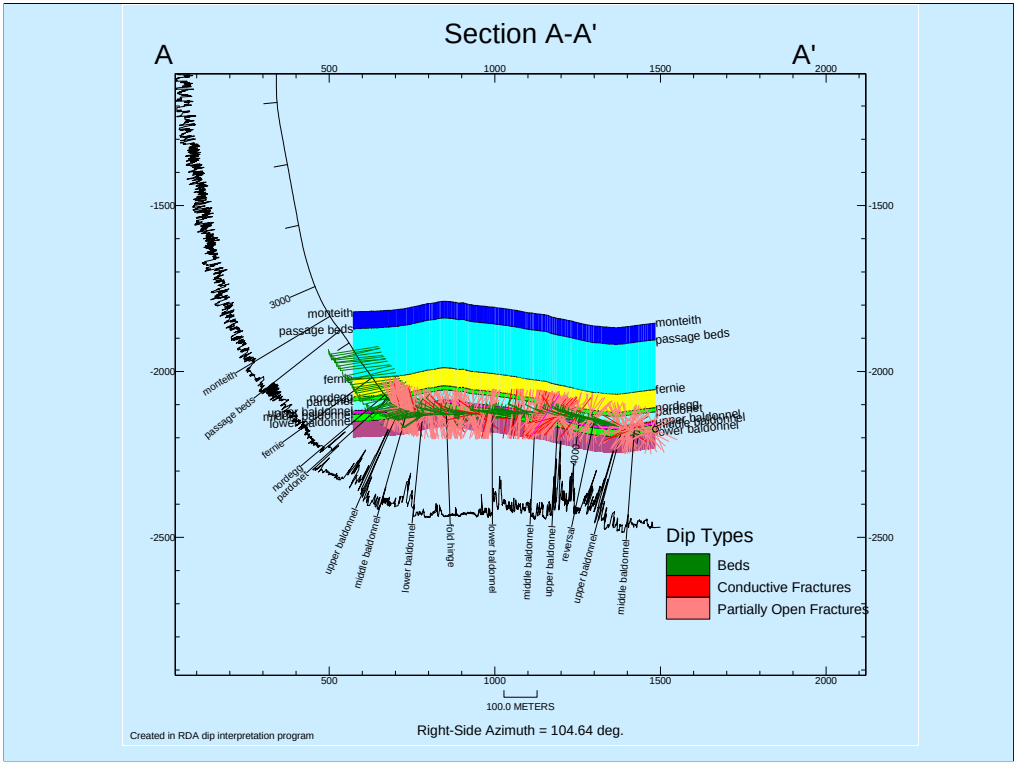


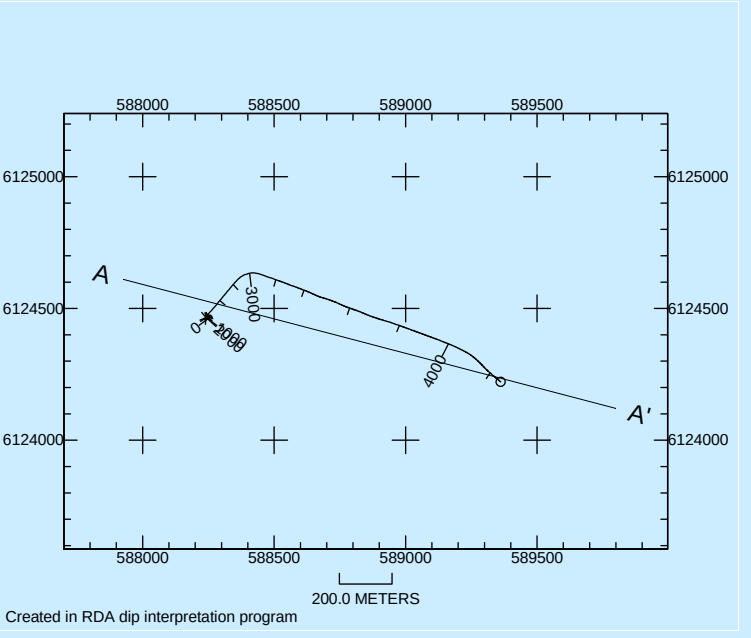

Relative Amplitude, Large Fractures
Relative Amplitude
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
10
20
30
40
50
60
70
80
90
β°
Scan Line
Approximation


