Integrating Full-Bore Formation Micro-Imager (FMI) Data for Niobrara Formation Reservoir Characterization, Postle Area, Wattenberg Field, Colorado, USA

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MS - 2023

COLORADO SCHOOL OF MINES
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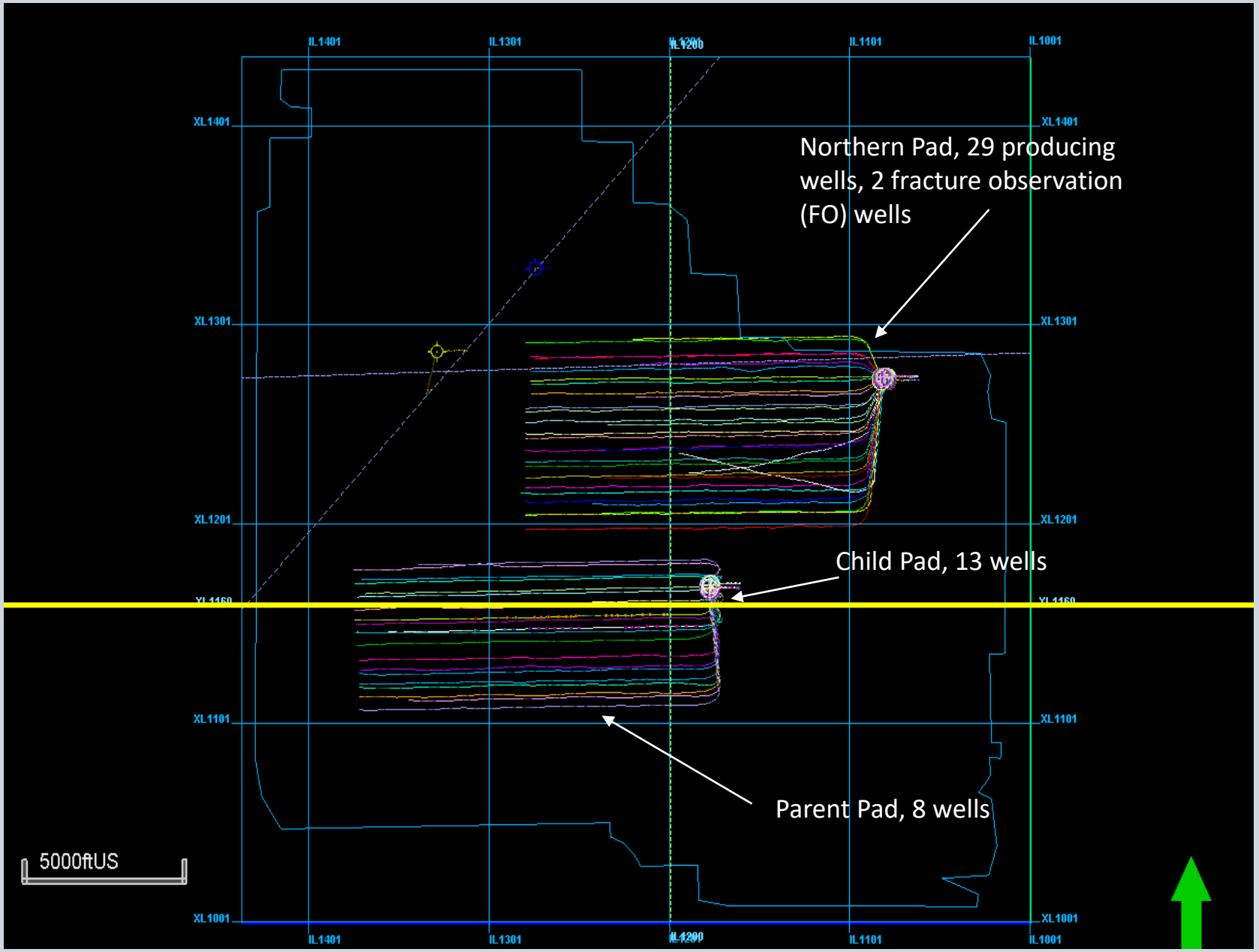
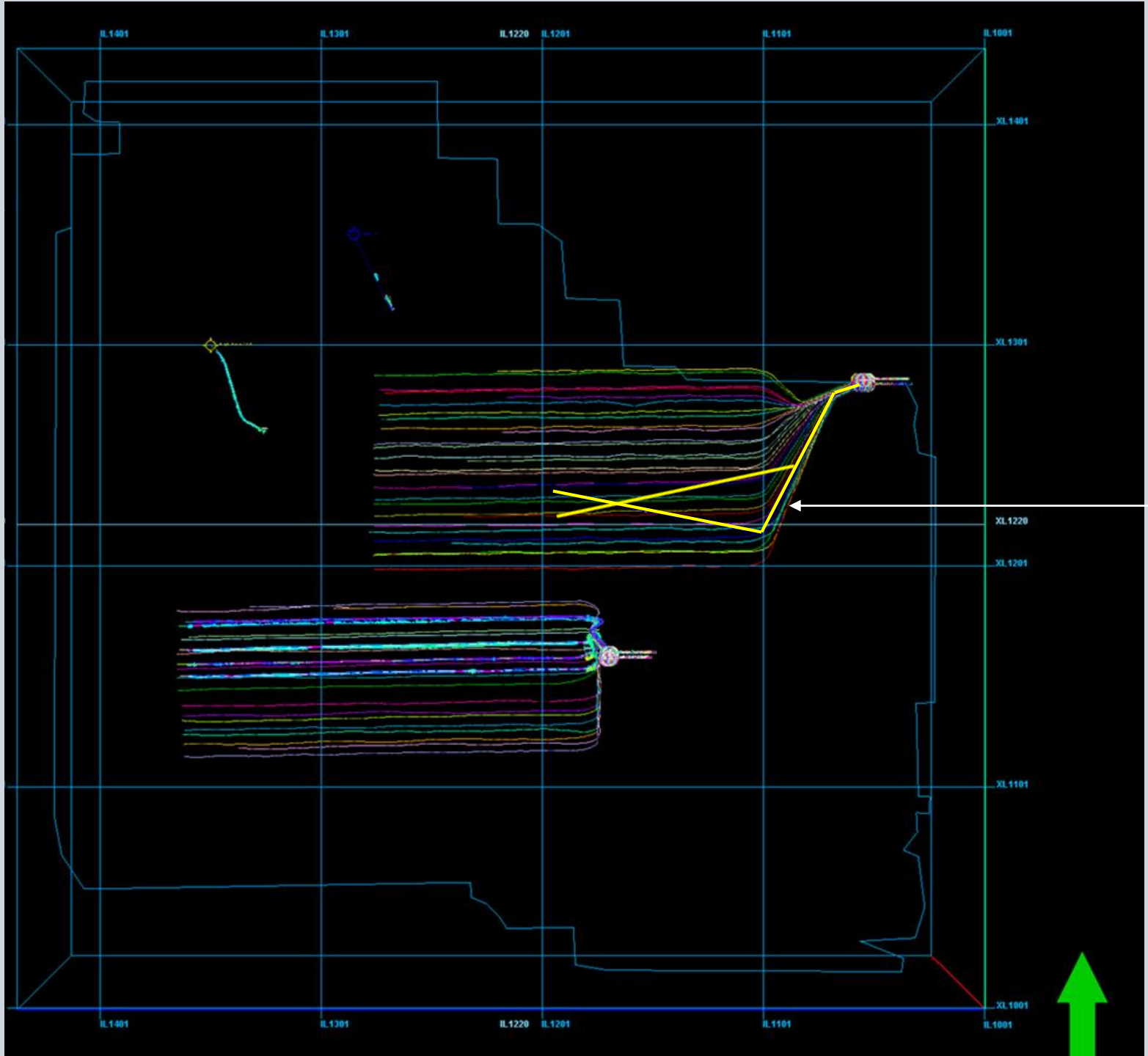
The purpose of my research is:

- Detailed reservoir characterization of the Niobrara Formation will be performed, including characterizing both natural and induced fractures, orientation, and density.
- Interpretation of the image log data can establish the spatial geometry of the natural & induced fractures related to hydrocarbon production.

Study Area


IL1401
IL1301
IL1200
IL1101
IL1001
XL1401
XL1301
XL1201
XL1101
XL1001
Northern Pad, 29 producing wells, 2 fracture observation (FO) wells
Child Pad, 13 wells
Parent Pad, 8 wells
5000ftUS



Fracture Observation (FO) Well 1

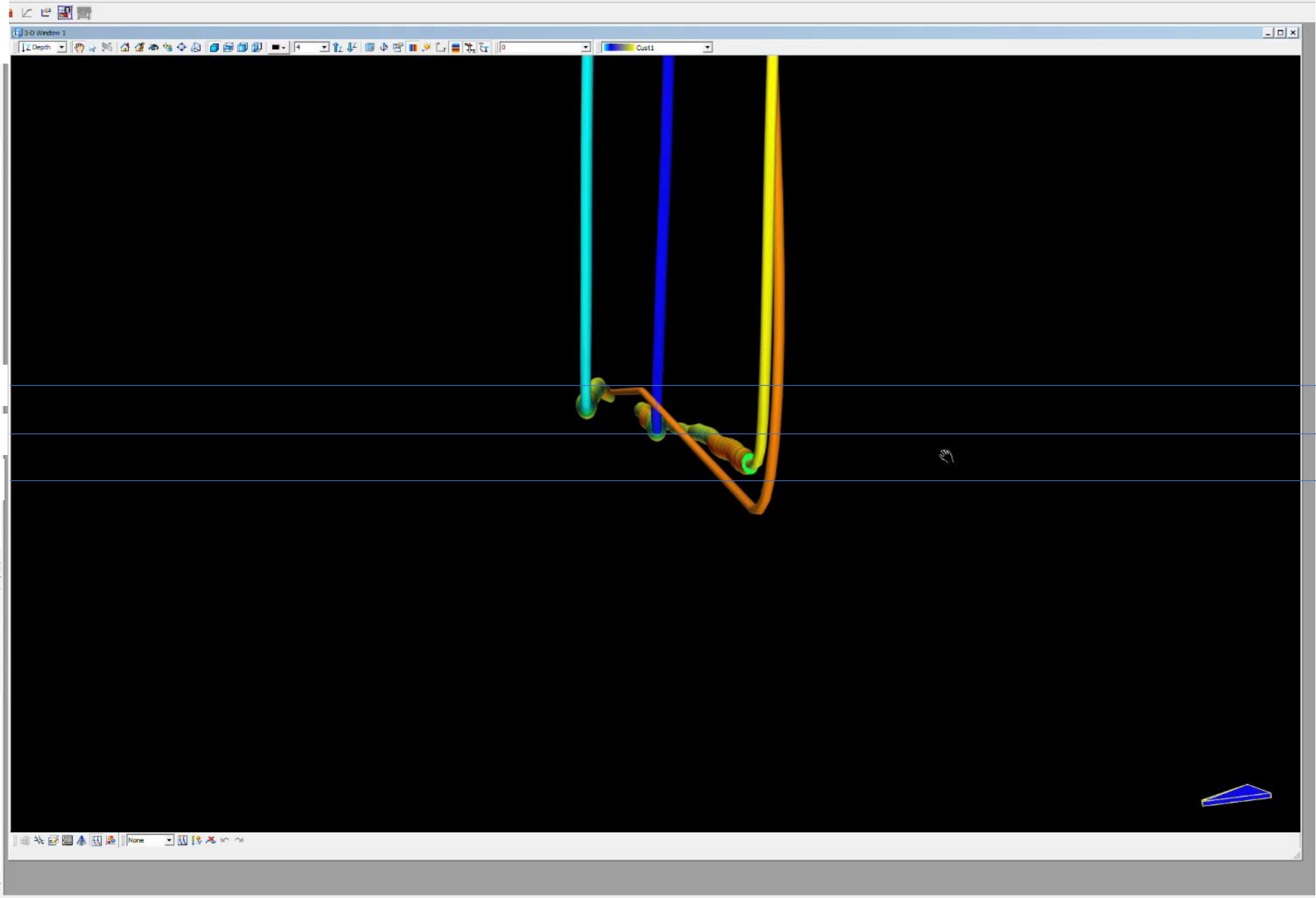
Deviated well is FO1 -- Codell up through Chalk A

