NRC-005F

DATA REPORT Rev. 1
GEOTECHNICAL EXPLORATION AND TESTING

| Rev. 1

VIRGINIA ELECTRIC AND POWER COMPANY
NORTH ANNA NUCLEAR POWER STATION
MINERAL, LOUISA COUNTY, VIRGINIA

| Rev. 1

September 28, 2007

| Rev. 1

VOLUME 3

APPENDIX E

Prepared For:

Virginia Electric and Power Company
Richmond, Virginia

| Rev. 1

Prepared By:

MACTEC Engineering and Consulting, Inc.
Raleigh, North Carolina

MACTEC Project No. 6468-06-1472

APPENDIX E.1

FIELD RESISTIVITY TEST

NORTH ANNA COL

DATA REPORT REV. 0
JANUARY 23, 2007

MACTEC PROJECT NO. 6468-06-1472

REPORT OF FIELD RESISTIVITY SOUNDINGS
North Anna COL Project
MACTEC Job No. 6468-06-1472

Work Instruction No. : 25
Method: Wenner Four Electrode (ASTM G 57-95a, reapproved 2001)

Data Collected by: Garrett J. Kasten, November 15, 2006
Equipment: Mini Res Resistivity Meter, LID # 1464
Calibration Date:May 23, 2006
Calibration Harness: #9450

Test Location (Center of Lines):	N 3,909,183.87 ft
(Identifed as Point R1/R2)	E 11,685,747.21 ft
Elevation at Center Point:	328.15 ft

Test R-1 **Compass Bearing N 75 E**

Probe Spacing (feet)	Low Range Resistance (ohms)	Resistivity[(1)] (ohm-cm)	Depth[(2)] (feet)
3	18.71	10748.90	3
5	16.12	15434.90	5
7.5	14.54	20883.08	7.5
10	13.57	25986.55	10
15	13.41	38520.23	15
30	9.38	53888.10	30
50	4.74	45385.50	50
100	2.10	40215.00	100

(1) Resistivity is based upon Low Range Resistivity reading from Field Resistivity Data Sheet
(2) Depth for resistivity reading is approximately equal to probe spacing for Wenner array.

Test R-2 **Compass Bearing N 40 W**

Probe Spacing feet	Low Range Resistance (ohms)	Resistivity[(1)] (ohm-cm)	Depth[(2)] (feet)
3	19.49	11197.01	3
5	15.90	15224.25	5
7.5	14.67	21069.79	7.5
10	13.41	25680.15	10
15	11.36	32631.60	15
30	7.48	42972.60	30
50	4.37	41842.75	50
100	1.95	37342.50	100

(1) Resistivity is based upon Low Range Resistivity reading from Field Resistivity Data Sheet
(2) Depth for resistivity reading is approximately equal to probe spacing for Wenner array.

Prepared by: [signature] Date: 1/19/07
Checked by: [signature] Date: 1-19-07

APPENDIX E.2

GEOVISION DOWNHOLE AND P-S LOGGING REPORT

NOTE THAT VOLUME 2 OF 2 CONSISTS OF DATA FILES ON DVD/CD THAT ARE ONLY INCLUDED IN THE ELECTRONIC FILES

NORTH ANNA COL

DATA REPORT REV. 0
JANUARY 23, 2007

MACTEC PROJECT NO. 6468-06-1472

GEOVision
geophysical services

FINAL REPORT

BORING GEOPHYSICAL LOGGING
BORINGS B-901, B-907 AND B-909

NORTH ANNA COL PROJECT
NORTH ANNA NUCLEAR STATION

Report 6410-01 vol 1 of 2 rev A

January 17, 2007

FINAL REPORT

BORING GEOPHYSICAL LOGGING
BORINGS B-901, B-907 AND B-909

NORTH ANNA COL PROJECT
NORTH ANNA NUCLEAR STATION

Report 6410-01 vol 1 of 2 rev A

January 17, 2007

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INTRODUCTION

Boring geophysical measurements were collected in three uncased borings located at the North Anna Nuclear Power Station, located in Louisa County, Virginia. Geophysical data acquisition was performed between August 28 and September 12, 2006 by Rob Steller of **GEO***Vision*. Data analysis and report preparation were performed by Rob Steller and reviewed by John Diehl of GEOVision. The work was performed under subcontract with MACTEC Engineering and Consulting, Inc., (MACTEC) with Steve Criscenzo serving as the point of contact for MACTEC.

This report describes the field measurements, data analysis, and results of this work.

SCOPE OF WORK

This report presents the results of boring geophysical measurements collected between August 28 and September 12, 2006, in three uncased borings, as detailed below. The purpose of these studies was to supplement stratigraphic information obtained during MACTEC's soil and rock sampling program and to acquire shear wave velocities and compressional wave velocities as a function of depth, as a component of the North Anna Combined Operating License Application (COL) Project.

BORING DESIGNATION	DATES LOGGED	ELEVATION*	COORDINATES* - FEET	
			NORTH	EAST
B-901	8/30-06; 9/11-12/06	309.42	3,909,777.72	11,685,928.59
B-907	8/30-31 and 9/11/06	322.71	3,909,607.90	11,685,938.35
B-909	8/30/06 and 9/12/06	304.90	3,909,695.46	11,686,107.40

* All points referenced to Control Monument 7 and adjusted to reflect the following Datums
Horizontal - NAD 83(CORS96)(EPOCH:2002)
Elevation - NAVD88 (Geoid03)

Table 1 Boring locations and logging dates

A Robertson Geologging USB Micrologger II digital recorder with a digital OYO P-S Suspension Logging Probe was used to obtain in-situ horizontal shear and compressional wave velocity measurements at 1.6 foot intervals. The acquired data were analyzed and a profile of velocity versus depth was produced for both compressional and horizontally polarized shear waves.

A Robertson Geologging 3ACS 3-arm mechanical caliper probe was used to collect boring diameter and natural gamma data at 0.05 foot intervals.

A Robertson Geologging ELXG probe was used to collect long and short normal resistivity, single point resistance, self potential, and natural gamma data at 0.05 foot intervals.

A Robertson Geologging High Resolution Acoustic Televiewer (HiRAT) probe was used to collect Acoustic televiewer images of the boring walls, and boring deviation data, at 0.008 foot intervals.

A detailed reference for the velocity measurement techniques used in this study is:

Guidelines for Determining Design Basis Ground Motions, Report TR-102293, Electric Power Research Institute, Palo Alto, California, November 1993, Sections 7 and 8.

INSTRUMENTATION

Suspension Instrumentation

Suspension soil velocity measurements were performed in all borings using the Robertson Geologging USB Micrologger II digital recorder with a digital OYO P-S Suspension Logging Probe. This system directly determines the average in-situ horizontal shear and compressional wave velocity measurements of a 3.3 foot high segment of the rock and soil column surrounding the boring of interest by measuring the elapsed time between arrivals of a wave propagating upward through the rock and soil column. The receivers that detect the wave, and the source that generates the wave, are moved as a unit in the boring producing relatively constant amplitude signals at all depths. Data are collected at 1.6 foot stations.

Winch Geovision 4-conductor
Sheave - Measuring Wheel Geovision S/N 102
Robertson Geologging USB Micrologger 2 digital recorder S/N 5310
OYO PS Logger Borehole Probe, includes:
Digital Telemetry/Reducer Model 3403 S/N 160023
Isolation Tube, 1m Model 3387B
Weight Model 3302W
OYO PS 170 Source Model 3304
Receiver/Sensor S/N 30086
Driver Model 3386A

The suspension system probe consists of a combined reversible polarity solenoid horizontal shear-wave source (S_H) and compressional-wave source (P), joined to two biaxial receivers by a flexible isolation cylinder, as shown in Figure 2. The separation of the two receivers is 3.3 feet, allowing average wave velocity in the region between the receivers to be determined by inversion of the wave travel time between the two receivers. The total length of the probe as used in these surveys is 19 feet, with the center point of the receiver pair 12.1 feet above the bottom end of the probe.

The probe receives control signals from, and sends the digitized receiver signals to, instrumentation on the surface via an armored 4 conductor cable. The cable is wound onto the drum of a winch and is used to support the probe. Cable travel is measured to provide probe depth data, using a 3.28 foot circumference sheave fitted with a digital rotary encoder.

The entire probe is suspended in the boring by the cable, therefore, source motion is not coupled directly to the boring walls; rather, the source motion creates a horizontally propagating impulsive pressure wave in the fluid filling the boring and surrounding the source. This pressure wave is converted to P and S_H-waves in the surrounding soil and rock as it passes through the casing and grout annulus and impinges upon the wall of the boring. These waves propagate through the soil and rock surrounding the boring, in turn causing a pressure wave to be generated in the fluid surrounding the receivers as the soil waves pass their location. Separation of the P and S_H-waves at the receivers is performed using the following steps:

1. Orientation of the horizontal receivers is maintained parallel to the axis of the source, maximizing the amplitude of the recorded S_H -wave signals.
2. At each depth, S_H-wave signals are recorded with the source actuated in opposite directions, producing S_H-wave signals of opposite polarity, providing a characteristic S_H-wave signature distinct from the P-wave signal.
3. The 6.3 foot separation of source and receiver 1 permits the P-wave signal to pass and damp significantly before the slower S_H-wave signal arrives at the receiver. In faster soils or rock, the isolation cylinder is extended to allow greater separation of the P- and S_H-wave signals.

4. In saturated soils, the received P-wave signal is typically of much higher frequency than the received S_H-wave signal, permitting additional separation of the two signals by low pass filtering.
5. Direct arrival of the original pressure pulse in the fluid is not detected at the receivers because the wavelength of the pressure pulse in fluid is significantly greater than the dimension of the fluid annulus surrounding the probe (meter versus centimeter scale), preventing significant energy transmission through the fluid medium.

In operation, a distinct, repeatable pattern of impulses is generated at each depth as follows:

1. The source is fired in one direction producing dominantly horizontal shear with some vertical compression, and the signals from the horizontal receivers situated parallel to the axis of motion of the source are recorded.
2. The source is fired again in the opposite direction and the horizontal receiver signals are recorded.
3. The source is fired again and the vertical receiver signals are recorded. The repeated source pattern facilitates the picking of the P and S_H-wave arrivals; reversal of the source changes the polarity of the S_H-wave pattern but not the P-wave pattern.