Relative Amplitude, Small Fractures
Relative Amplitude
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
10
20
30
40
50
60
70
80
90
β°
Scan Line
Approximation

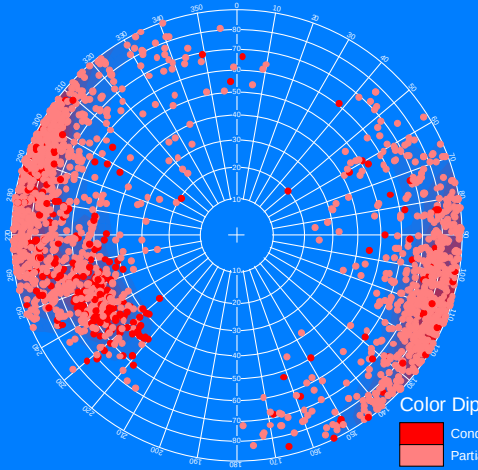

Attenuation, Small Fractures
Attenuation
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
10
20
30
40
50
60
70
80
90
β°
Scan Line
Approximation

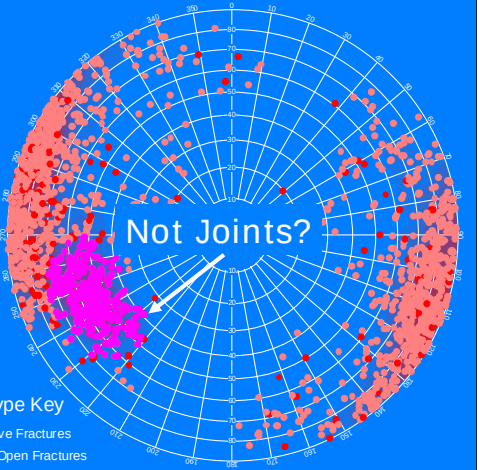

Bias Correction with Priest (1993) Cutoff
Bias Coirrection
20
18
16
14
12
10
8
6
4
2
0
0
10
20
30
40
50
60
70
80
90
β°
Scan Line
Approximation
Priest (1993)


Section A-A'
A
A'
500
1000
1500
2000
-1500
-2000
-2500
3000
monteith
passage beds
fernie
nordegg
pardonnet
upper baldonnel
middle baldonnel
lower baldonnel
old tinnie
lower baldonnel
middle baldonnel
upper baldonnel
reversal
upper baldonnel
middle baldonnel
Dip Types
Beds
Conductive Fractures
Partially Open Fractures
100.0 METERS
Created in RDA dip interpretation program
Right-Side Azimuth = 104.64 deg.


588000
588500
589000
589500
6125000
6124500
6124000
A
A'
3000
2000
4000
200.0 METERS
Created in RDA dip interpretation program

