

HALLIBURTON

XRMI Image Log Summary Report

**Lebsack Oil Production Inc.
Bensch #4
Rice County, KS
Sect. 33 Twp. 20S Rge. 10W
API: 15-159-22830**

Date: 11-May-2016
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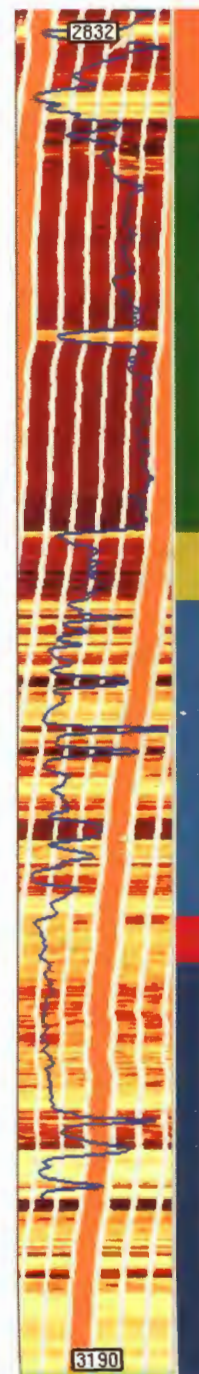


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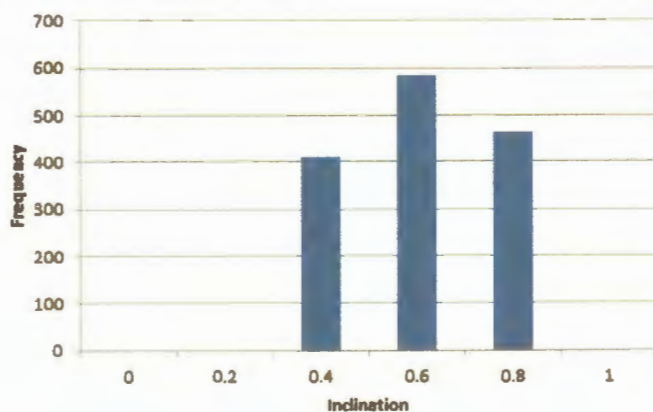
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Log Environment

- Imaged Intervals: 3,190' – 2,832'
 - Image available: 3,190' - 2,393'
- Bit size: 7.875 inches
- Max Deviation: 0.79°



Inclination Statistics

Top Depth:	2,832 ft
Bottom Depth:	3,190 ft
Depth Range:	358 ft
Mean Value:	0.50
Standard Deviation:	0.18
Median Value:	0.49
Minimum Value:	0.205
at depth:	2,963 ft
Maximum Value:	0.791
at depth:	3,116 ft

- Magnetic Declination: 4.485°E True North
- Max Temperature: 113.0 degF @ 3,216.0 ft.
- Mud Sample: Mud Pit
 - Rm: 0.770 ohm-m @ 75.00 degF
 - Rm: 0.53 ohm-m @ BHT (113.0 degF)
 - Rmf: 0.58 ohm-m @ 75.00 degF
 - Rmc: 0.920 ohm-m @ 75.00 degF
- Mud Type: Water Based Mud
 - Density: 8.7 ppg
 - Viscosity: 59.00 s/qt
 - pH: 10.00
 - Fluid Loss: 6.8 cpm
- Lithology: Carbonates, Shale
- Services: ACRT, XRMI, SDLT/DSNT, Microlog

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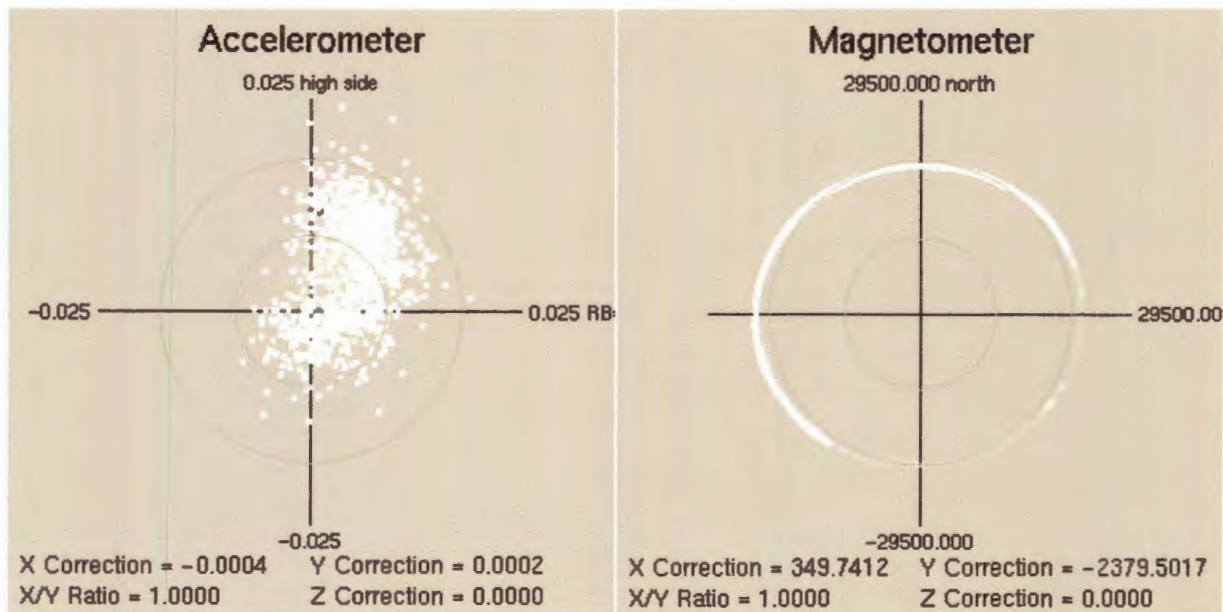
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Raw XRFI Data QC

The cross-plots of the X- and Y-axes of the accelerometer and magnetometer sensors were well centered indicating that the magnetometer readings were correct and required little post-processing corrections.



The AZI1 and RB are tracking each other parallel also indicating that the tool's orientation unit is functioning properly for the main run.

Motivation

At the request of **Lebsack Oil Production Inc.**, the XRMI data recorded by Halliburton Energy Services in the well **Bensch #4, 15-159-22830, Grove Field, Rice County, Kansas**, was interpreted for the intervals **3,190'- 2,832'**. In addition to the standard image processing, manual dip picking was performed interactively on the XRMI image. General stratigraphic, sedimentologic, and structural interpretations were carried out over the reservoir section.

The main objectives of this work were:

- a) Distinguish between stratigraphic and structural dips in the logged formations
- b) Accurately interpret structural dip azimuths and magnitudes in the logged formations
- c) Interpret fracture types, orientations, abundance, frequency within logged interval
- d) Identify present day stress field orientations where sufficient induced fracture and borehole breakout information is present

Image log processing and analysis consisted of:

- speed correction
- depth shift to primary log (triple combo)
- navigation reconstruction
- center re-projection
- static and dynamic equalization
- image enhancement
- borehole geometry/breakout analysis
- manual dip picking and analysis
- manual fracture picking and analysis

Executive Summary

Data Quality

The data quality for the image interval from 3,190 ft to 2,832 ft was great. However, there is no image data for pad 6.

Borehole Stress (2 Drilling Induced Fractures Picked)

Borehole breakout was not seen in the image. A couple of drilling induced fractures were observed in the ENE-WSW strike direction.

Natural Fractures (2 Open, 1 Closed, and 20 Partial Fractures Pick)

A few partial fractures were observed in image intervals. It was difficult to identify natural fractures that cut across the entire borehole. Most of the fractures were observed in the Lower Lansing.

Faulting (0 Faults Picked)

No fault or micro faults were observed in the image interval.

Bedding

The image interval was dominated by planar bedding. Low angle beds were common in the borehole image. Some concern on the direction of very low angle bedding. Also, deformation and sedimentary bedding were also classified and used to identify bedding over 10°. Some of the bedding with a different orientation from the surrounding planar bedding was label as deformation bedding. Most of the sedimentary bedding was only observed in the "F" zone.

Porosity

Porosity was visble in the Lansing and "F" Zone. The porosity appears as brown, light red, and orange color in the static image, expecially in the "F" zone. "F" zone is dominate by intraparticle that has possible connection with other pores. Moldic and intarparticle porosity was observed in the Lansing.

Dip Classification Scheme

The tadpole and fracpole (strike and dip) color and symbol scheme used throughout this report, as well as on the attached log plots, is as follows:

Bedding tadpoles:

	Blue Tadpoles	= Sedimentary Dip
	Red Tadpoles	= Unconformity
	Medium Green Tadpoles	= Planar Laminations/Bed Boundary
	Magenta Tadpoles	= Erosional Surface/Sequence Boundary
	Black Tadpoles	= Formation Top
	Orange Tadpoles	= Slump/Deformation Bedding
	Brown Tadpoles	= Stylolites Bedding

Fracture symbols:

	Blue Fracpoles	= Open Fracture (conductive)
	Red Fracpoles	= Mineralized Fracture (resistive)
	Green Fracpoles	= Fault
	Black Fracpoles	= Induced Fracture
	Pink Fracpoles	= Partial Fracture
	Orange Fracpoles	= Micro Fault
	Teal Fracpoles	= Borehole Breakout

The quality of the pick has either been assigned manually by the interpreter or assessed computationally by the programs Shiva and Autodip™. In either case, the quality can be identified by the fill inside the head of the tadpole or the base of the fracpole. Five quality levels are presented below:

Highest quality  Lowest quality

Highest quality  Lowest quality

Processing***Handpicked Dip*****Principle**

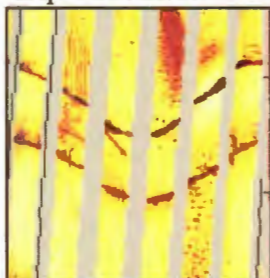
Unlike dip meter processing, which uses only one resistivity curve per pad, manual dip picking from the XRMI/OMRI image can provide good quality dips even when the formation resistivity contrast is poor or when the image quality is degraded. This noticeable improvement, both in dip density and dip quality, is mainly due to the fact that manual picking takes full advantage of both the borehole coverage of the six image tracks and the accuracy of the human eye. Interactive dip picking is performed using a sliding sine wave with which both the amplitude and azimuth can be manually fitted to a planar feature on the XRMI/ORMI image. When the interpreter estimates that the fit between the sine wave and the feature is satisfactory, the true dip is computed. The dips interactively picked on the XRMI/OMRI are then classified into dip sets by the interpreter.

Strike and Dip Orientation Convention

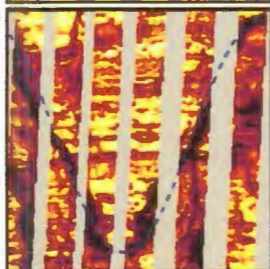
Strike and dip orientations in this report are presented as follows: $5^{\circ} / 300^{\circ}$ (where the first number represents the dip magnitude, and the second represents dip azimuth with respect to true north – corrected for magnetic declination). For strike orientations, the following is used: $090^{\circ} / 270^{\circ}$ (which would be striking E/W). All measurements have been corrected for borehole deviation. Average strike values are calculated using vector addition.