The data from each receiver during each source activation are recorded as a different channel on the recording system. The Suspension PS system has six channels (two simultaneous recording channels), each with a 1024 sample record. The recorded data are displayed on a CRT or LCD display as six channels with a common time scale. Data are stored on disk for further processing. Up to 8 sampling sequences can be summed to improve the signal to noise ratio of the signals.

Review of the displayed data on the recorder or computer screen allows the operator to set the gains, filters, delay time, pulse length (energy), sample rate, and summing number to optimize the quality of the data before recording. Verification of the calibration of the Suspension PS digital recorder is performed every twelve months using a NIST traceable frequency source and counter, as outlined in Appendix D.

Caliper / Natural Gamma Instrumentation

Caliper and natural gamma data were collected using a Model 3ACS 3-leg caliper probe, serial number 2915, manufactured by Robertson Geologging, Ltd. With the short arm configuration used in these surveys, the probes permitted measurement of boring diameters between 1.6 and 16 inches. With this tool, caliper measurements were collected concurrent with measurement of natural gamma emission from the boring walls. The probe was 6.82 feet long, and 1.5 inches in diameter.

This probe is useful in the following studies:

- Measurement of boring diameter and volume
- Location of hard and soft formations
- Location of fissures, caving, pinching and casing damage
- Bed boundary identification
- Strata correlation between borings

The probe receives control signals from, and sends the digitized measurement values to, a Robertson Micrologger II, S/N 5310, on the surface via an armored 4 conductor cable. The cable is wound onto the drum of a winch and is used to support the probe. Cable travel is measured to provide probe depth data, using a 3.28 foot circumference sheave fitted with a digital rotary encoder. The probe and depth data are transmitted by USB link from the Micrologger unit to a laptop computer where it is displayed and stored on hard disk.

The caliper consists of three arms, each with a toothed quadrant at their base, pivoted in the lower probe body. A toothed rack engages with each quadrant, thus constraining the arms to move together. Linear movement of the rack is converted to opening and closing of the arms. Springs hold the arms open in the operating position. A motor drive is provided to retract the arms, allowing the probe to be lowered into the boring. The rack is coupled to a potentiometer which converts movement into a voltage sensed by the probe's microprocessor.

Natural gamma measurements rely upon small quantities of radioactive material contained in all rocks to emit gamma radiation as they decay. Trace amounts of Uranium and Thorium are present in a few minerals, whereas potassium-bearing minerals such as feldspar, mica and clays will include traces of a radioactive isotope of Potassium. These emit gamma radiation as they decay with an extremely long half-life. This radiation is detected by scintillation - the production of a tiny flash of light when gamma rays strike a crystal of sodium iodide. The light is converted into an electrical pulse by a photomultiplier tube. Pulses above a threshold value of 60 KeV are counted by the probe's microprocessor. The measurement is useful because the radioactive elements are concentrated in certain rock types e.g. clay or shales, and depleted in others e.g. sandstone or coal.

Resistivity / Spontaneous Potential / Natural Gamma Instrumentation

Resistivity, spontaneous potential and natural gamma data were collected using a Model ELXG electric log probe, S/N 5490, manufactured by Robertson Geologging, Ltd. This probe measures Single Point Resistance (SPR), short normal (16") resistivity, long normal (64") resistivity, Spontaneous Potential (SP) and natural gamma. The probe is 8.20 feet long, and 1.73 inches in diameter.

This probe is useful in the following studies:

- Bed boundary identification
- Strata correlation between borings
- Strata geometry and type (shale indication)

The probe receives control signals from, and sends the digitized measurement values to, a Robertson Micrologger II, S/N 5310, on the surface via an armored 4 conductor cable. The cable is wound onto the drum of a winch and is used to support the probe. Cable travel is measured to provide probe depth data, using a 3.28 foot circumference sheave fitted with a digital rotary encoder. The probe and depth data are transmitted by USB link from the Micrologger unit to a laptop computer where they are displayed and stored on hard disk.

The resistivity section of the probe operates by driving an alternating current into the formation from the central SPR/DRIVE electrode. The current returns via the logging cable armor. To ensure adequate penetration of the formation the logging cable is insulated for approximately 30 feet from the cablehead. Voltages are measured between the 16" and 64" electrodes and the remote earth connection at surface, as noted below:

- Single Point Resistance (SPR): The current flowing to the cable armor is measured along with the voltage at the SPR electrode. The voltage divided by current gives resistance.

- Self Potential (SP): This is the DC bias of the 16" electrode with respect to the voltage return at the surface (ground stake).

Data quality is dependant upon good grounding at the surface. This is achieved with a metal stake driven into the mud-pit or the soil adjacent to the boring.

Acoustic Televiewer / Boring Deviation Instrumentation

An acoustic image and boring deviation data were collected in all three borings using a High Resolution Acoustic Televiewer probe (HiRAT), serial number 5174, manufactured by Robertson Geologging, Ltd. The probe is 7.58 feet long, and 1.9 inches in diameter, and is fitted with upper and lower four-band centralizers.

In this application, this probe is useful in the following studies:

- Measurement of boring inclination and deviation from vertical
- Determination of need to correct soil and geophysical log depths to true vertical depths
- Acoustic imaging of the boring wall to identify fractures, dikes, and weathered zones, and determine dip and azimuth of these features

The probe receives control signals from, and sends the digitized measurement values to, a Robertson Micrologger II, S/N 5310, on the surface via an armored 4 conductor cable. The cable is wound onto the drum of a winch and is used to support the probe. Cable travel is measured to provide probe depth data, using a 3.28 foot circumference sheave fitted with a digital rotary encoder. The probe and depth data are transmitted by USB link from the Micrologger unit to a laptop computer where it is displayed and stored on hard disk.

This system produces images of the boring wall based upon the amplitude and travel time of an ultrasonic beam reflected from the formation wall. The ultrasonic energy is generated by a piezoelectric transducer at a frequency of 1.4 MHz. A periodic acoustic energy wave is emitted by the transducer and travels through the acoustic head and boring fluid until it reaches the interface between the boring fluid and the boring wall. Here a portion of the energy is reflected back to the transducer, the remainder continuing on into the formation. By careful time sequencing, the piezoelectric transducer acts as both the transmitter of the ultrasonic pulse and receiver of the reflected wave. The travel time of the energy wave is the period between transmission of the source energy pulse and the return of the reflected wave measured at the point of maximum wave amplitude. The magnitude of the wave energy is measured in dB, a unit-less ratio of the detected echo wave amplitude divided by the amplitude of the transmitted wave. The strength of the reflected signal depends primarily upon the impedance contrast of the boring fluid and the boring wall formation. In these rock borings, the contrast between the clear water filling the boring and the rock formation generally provides high contrast. The changes in contrast between native rock and dikes provide imaging of fracture fillings.

The acoustic wave propagates along the axis of the probe and then is reflected perpendicular to this axis by a reflector that focuses the beam to a 0.1-inch diameter spot about 2 inches from the central axis of the probe. This reflector is mounted on the shaft of a stepper motor enabling the position of the measurement to be rotated through 360°. Sampling rates of 90, 180 and 360 measured points per revolution are available. During these surveys, data were collected at 360 samples per revolution. It should be noted that during logging the probe is moving in the boring, so that the measured points describe a very fine pitch spiral.

The probe contains a fluxgate magnetometer to monitor magnetic north, and all raw televiewer data are referenced to magnetic north. Also, a three-axis accelerometer is enclosed in the probe, and boring deviation data are recorded during the logging runs, to permit correction of structure dip angle from apparent dip, (referenced to boring axis), to true dip (referenced to a vertical axis) in non-vertical borings.

The data are presented on a computer screen for operator review during the logging run, and stored on hard disk for later processing.

MEASUREMENT PROCEDURES

Suspension Measurement Procedures

All three borings were logged as partially cased borings, filled with clear water or polymer based drilling mud, with a 4-inch PVC or steel casing placed in the top 40 to 80 feet of softer soils above bedrock contact during the measurements in the lower rock portion of the borings. The casing was then removed, and measurements were performed in the upper soil potion of the borings, as indicated in Table 2. Measurements followed the **GEO***Vision* Procedure for P-S Suspension Seismic Velocity Logging, revision 1.3, as presented in Appendix F. These procedures were supplied and approved in advance of the work. In each boring, the probe was positioned with the top of the probe at the top of the casing, and the electronic depth counter was set to 8.2 feet, the distance between the mid-point of the receiver and the top of the probe, minus the height of the casing stick-up, as verified with a tape measure, and recorded on the field logs. The probe was lowered to the bottom of the boring, and then returned to the surface, stopping at 1.6 foot intervals to collect data, as summarized in Table 2.

At each measurement depth the measurement sequence of two opposite horizontal records and one vertical record was performed, and the gains were adjusted as required. The data from each depth was reviewed on the computer display, and recorded on disk before moving to the next depth.

Upon completion of the measurements, the probe zero depth indication at the depth reference point was verified prior to removal from the boring.

Caliper / Natural Gamma Measurement Procedures

All three borings were logged as partially cased borings, filled with clear water or polymer based drilling mud, with a 4-inch PVC or steel casing placed in the top 40 to 80 feet of softer soils above bedrock contact during the measurements in the lower rock portion of the borings. The casing was then removed, and measurements were performed in the upper soil potion of the borings, as indicated in Table 2. Measurements followed ASTM D6167, Conducting Borehole Geophysical Logging – Mechanical Caliper, as presented in Appendix F.

Prior to and following each logging run, the caliper tool was verified, using the manufacturer's supplied three point calibration jig, which is a circular plate with a series of holes in the top surface into which the tips of the caliper arms fit. This has circles of diameters from 2" to 12", with NIST traceable calibration as documented in Appendix C. The calibration jig is placed over a bucket with the probe standing upright with its nose section passing through the jig's central hole. The caliper probe arms are opened under program control, and a log is recorded as the tips of the arms are placed in the holes on the calibration jig. The measured dimensions, as displayed on the recording computer screen was recorded on the field log sheet, as well as in the digital record, and compared with the calibration jig dimensions. If the verification records did not fall within +/- 0.05 inches of the calibration jig values, the caliper tool was re-calibrated, using the three point calibration jig, and the log repeated. As with the verification, the tips of the caliper arms are placed in the holes marked with the required diameter. During calibration, the value of the current calibration point, as stamped on the jig, is entered via the control computer. The system counts for 15 seconds to make an average of the response. The procedure is repeated for the second and third required openings.