All Fractures



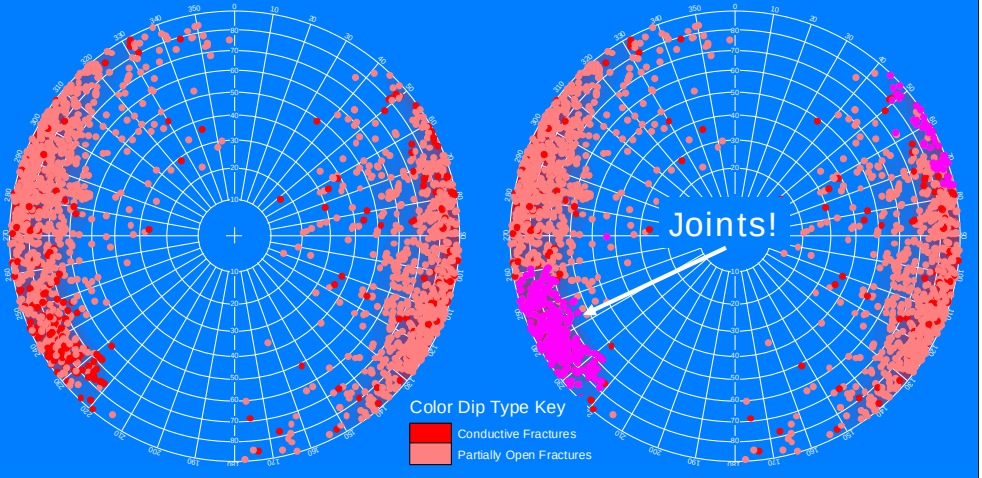


Color Dip Type Key

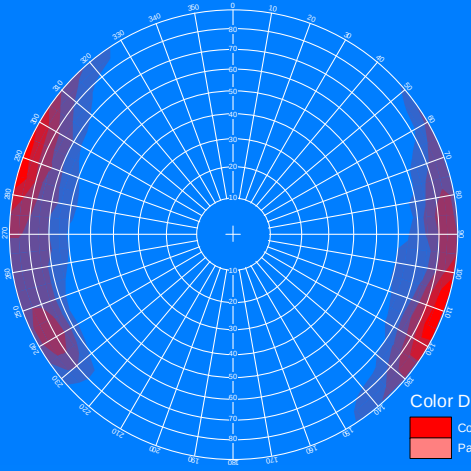
Conductive Fractures

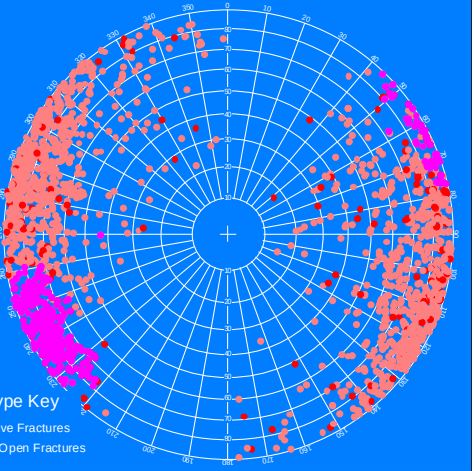
Partially Open Fractures

All Fractures-Residual Dips



All Fractures-Residual Dips





Color Dip Type Key

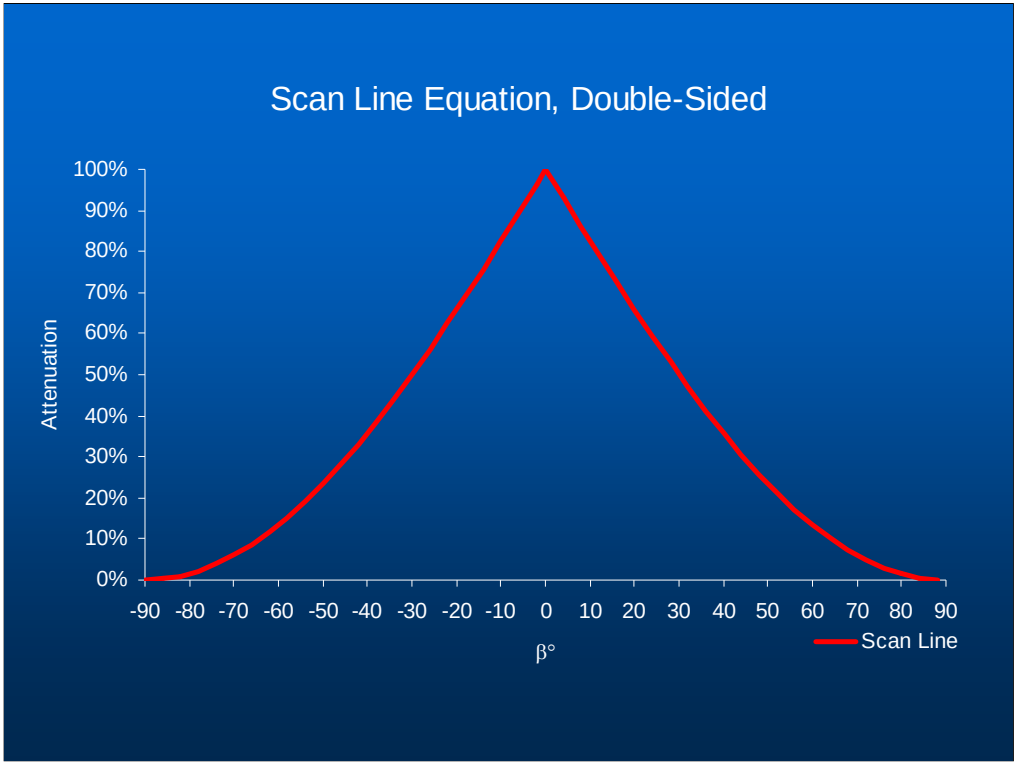
Conductive Fractures