Fracture Definitions

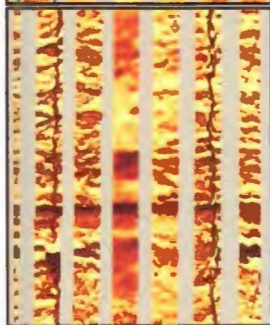
Fractures picked from the image may include the following types of fractures: **natural open fractures**, **natural closed/mineralized fractures**, **faults/microfaults**, and **drilling induced fractures**. The fractures picked on the images are coded according to the colors shown in the “Dip Classification Scheme” section. Fractures were typed with the following criteria.



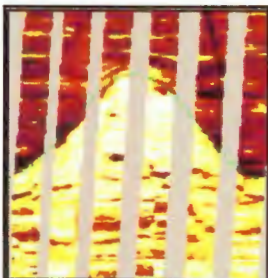
Natural open fractures are conductive as they are usually filled with drilling mud and appear as traces that are darker than the surrounding formation rock. Natural fractures are generally symmetrical allowing a sine wave to be fit to them. Natural fractures often terminate in a single lithology, whereas induced fractures often continue through several lithologies. If the orientation is the same as an induced fracture, then it may not be possible to differentiate between the two types. The examples to the left show some natural open fractures.



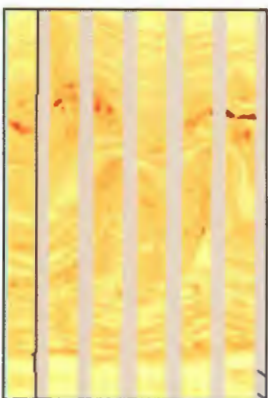
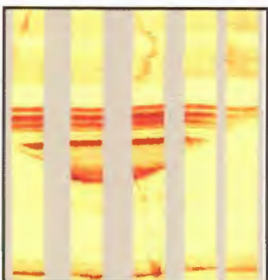
Natural closed/mineralized fractures are those that have been filled by secondary mineralization making them more resistive than open fractures which are usually filled with drilling mud. Closed fractures generally appear as traces that are brighter than the surrounding rock and sometimes demonstrate a “halo” appearance due to the resistivity of the secondary mineralization. Natural closed fractures are generally symmetrical, and a sine wave can be fit to them. The example to the left shows a mineralized fracture.



Induced fractures are generated during different stages of the drilling process. Induced fractures are open fractures, thus will be conductive and show a dark fracture trace. There are different types of induced fractures. Petal and centerline fractures form ahead of the bit while drilling and are caused by the weight of the bit and/or mud pressure. Tensile fractures can form from hydraulic fracturing with mud behind the bit. Since tensile fractures develop after the wellbore was cut they develop in isolation and will be asymmetrical. The example to the left shows a drilling induced tensile centerline fracture. Induced fractures typically do not terminate in a single lithology.



Faults occur when there is displacement along a fracture plane. On image logs, faults can be distinguished where bedding planes are terminated by the fault plane. Often a change in dip azimuth occurs above a fault zone. **Microfaults** are faults that display minor displacement in bedding along the fracture plane. These micro faults can occur above and below a fault zone. The examples to the left show faults.



Slumps are mass movement processes of slope failure, where the rock or unconsolidated material drops along a concave slip surface. Slumps usually move down slope as an intact unit without internal deformation.

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Formation Tops and Zone of Interest Information

Formation Tops	feet
Heebner	2,832'
Douglas	2,861'
Brown Lime	2,969'
Lansing	2,987'
"F" Zone (<i>zone of interest</i>)	3,070'
Lansing	3,082'

For the report, Lansing Formation above "F" zone was label as Upper Lansing and formation below "F" Zone as Lower Lansing.

Imaged Interval for Logs: 3,190' to 2,832'.

**Note: Tops were supplied by the geologist at Lebsack Oil Production Inc.*

Borehole Stress and Condition

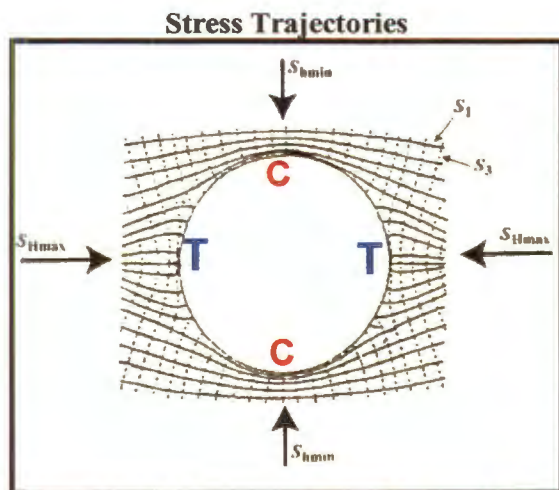
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FRACTURE/STRESS REVIEW



From: Zoback, M. *Reservoir Geomechanics*. 2007

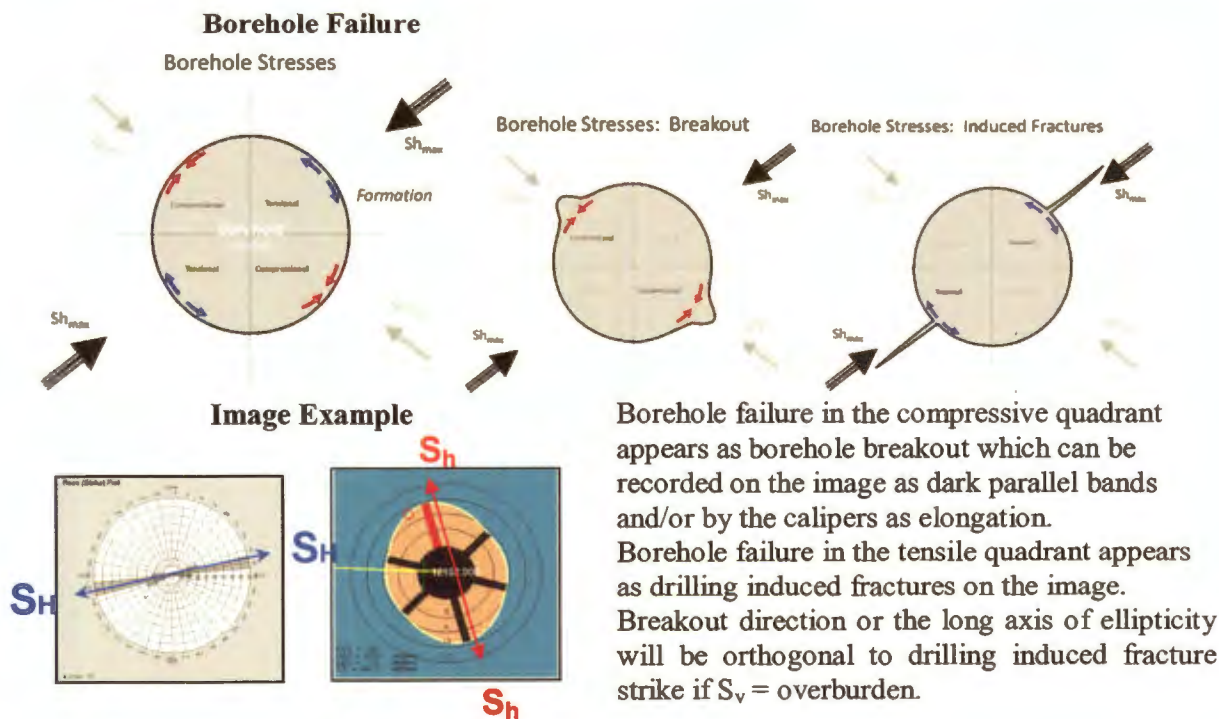
T = Tensile quadrants

C = Compressive quadrants

Principal stress (S_v) occurs along a vector pointing into the page

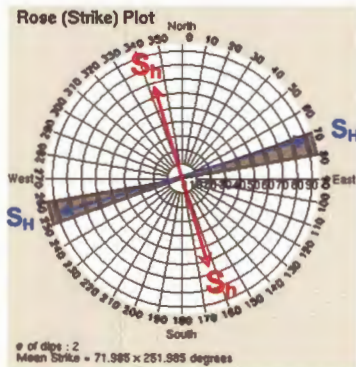
The creation of a cylindrical opening (like a wellbore) causes the stress trajectories to bend in such a way as to be parallel and perpendicular to the wellbore wall. The wellbore stress field reacts in this manner because it is a free surface that cannot sustain shear traction. As the material is removed, it is no longer available to support far field stresses, which can result in stress concentration around the well. The way in which a formation responds to the stress concentration is a function of both the stress field and rock strength. The stress concentration around a vertical well drilled parallel to the principal stress (S_v) reveals information about the present day *in situ* stress when borehole failure occurs (induced fractures and/or breakout).

The bunching up of stresses at the azimuth of S_{hmin} , indicates strongly amplified compressive stress, and spreading out of stress trajectories at S_{Hmax} indicates a decrease in compressive stress.



More information at www.naturalfractures.com

BOREHOLE STRESS CONDITIONS



DRILLING INDUCED FRACTURES

(n = 2)

Average strike: 72° / 252°

≡ Mean S_H orientation

The orientation of the present day in situ state of stress can be determined from the orientations of borehole breakout and drilling induced fractures if the data is reliable and consistent throughout the wellbore. It is important to note that in deviated boreholes the relationship between the drilling induced fractures and the borehole breakout orientation may not be directly correlative to the maximum and minimum horizontal stresses.

The Rose Plot diagram to the left shows the overall strike orientation of **drilling induced fractures** that were observed/interpreted in the logged interval. The induced fractures provide evidence to estimate the orientation of the maximum horizontal stress direction or S_H . The orientation of the S_h (minimum horizontal stress) on the polar plot is from the orientation above and is orthogonal to the strike of the drilling induced fractures.