The computation and generation of the calibration coefficient file is entirely automatic. The calibration file is simply the set of coefficients of a quadratic curve which fits the three data points. Figure 1 shows the response of a caliper probe using data gathered during calibration.

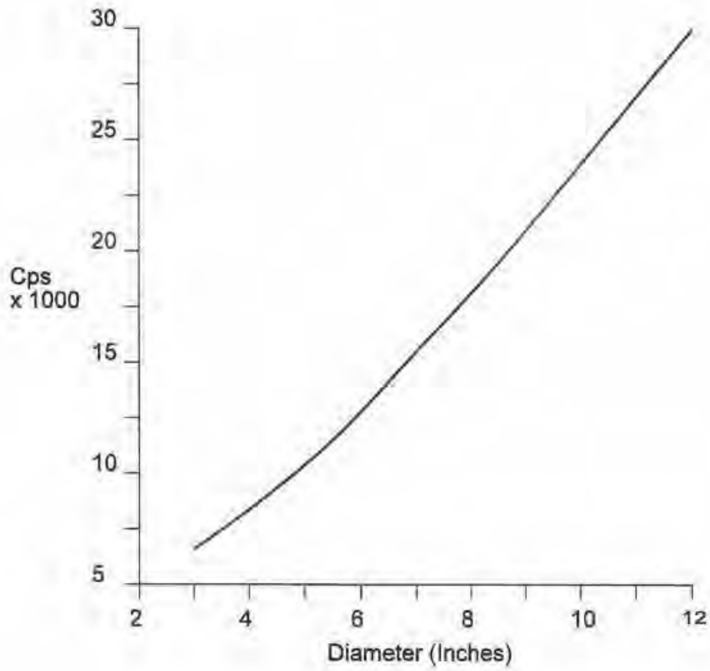


Figure 1. Example Calibration Curve for Caliper Probe

Natural gamma was not calibrated in the field, as it is a qualitative measurement, not a quantitative value, and is used only to assist in picking transitions between stratigraphic units, as described in ASTM D6274, Conducting Borehole Geophysical Logging - Gamma, which is included in Appendix F.

In each boring, the probe was positioned with the top of the probe at the top of the mud box, and the electronic depth counter was set to 6.82 feet, the specified length of the probe, minus the height of the mud box, as verified with a tape measure, and recorded on the field logs. The probe was lowered to the bottom of the boring, where the caliper legs were opened, and data collection begun. The probe was then returned to the surface at 10 feet/minute, collecting data continuously at 0.05 foot spacing, as summarized in Table 2.

Upon completion of the measurements, the probe zero depth indication at the depth reference point was verified prior to removal from the boring, as summarized in Table 3.

Resistivity / Spontaneous Potential Measurement Procedures

All three borings were logged as partially cased borings, filled with clear water or polymer based drilling mud, with a 4-inch PVC or steel casing placed in the top 40 to 80 feet of softer soils above bedrock contact during the measurements in the lower rock portion of the borings. The casing was then removed, and measurements were performed in the upper soil potion of the borings, as indicated in Table 2. The probe was connected to the logging cable using a 32.8 foot long insulating cable section or "yoke". The probe head was insulated by wrapping all exposed metal of the cablehead and probe with self-amalgamating insulation tape. The 32.8 foot insulating yoke was checked for any damage, and repaired with self-amalgamating insulation tape as needed.

The reference ground stake was driven firmly into the mud pit, and connected to the ground socket on the winch switch box.

This probe was not calibrated in the field, as it is used to provide qualitative measurements, not quantitative values, and is used only to assist in picking transitions between stratigraphic units, as described in ASTM D5753, Planning and Conducting Borehole Geophysical Surveys, which is included in Appendix F.

In each boring, the probe was positioned with the top of the probe at the top of the casing or mud box, and the electronic depth counter was set to 8.2 feet, the specified length of the probe, minus the height of the casing stick-up or mud box, as verified with a tape measure. When logging on smaller drill rigs, the depth was zeroed to the top of the yoke, and 32.8 feet was added to the zero depth, as recorded in the field logs. The probe was lowered to the bottom of the boring, where data collection was begun. The probe was then returned to the surface at 10 feet/minute, collecting data continuously at 0.05 foot spacing, as summarized in Table 2. The natural gamma data collected in these logs is redundant with the data collected in the caliper / natural gamma logs, and the caliper / natural data may be used to verify the natural gamma data collected in these logs.

Normally, when the un-insulated section of the logging cable leaves the boring fluid, the log is terminated, as the electrical measurements do not function under these conditions. However, in these surveys, the log was continued, in order to collect as much natural gamma data as possible before the yoke connector reached the measuring wheel.

Upon completion of the measurements, the probe zero depth indication at the depth reference point was verified prior to removal from the boring, as summarized in Table 3.

Acoustic Televiewer / Boring Deviation Measurement Procedures

All three borings were logged as partially cased borings, filled with clear water or polymer based drilling mud, with a 4-inch PVC or steel casing placed in the top 40 to 80 feet of softer soils above bedrock contact during the measurements in the lower rock portion of the borings. The casing was then removed, and measurements were performed in the upper soil potion of the borings, as indicated in Table 2. Although the acoustic televiewer cannot image through PVC casing, the logs were run to the surface in order to provide a deviation log for the entire boring depth. Measurements followed the **GEO***Vision* standard field procedures, as presented in Appendix F.

Prior to use, the HiRAT probe tiltmeter and compass functions were checked by comparison with a Brunton surveyors' compass.

In each boring, the HiRAT probe was positioned with the top of the probe at the top of the casing, and the electronic depth counter was set to 4.71 feet, the specified length of the probe, minus the height of the casing stick-up, as verified with a tape measure, and recorded on the field logs. The probe was lowered to the bottom of the boring, and data collection begun. The probe was then returned to the surface at 3.0 feet/minute, collecting data continuously at 0.008 foot intervals, as summarized in Table 2.

Upon completion of the measurements, the probe zero depth indication at grade was verified prior to removal from the boring. The log was reviewed in the field, and the un-processed log images, in .htm web-browser format was supplied to the client with the raw data on CDR at the end of each field day. These .htm files are included in the boring specific sub-directories of the data directory on volume 2 of 2 (DVD-R) of this report.

BORING NUMBER	TOOL AND RUN NUMBER	DEPTH RANGE (FEET)	OPEN HOLE (FEET)	DEPTH TO BOTTOM OF CASING (FEET)	SAMPLE INTERVAL (FEET)	DATE LOGGED
B-901	SUSPENSION 1	41.0 – 287.1	299.0	38.0 STEEL	1.6	8/28/06
B-901	CALIPER/GAMMA 1	298.0 – 0	298.0	38.0 STEEL	0.05	8/29/06
B-901	ACOUSTIC TELEVIEWER 1	298.0 – 2.7	298.0	38.0 STEEL	0.008	8/29/06
B-901	ELOG/GAMMA 1	298.0 – 36.0	298.0	38.0 STEEL	0.05	8/29/06
B-901	ACOUSTIC TELEVIEWER 2	125.0 – 100.0	-	38.0 STEEL	.008	9/11/06
B-901	ACOUSTIC TELEVIEWER 3	125.0 – 100.0	-	38.0 STEEL	.008	9/11/06
B-901	CALIPER/GAMMA 2	60.0 - 0	-	NONE	0.05	9/12/06
B-901	SUSPENSION 2	1.6 – 67.3	-	NONE	1.6	9/12/06
B-901	ELOG/GAMMA 2	80.0 – 24.9	-	NONE	0.05	9/12/06
B-907	SUSPENSION 1	37.7 – 183.7	195.8-	38.0 PVC	1.6	8/30/06
B-907	CALIPER/GAMMA 1	188.0 – 1.0	188.0	38.0 PVC	0.05	8/30/06
B-907	CALIPER/GAMMA 2	182.0 – 1.0	-	38.0 PVC	0.05	8/30/06
B-907	ELOG/GAMMA 1	170.7 – 38.9	170.7	38.0 PVC	0.05	8/31/06
B-907	ACOUSTIC TELEVIEWER 1	158.3 – 1.5	-	38.0 PVC	.008	8/31/06
B-907	ACOUSTIC TELEVIEWER 2	140.0 – 167.2	-	38.0 PVC	.008	8/31/06
B-907	ACOUSTIC TELEVIEWER 3	167.2 – 150.0	167.2	38.0 PVC	.008	8/31/06
B-907	CALIPER/GAMMA 3	80.0 - 0	-	NONE	0.05	9/11/06
B-907	SUSPENSION 2	1.6 – 65.6	-	NONE	1.6	9/11/06
B-907	ELOG/GAMMA 2	83.0 – 25.0	-	NONE	0.05	9/11/06
B-909	ELOG/GAMMA 1	200.0 – 35.3	200.0	80.0 PVC	0.05	8/30/06
B-909	CALIPER/GAMMA 1	200.0 – 1.0	200.0	80.0 PVC	0.05	8/30/06
B-909	ACOUSTIC TELEVIEWER 1	200.0 – 2.0	200.0	80.0 PVC	0.008	8/30/06
B-909	SUSPENSION 1	82.0 – 188.7	200.0	80.0 PVC	1.6	8/30/06
B-909	CALIPER/GAMMA 2	110.0 - 0	-	NONE	0.05	9/12/06
B-909	SUSPENSION 2	1.6 – 98.4	-	NONE	1.6	9/12/06
B-909	ACOUSTIC TELEVIEWER 2	100.0 - 3.1	-	NONE	0.008	9/12/06
B-909	ELOG/GAMMA 2	120.0 – 25.2	-	NONE	0.05	9/12/06