Partially Open Fractures

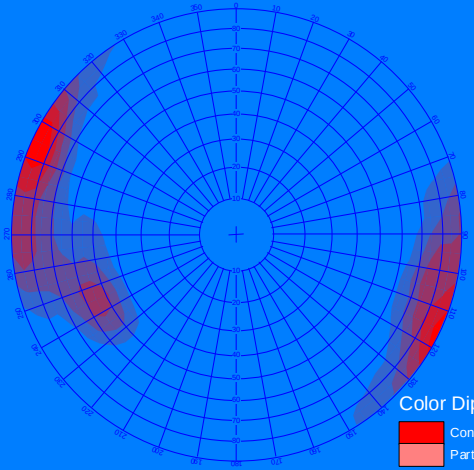
Contours Only

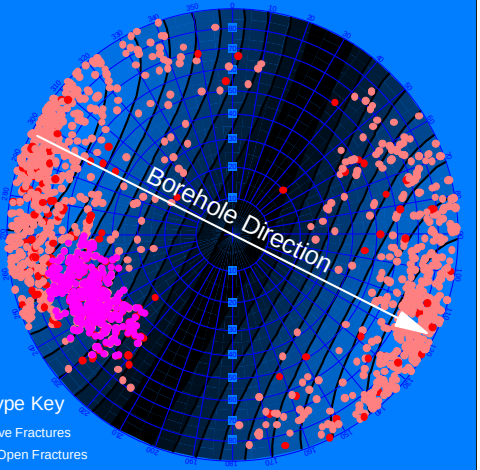
Poles Only

Fractures are Highly Clustered Perpendicular to Bedding


Scan Line Equation, Double-Sided
Attenuation
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
-90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90
β°
Scan Line