WN5A – A Chalk

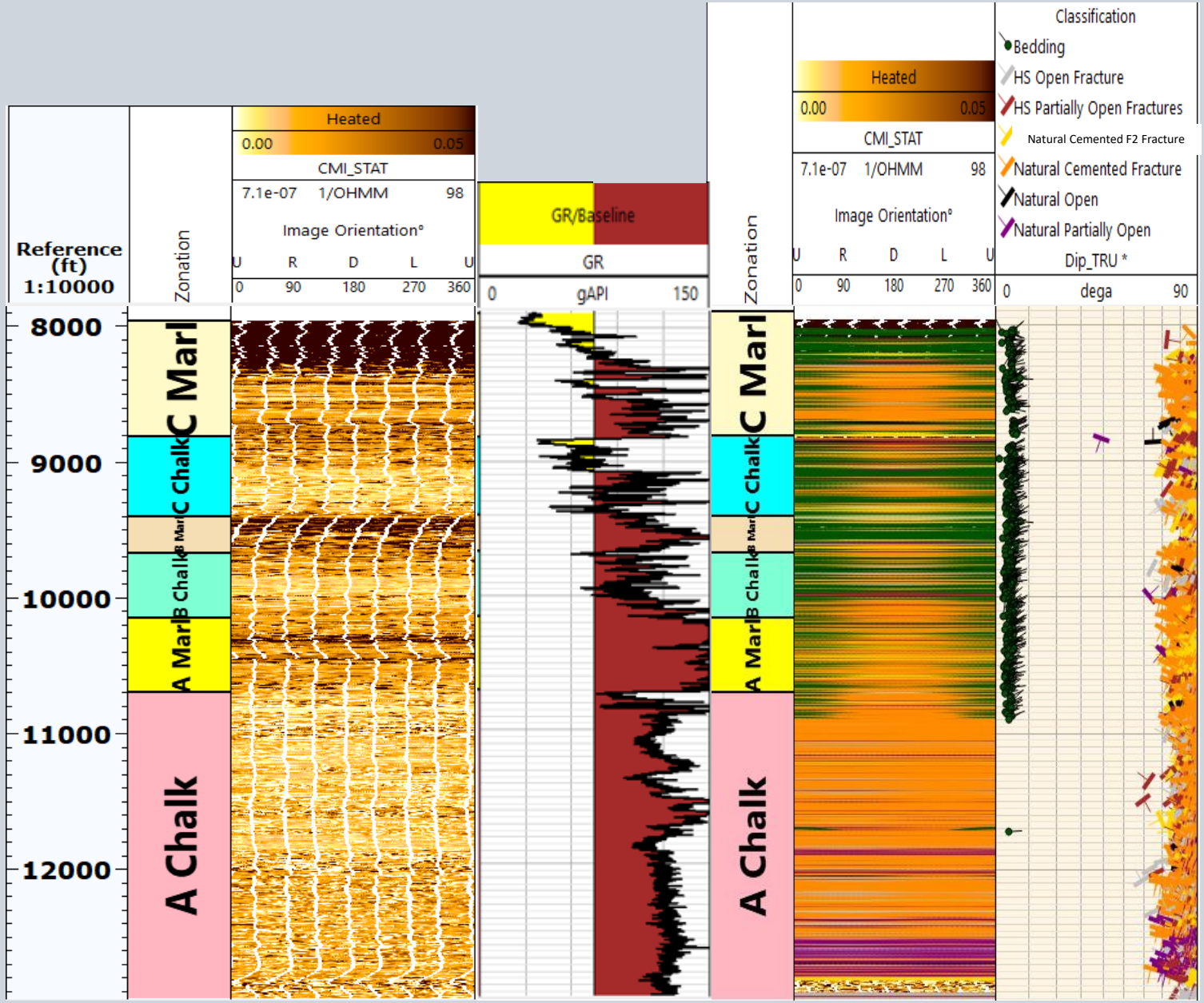
WN6B – B Chalk

WN5C – C Chalk

Credit to: Damon Parker

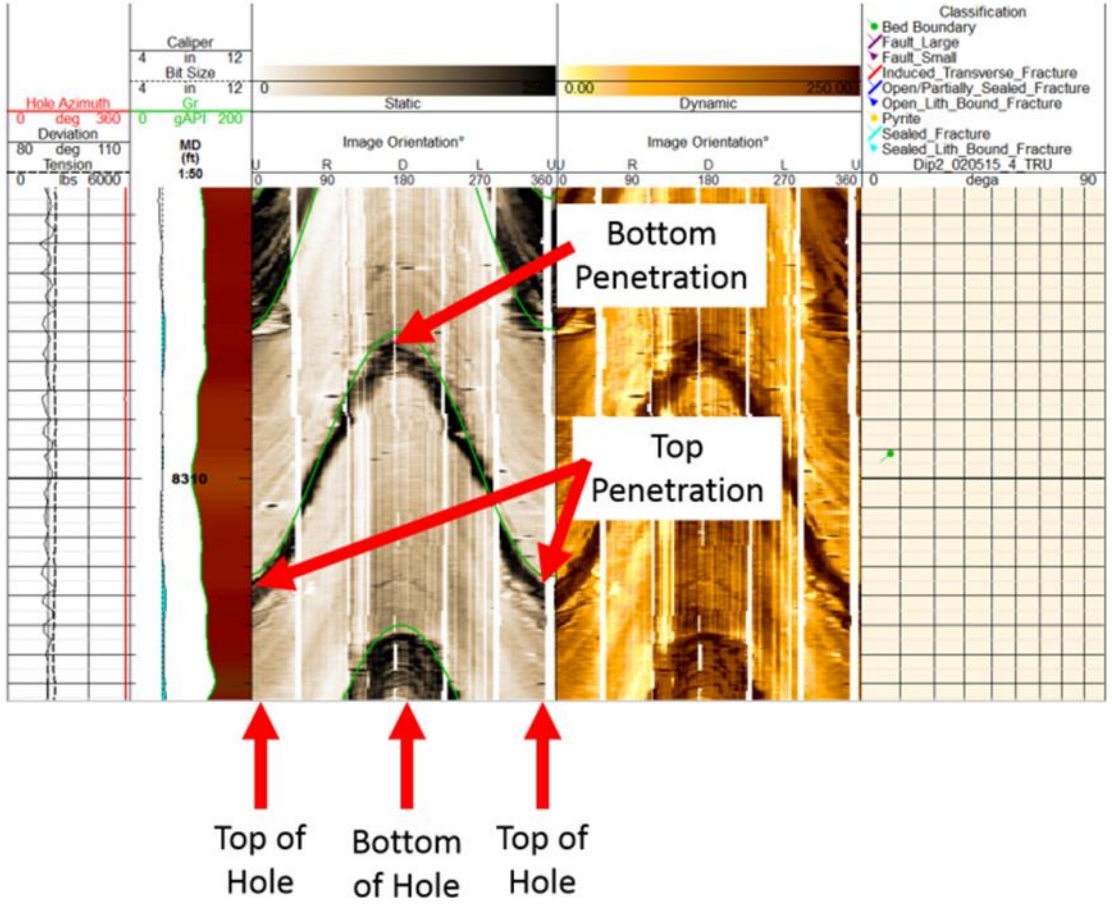


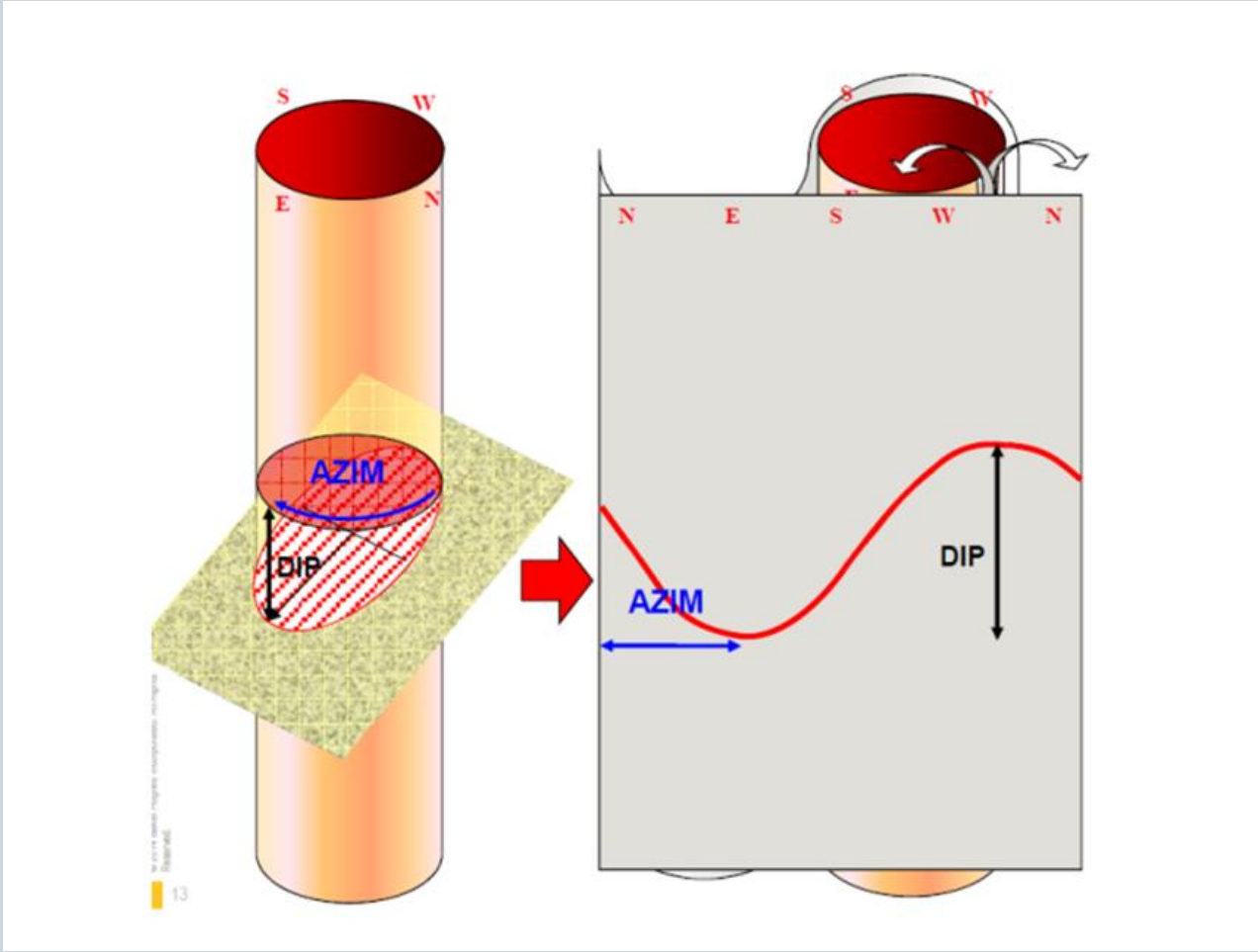
Dip Classifications



- Log layout detailing the entire uninterpreted & interpreted image log of the FO1 well
  - 359 Total HS Fractures
  - 2,727 Total Natural Fractures
  - 3,086 combined fracture picks