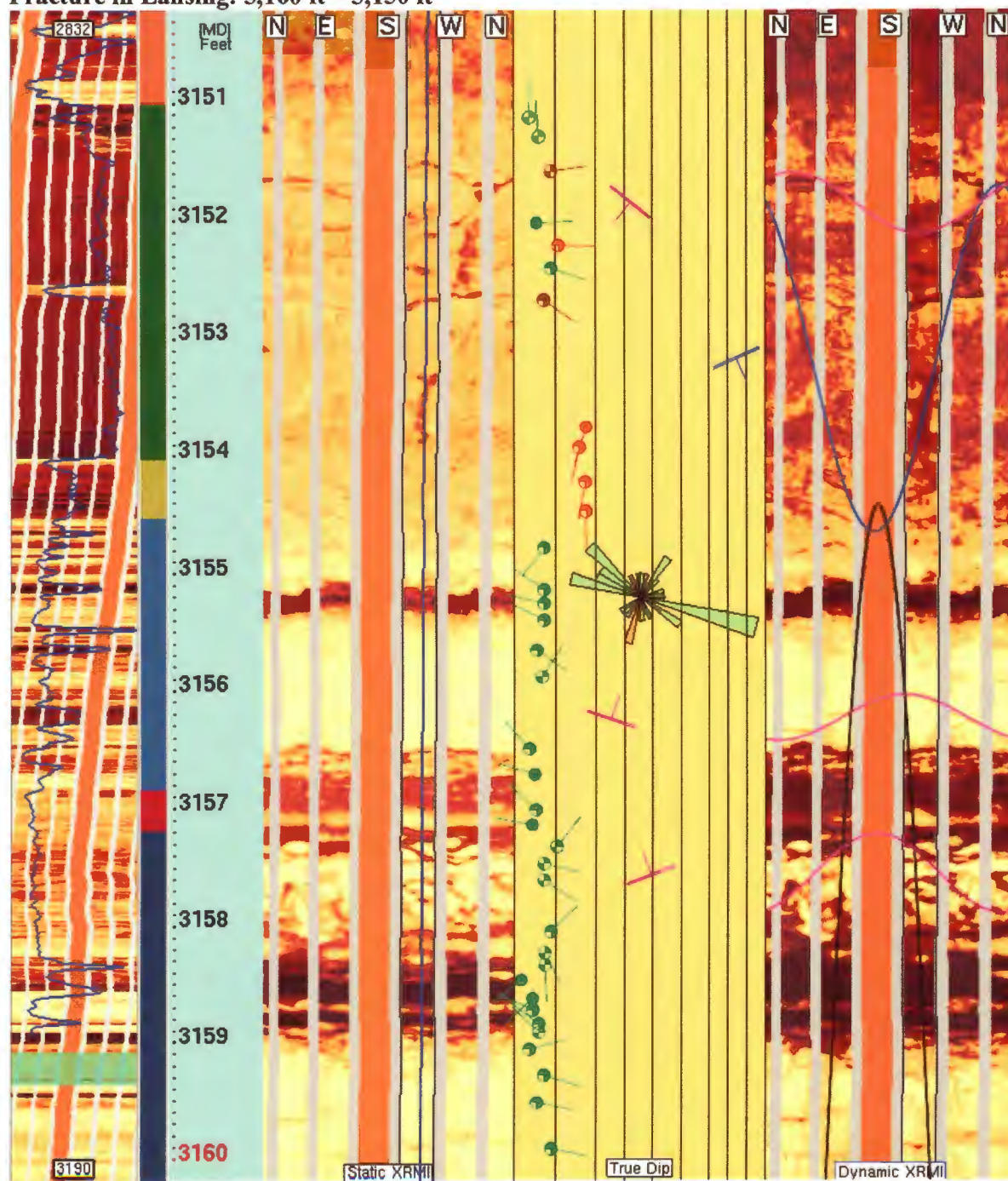
Image Log Examples

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Fracture in Lansing: 3,160 ft – 3,150 ft

Above figure is a closeup of the static and dynamic image in the Lansing. A few low-quality fractures were observed. Identifying natural open and closed fractures was difficult. Partial fractures appear in three pads or less and shown with pick tadpoles. Mostly natural fractures were found in the Lansing Formation.

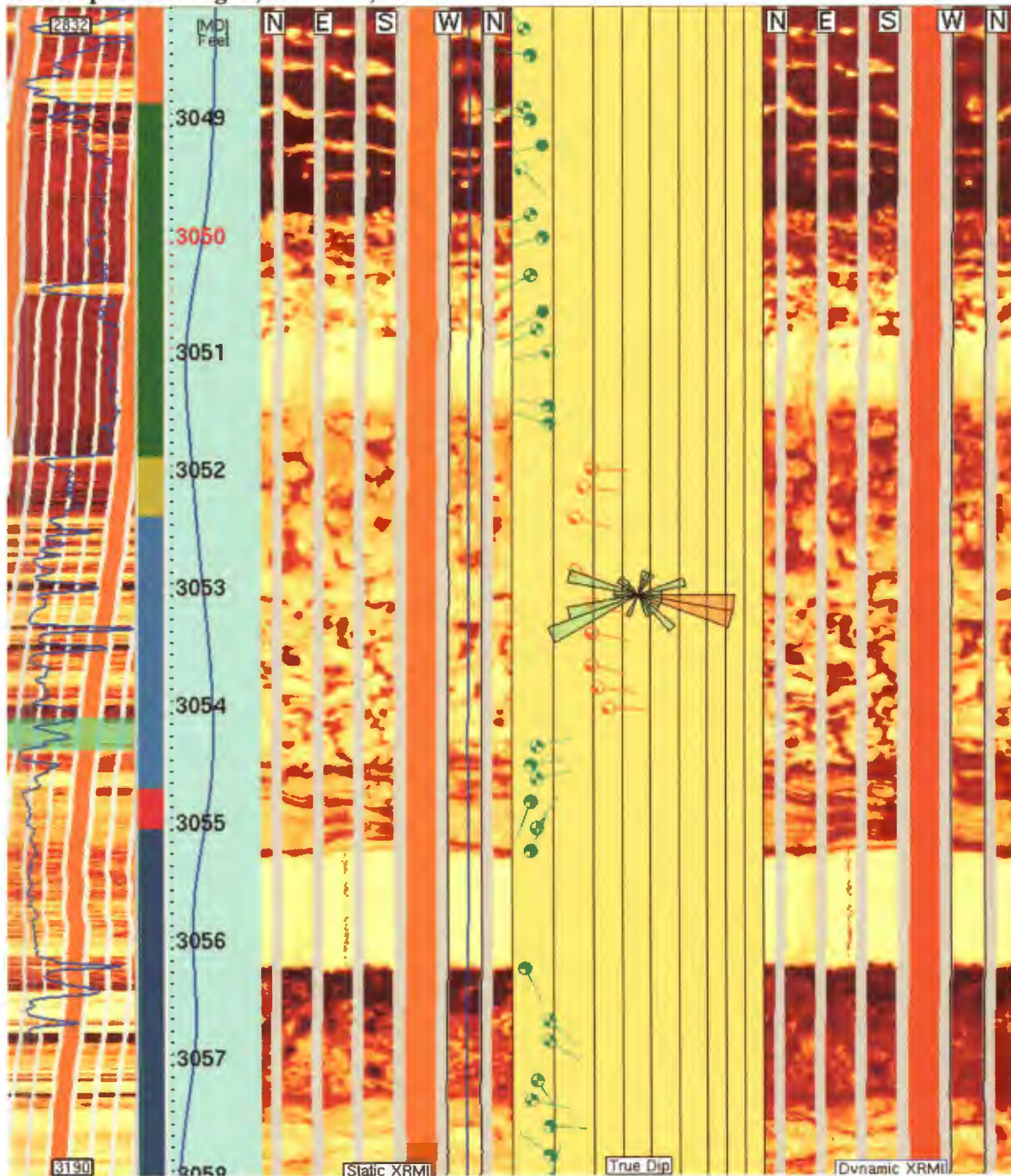
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Close-up of Lansing: 3,057 ft. – 3,047 ft



Above figure is a closeup of the static and dynamic image in the Lansing. The limestone around 3055.8 ft and 3,051.2 ft appears to fossiliferous limestone whereas the unit between 3,054.5 ft to 3,051.4 ft was observed as limestone with moldic porosity. At 3,055 ft is a dissolution feature.

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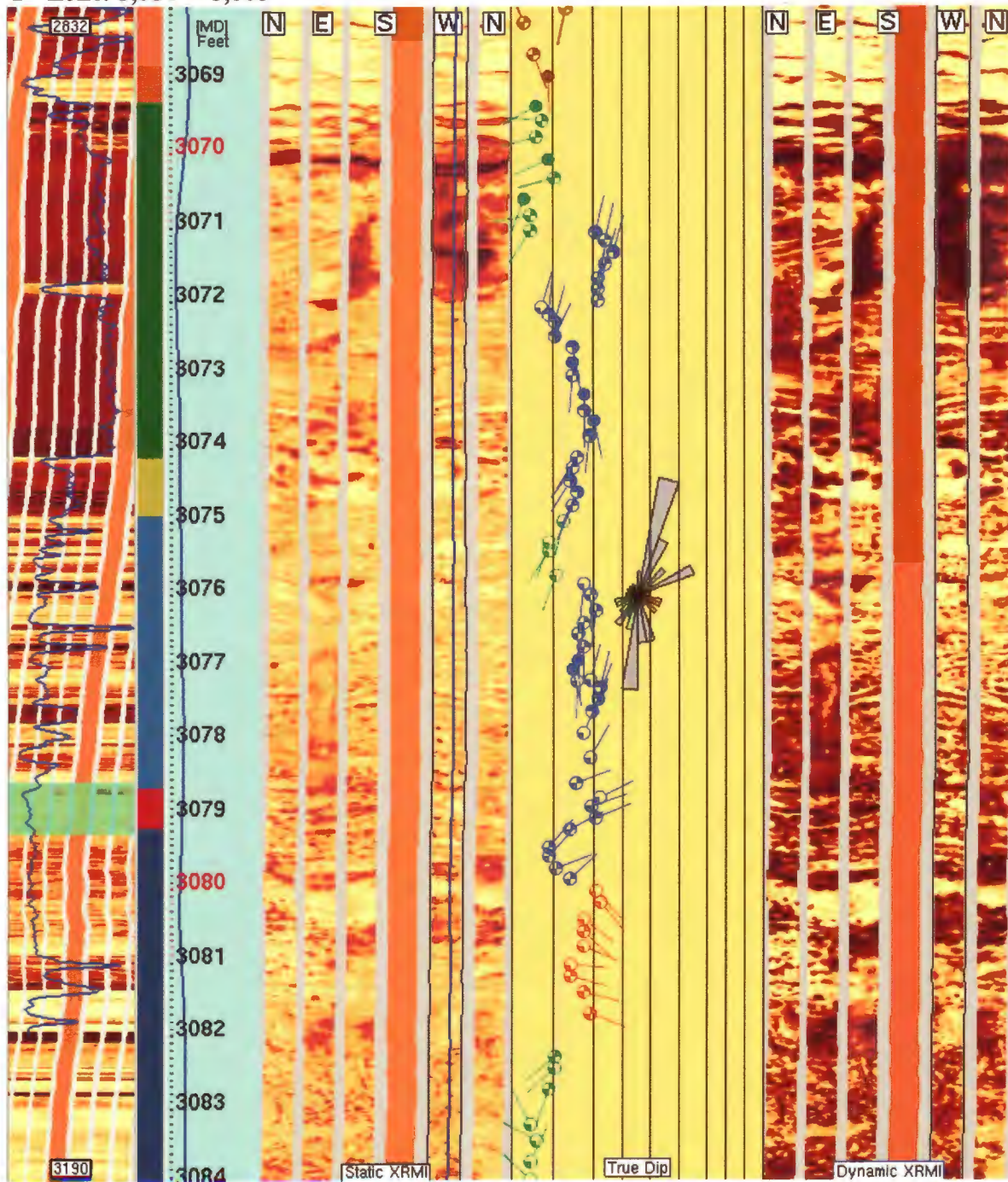
"F" Zone: 3,084' – 3,068'

Image sample of the static and dynamic image of "F" Zone with ~2 ft above and below the zone. The "F" Zone occurs from 3,082 ft to 3,070 ft. Below the "F" Zone is low-quality planar bedding follow-up deformation bedding, whereas above "F" zone is limestone with stylolite features. The "F" zones consist of crossbedding oolitic limestone and label with blue tadpoles. The dark browns and orange colors suggest porosity.