Shadow Zone—10% Contour Interval





Color Dip Type Key

Conductive Fractures

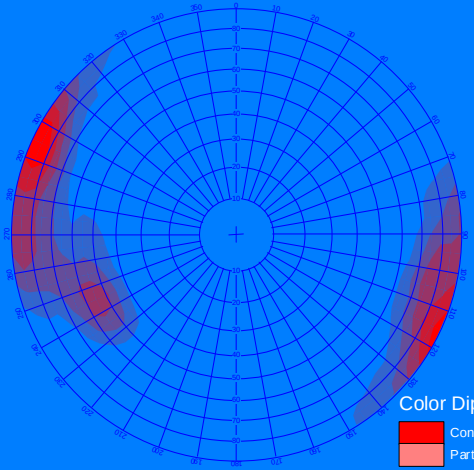
Partially Open Fractures

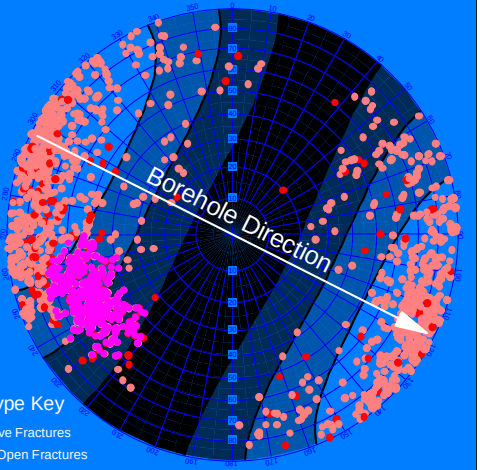
Contours Only

Poles With

Shadow Zone

Shadow Zone—25% Contour Interval





Color Dip Type Key

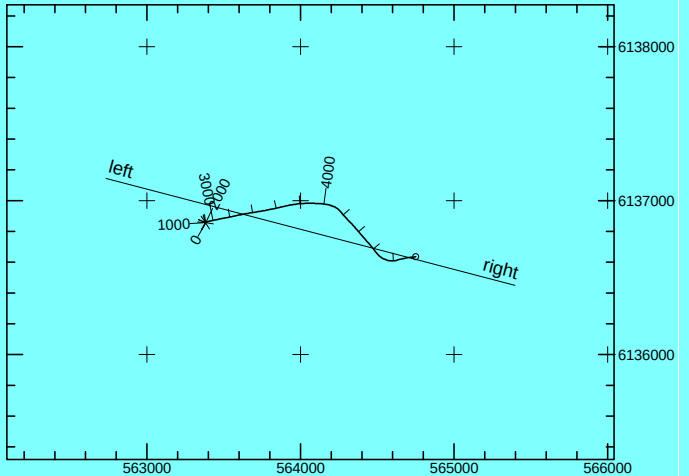
Conductive Fractures

Partially Open Fractures

Contours Only

Poles With

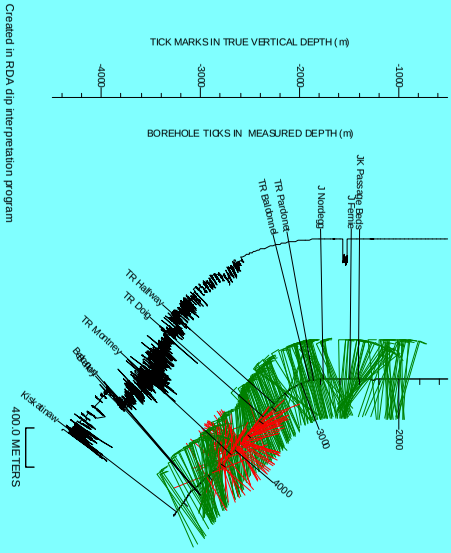
Shadow Zone



BOREHOLE TICKS IN MEASURED DEPTH (m)

BOREHOLE DEVIATION MAP
X-Y GRID IN METERS

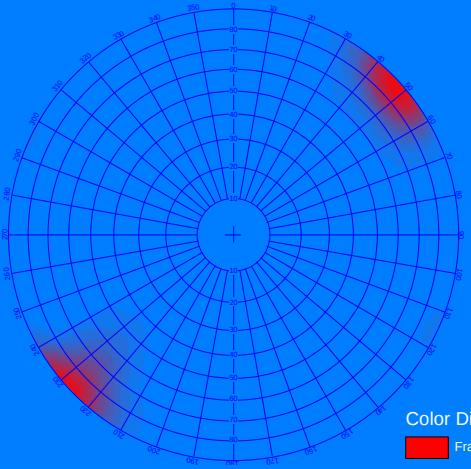
Created in RDA dip interpretation program



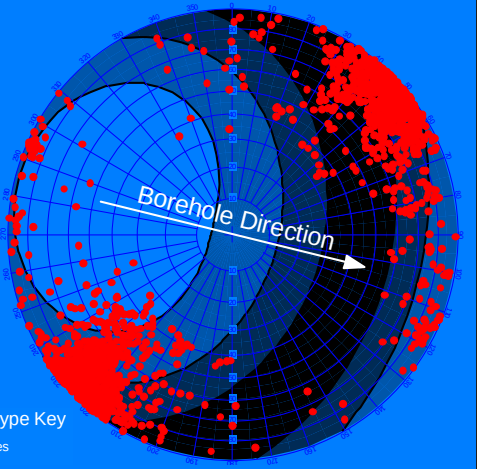
DEPTH SECTION

RIGHT-SIDE AZIMUTH OF 104.6 DEG.