Wellbore Relation to Bedding Plane Geometry

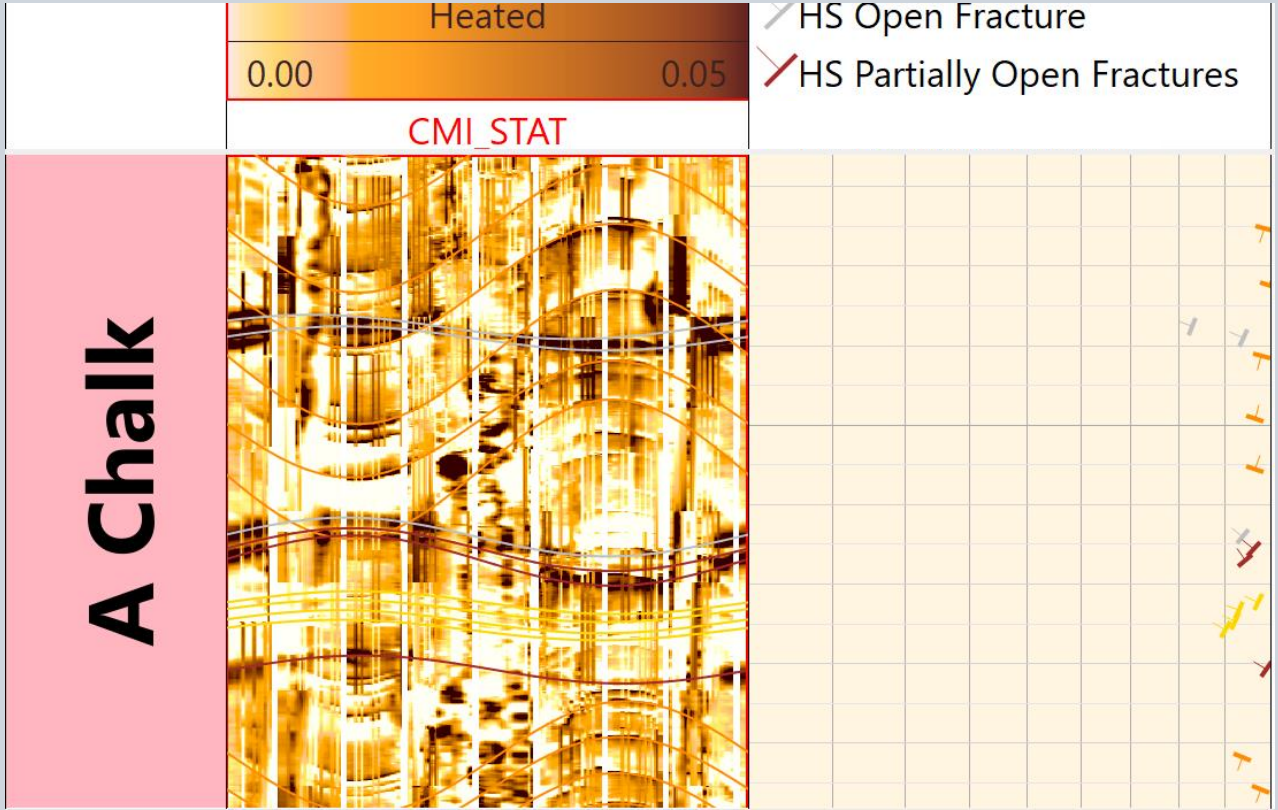


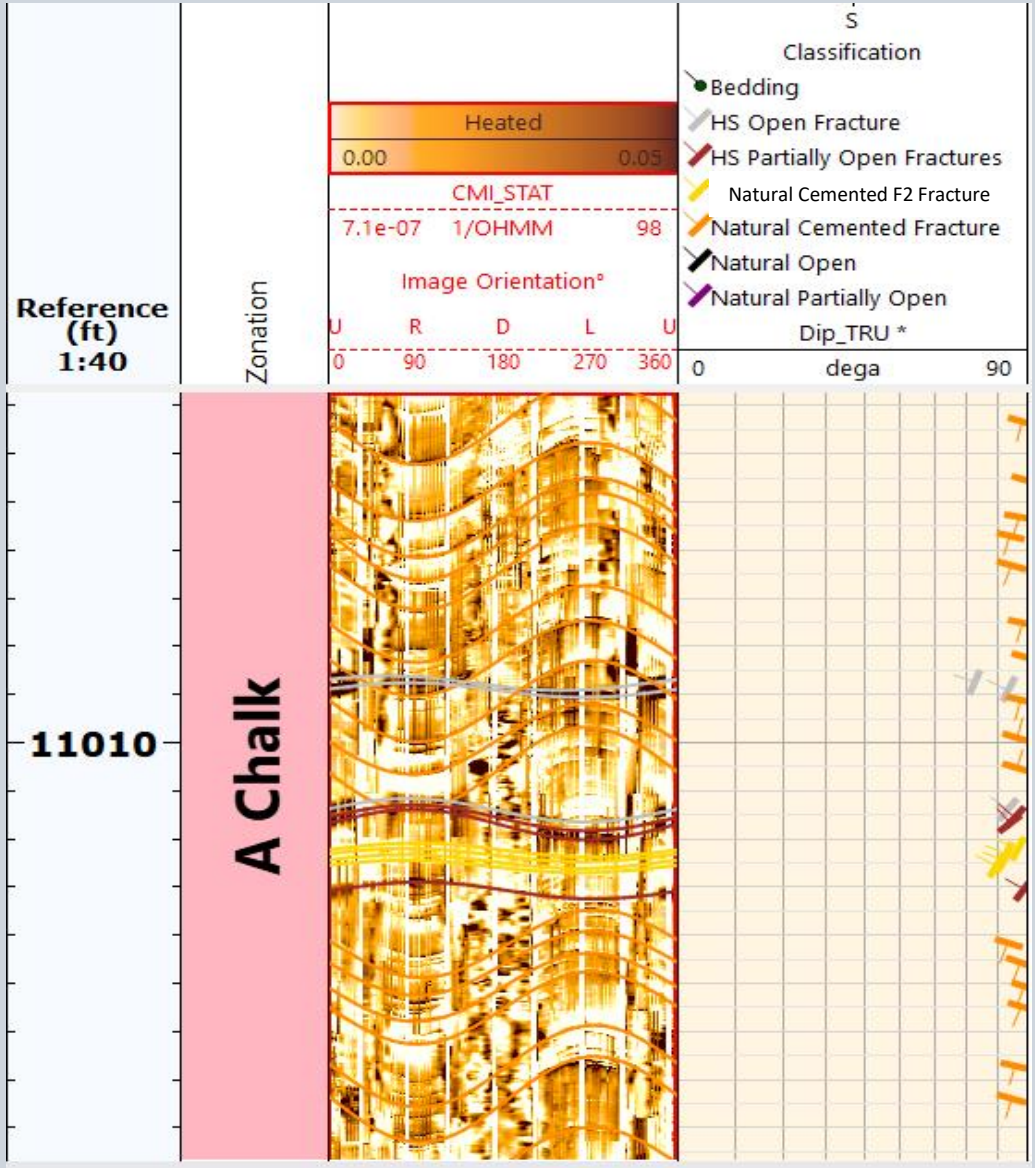


(From Dudley, 2015)

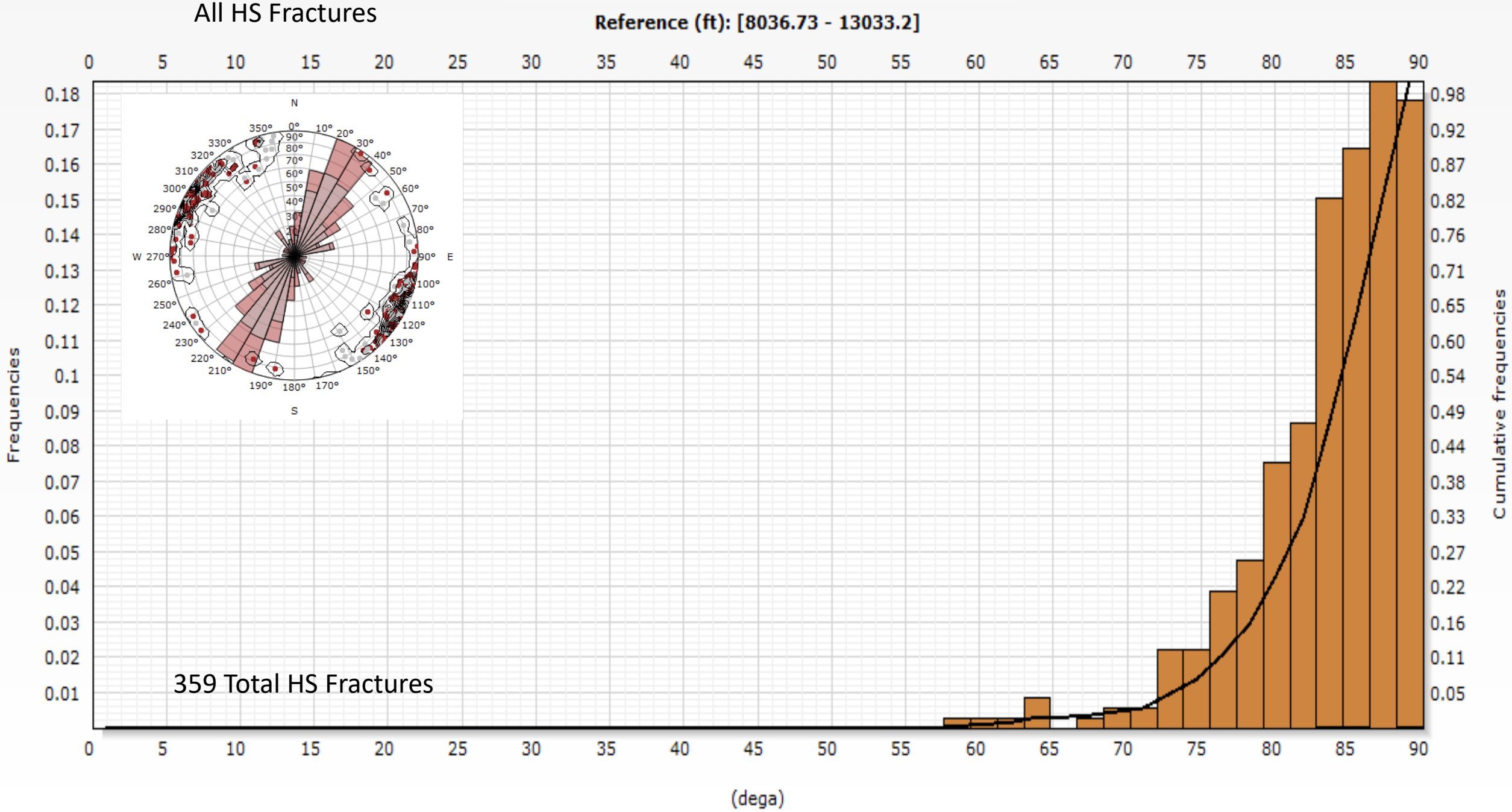
HS Fractures: Open & Partially-Open

- Low amplitude
- HS Open & Partially Open: appear conductive (dark). Partially Open does not cross the entire image, bounded by lithology or could be an effect of the processed image.