- PROBE DID NOT TOUCH BOTTOM OF BORING

Table 2. Logging dates and depth ranges

BORING NUMBER	TOOL AND RUN NUMBER	TOOL HIT BOTTOM DEPTH (FEET)	DRILLER DEPTH (FEET)	STARTING DEPTH REF. (FEET)	ENDING DEPTH REF. (FEET)	ASDE (FEET)
B-901	SUSPENSION 1	299.0	300.0	6.20	6.13	-0.07
B-901	CALIPER/GAMMA 1	298.0		4.82	4.75	-0.07
B-901	ACOUSTIC TELEVIEWER 1	298.0		2.72	2.66	-0.06
B-901	ELOG/GAMMA 1	298.0		39.00	38.95	-0.05
B-901	ACOUSTIC TELEVIEWER 2	-		2.72	2.72	0
B-901	ACOUSTIC TELEVIEWER 3	-		2.72	2.72	0
B-901	CALIPER/GAMMA 2	-		6.82	6.82	0
B-901	SUSPENSION 2	-		8.20	8.20	0
B-901	ELOG/GAMMA 2	-		41.00	41.00	0
B-907	SUSPENSION 1	195.8-	200.0	6.14	6.10	-0.04
B-907	CALIPER/GAMMA 1	188.0		4.74	4.80	0.06
B-907	CALIPER/GAMMA 2	-		4.74	4.80	0.06
B-907	ELOG/GAMMA 1	170.7		38.90	38.92	0.02
B-907	ACOUSTIC TELEVIEWER 1	-		2.64	2.64	0
B-907	ACOUSTIC TELEVIEWER 2	-		2.64	2.64	0
B-907	ACOUSTIC TELEVIEWER 3	167.2		2.64	2.64	0
B-907	CALIPER/GAMMA 3	-		5.07	5.07	0
B-907	SUSPENSION 2	-		6.56	6.56	0
B-907	ELOG/GAMMA 2	-		39.25	39.25	0
B-909	ELOG/GAMMA 1	200.0	200.0	40.25	40.25	0
B-909	CALIPER/GAMMA 1	200.0		6.07	6.10	0.03
B-909	ACOUSTIC TELEVIEWER 1	200.0		3.97	4.05	0.08
B-909	SUSPENSION 1	200.0		7.45	7.45	0
B-909	CALIPER/GAMMA 2	-		5.24	5.20	-0.04
B-909	SUSPENSION 2	-		6.63	6.66	0.03
B-909	ACOUSTIC TELEVIEWER 2	-		3.14	3.14	0
B-909	ELOG/GAMMA 2	-		39.42	39.40	-0.02

- PROBE DID NOT TOUCH BOTTOM OF BORING

Table 3. Boring Bottom Depths and After Survey Depth Error (ASDE)

DATA ANALYSIS

Suspension Analysis

Using the proprietary OYO program PSLOG.EXE version 1.0, included in volume 2 of 2 (DVD-R) of this report, the recorded digital waveforms were analyzed to locate the most prominent first minima, first maxima, or first break on the vertical axis records, indicating the arrival of P-wave energy. The difference in travel time between receiver 1 and receiver 2 (R1-R2) arrivals was used to calculate the P-wave velocity for that 3.3 foot segment of the soil column. When observable, P-wave arrivals on the horizontal axis records were used to verify the velocities determined from the vertical axis data. The time picks were then transferred into an EXCEL template (EXCEL version 2003 SP2) to complete the velocity calculations based upon the arrival time picks made in PSLOG. The PSLOG pick files and the EXCEL analysis files are included in the boring specific directories on volume 2 of 2 (DVD-R) of this report.

The P-wave velocity over the 6.3 foot interval from source to receiver 1 (S-R1) was also picked using PSLOG, and calculated and plotted in EXCEL, for quality assurance of the velocity derived from the travel time between receivers. In this analysis, the depth values as recorded were increased by 4.8 feet to correspond to the mid-point of the 6.3 foot S-R1 interval. Travel times were obtained by picking the first break of the P-wave signal at receiver 1 and subtracting 0.3 milliseconds, the calculated and experimentally verified delay from source trigger pulse (beginning of record) to source impact. This delay corresponds to the duration of acceleration of the solenoid before impact.

As with the P-wave records, using PSLOG, the recorded digital waveforms were analyzed to locate the presence of clear S_H-wave pulses, as indicated by the presence of opposite polarity pulses on each pair of horizontal records. Ideally, the S_H-wave signals from the 'normal' and 'reverse' source pulses are very nearly inverted images of each other. Digital FFT - IFFT lowpass filtering was used to remove the higher frequency P-wave signal from the S_H-wave signal. Different filter cutoffs were used to separate P- and S_H-waves at different depths, ranging from 600 Hz in the slowest zones to 4000 Hz in the regions of highest velocity. At each depth, the filter frequency was selected to be at least twice the fundamental frequency of the S_H-wave signal being filtered.

Generally, the first maxima were picked for the 'normal' signals and the first minima for the 'reverse' signals, although other points on the waveform were used if the first pulse was distorted. The absolute arrival time of the 'normal' and 'reverse' signals may vary by +/- 0.2 milliseconds, due to differences in the actuation time of the solenoid source caused by constant mechanical bias in the source or by boring inclination. This variation does not affect the R1-R2 velocity determinations, as the differential time is measured between arrivals of waves created by the same source actuation. The final velocity value is the average of the values obtained from the 'normal' and 'reverse' source actuations.

As with the P-wave data, S_H-wave velocity calculated from the travel time over the 6.3 foot interval from source to receiver 1 was calculated and plotted for verification of the velocity derived from the travel time between receivers. In this analysis, the depth values were increased by 4.8 foot to correspond to the mid-point of the 6.3 foot S-R1 interval. Travel times were obtained by picking the first break of the S_H-wave signal at the near receiver and subtracting 0.3 milliseconds, the calculated and experimentally verified delay from the beginning of the record at the source trigger pulse to source impact.

These data and analysis were reviewed by John Diehl and Tony Martin as a component of **GEO***Vision*'s in-house QA-QC program.

Figure 3 shows an example of R1 - R2 measurements on a sample filtered suspension record. In Figure 3, the time difference over the 3.3 foot interval of 1.88 milliseconds for the horizontal signals is equivalent to an S_H-wave velocity of 1745 feet/second. Whenever possible, time differences were determined from several phase points on the S_H-waveform records to verify the data obtained from the first arrival of the S_H-wave pulse. Figure 4 displays the same record before filtering of the S_H-waveform record with a 1400 Hz FFT - IFFT digital lowpass filter, illustrating the presence of higher frequency P-wave energy at the beginning of the record, and distortion of the lower frequency S_H-wave by residual P-wave signal.

Caliper / Natural Gamma Analysis

No analysis is required with the caliper or natural gamma data, however depths to identifiable boring features were compared to verify compatible depth readings on all logs. Using Robertson Geologging Winlogger software version 3.74J, these data were combined with the resistivity, ELOG based natural gamma and spontaneous potential (SP) logs, and converted to LAS and PDF formats for transmittal to the client.

Resistivity / Natural Gamma / Spontaneous Potential Analysis

No analysis is required with the resistivity, natural gamma or spontaneous potential data, however depths to identifiable boring features were compared to verify compatible depth readings on all logs. Using Robertson Geologging Winlogger software version 3.74J, these data were combined with the caliper and caliper-based natural gamma logs, and converted to LAS and PDF formats for transmittal to the client.

Acoustic Televiewer / Boring Deviation Analysis

The collected Acoustic Televiewer data was processed with Robertson Geologging's RGLDIP program, version 6.2, to identify boring features and to extract the deviation data and produce an ASCII file and plots of deviation data.

Sinusoidal projections of both open and healed fractures and dikes in the boring walls were interactively picked on the acoustic reflection image or acoustic travel time image, and are presented on the logs as red sinusoids superimposed over the televiewer images. Bedrock contact, where visible, was picked on the same images, and is presented on the logs as a green sinusoid. The sinusoidal projections were processed to correct for the plunge of the borings using the recorded data from the accelerometers located in the probe, and presented graphically, in what is referred to as "tadpole", or "arrow" format, with true dip indicated by the position of the arrow head on the plot. Direction of dip (not strike) is indicated by the direction of the arrow tail, with true north being "up". These values are presented numerically in columns to the left of the arrow graphic plots. These depth and dip data of the joints and foliation are also presented as .txt files in the boring specific sub-directories in the data directory on volume 2 of 2 (DVD-R) of this report.

The televiewer images were processed to create a simulated core image of the borings. It should be considered that the pseudo-core represents a core that would have the full 3.75-inch diameter of the boring, not the 2.5-inch diameter of the cores removed during drilling, so that direct comparison is not possible. Also, the unwrapped image is viewed from the perspective of an observer in the center of the boring looking outward. The simulated core image is viewed from the "outside" of the boring looking inward, so there is a reversal of the position of east and west relative to north between the two images.

RESULTS

Suspension Results

Suspension R1-R2 P- and S_H-wave velocities are plotted in Figures 5, 6, 10, 11, 15 and 16. The suspension velocity data presented in these figures are presented in Tables 5 - 10. The PSLOG and EXCEL analysis files for each boring are included in the boring specific directories on volume 2 of 2 (DVD-R) of this report, along with the raw and filtered waveforms.

P- and S_H-wave velocity data from R1-R2 analysis and quality assurance analysis of S-R1 data, as discussed in the "Suspension Analysis" section of this report, are plotted together in Figures A-1 through A-6 to aid in visual comparison. It must be noted that R1-R2 data is an average velocity over a 3.3 foot segment of the soil column; S-R1 data is an average over 6.3 feet, creating a significant smoothing relative to the R1-R2 plots. S-R1 data are presented in Tables A-1 through A-6, and included in the EXCEL analysis files for each boring on volume 2 of 2 (DVD-R) of this report.

Calibration procedures and records for the suspension measurement system are presented in Appendix D.

The **GEO***Vision* standard field log sheets for all borings are reproduced in Appendix E.

The **GEO***Vision* standard field procedures are reproduced in Appendix F.

Caliper/ Natural Gamma Results

Caliper and natural gamma data are presented in combined log plots with resistivity and spontaneous potential as single page logs in Figures 7, 8, 12, 13, 17 and 18, as well as multi-page logs in Appendix B. On all of these logs, the following acronyms are used:

- NGAM; Natural Gamma collected with the Caliper/Natural Gamma probe
- EGAM; Natural Gamma collected with the ELOG/Natural Gamma probe
- SP; Spontanous (or Self) Potential
- LON; Long Normal (64 inch) Resistivity
- SHN; Short Normal (16 inch) Resistivity
- SPR; Single Point Resistance, comparable with the long and short normal resistance
- CALP; Caliper measured with a 3 arm mechanical Caliper/Natural Gamma probe

LAS 2.0 data and Acrobat files of the plots for each boring are included in the boring specific sub-directories in the data directory on volume 2 of 2 (DVD-R) of this report.