All Data-3365m to 4534m



Contours Only



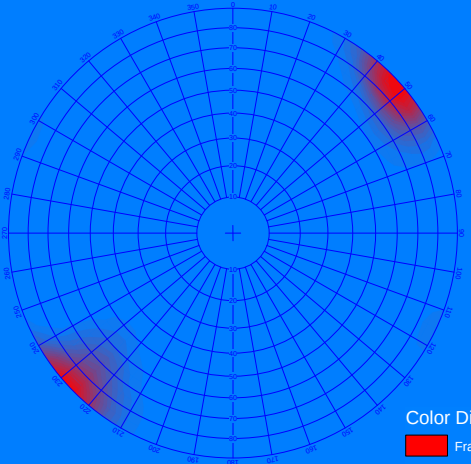
Color Dip Type Key

Fractures

Poles With

Shadow Zone

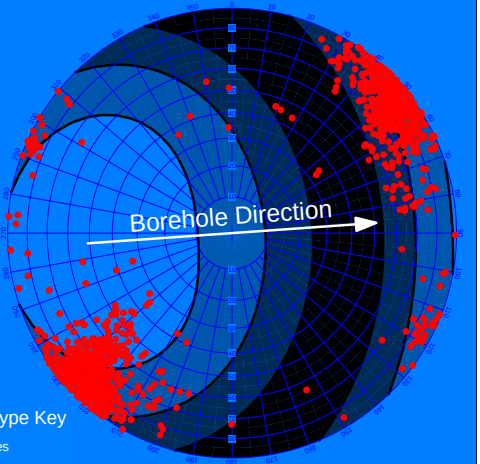
Upper Segment-3365m to 4100m



Contours Only

Color Dip Type Key

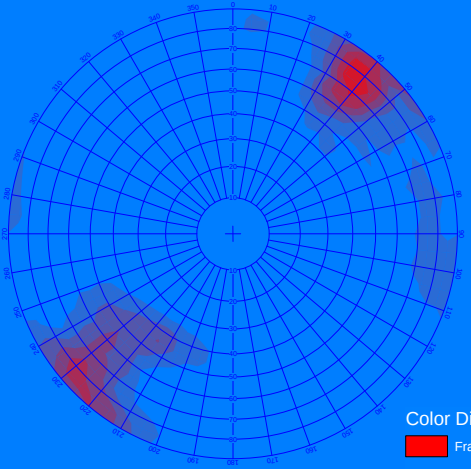
Fractures

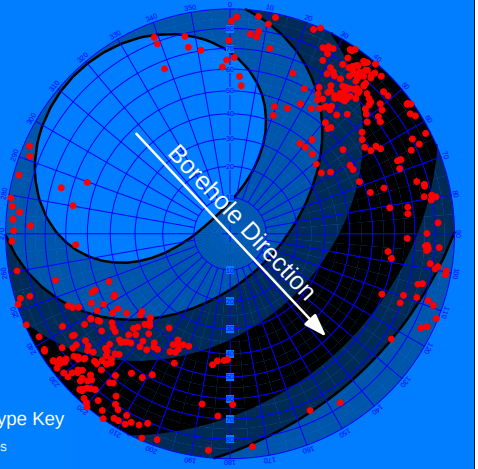


Poles With

Shadow Zone

Lower Segment 4100m to 4534m





Color Dip Type Key

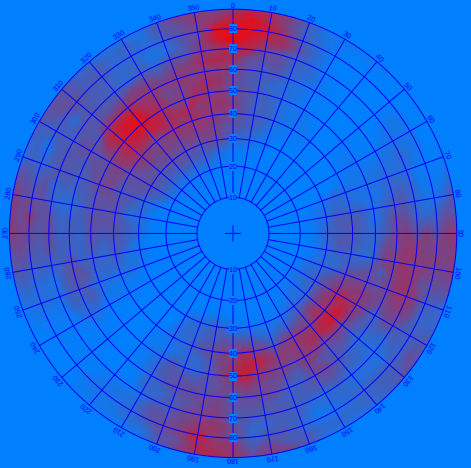
Fractures

Contours Only

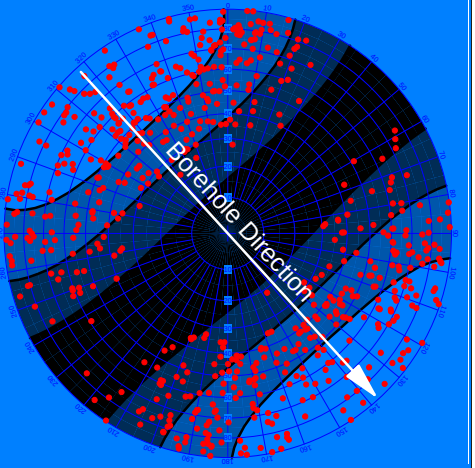
Poles With

Shadow Zone

Cardium Example



Contours Only



Poles With

Shadow Zone

Conclusions

- Be aware of the dips likely to be encountered in the fractured zones
- Know likely fracture orientations when planning borehole trajectory
- Try not to let drilling or other considerations override orientation issues.
  - A typical example would be that it is easier to drill a well perpendicular to bedding. Because of typical joint/bedding relationships, this may not always be a good idea
- In low-dip shale gas plays, fractures in nearby vertical wells may be attenuated relative to subsequent horizontal holes.
  - “We didn’t see any fractures in the vertical well, therefore the frac job must have created the fractures.”