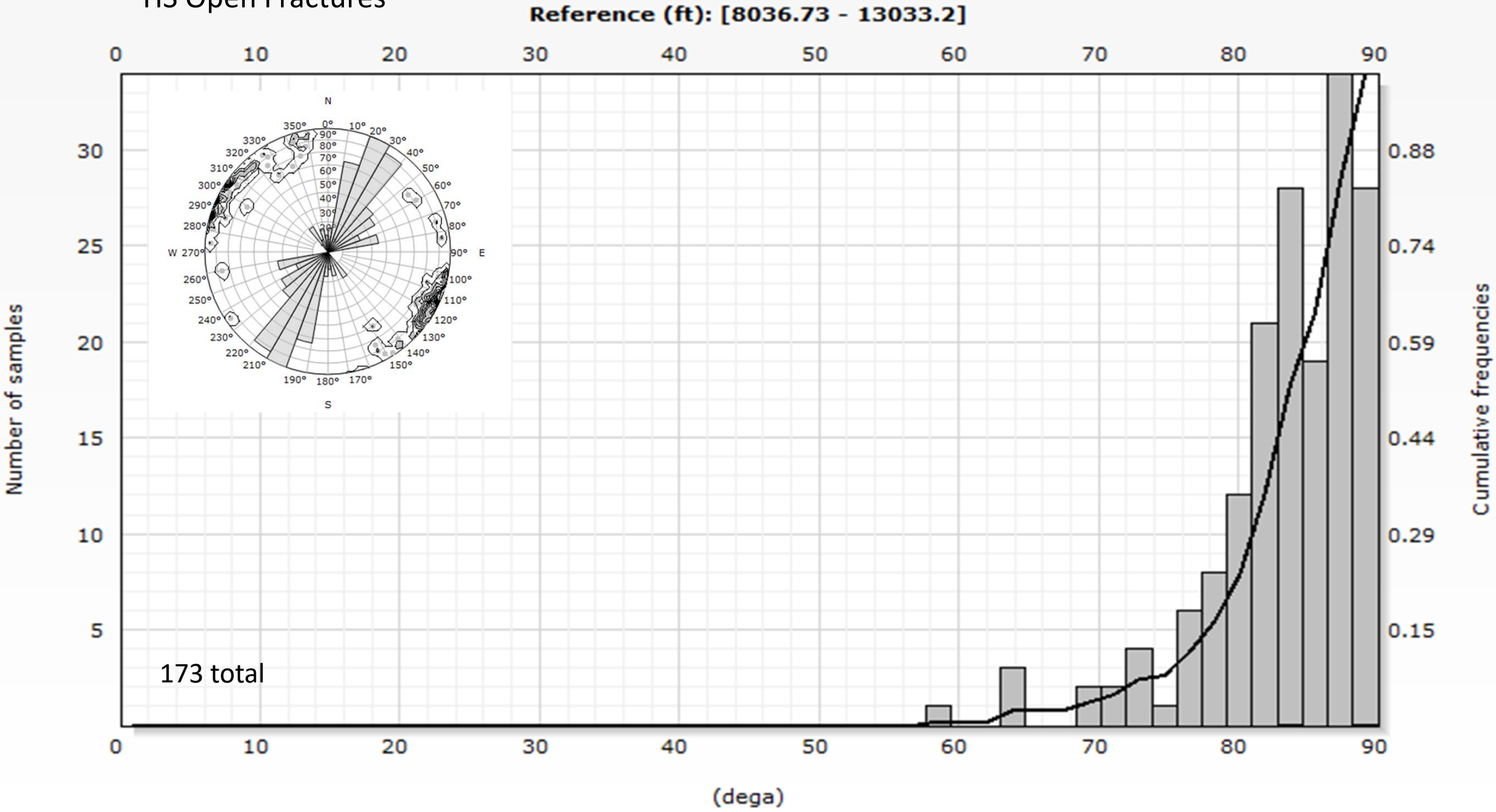




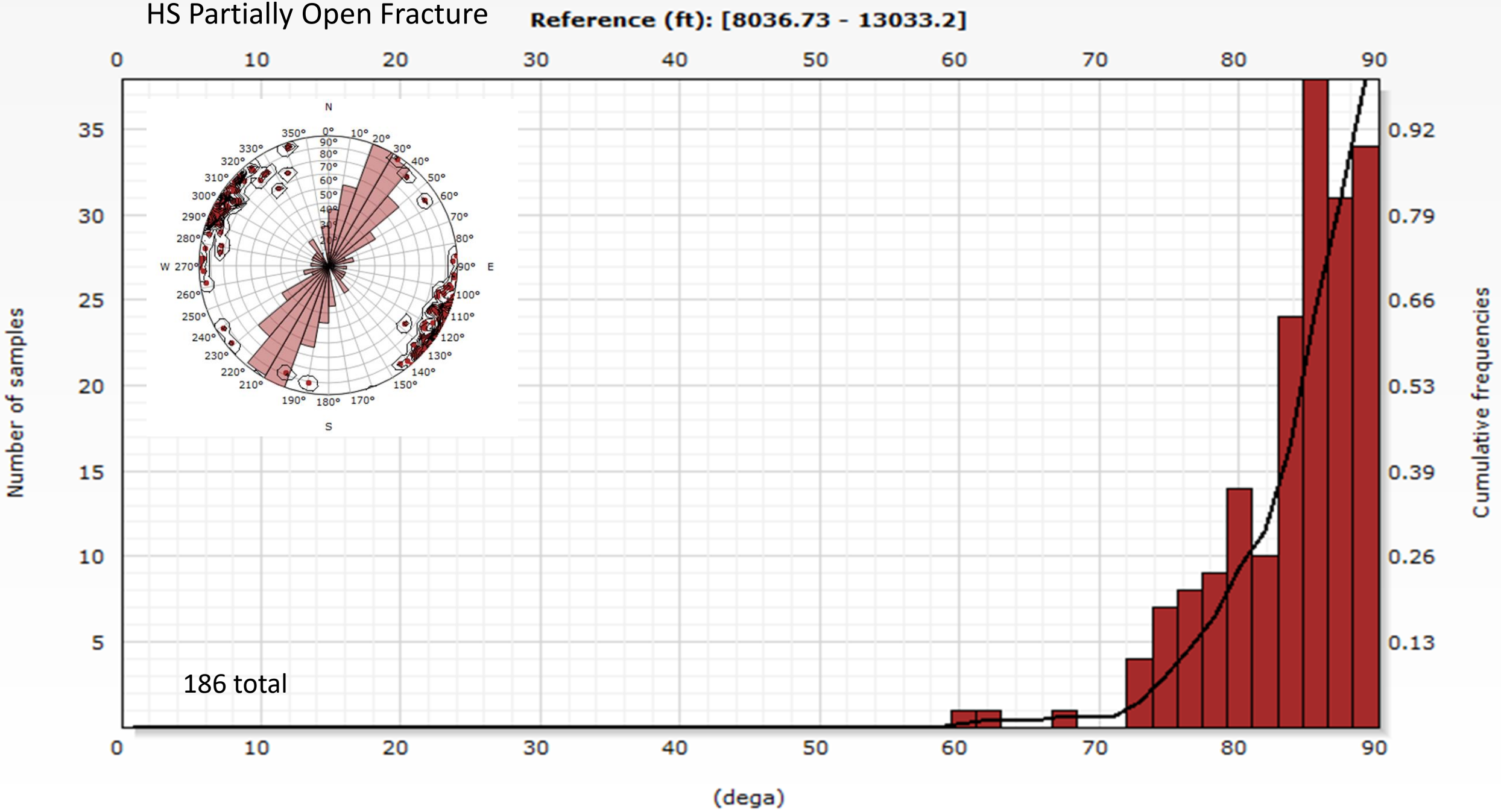
All HS Fractures



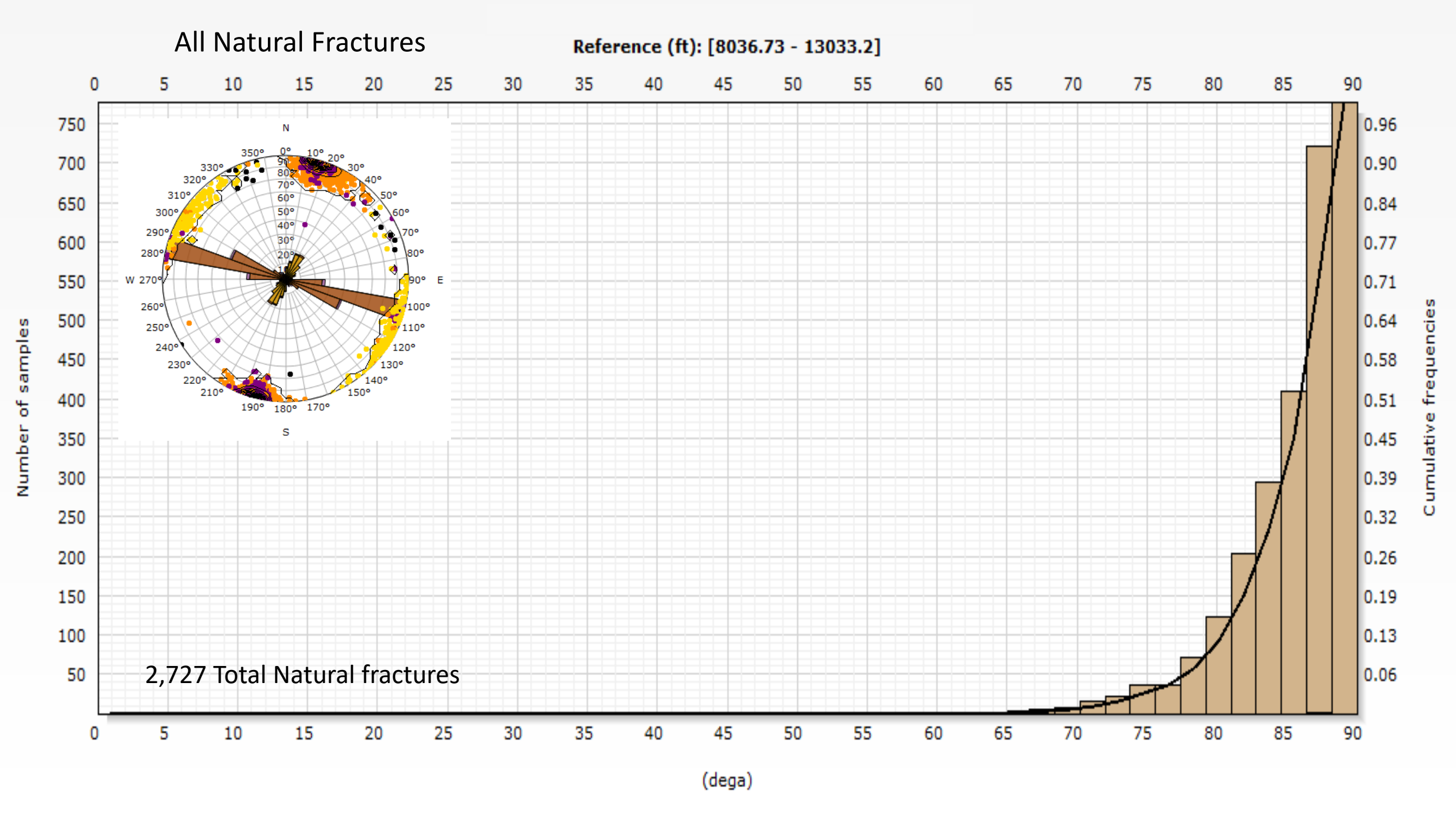
HS Open Fractures



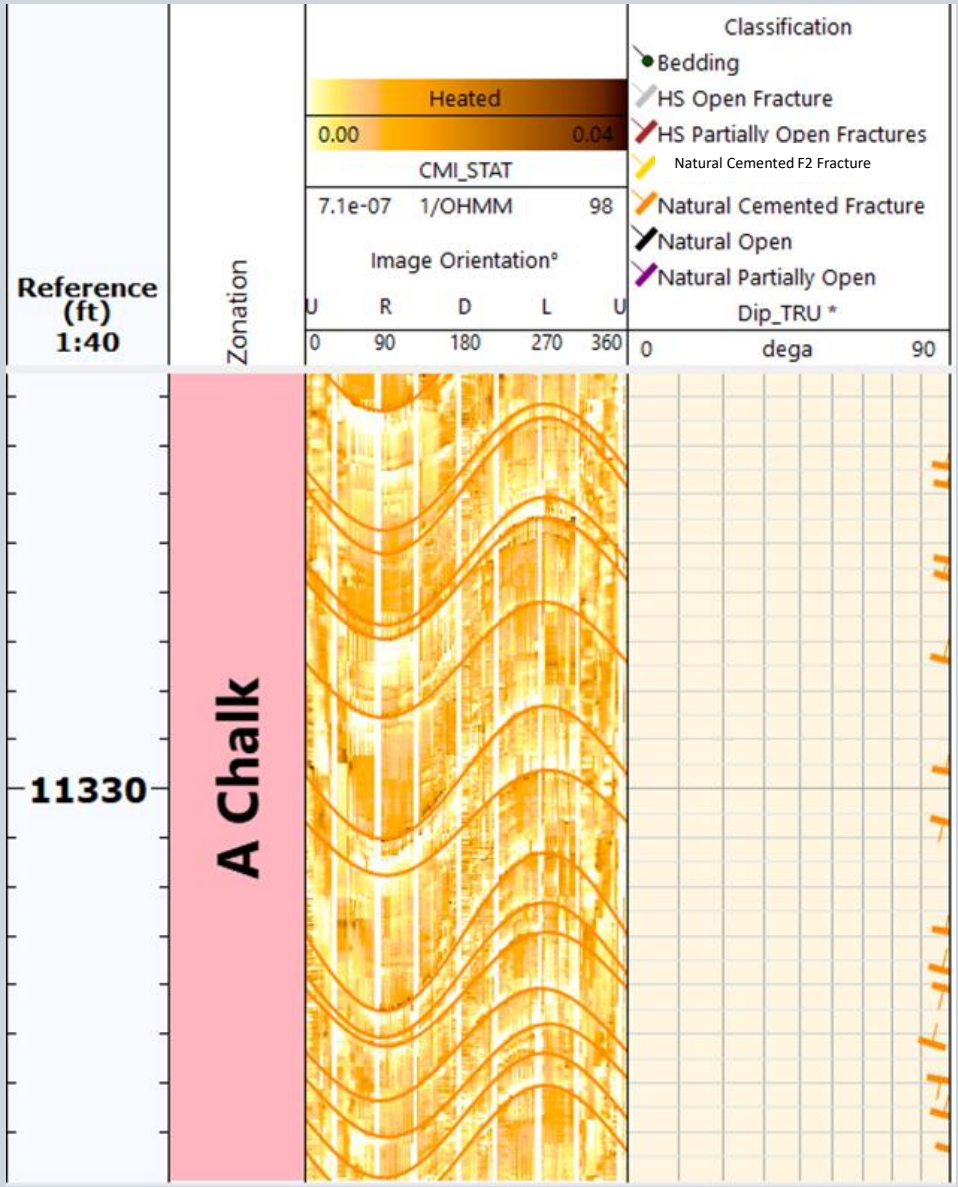
HS Partially Open Fracture

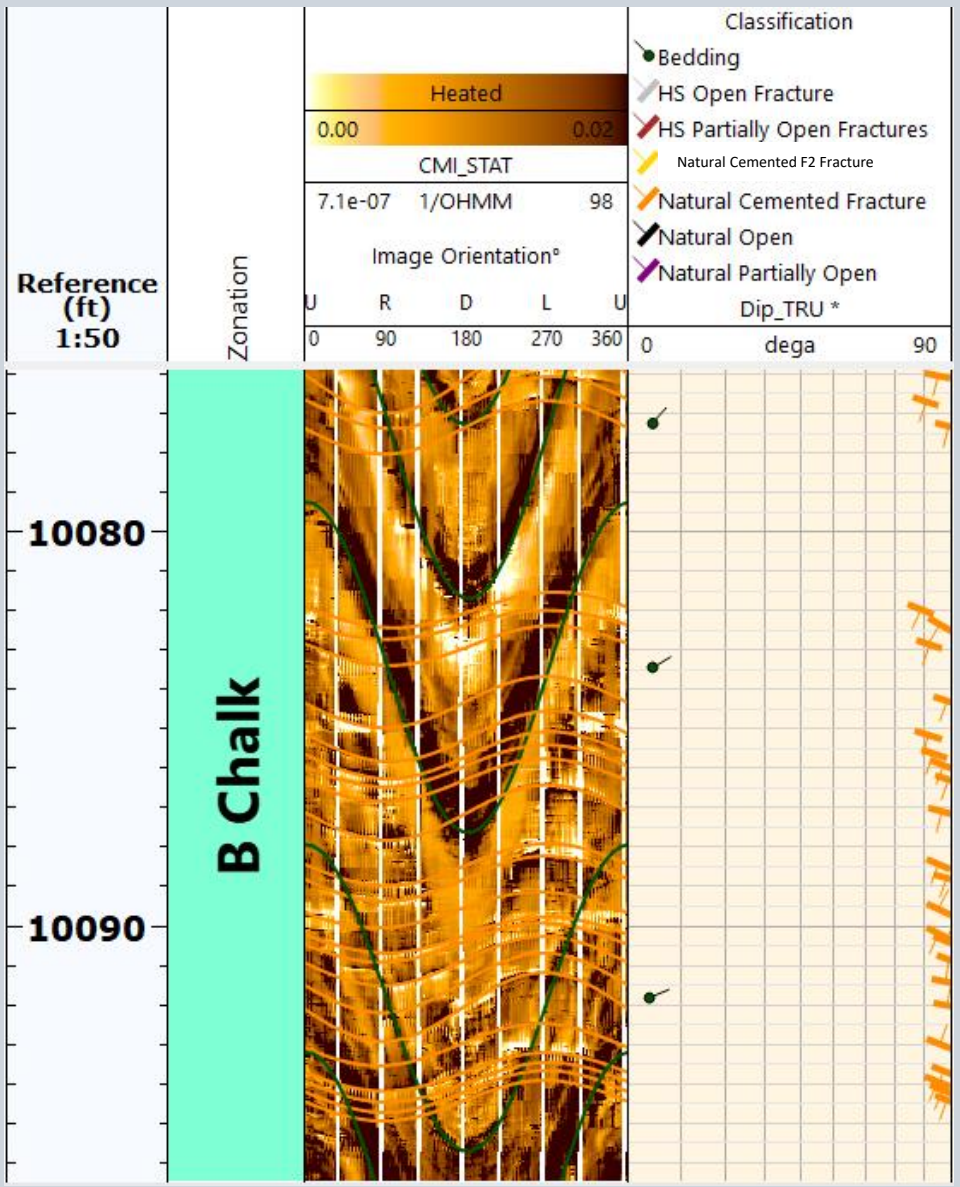


All Natural Fractures