Continuous Image and Dip Azimuth Plots

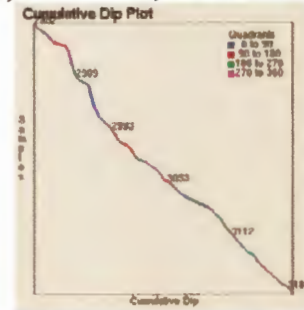
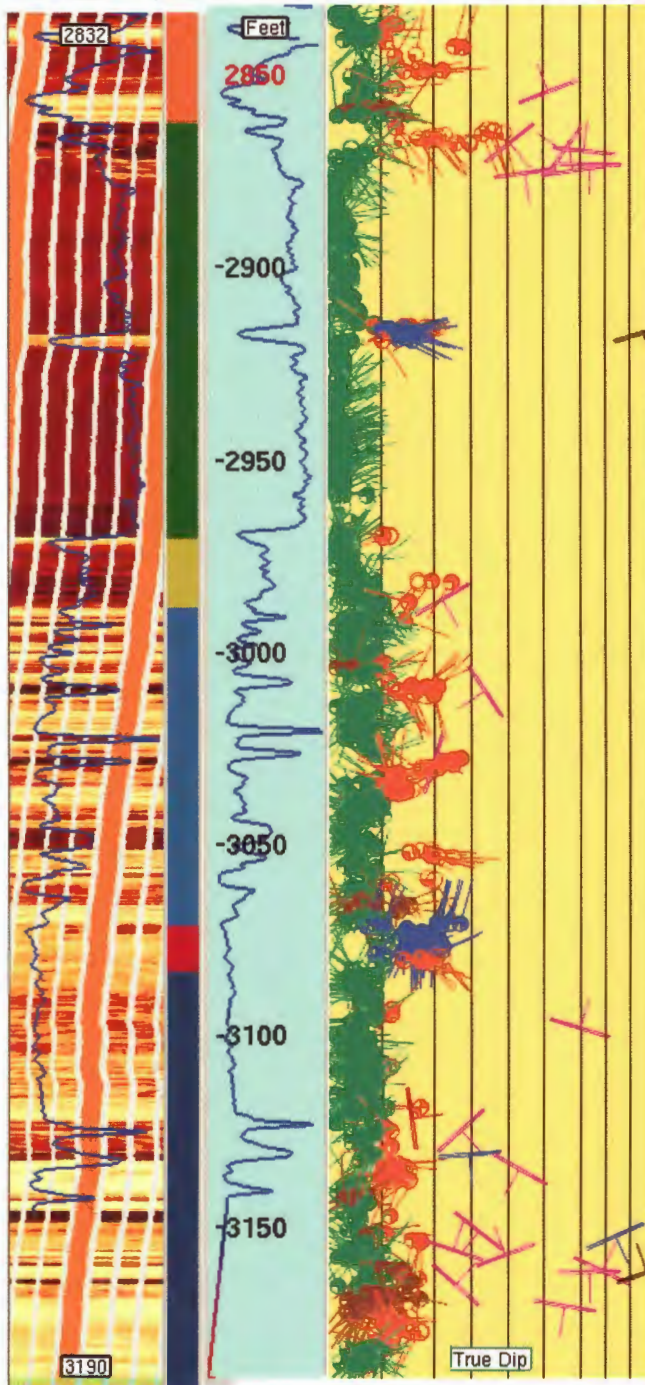
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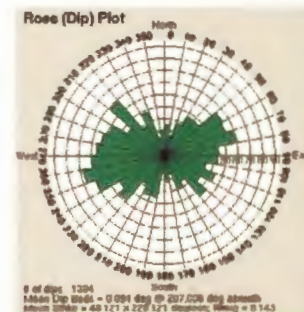
CONTINUOUS IMAGE AND CUMULATIVE DIP PLOT 11,600 ft. – 10,300 ft



The cumulative dip plot pictured above plots the average dip magnitude vs depth. A decrease in slope represents an increase in the average bedding dip magnitude.



The dip-azimuth plot above shows the general dip direction. The beds had slightly trending to the ENE-WSW direction.



Bedding
(n = 1304)
Average strike: 0.9°/208°

Continuous image and cumulative dip plot showing all manually picked beds and fractures within the logged interval of the Bensch #4 well (3,190' – 2,832'). The continuous plot is a small scale view of the logged interval and provides a way to view the occurrence and distribution of the different types of bedding and fractures that were interpreted. The cumulative dip plot method provides a way to analyze dip angle as a function of depth and is used for determining/detecting faults and unconformable surfaces by deflection points in the bedding dip data. Please see the more detailed summary bedding and fracture data and formation statistics on the following pages.

Fracture Typing, Frequency, and Orientation

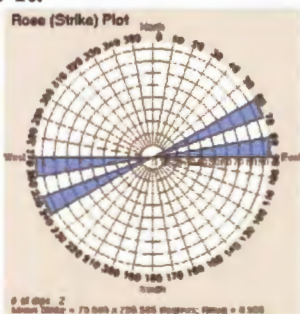
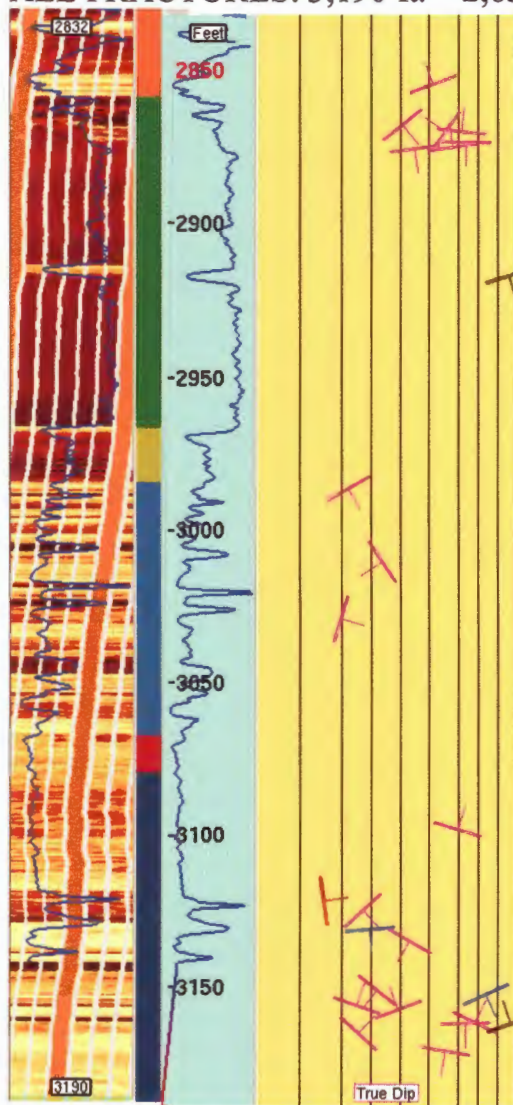
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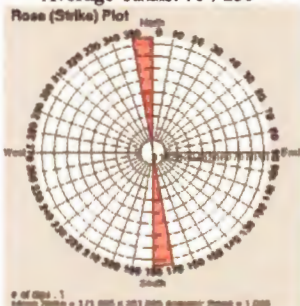
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ALL FRACTURES: 3,190 ft. – 2,832 ft.



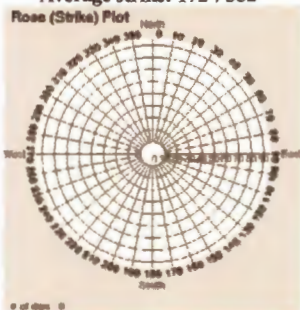
NATURAL OPEN FRACTURES
(n=2)

Average strike: 76°/256°



CLOSED FRACTURES
(n=1)

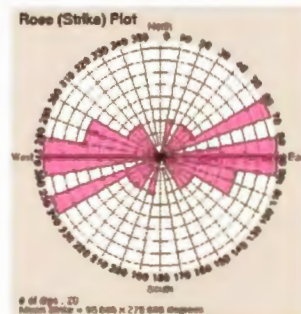
Average strike: 172°/352°



FAULT

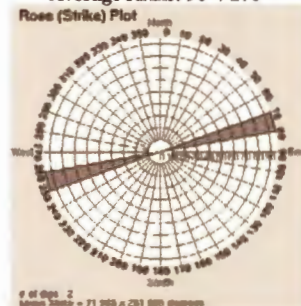
(n=0)

Average strike: 0°/0°



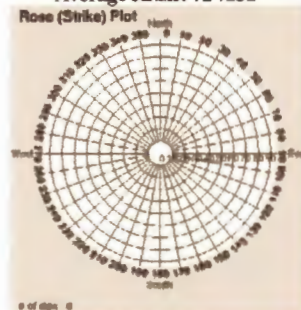
PARTIAL FRACTURES
(n=20)

Average strike: 96°/276°



INDUCED FRACTURES
(n=2)

Average strike: 72°/252°



MICRO FAULT

(n=0)

Average strike: 0°/0°

Continuous image showing the orientations and distributions of **natural open**, **mineralized closed**, **partial**, and **drilling-induced** fractures as well as **faults** and **micro faults** that were observed in the logged interval of the **Bensch #4** well. Rose plots to the right show the overall orientation of all fractures types and average strikes within this interval.

Formation Statistics

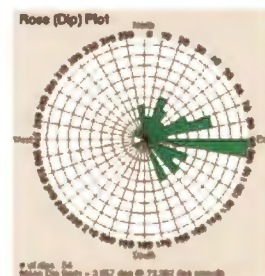
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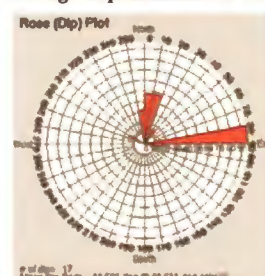
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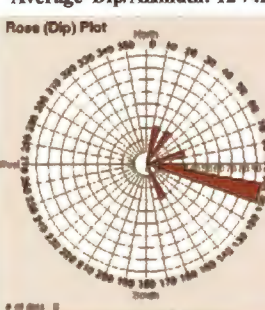
Heebner: 2,861 ft. – 2,832 ft.