Resistivity / Spontaneous Potential Results

Resistivity and spontaneous potential data is presented in combined log plots with caliper and natural gamma data as single page logs in Figures 7, 8, 12, 13, 17 and 18, as well as multi-page logs in Appendix B. LAS 2.0 data and Acrobat files for each boring are included in the boring specific sub-directories in the data directory on volume 2 of 2 (DVD-R) of this report.

Acoustic Televiewer / Boring Deviation Results

Acoustic televiewer amplitude images and simulated core images are presented in Appendix C, with identified features super-imposed on the images. Features were picked only as planar features (as identified as features only present on the amplitude display) and fractures (as identified as features present on both amplitude and travel-time displays). The same logs are presented in .pdf format in the boring specific sub-directories of the data directory on volume 2 of 2 (DVD-R) of this report. Fracture and planar feature depth, dip angle and azimuth of dip data are provided numerically on the log sheets, as well as in text format on volume 2.

Boring deviation data is presented graphically in Figures 9, 14 and 19, and summarized in Table 4. Deviation data plots in Acrobat format and deviation data at 1.0 foot stations are presented in text format in the boring specific sub-directories of the data directory on volume 2 of 2 (DVD-R) of this report.

SUMMARY

Discussion of Suspension Results

Suspension PS velocity data are ideally collected in an uncased fluid filled boring, drilled with rotary mud (rotary wash) methods. The lower portion of the borings at this site were ideal for collection of suspension PS velocity data. The upper portion of the borings provided mixed results due to erosion of the boring walls, as well as the inability to hold fluid to ground level. Each boring is discussed in more detail below.

Suspension PS velocity data quality is judged based upon 5 criteria:

1. Consistent data between receiver to receiver (R1 – R2) and source to receiver (S – R1) data.
2. Consistent relationship between P-wave and S_H -wave (excluding transition to saturated soils)
3. Consistency between data from adjacent depth intervals.
4. Clarity of P-wave and S_H-wave onset, as well as damping of later oscillations.
5. Consistency of profile between adjacent borings, if available.

B-901: These data show excellent correlation between R1 – R2 and S – R1 data, as well as excellent correlation between P-wave and S_H-wave velocities. S_H-wave onsets are generally clear, and later oscillations are well damped. P-wave arrivals are weak, as is generally the case in hard rock borings, and above water table in soil. This is an excellent rock velocity data set, with good soil velocity data.

B-907: These data show excellent correlation between R1 – R2 and S – R1 data, as well as excellent correlation between P-wave and S_H-wave velocities. S_H-wave onsets are generally clear, and later oscillations are well damped. P-wave arrivals are weak, as is generally the case in hard rock borings, and above water table in soil. This is an excellent rock velocity data set, with good soil velocity data.

B-909: These data show excellent correlation between R1 – R2 and S – R1 data, as well as excellent correlation between P-wave and S_H-wave velocities. S_H-wave onsets are generally clear, and later oscillations are well damped. P-wave arrivals are weak, as is generally the case in hard rock borings, and above water table in soil. The soil portion of this boring produced fair quality data. This is an excellent rock velocity data set, with good soil velocity data.

Discussion of Caliper / Natural Gamma Results

Caliper and natural gamma data was collected for the entire depth of each boring, as natural gamma data can be collected through casing. The caliper logs for all these borings show very consistent gauge in competent rock, with minor tapering downhole due to bit wear. Some fracturing is noted, but below approximately 130 feet, all borings are tight. Natural gamma was collected with this tool in all the borings, as well as with the ELOG probe, and the comparison between the two data sets provides an almost exact match, verifying the performance of the natural gamma measuring systems.

Discussion of Resistivity / Spontaneous Potential Results

Both long and short normal resistivity and single point resistance provide clear delineation of different lithologic units and changes within the bedrock, showing drops in resistivity at weathered zones that correspond with changes in natural gamma and velocity data. The electrical data is not valid above 40 feet, as the upper yoke electrode moves out of the boring fluid at this depth. The natural gamma data remains valid up into the casing, and agrees well with the natural gamma data collected with the caliper probe. The comparison between the two data sets provides an almost exact match, verifying the performance of the natural gamma measuring systems.

Discussion of Acoustic Televiewer / Boring Deviation Results

The acoustic televiewer data quality in all three borings is very good, providing clear images of a number of fractures and weathered zones. Many of the borings exhibit diagonal banding (zebra striping) caused by rapid reaming down the boring with new core bits that are slightly larger than the gauge of the original boring. This creates a spiral wear pattern in the boring that alters the characteristic smooth surface of diamond cored borings. This wear pattern can have a significant impact on acoustic televiewer image quality, and in these borings may conceal smaller dikes. It will not conceal fractures, however.

Location of fractures and weathered zones on the televiewer logs correspond precisely with increases in caliper log diameter and suspension PS velocity drops.

All three borings were inclined at 2.4 degrees, or less, from vertical, and the maximum error in depth value was 0.2 feet in 158 ft, or less than 0.2 percent, as presented in Table 4. This error is less than depth errors from other causes, and no adjustment of log depth is indicated.

BORING NUMBER	MEAN DEVIATION AND AZIMUTH (DEGREES)	SURVEY DEPTH (FEET)	VERTICAL DEPTH (FEET)	DEPTH ERROR (FEET)	HORIZONTAL OFFSET (FEET)
B-901	1.9 – N350	297.9	297.7	0.2	9.7
B-907	2.4 – N23	158.3	158.1	0.2	6.6
B-909	1.6 – N232	199.9	199.8	0.1	5.7

Table 4. Boring Deviation Data Summary

Quality Assurance

These boring geophysical measurements were performed using industry-standard or better methods for measurements and analyses. All work was performed under **GEO***Vision* quality assurance procedures, which include:

- Use of NIST-traceable calibrations, where applicable, for field and laboratory instrumentation
- Use of standard field data logs
- Use of independent verification of velocity data by comparison of receiver-to-receiver and source-to-receiver velocities
- Independent review of calculations and results by a registered professional engineer, geologist, or geophysicist.

Suspension Data Reliability

P- and S_H-wave velocity measurement using the Suspension Method gives average velocities over a 3.3 foot interval of depth. This high resolution results in the scatter of values shown in the graphs. Individual measurements are very reliable with estimated precision of +/- 5%. Standardized field procedures and quality assurance checks contribute to the reliability of these data.