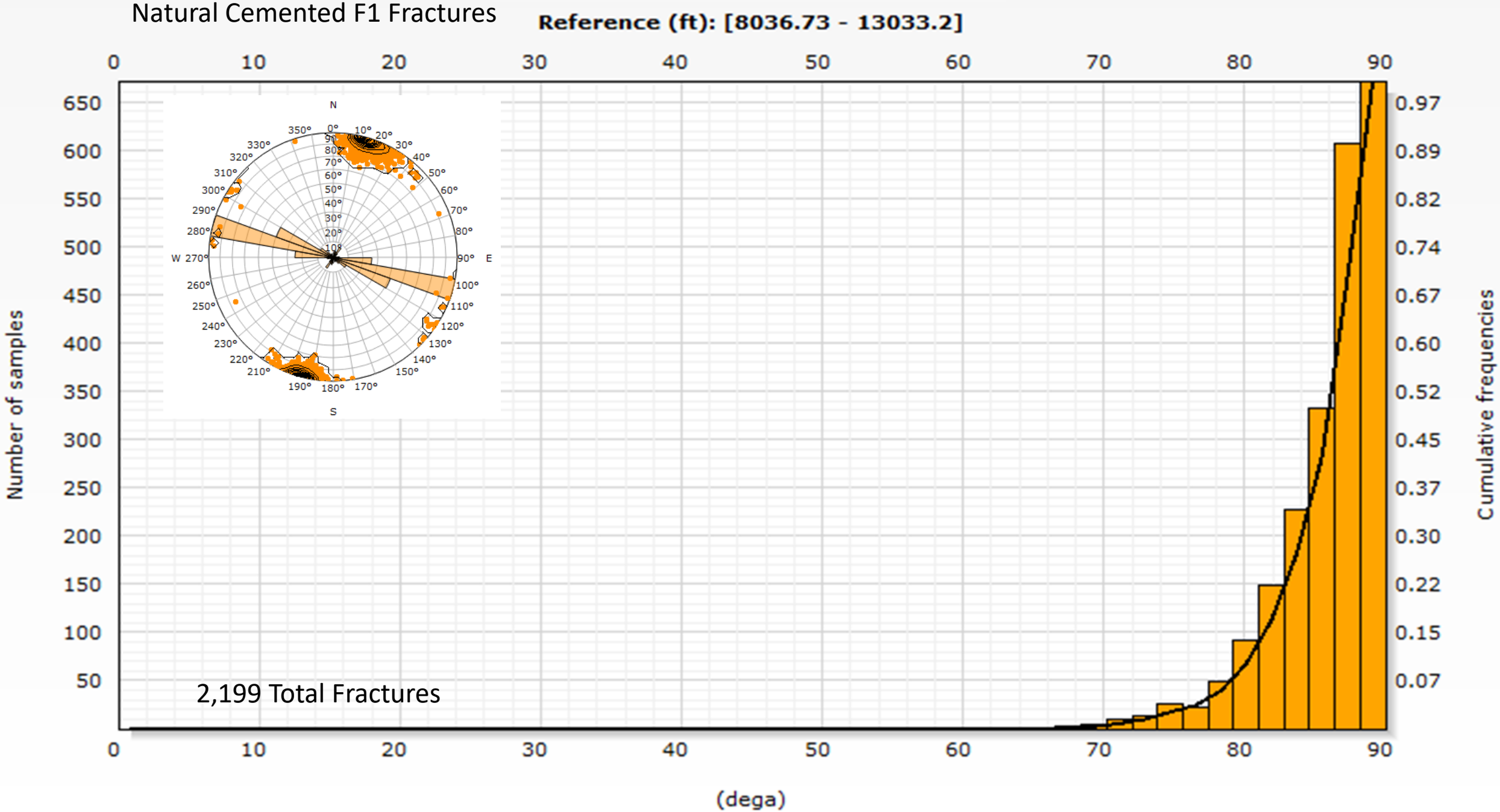


Natural Cemented F1 Fractures

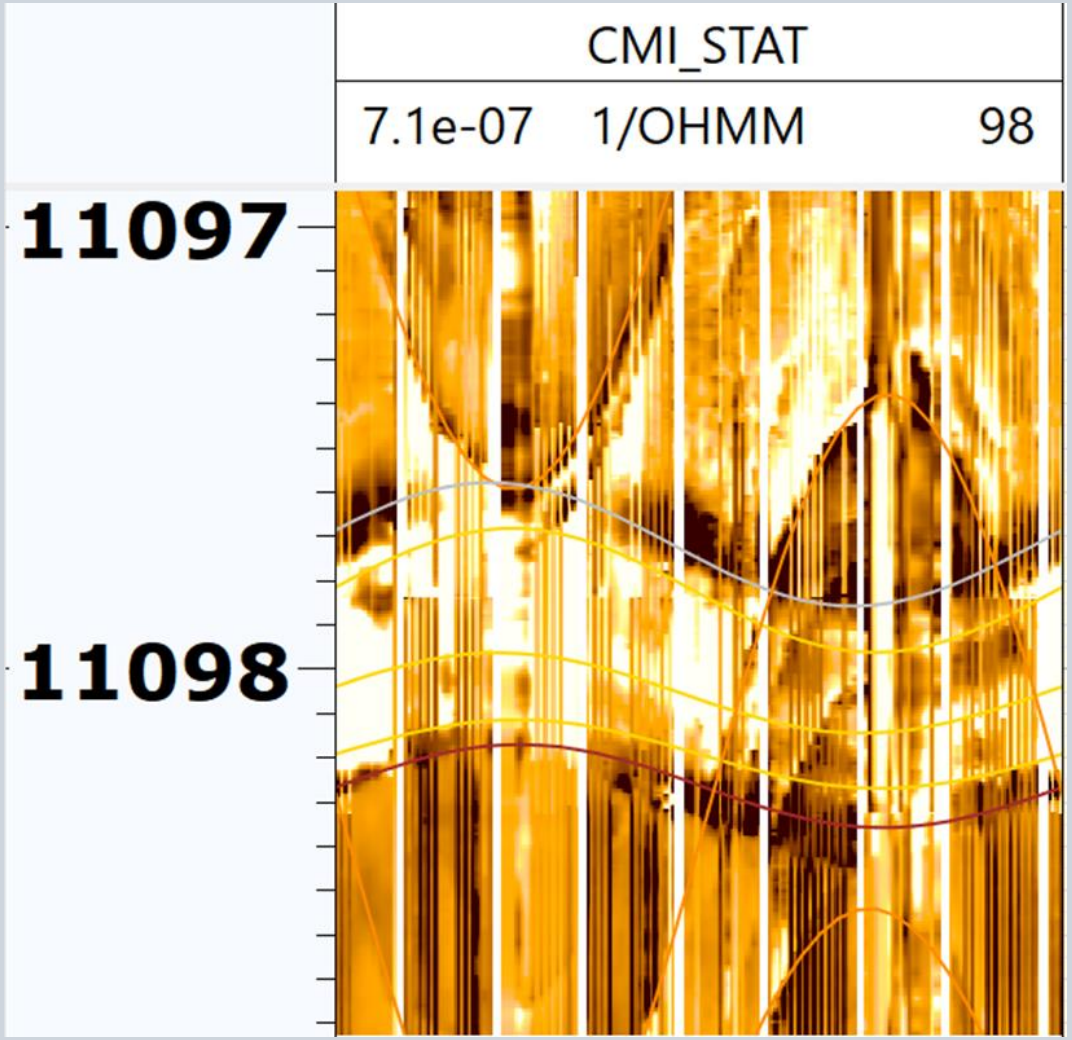


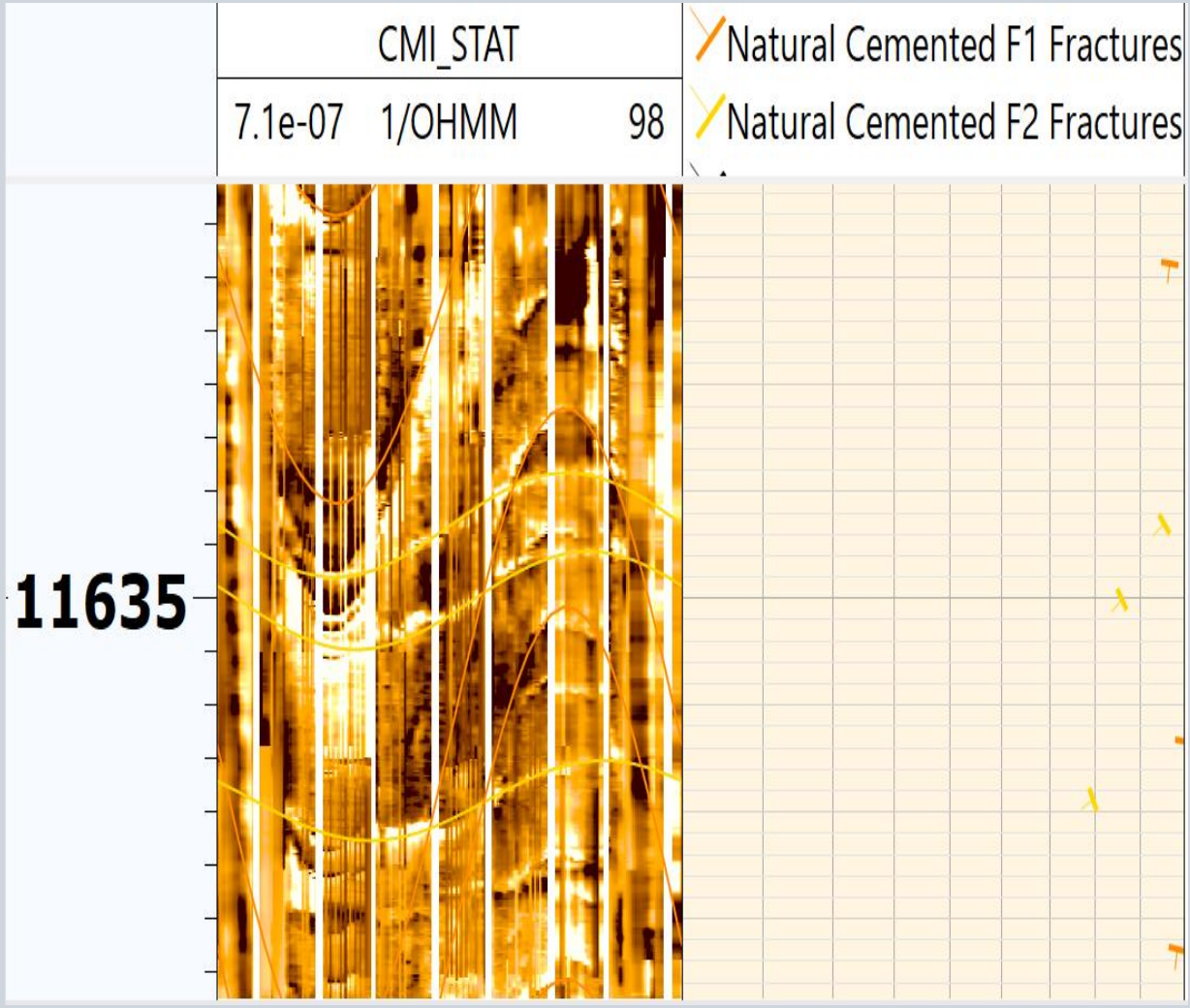


Natural Cemented F1 Fractures

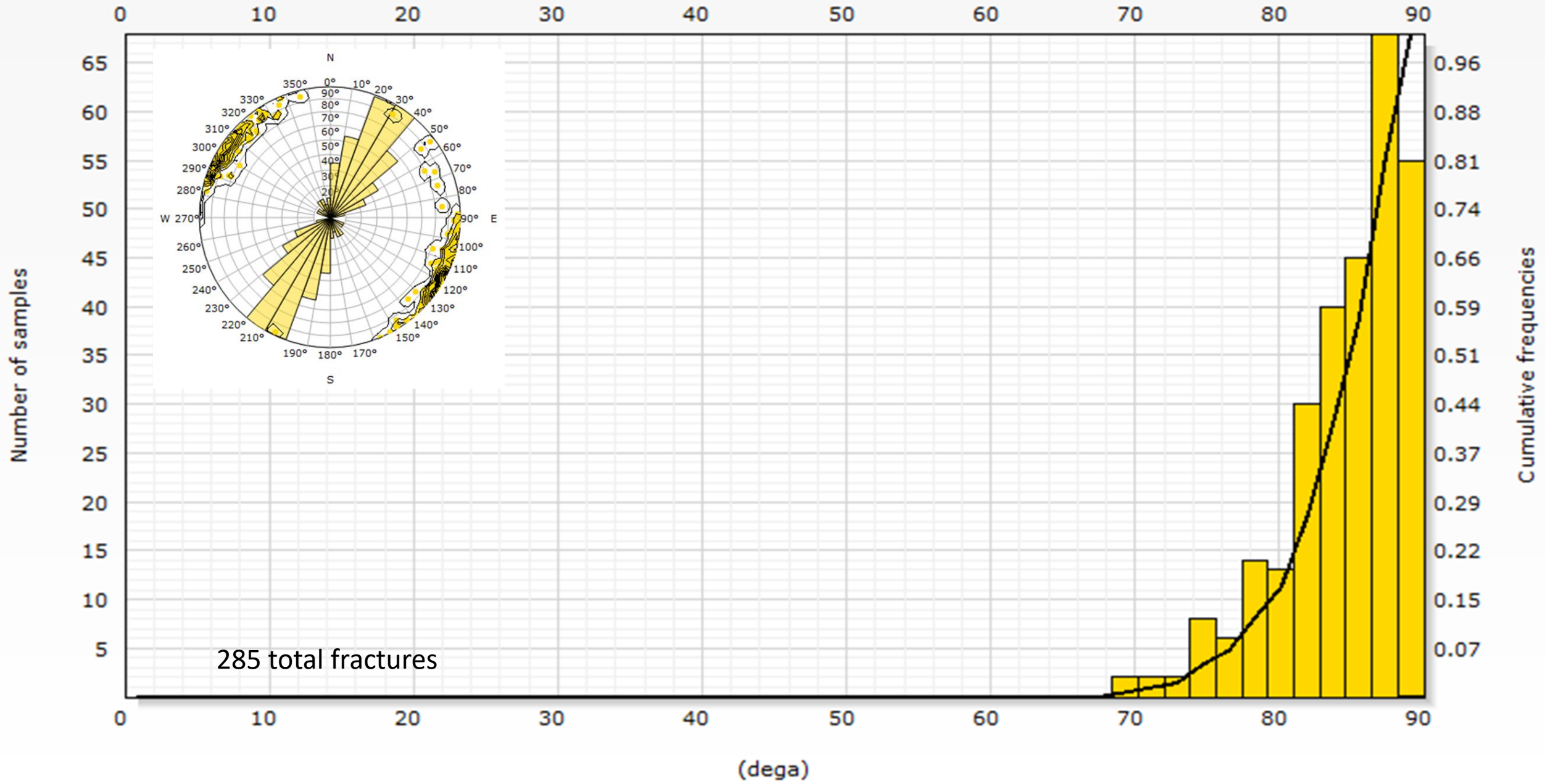


Natural Cemented F2 Fractures



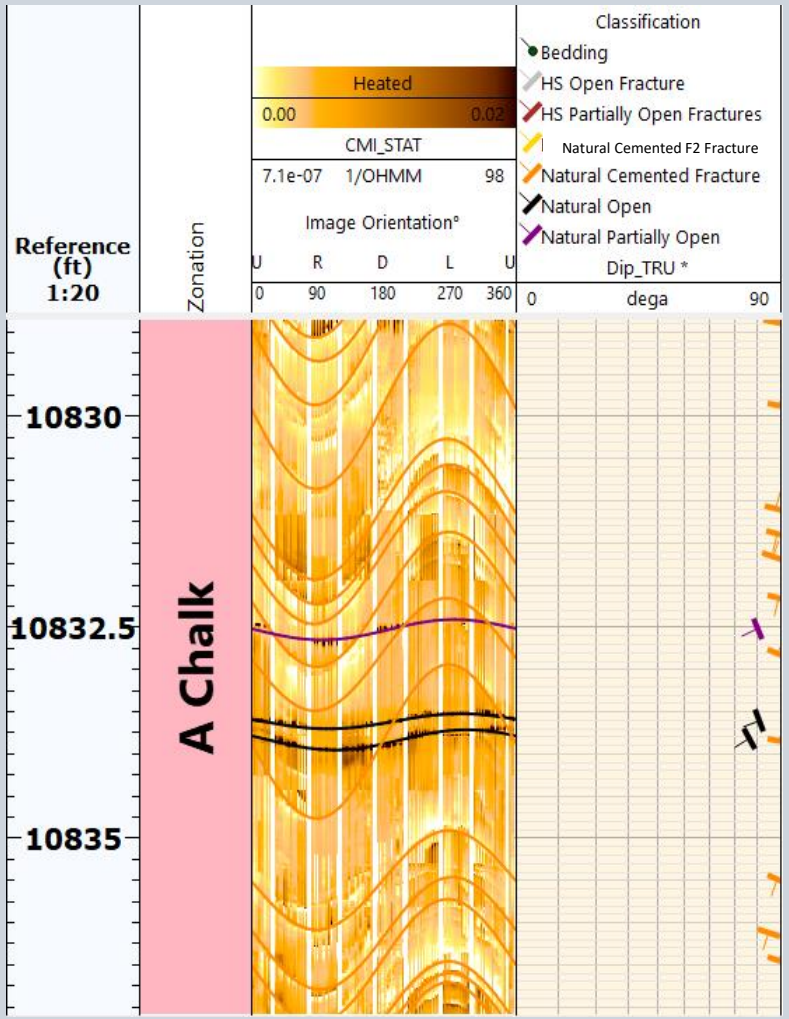