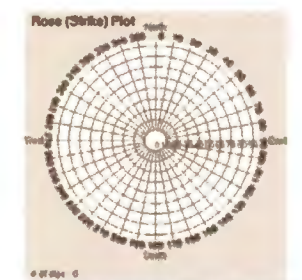
Average Dip/Azimuth: 3.0°/ 73°



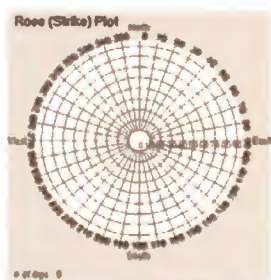
Average Dip/Azimuth: 12°/42°



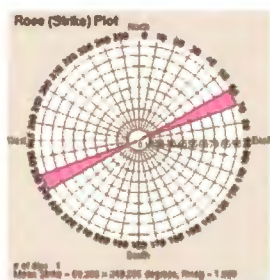
Average strike: 6.4°/88°



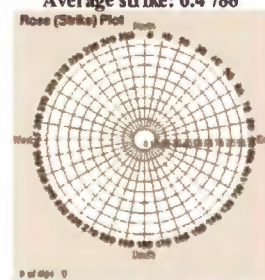
Average strike: 0°/0°



Average strike: 0°/0°



Average strike: 69°/ 249°



Average strike: 0°/0°

Heebner was observed as limestone and shale beds. Some deformation bedding was observed in the shale bed.

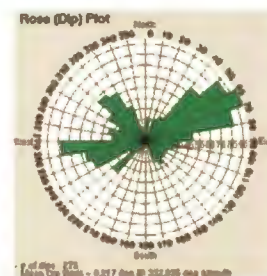
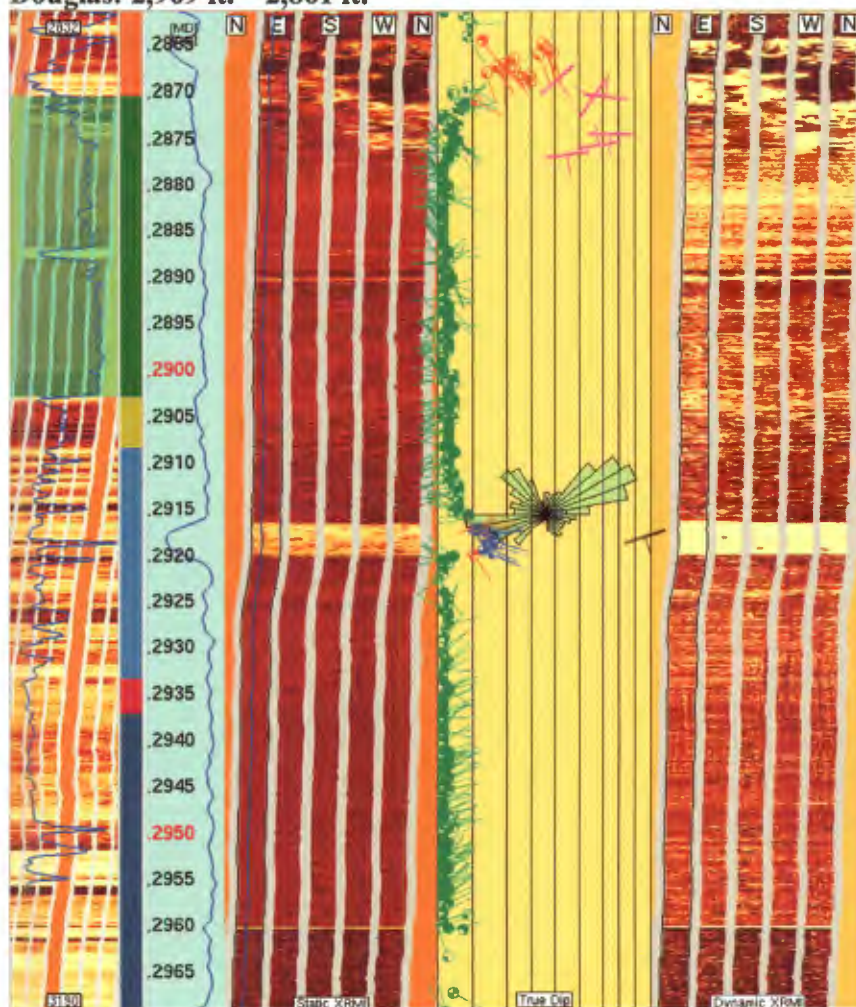
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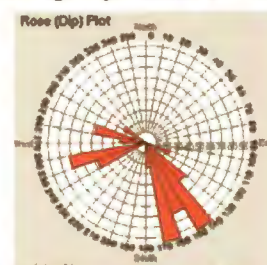
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Douglas: 2,969 ft. – 2,861 ft.



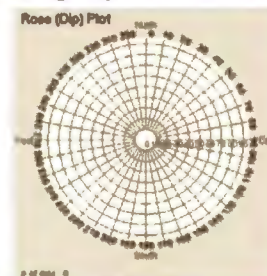
Bedding
(n = 275)

Average Dip/Azimuth: 0.2°/ 332°



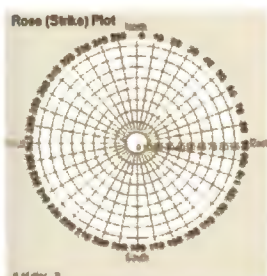
DEFORMATION BEDDING
(n = 24)

Average Dip/Azimuth: 14°/ 186°



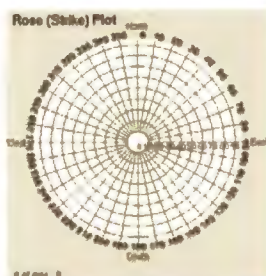
STYLOLITE
(n = 0)

Average Dip/Azimuth: 0°/0°



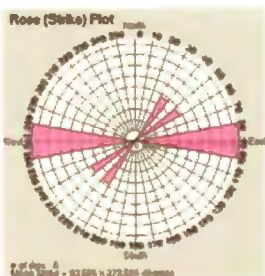
NATURAL OPEN FRACTURES
(n = 0)

Average strike: 0°/ 0°



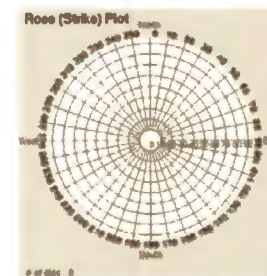
CLOSED FRACTURES
(n = 0)

Average strike: 0°/ 0°



PARTIAL FRACTURES
(n = 6)

Average strike: 94° / 275°



INDUCED FRACTURES
(n = 1)

Average strike: 73°/ 253°

The Douglas image interval was observed as planar shale beds. Based currently observed it appears from 2,965 ft to 2,920 ft appear dipping to the northeast. Then about 5 ft of limestone was deposited with a dip between 10° and 20° in the east direction. The shale above the limestone appears have a west dip direction. However, there may be some discrepancy with very low angle bedding. Deformation bedding was observed in the top 10 ft of the Douglas.

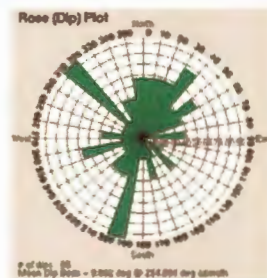
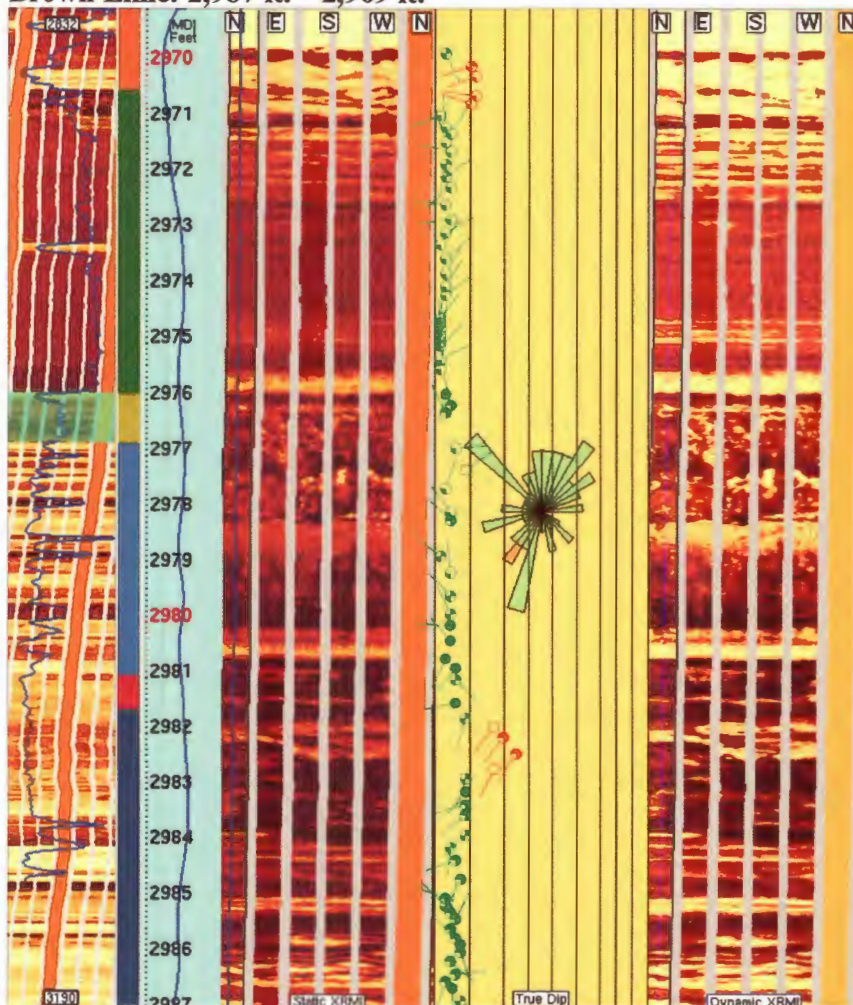
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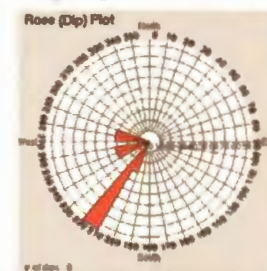
5/16/2016

Brown Lime: 2,987 ft. – 2,969 ft.