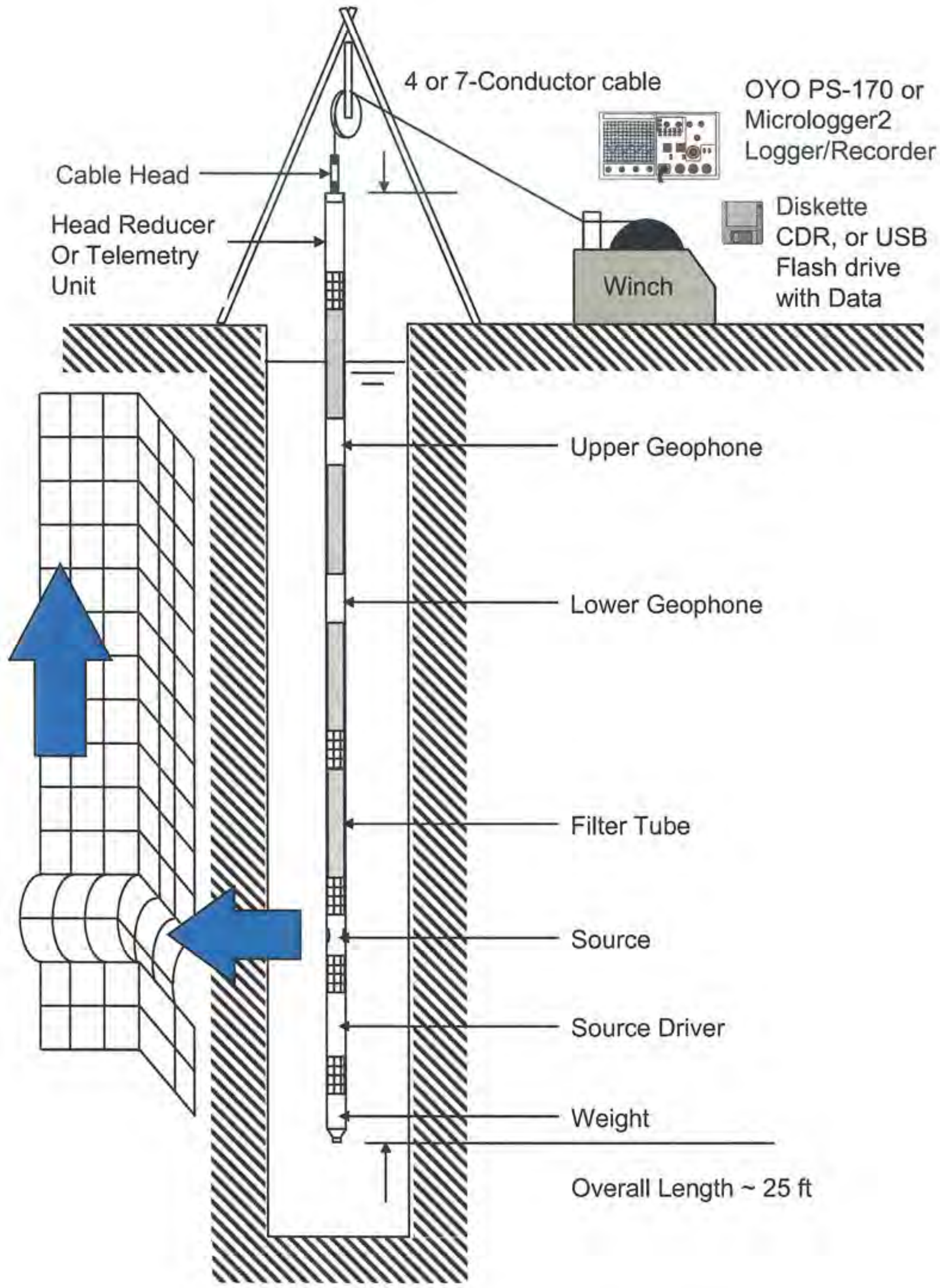


Figure 2: Concept illustration of P-S logging system

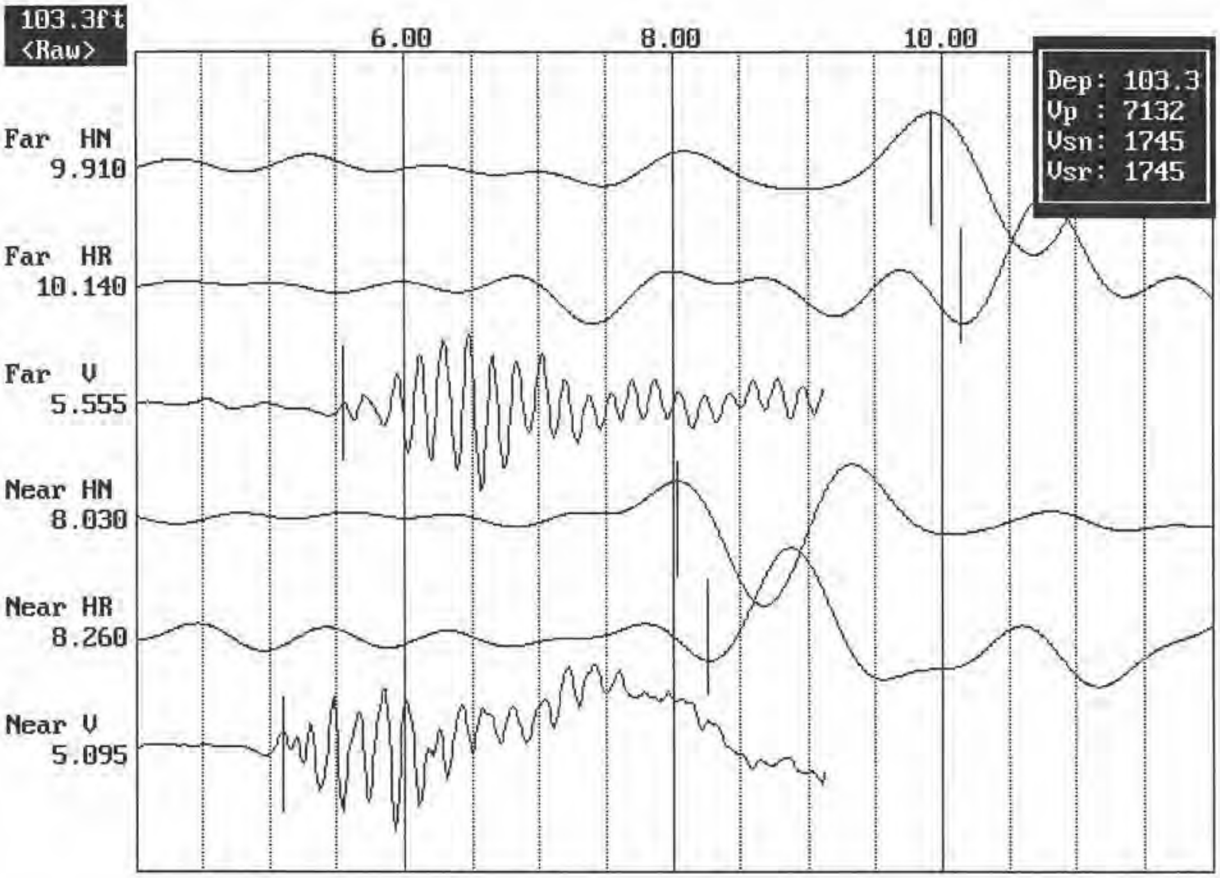


Figure 3: Example of filtered (1400 Hz lowpass) record

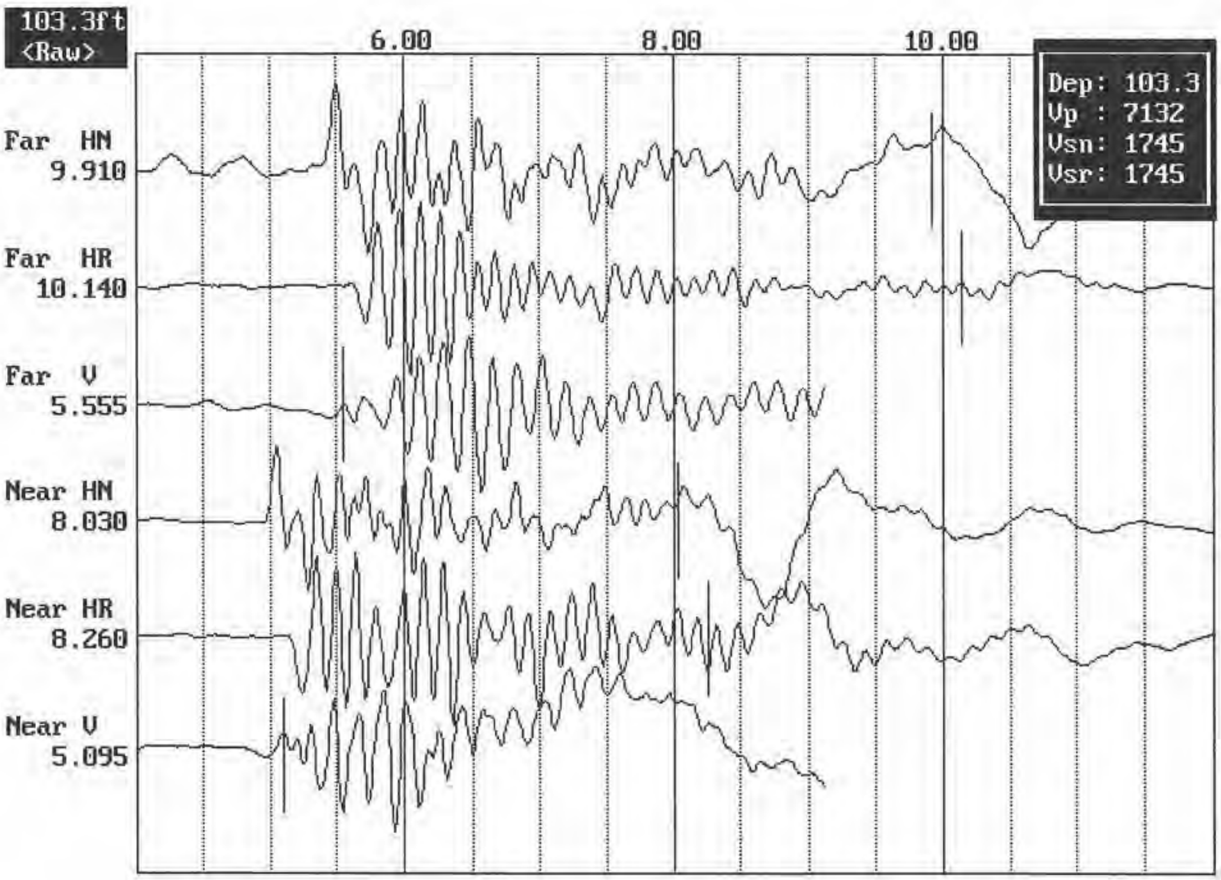


Figure 4. Example of unfiltered record

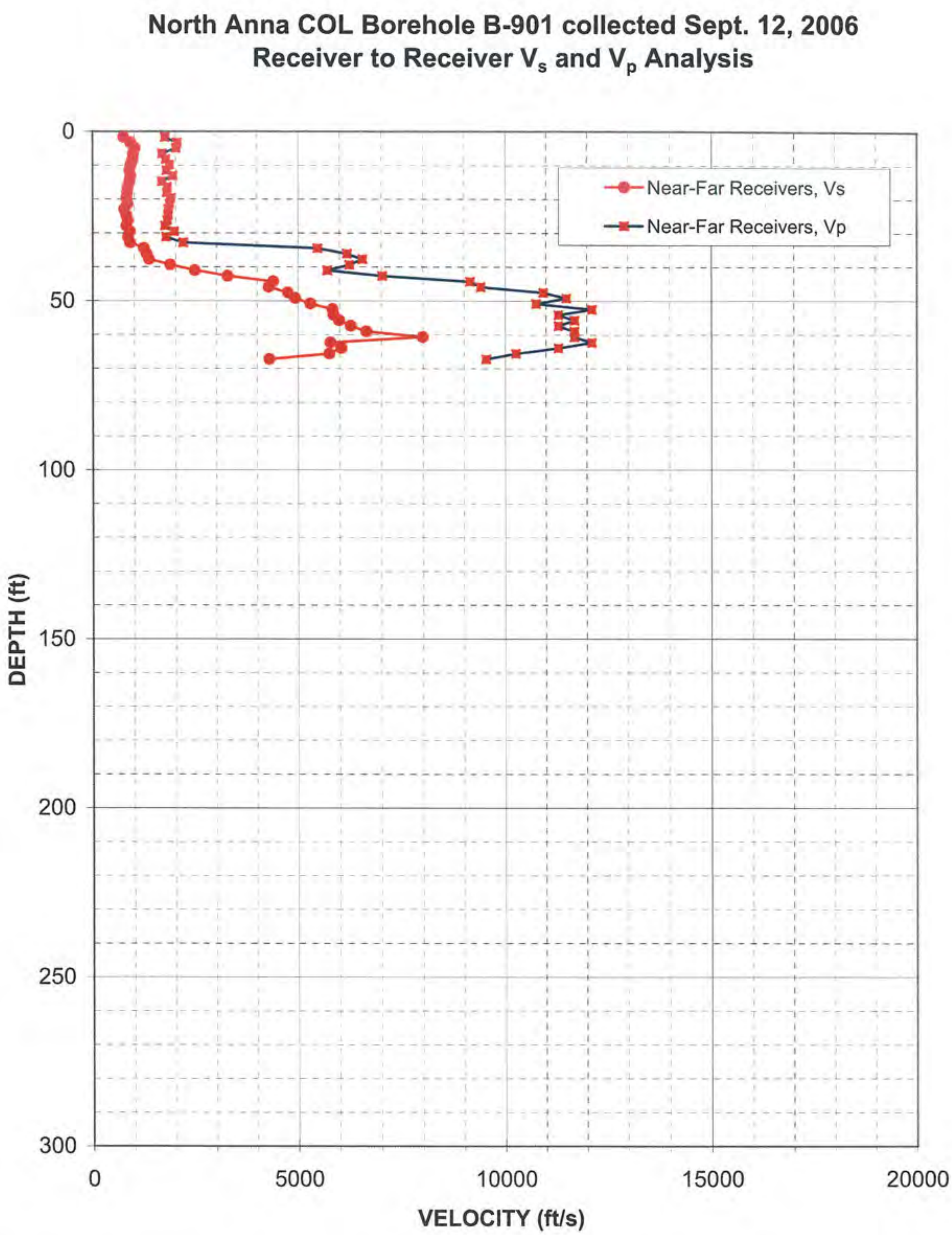


Figure 5: Boring B-901, Top Section, Suspension R1-R2 P- and S_H-wave velocities

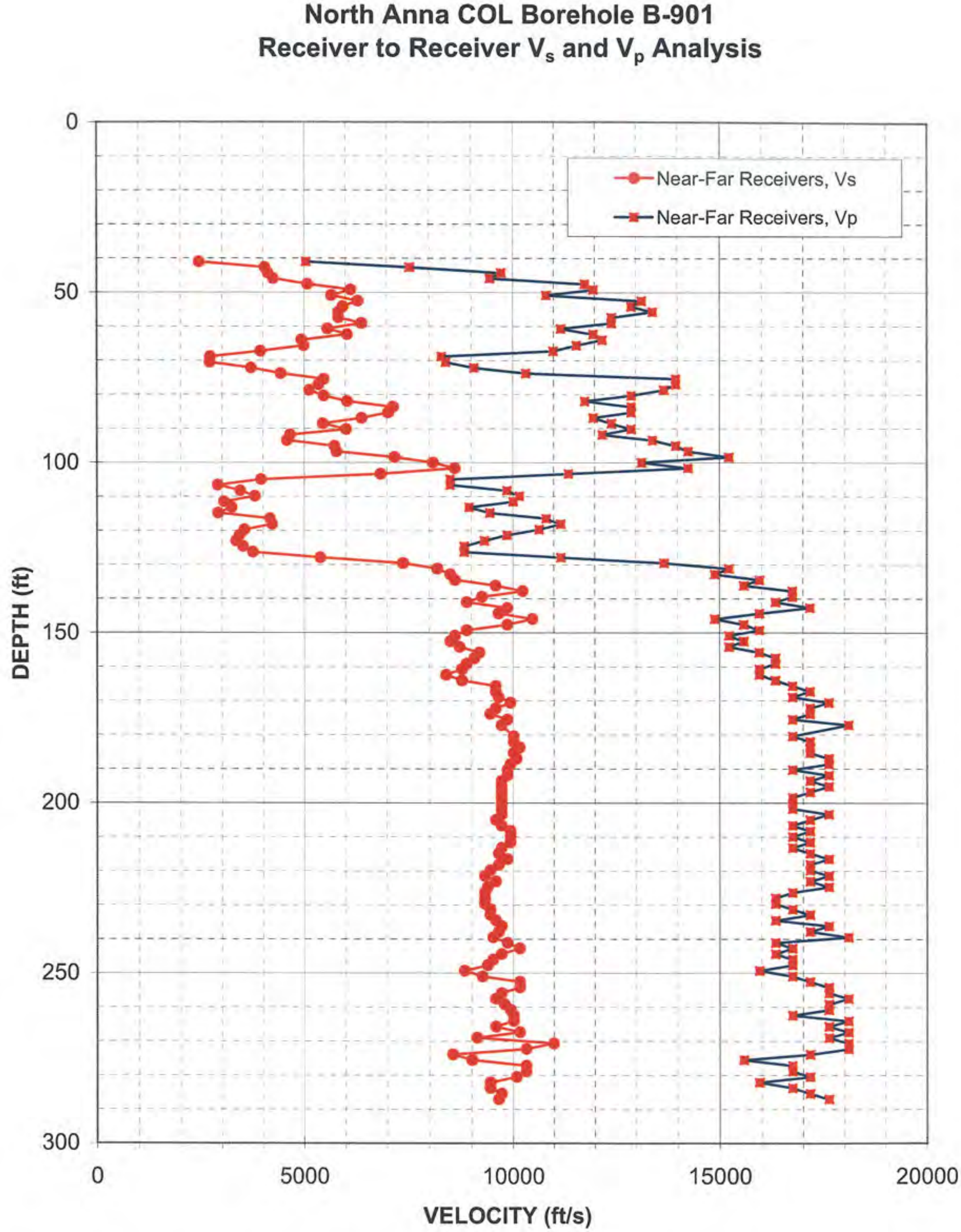


Figure 6: Boring B-901, Bottom Section, Suspension R1-R2 P- and SH-wave velocities

Table 5. Boring B-901, Top Section, Suspension R1-R2 depths and P- and SH-wave velocities

Summary of Compressional Wave Velocity, Shear Wave Velocity, and Poisson's Ratio Based on Receiver-to-Receiver Travel Time Data - Borehole B-901

American Units				Metric Units			
Depth at Midpoint Between Receivers	Velocity		Poisson's Ratio	Depth at Midpoint Between Receivers	Velocity		Poisson's Ratio
	V_s	V_p			V_s	V_p	
(ft)	(ft/s)	(ft/s)		(m)	(m/s)	(m/s)	
1.6	730	1740	0.39	0.5	220	530	0.39
3.3	900	2030	0.38	1.0	270	620	0.38
4.9	1000	2010	0.33	1.5	310	610	0.33
6.6	970	1670	0.25	2.0	290	510	0.25
8.2	950	1750	0.29	2.5	290	530	0.29
9.8	910	1840	0.34	3.0	280	560	0.34
11.5	870	1770	0.34	3.5	270	540	0.34
13.1	900	1930	0.36	4.0	270	590	0.36
14.8	870	1660	0.31	4.5	270	510	0.31
16.4	830	1790	0.36	5.0	250	550	0.36
18.0	820	1780	0.37	5.5	250	540	0.37
19.7	810	1870	0.39	6.0	250	570	0.39
21.3	830	1840	0.37	6.5	250	560	0.37
23.0	750	1810	0.40	7.0	230	550	0.40
24.6	800	1810	0.38	7.5	240	550	0.38
26.3	830	1790	0.36	8.0	250	550	0.36
27.9	800	1740	0.36	8.5	240	530	0.36
29.5	890	1960	0.37	9.0	270	600	0.37
31.2	840	1760	0.35	9.5	260	540	0.35
32.8	890	2180	0.40	10.0	270	660	0.40
34.5	1230	5460	0.47	10.5	370	1670	0.47
36.1	1290	6170	0.48	11.0	390	1880	0.48
37.7	1340	6540	0.48	11.5	410	1990	0.48
39.4	1860	6230	0.45	12.0	570	1900	0.45
41.0	2460	5700	0.39	12.5	750	1740	0.39
42.7	3270	7020	0.36	13.0	1000	2140	0.36
44.3	4390	9130	0.35	13.5	1340	2780	0.35
45.9	4270	9390	0.37	14.0	1300	2860	0.37
47.6	4740	10930	0.38	14.5	1450	3330	0.38
49.2	4920	11490	0.39	15.0	1500	3500	0.39
50.9	5290	10750	0.34	15.5	1610	3280	0.34
52.5	5820	12120	0.35	16.0	1770	3690	0.35
54.1	5850	11300	0.32	16.5	1780	3440	0.32
55.8	5980	11700	0.32	17.0	1820	3560	0.32

Summary of Compressional Wave Velocity, Shear Wave Velocity, and Poisson's Ratio Based on Receiver-to-Receiver Travel Time Data - Borehole B-901

American Units			