Natural Cemented F2 Fractures

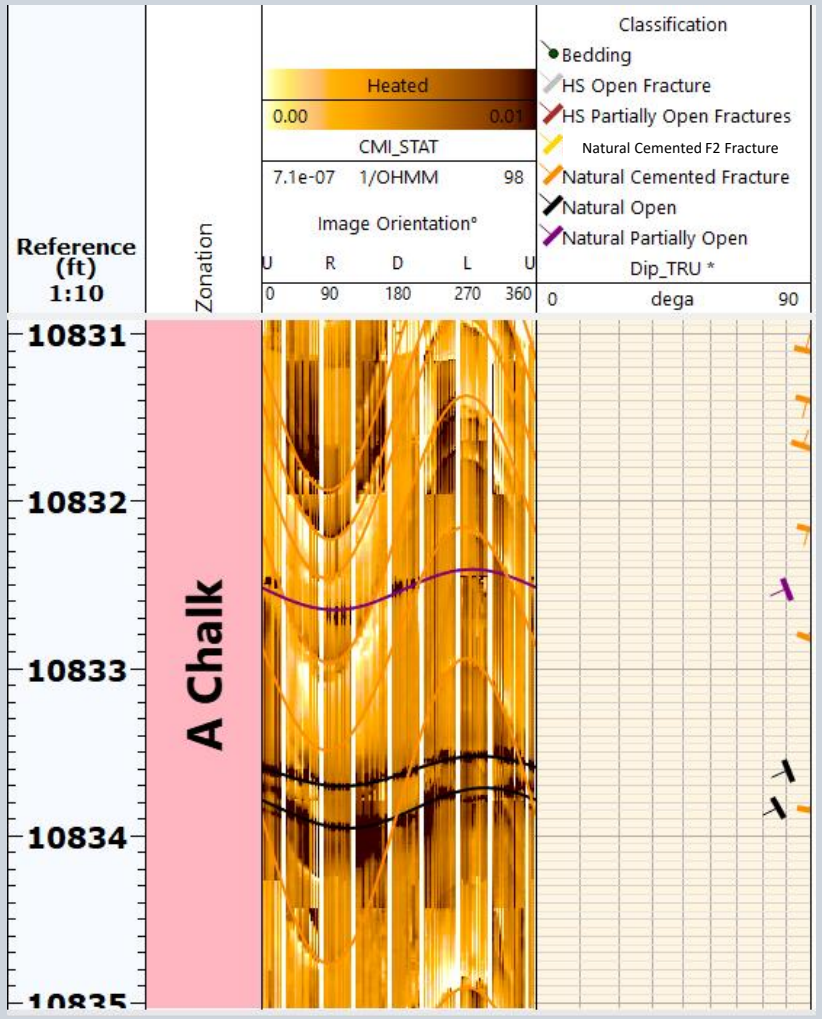


Natural Open/Partially Open

- Low amplitude sinusoids
- Natural open: cross the entire image
- Partially Open: do not cross the entire image, bounded by lithology or could be an effect of the processed image.