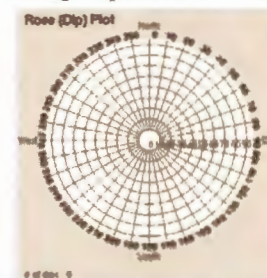
Bedding
(n = 65)

Average Dip/Azimuth: 0.6°/254°



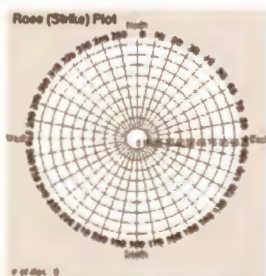
DEFORMATION BEDDING
(n = 8)

Average Dip/Azimuth: 14°/232°



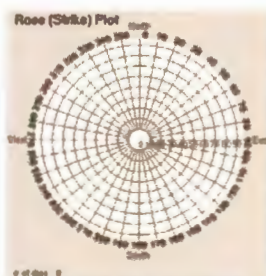
STYLOLITE
(n = 0)

Average Dip/Azimuth: 0°/0°



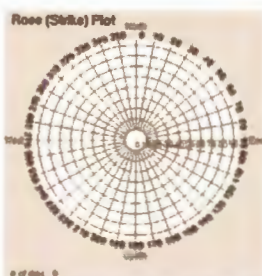
NATURAL OPEN FRACTURES
(n = 0)

Average strike: 0°/0°



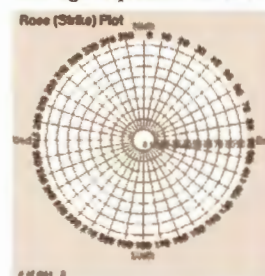
CLOSED FRACTURES
(n = 0)

Average strike: 0°/0°



PARTIAL FRACTURES
(n = 0)

Average strike: 0°/0°



INDUCED FRACTURES
(n = 0)

Average strike: 0°/0°

Image of Brown Lime comprised low angle limestone and shale beds that average around 0.6°. The beds were observed at very low angles, so there can be some discrepancy with very low angle bedding.

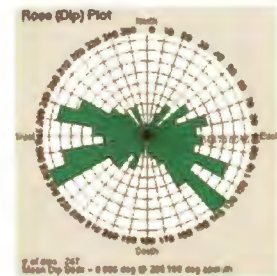
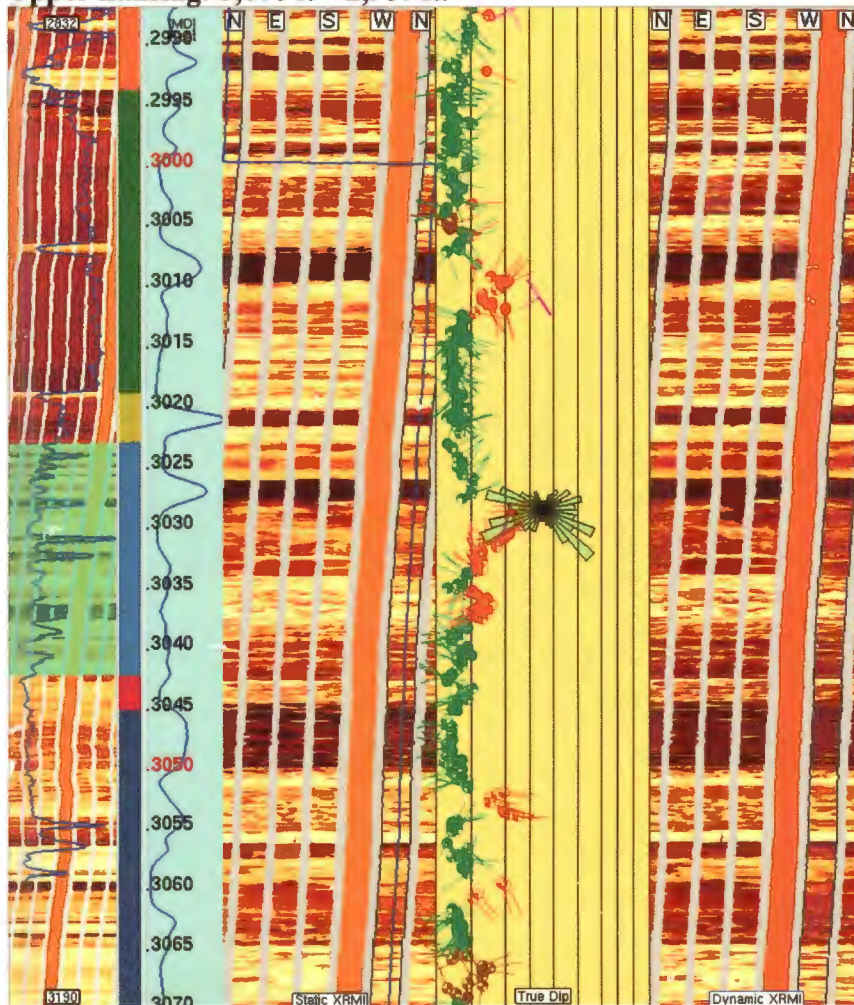
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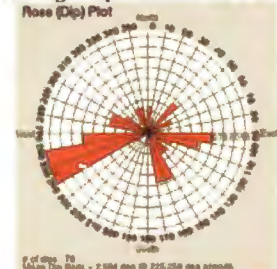
5/16/2016

Upper Lansing: 3,070 ft – 2,987 ft.



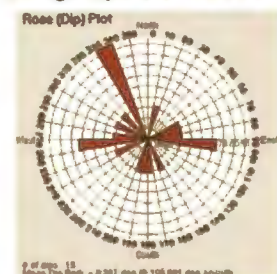
Bedding
(n = 247)

Average Dip/Azimuth: 0.8°/ 206°



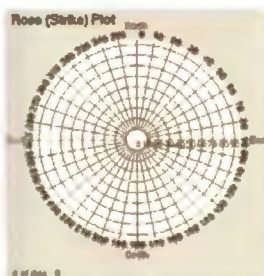
DEFORMATION BEDDING
(n = 70)

Average Dip/Azimuth: 2.6°/ 225°



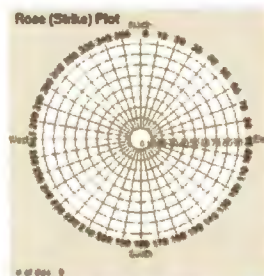
STYLOLITE
(n = 19)

Average Dip/Azimuth: 0.3°/107°



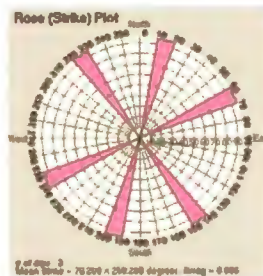
NATURAL OPEN FRACTURES
(n = 0)

Average strike: 0°/ 0°



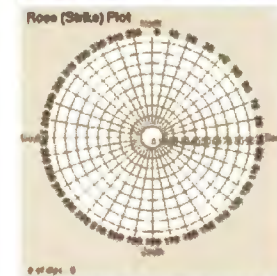
CLOSED FRACTURES
(n = 0)

Average strike: 0°/ 0°



PARTIAL FRACTURES
(n = 3)

Average strike: 70° / 250°



INDUCED FRACTURES
(n = 0)

Average strike: 0°/ 0°

The upper Lansing was observed as limestone and shale beds. The possible bimodal direction, but there may be some discrepancy with very low angle bedding. Some limestone beds are interbedded with clay or contain stylolite features. Few limestone beds appear to contain several fossil fragments. Few partial fractures were observed.

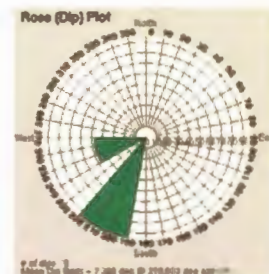
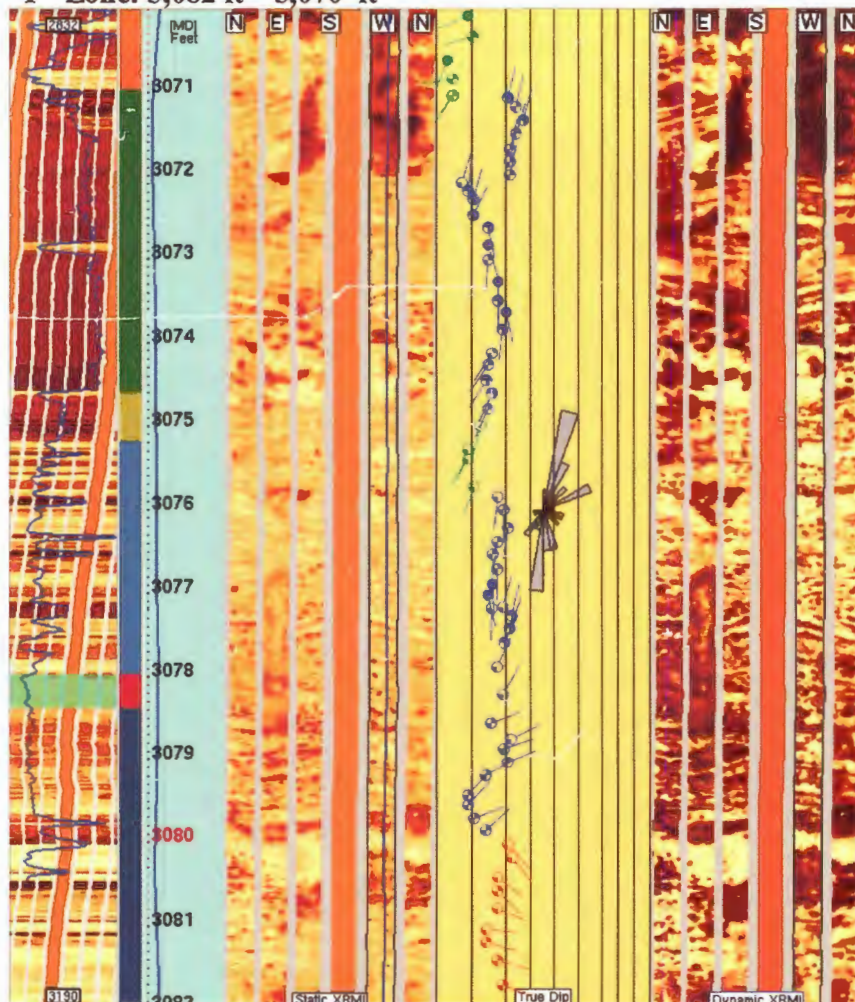
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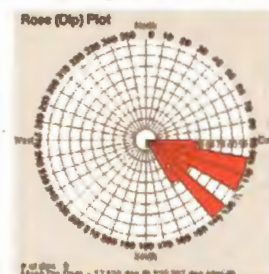
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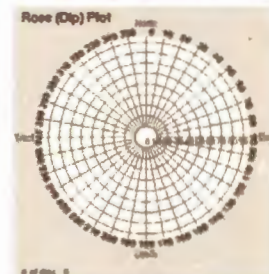
"F" Zone: 3,082 ft – 3,070 ft



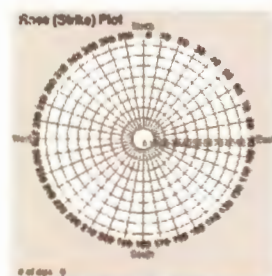
BEDDING
(n=9)
Average Dip/Azimuth: 7.3°/218°



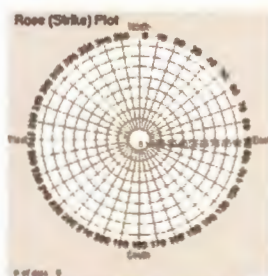
DEFORMATION BEDDING
(n=9)
Average Dip/Azimuth: 17°/120°



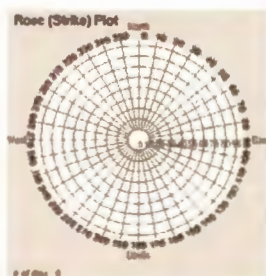
STYLOLITE
(n=0)
Average Dip/Azimuth: 0°/0°



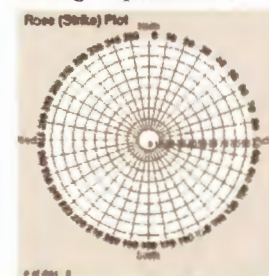
NATURAL OPEN FRACTURES
(n=0)
Average strike: 0°/0°



CLOSED FRACTURES
(n=0)
Average strike: 0°/0°



PARTIAL FRACTURES
(n=0)
Average strike: 0°/0°



INDUCED FRACTURES
(n=0)
Average strike: 0°/0°

Image interval of the "F" zone which was considered as the zone of interest. There was reworking occurred for this zone. The oolitic facies was observed for the sedimentary bedding indicated by the blue tadpoles. The dark conductivity spots are possible mud filled porosity. The orange color of the static image suggests porosity may be interconnected.