Depth at Midpoint Between Receivers	Velocity		Poisson's Ratio
	V_s	V_p	
(ft)	(ft/s)	(ft/s)	
57.4	6260	11300	0.28
59.1	6630	11700	0.26
60.7	7980	11700	0.06
62.3	5770	12120	0.35
64.0	6030	11300	0.30
65.6	5750	10260	0.27
67.3	4290	9520	0.37

Metric Units			
Depth at Midpoint Between Receivers	Velocity		Poisson's Ratio
	V_s	V_p	
(m)	(m/s)	(m/s)	
17.5	1910	3440	0.28
18.0	2020	3560	0.26
18.5	2430	3560	0.06
19.0	1760	3690	0.35
19.5	1840	3440	0.30
20.0	1750	3130	0.27
20.5	1310	2900	0.37

Table 6. Boring B-901, Bottom Section, Suspension R1-R2 depths and P- and S_H-wave velocities

Summary of Compressional Wave Velocity, Shear Wave Velocity, and Poisson's Ratio Based on Receiver-to-Receiver Travel Time Data - Borehole B-901

American Units				Metric Units			
Depth at Midpoint Between Receivers	Velocity		Poisson's Ratio	Depth at Midpoint Between Receivers	Velocity		Poisson's Ratio
	V_s	V_p			V_s	V_p	
(ft)	(ft/s)	(ft/s)		(m)	(m/s)	(m/s)	
41.0	2430	5030	0.35	12.5	740	1530	0.35
42.7	4030	7520	0.30	13.0	1230	2290	0.30
44.3	4110	9700	0.39	13.5	1250	2960	0.39
45.9	4240	9430	0.37	14.0	1290	2870	0.37
47.6	5070	11740	0.39	14.5	1550	3580	0.39
49.2	6110	11950	0.32	15.0	1860	3640	0.32
50.9	5650	10800	0.31	15.5	1720	3290	0.31
52.5	6280	13120	0.35	16.0	1920	4000	0.35
54.1	5920	12870	0.37	16.5	1810	3920	0.37
55.8	5820	13390	0.38	17.0	1770	4080	0.38
57.4	5820	12400	0.36	17.5	1770	3780	0.36
59.1	6370	12400	0.32	18.0	1940	3780	0.32
60.7	5550	11160	0.34	18.5	1690	3400	0.34
62.3	6030	11950	0.33	19.0	1840	3640	0.33
64.0	4920	12170	0.40	19.5	1500	3710	0.40
65.6	4980	11540	0.39	20.0	1520	3520	0.39
67.3	3930	10970	0.43	20.5	1200	3340	0.43
68.9	2700	8260	0.44	21.0	820	2520	0.44
70.5	2690	8370	0.44	21.5	820	2550	0.44
72.2	3700	9050	0.40	22.0	1130	2760	0.40
73.8	4420	10300	0.39	22.5	1350	3140	0.39
75.5	5460	13940	0.41	23.0	1670	4250	0.41
77.1	5330	13940	0.41	23.5	1630	4250	0.41
78.7	5110	13660	0.42	24.0	1560	4160	0.42
80.4	5460	12870	0.39	24.5	1670	3920	0.39
82.0	6030	11740	0.32	25.0	1840	3580	0.32
83.7	7120	12870	0.28	25.5	2170	3920	0.28
85.3	7010	12870	0.29	26.0	2140	3920	0.29
86.9	6370	11950	0.30	26.5	1940	3640	0.30
88.6	5440	12400	0.38	27.0	1660	3780	0.38
90.2	6000	12870	0.36	27.5	1830	3920	0.36
91.9	4650	12170	0.41	28.0	1420	3710	0.41
93.5	4570	13390	0.43	28.5	1390	4080	0.43
95.1	5720	13940	0.40	29.0	1740	4250	0.40
96.8	5770	14240	0.40	29.5	1760	4340	0.40
98.4	7160	15210	0.36	30.0	2180	4640	0.36