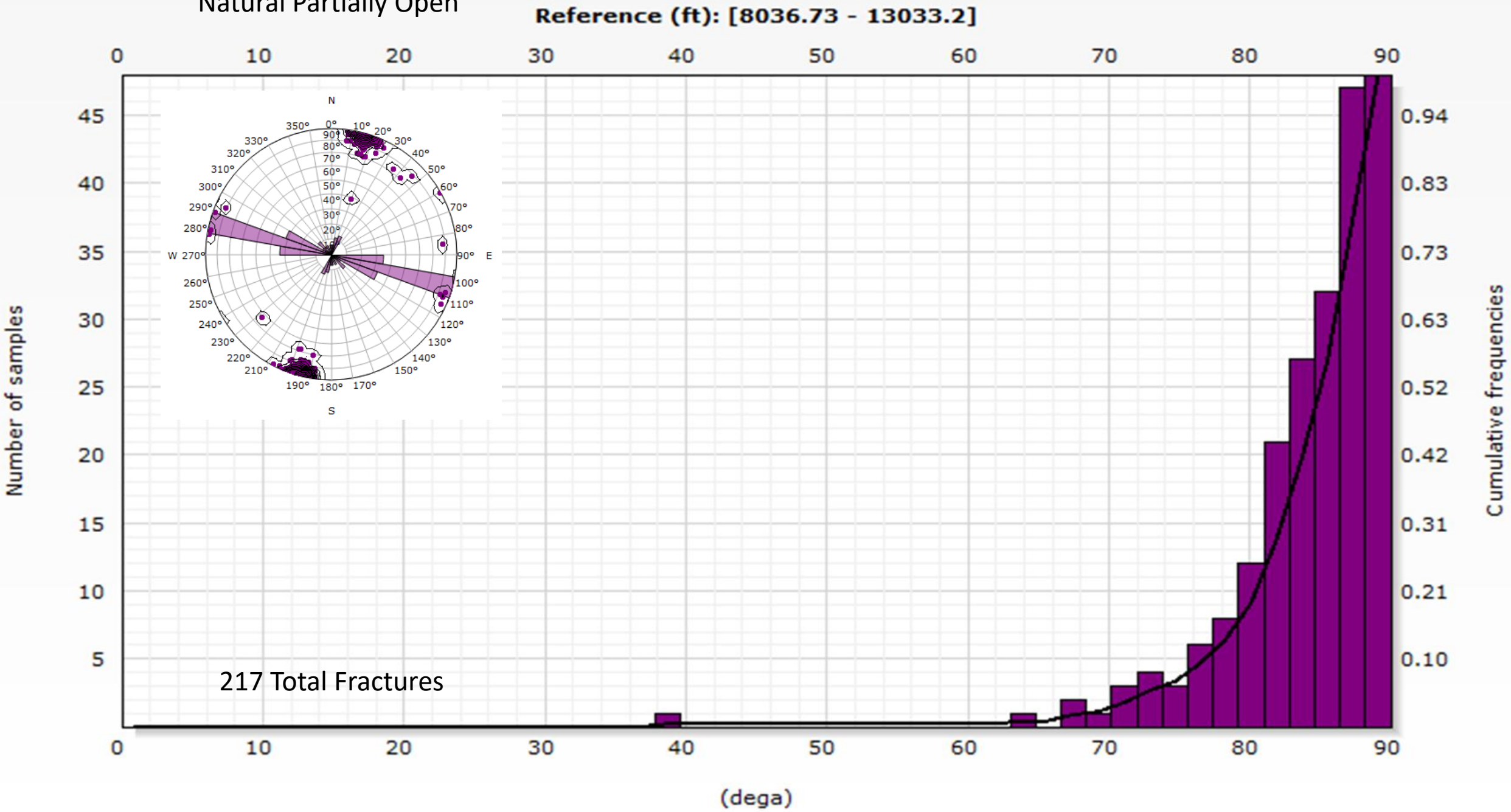


Upper limit: 0.02

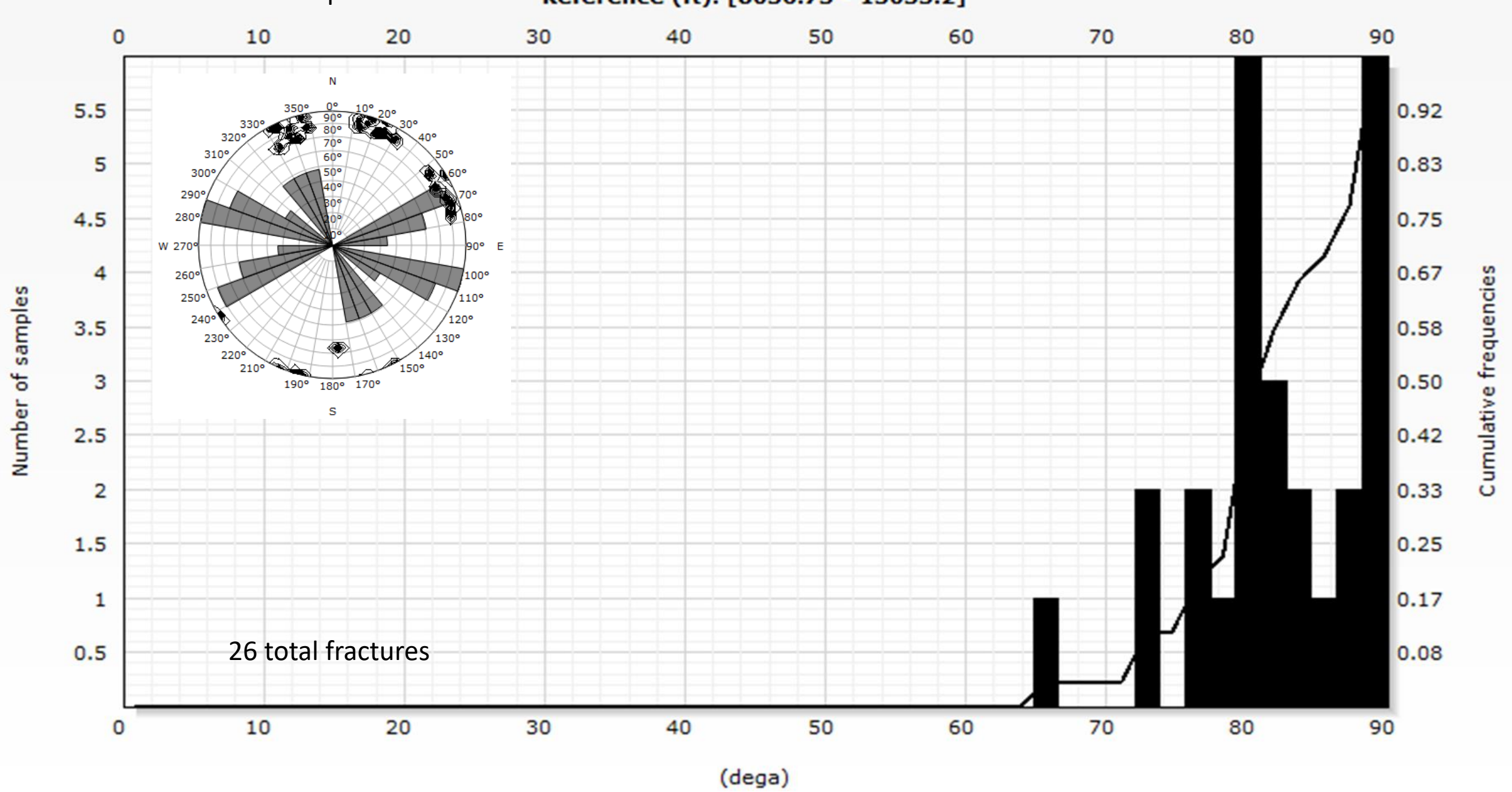


Upper limit: 0.03

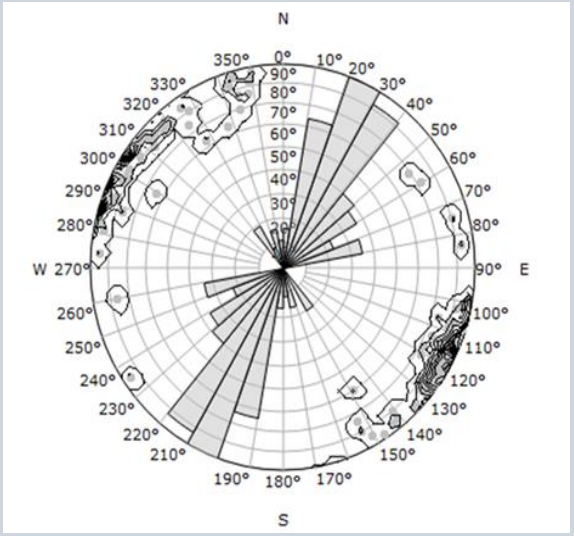
Natural Partially Open



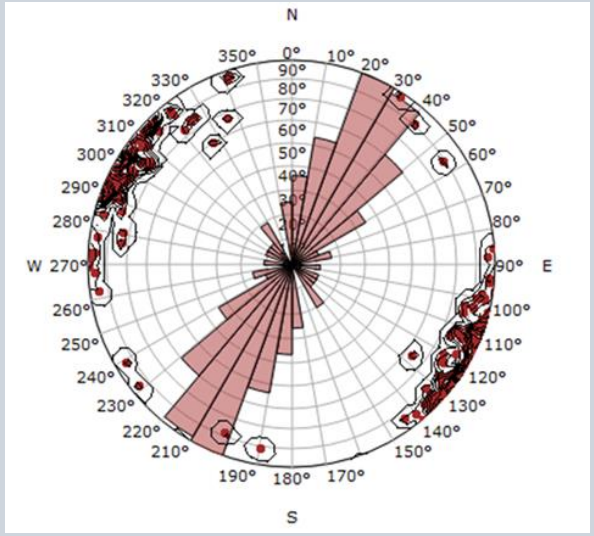
Natural Open Fractures



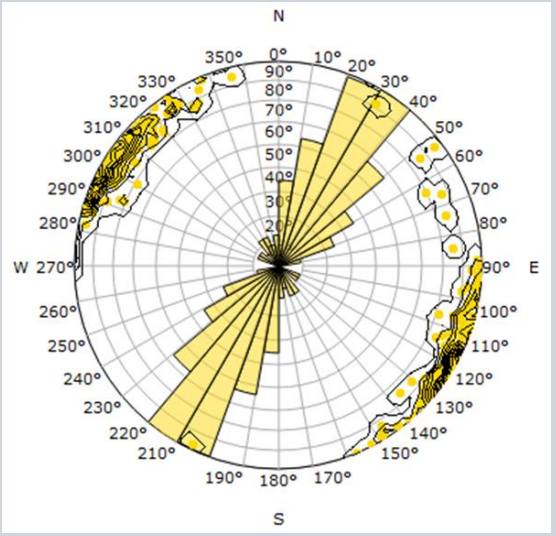
26 total fractures



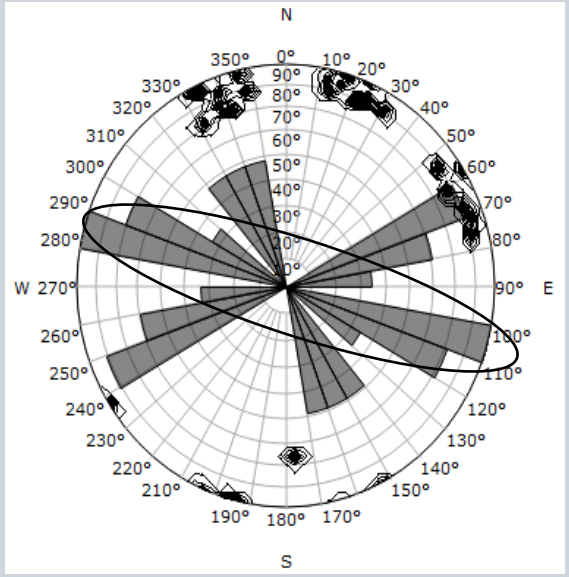
HS Open



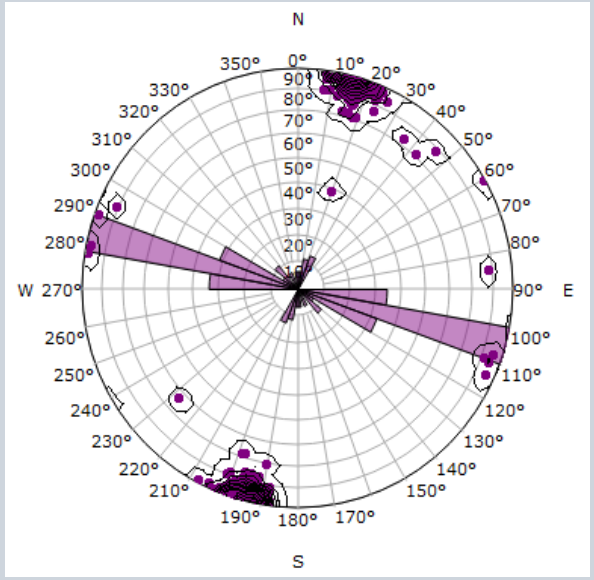
HS Partially Open



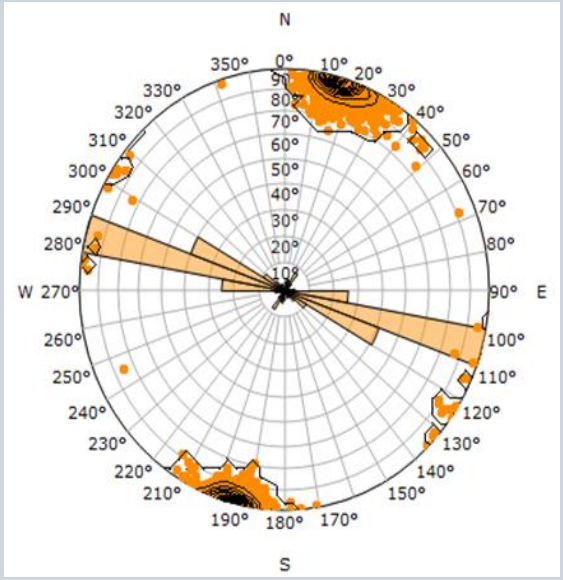
Nat. Cemented F2



Nat. Open



Nat. Partially Open



Nat. Cemented F1

Fracture Set 2, N30E

HS Open = 173
HS Partially Open = 186
Cemented F2 = 285
Total = 644

Fracture Set 1, N70W or 110

Nat. Open = 13
Nat. Partially Open = 217
Cemented F1 = 2,199
Total = 2,429

Comparisons

All Fractures

Set 2:Set 1
= 644/2,429 = 0.26, **1:4 ratio**

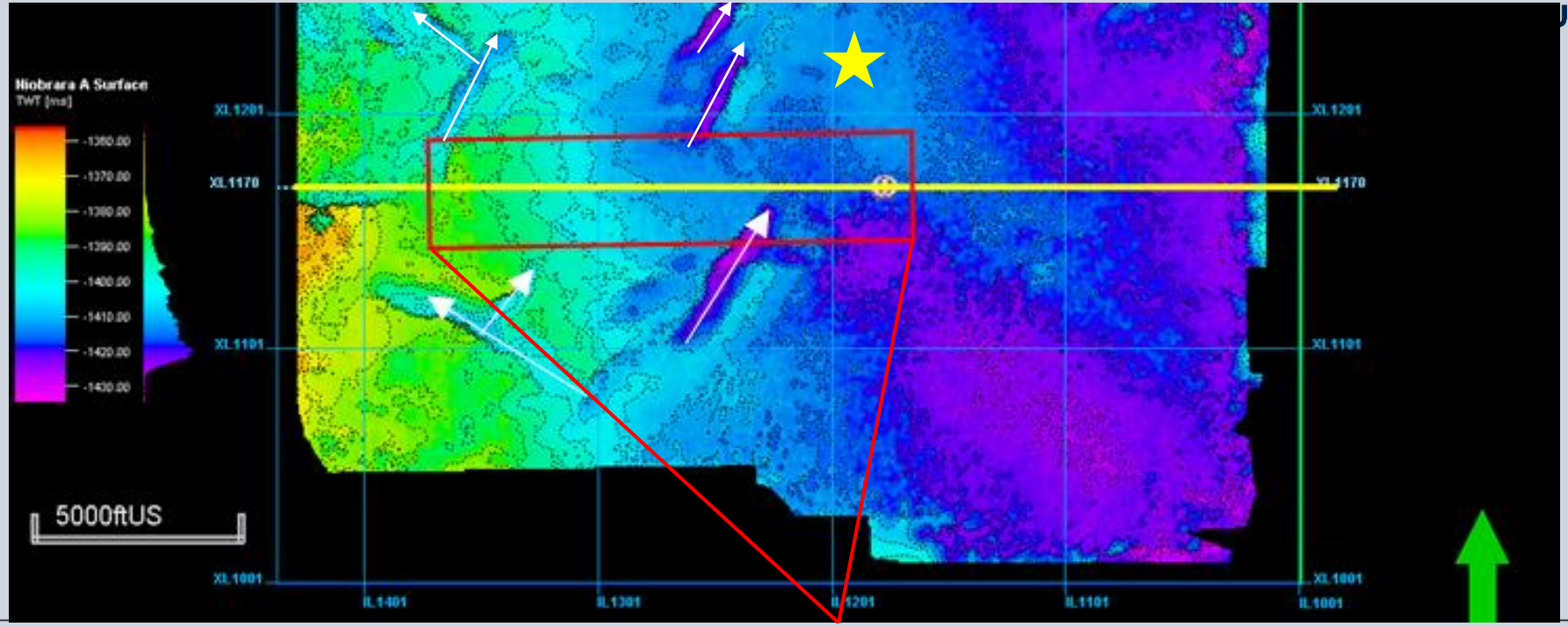
Open & Partially Open Fractures

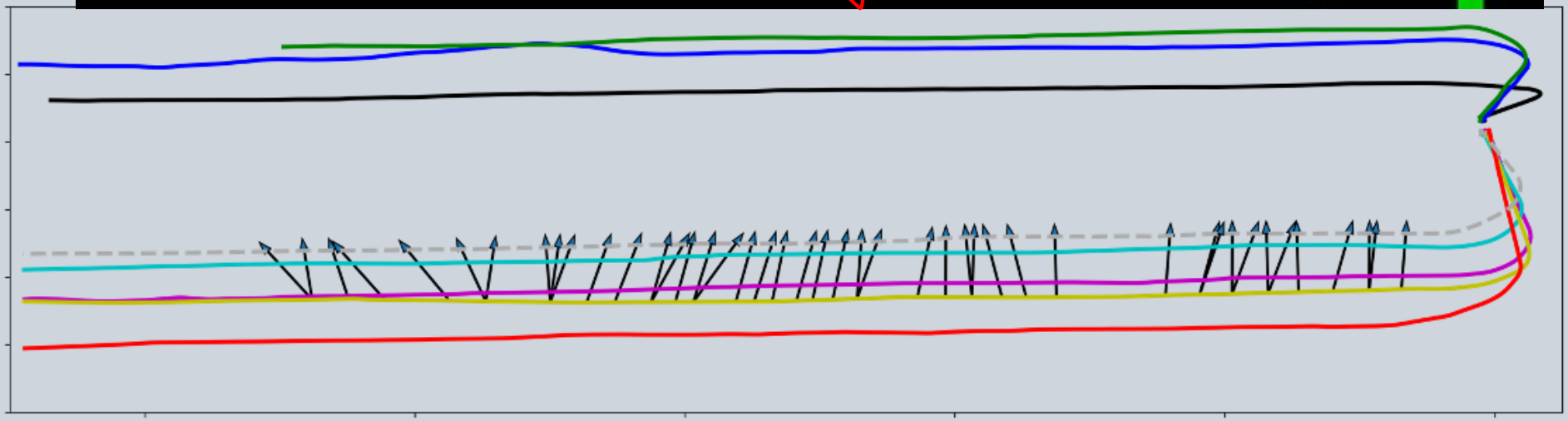
Set 2:Set 1
= 359/230 = 1.5, **3:2 ratio**

Fluid movement more capable in N30E fracture set

Seismic Integration

- Geophysical Characterization of structural and lithological variations using attribute and inversion results.
- Utilizing fiber to analyze fracture velocity and direction.

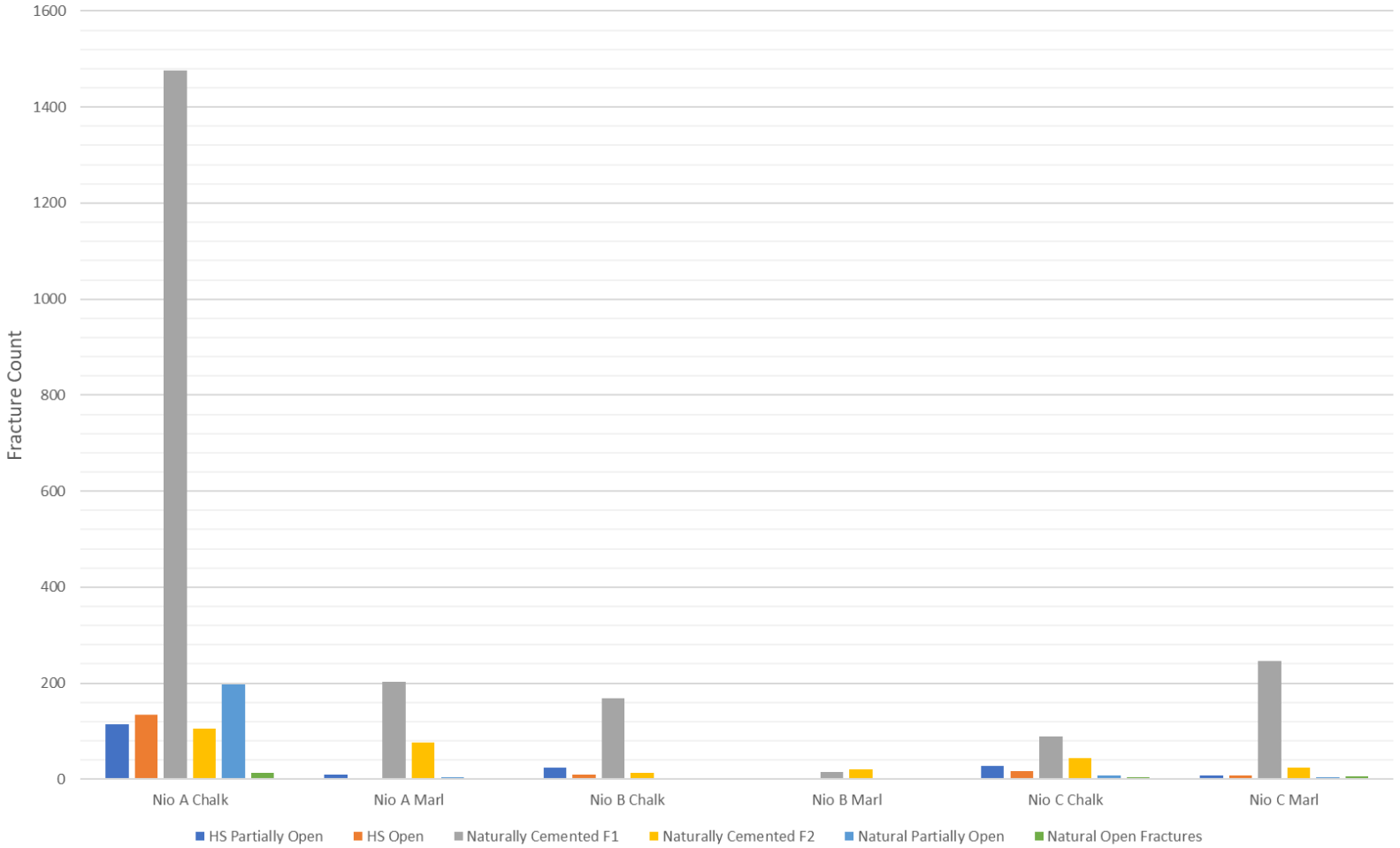