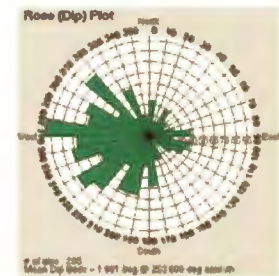
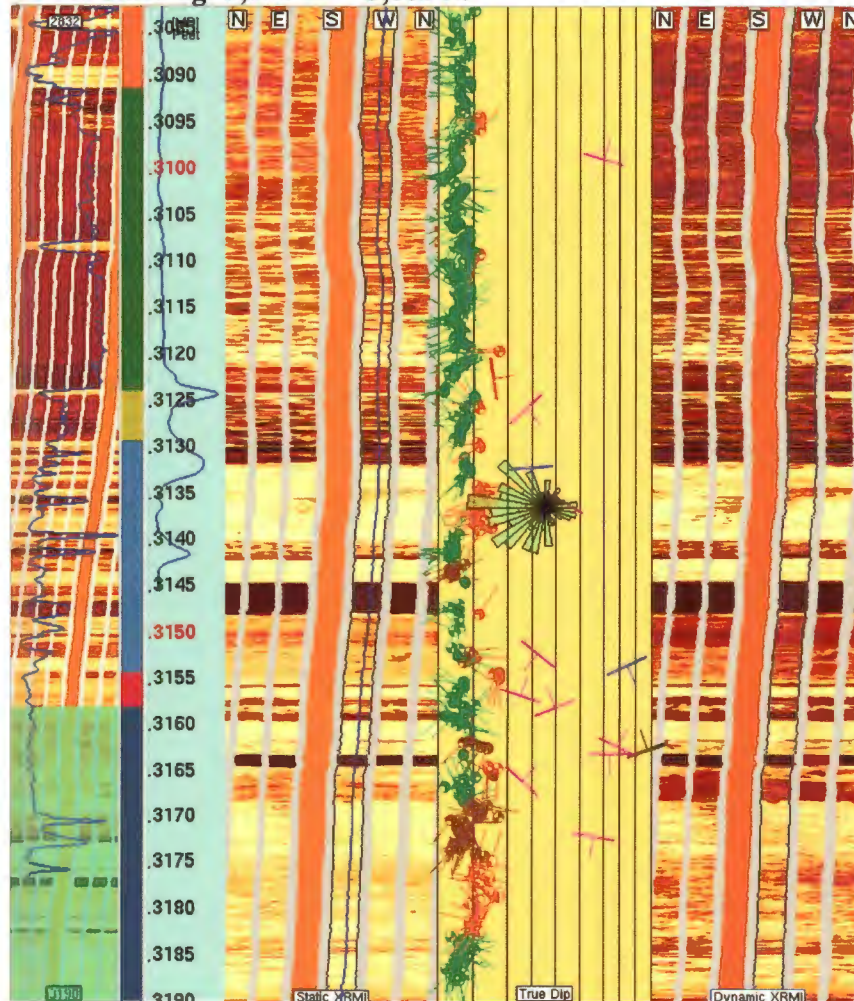
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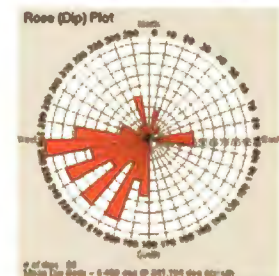
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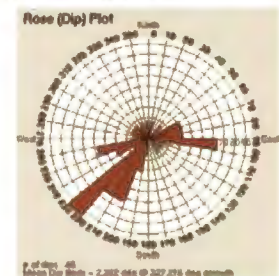
Lower Lansing: 3,190 ft. – 3,082 ft.



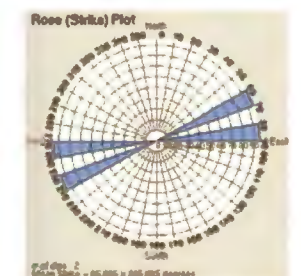
Average Dip/Azimuth: 2.0° / 253°



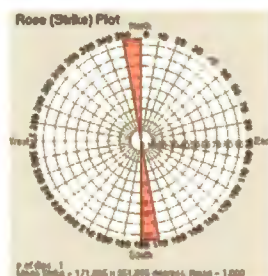
Average Dip/Azimuth: 6.4° / 241°



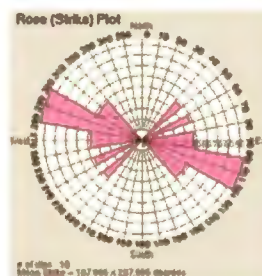
Average Dip/Azimuth: 2.3° / 227°



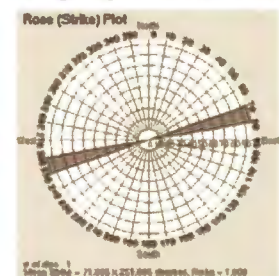
Average strike: 65° / 246°



Average strike: 172° / 351°



Average strike: 107° / 288°



Average strike: 71° / 251°

The Lower Lansing was observed as limestone and shale beds. From 3,130 to 3,082 ft appears limestone with interbedded shales. Planar and deformation bedding along with stylolite was observed dipping to the southeast direction. Natural conductive, resistive, and partial fractures were seen in slightly random in directions. Fractures were mostly seen in the Lower Lansing.

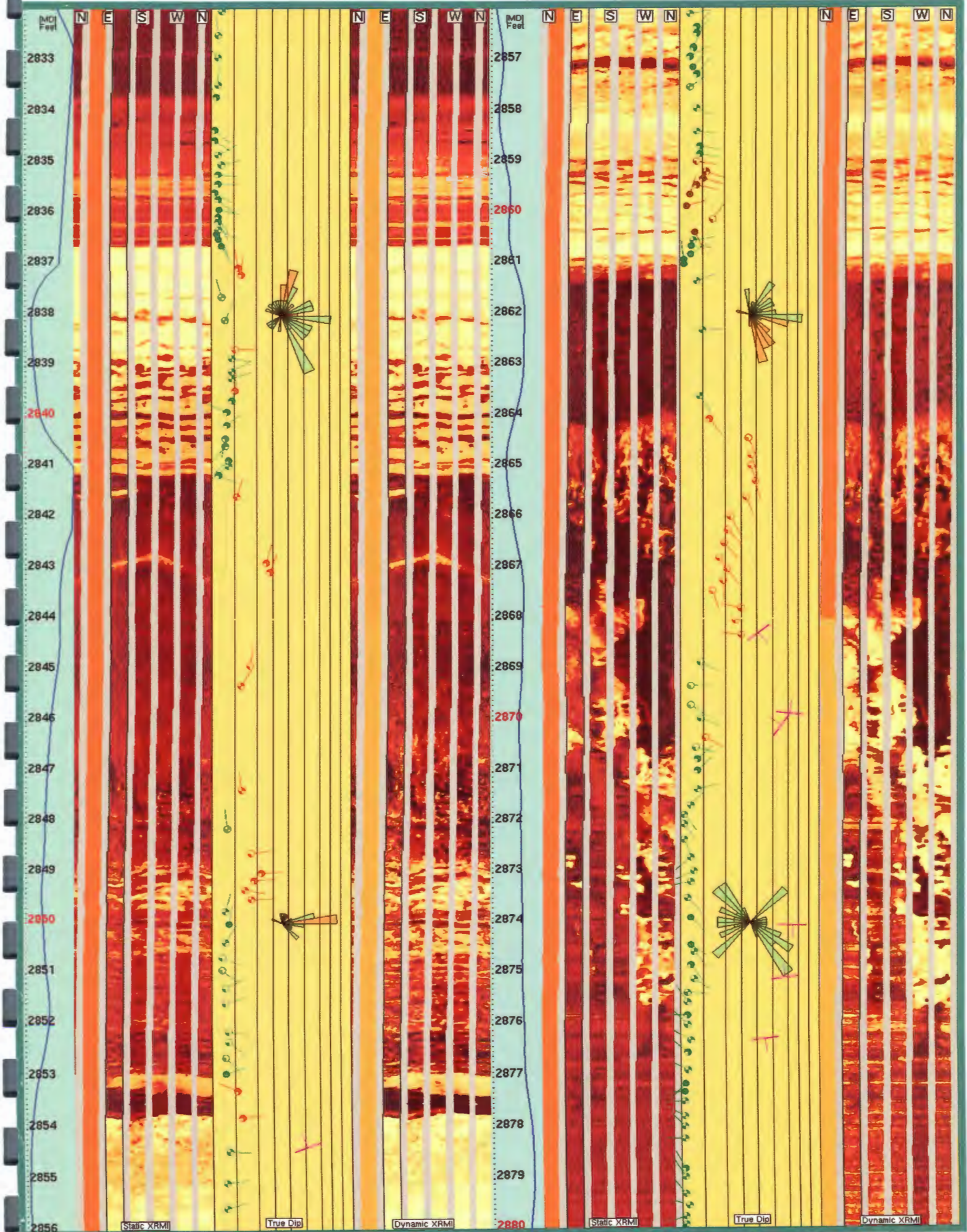
Disclaimer*DISCLAIMER*

Halliburton does not guarantee the accuracy of any interpretation of the log data, conversion of log data to physical rock properties or recommendations which may be given by Halliburton personnel or which appear on the log or in any other form. Any user of such data, interpretations, conversions, or recommendations agrees that Halliburton is not responsible except where due to gross negligence or willful misconduct, for any loss, damages, or expenses resulting from the use thereof.