Fracture Density

Formation	# of Fractures	MD (ft)	Fractures/Ft	Fractures/100 ft
Nio. A Chalk	2,042	2,360	0.865	86.52
Nio. A Marl	297	550	0.540	54.00
Nio. B Chalk	220	480	0.458	45.83
Nio. B Marl	42	270	0.155	15.55
Nio. C Chalk	190	580	0.327	32.75
Nio. C Marl	295	826	0.357	35.71
Total	3,086	5,066	0.609	60.91

FMI Fracture Analysis



	HS Partially Open	HS Open	Naturally Cemented F1	Naturally Cemented F2	Natural Partially Open	Natural Open Fractures
Nio A Chalk	114	135	1,477	106	197	13
Nio A Marl	10	2	203	77	4	1
Nio B Chalk	24	9	169	14	2	2
Nio B Marl	2	3	15	20	2	0
Nio C Chalk	28	17	89	44	8	4
Nio C Marl	8	7	246	24	4	6
Total	186	173	2,199	285	217	26

Conclusions

- The geophysics team will integrate the natural fractures with the fault system to understand the hydraulic fracture propagation.
- Fracture sets show a consistency with the faults in the area.
- Fluid movement is more capable with the N30E fracture set which contains the hydraulically stimulated open fractures.
- Stereonets indicate two strike directions. The dominant strike direction being N70W or 110° with 2,429 total fractures. The secondary strike direction being N30E with 644 total fractures.

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