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Core boxes

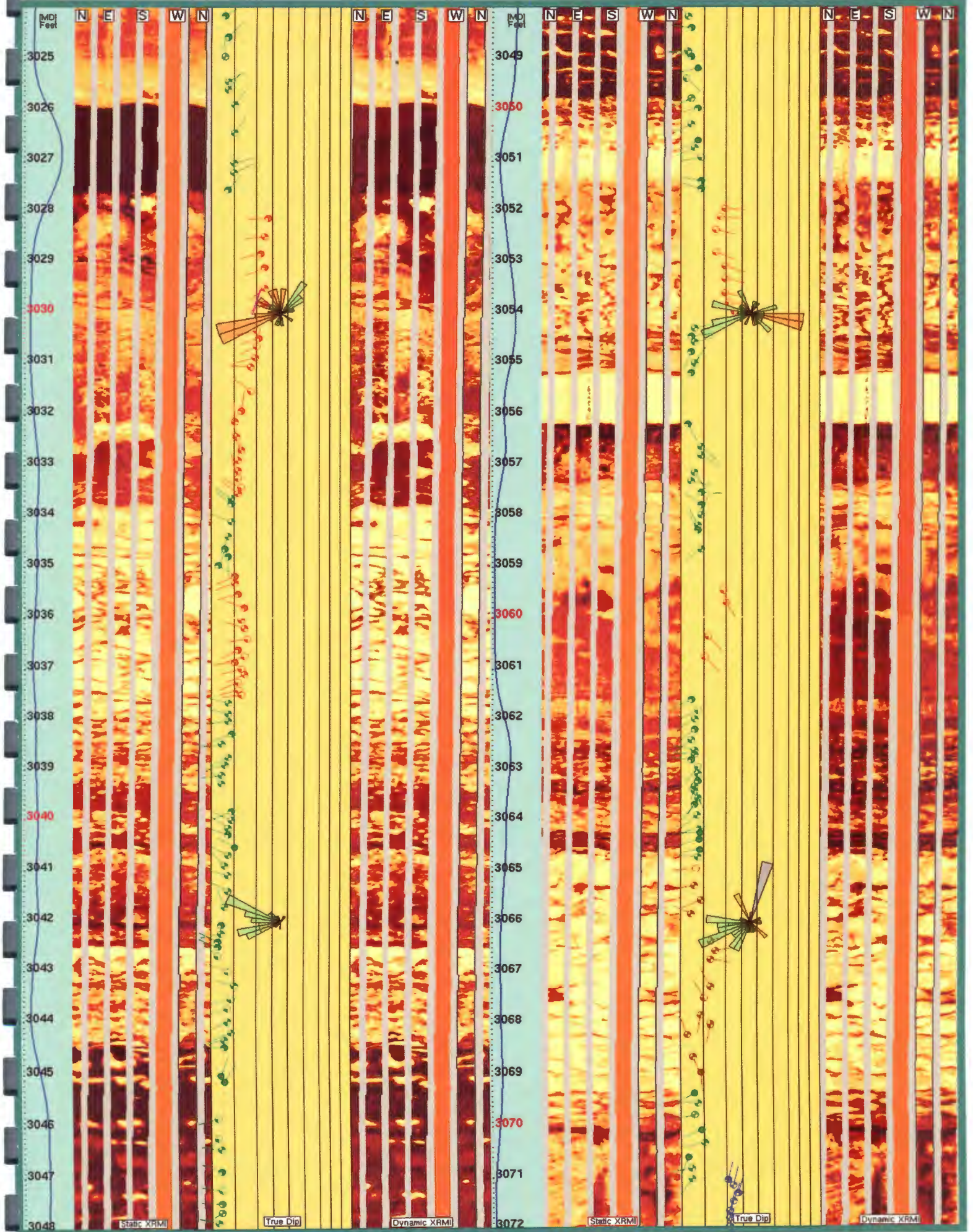
3,190 ft. – 2,832 ft.

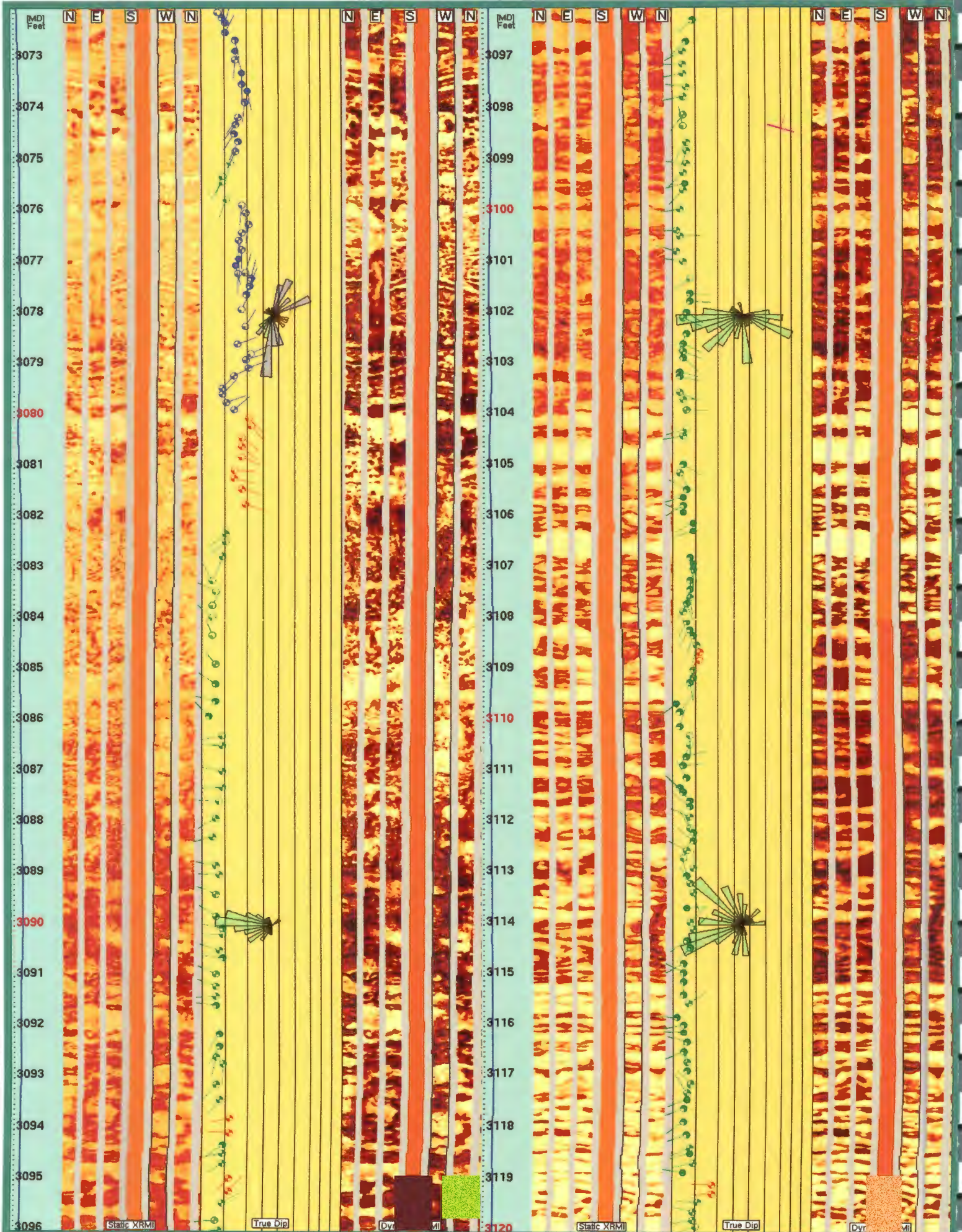












Static XRMII

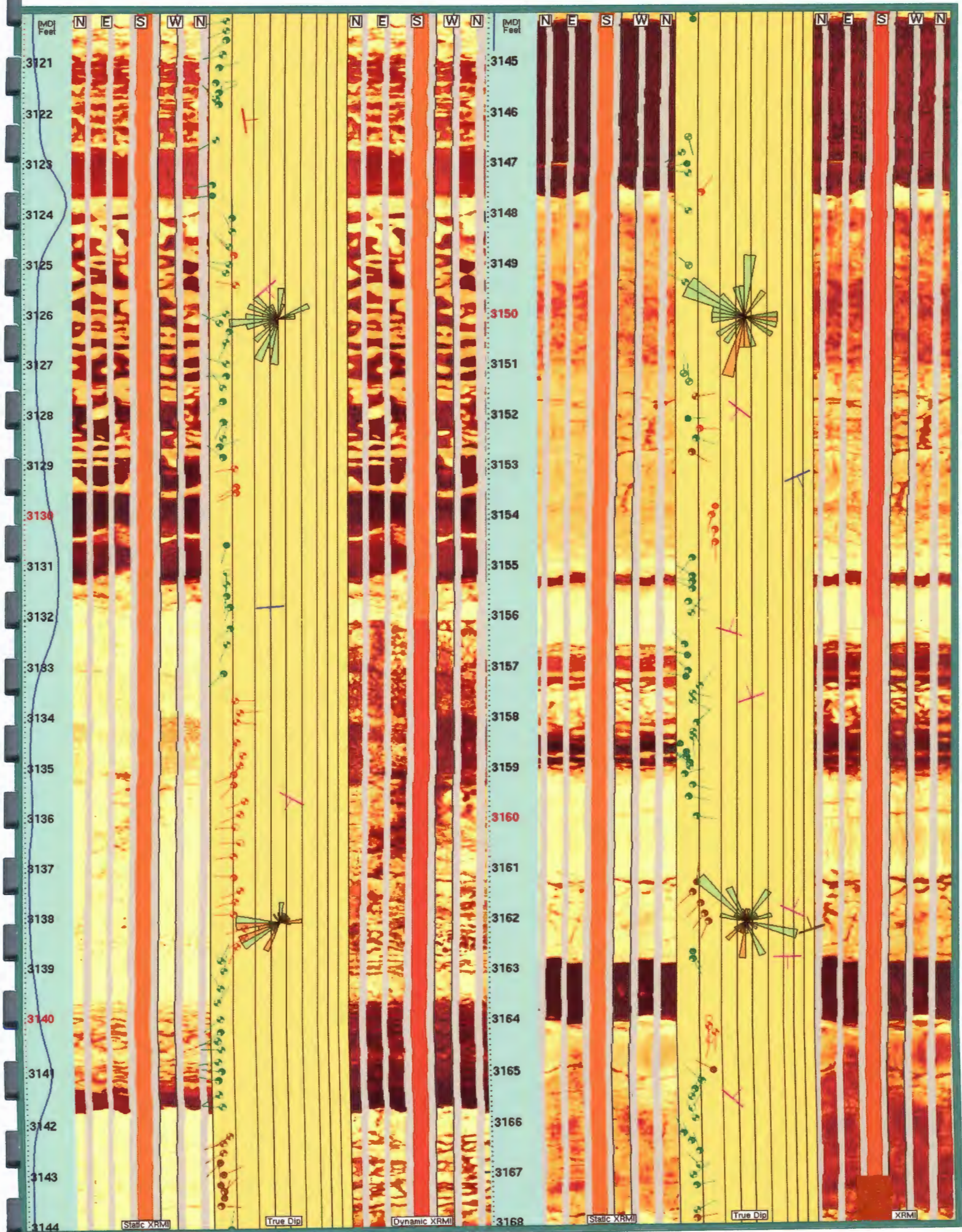
True Dip

Dyr

Static XRMII

True Dip

Dyr



Static XRM

True Dip

Dynamic XRM

Static XRM

True Dip

XRM