Summary of Compressional Wave Velocity, Shear Wave Velocity, and Poisson's Ratio Based on Receiver-to-Receiver Travel Time Data - Borehole B-901

American Units				Metric Units			
Depth at Midpoint Between Receivers	Velocity		Poisson's Ratio	Depth at Midpoint Between Receivers	Velocity		Poisson's Ratio
	V_s	V_p			V_s	V_p	
(ft)	(ft/s)	(ft/s)		(m)	(m/s)	(m/s)	
100.1	8060	13120	0.20	30.5	2460	4000	0.20
101.7	8580	14240	0.21	31.0	2620	4340	0.21
103.4	6830	11340	0.22	31.5	2080	3460	0.22
105.0	3940	8470	0.36	32.0	1200	2580	0.36
106.6	2890	8470	0.43	32.5	880	2580	0.43
108.3	3430	9840	0.43	33.0	1050	3000	0.43
109.9	3790	10140	0.42	33.5	1160	3090	0.42
111.6	3040	9990	0.45	34.0	930	3040	0.45
113.2	3230	8920	0.42	34.5	980	2720	0.42
114.8	2900	9430	0.45	35.0	880	2870	0.45
116.5	4160	10800	0.41	35.5	1270	3290	0.41
118.1	4210	11160	0.42	36.0	1280	3400	0.42
119.8	3530	10620	0.44	36.5	1080	3240	0.44
121.4	3410	9840	0.43	37.0	1040	3000	0.43
123.0	3330	9300	0.43	37.5	1010	2830	0.43
124.7	3500	8810	0.41	38.0	1070	2680	0.41
126.3	3740	8810	0.39	38.5	1140	2680	0.39
128.0	5380	11160	0.35	39.0	1640	3400	0.35
129.6	7360	13660	0.30	39.5	2240	4160	0.30
131.2	8160	15210	0.30	40.0	2490	4640	0.30
132.9	8470	14870	0.26	40.5	2580	4530	0.26
134.5	8580	15940	0.30	41.0	2620	4860	0.30
136.2	9560	15570	0.20	41.5	2910	4740	0.20
137.8	10220	16730	0.20	42.0	3110	5100	0.20
139.4	9230	16730	0.28	42.5	2810	5100	0.28
141.1	8870	16330	0.29	43.0	2700	4980	0.29
142.7	9840	17160	0.25	43.5	3000	5230	0.25
144.4	9630	15940	0.21	44.0	2940	4860	0.21
146.0	10460	14870	0.01	44.5	3190	4530	0.01
147.6	9840	15570	0.17	45.0	3000	4740	0.17
149.3	8870	15940	0.28	45.5	2700	4860	0.28
150.9	8580	15210	0.27	46.0	2620	4640	0.27
152.6	8470	15570	0.29	46.5	2580	4740	0.29
154.2	8690	15210	0.26	47.0	2650	4640	0.26
155.8	9170	15940	0.25	47.5	2790	4860	0.25
157.5	9050	16330	0.28	48.0	2760	4980	0.28
159.1	8870	16330	0.29	48.5	2700	4980	0.29
160.8	8750	15940	0.28	49.0	2670	4860	0.28
162.4	8370	15940	0.31	49.5	2550	4860	0.31

Summary of Compressional Wave Velocity, Shear Wave Velocity, and Poisson's Ratio Based on Receiver-to-Receiver Travel Time Data - Borehole B-901

American Units			
Depth at Midpoint Between Receivers	Velocity		Poisson's Ratio
	V_s	V_p	
(ft)	(ft/s)	(ft/s)	
164.0	8750	16330	0.30
165.7	9560	16730	0.26
167.3	9560	17160	0.27
169.0	9630	16730	0.25
170.6	9920	17610	0.27
172.2	9560	17160	0.27
173.9	9430	17160	0.28
175.5	9840	16730	0.24
177.2	9700	18090	0.30
180.5	9990	16730	0.22
182.1	9990	17160	0.24
183.7	10140	17160	0.23
185.4	9990	17160	0.24
187.0	10070	17610	0.26
188.7	9920	17610	0.27
190.3	9840	16730	0.24
191.9	9840	17610	0.27
193.6	9700	17160	0.27
195.2	9700	17610	0.28
196.9	9700	17160	0.27
198.5	9700	16730	0.25
200.1	9700	16730	0.25
201.8	9700	16730	0.25
203.4	9700	17610	0.28
205.1	9560	17160	0.27
206.7	9700	16730	0.25
208.3	9920	17160	0.25
210.0	9920	16730	0.23
211.6	9920	17160	0.25
213.3	9700	16730	0.25
214.9	9630	17160	0.27
216.5	9840	17610	0.27
218.2	9630	17160	0.27
219.8	9430	17160	0.28
221.5	9300	17610	0.31
223.1	9560	17160	0.27
224.7	9360	17610	0.30
226.4	9300	16730	0.28
228.0	9300	16330	0.26

Metric Units			
Depth at Midpoint Between Receivers	Velocity		Poisson's Ratio
	V_s	V_p	
(m)	(m/s)	(m/s)	
50.0	2670	4980	0.30
50.5	2910	5100	0.26
51.0	2910	5230	0.27
51.5	2940	5100	0.25
52.0	3020	5370	0.27
52.5	2910	5230	0.27
53.0	2870	5230	0.28
53.5	3000	5100	0.24
54.0	2960	5510	0.30
55.0	3040	5100	0.22
55.5	3040	5230	0.24
56.0	3090	5230	0.23
56.5	3040	5230	0.24
57.0	3070	5370	0.26
57.5	3020	5370	0.27
58.0	3000	5100	0.24
58.5	3000	5370	0.27
59.0	2960	5230	0.27
59.5	2960	5370	0.28
60.0	2960	5230	0.27
60.5	2960	5100	0.25
61.0	2960	5100	0.25
61.5	2960	5100	0.25
62.0	2960	5370	0.28
62.5	2910	5230	0.27
63.0	2960	5100	0.25
63.5	3020	5230	0.25
64.0	3020	5100	0.23
64.5	3020	5230	0.25
65.0	2960	5100	0.25
65.5	2940	5230	0.27
66.0	3000	5370	0.27
66.5	2940	5230	0.27
67.0	2870	5230	0.28
67.5	2830	5370	0.31
68.0	2910	5230	0.27
68.5	2850	5370	0.30
69.0	2830	5100	0.28
69.5	2830	4980	0.26

Summary of Compressional Wave Velocity, Shear Wave Velocity, and Poisson's Ratio Based on Receiver-to-Receiver Travel Time Data - Borehole B-901

American Units				Metric Units			
Depth at Midpoint Between Receivers	Velocity		Poisson's Ratio	Depth at Midpoint Between Receivers	Velocity		Poisson's Ratio
	V_s	V_p			V_s	V_p	
(ft)	(ft/s)	(ft/s)		(m)	(m/s)	(m/s)	
229.7	9300	16330	0.26	70.0	2830	4980	0.26
231.3	9430	16730	0.27	70.5	2870	5100	0.27
232.9	9430	17160	0.28	71.0	2870	5230	0.28
234.6	9560	16330	0.24	71.5	2910	4980	0.24
236.2	9700	17610	0.28	72.0	2960	5370	0.28
237.9	9630	17160	0.27	72.5	2940	5230	0.27
239.5	9490	18090	0.31	73.0	2890	5510	0.31
241.1	9840	16330	0.21	73.5	3000	4980	0.21
242.8	10140	16730	0.21	74.0	3090	5100	0.21
244.4	9700	16330	0.23	74.5	2960	4980	0.23
246.1	9490	16730	0.26	75.0	2890	5100	0.26
247.7	9360	16730	0.27	75.5	2850	5100	0.27
249.3	8810	15940	0.28	76.0	2680	4860	0.28
251.0	9230	16730	0.28	76.5	2810	5100	0.28
252.6	10140	17160	0.23	77.0	3090	5230	0.23
254.3	10140	17610	0.25	77.5	3090	5370	0.25
255.9	9700	17610	0.28	78.0	2960	5370	0.28
257.6	9560	18090	0.31	78.5	2910	5510	0.31
259.2	9770	17610	0.28	79.0	2980	5370	0.28
260.8	9920	17610	0.27	79.5	3020	5370	0.27
262.5	9990	16730	0.22	80.0	3040	5100	0.22
264.1	9990	18090	0.28	80.5	3040	5510	0.28
265.8	9560	17610	0.29	81.0	2910	5370	0.29
267.4	10140	18090	0.27	81.5	3090	5510	0.27
269.0	9110	17610	0.32	82.0	2780	5370	0.32
270.7	10970	18090	0.21	82.5	3340	5510	0.21
272.3	10300	18090	0.26	83.0	3140	5510	0.26
274.0	8530	17160	0.34	83.5	2600	5230	0.34
275.6	8980	15570	0.25	84.0	2740	4740	0.25
277.2	10300	16730	0.20	84.5	3140	5100	0.20
278.9	10300	16730	0.20	85.0	3140	5100	0.20
280.5	10070	17160	0.24	85.5	3070	5230	0.24
282.2	9430	15940	0.23	86.0	2870	4860	0.23
283.8	9430	16730	0.27	86.5	2870	5100	0.27
285.4	9700	17160	0.27	87.0	2960	5230	0.27
287.1	9630	17610	0.29	87.5	2940	5370	0.29

Notes: "-" means no data available at that particular interval of depth.

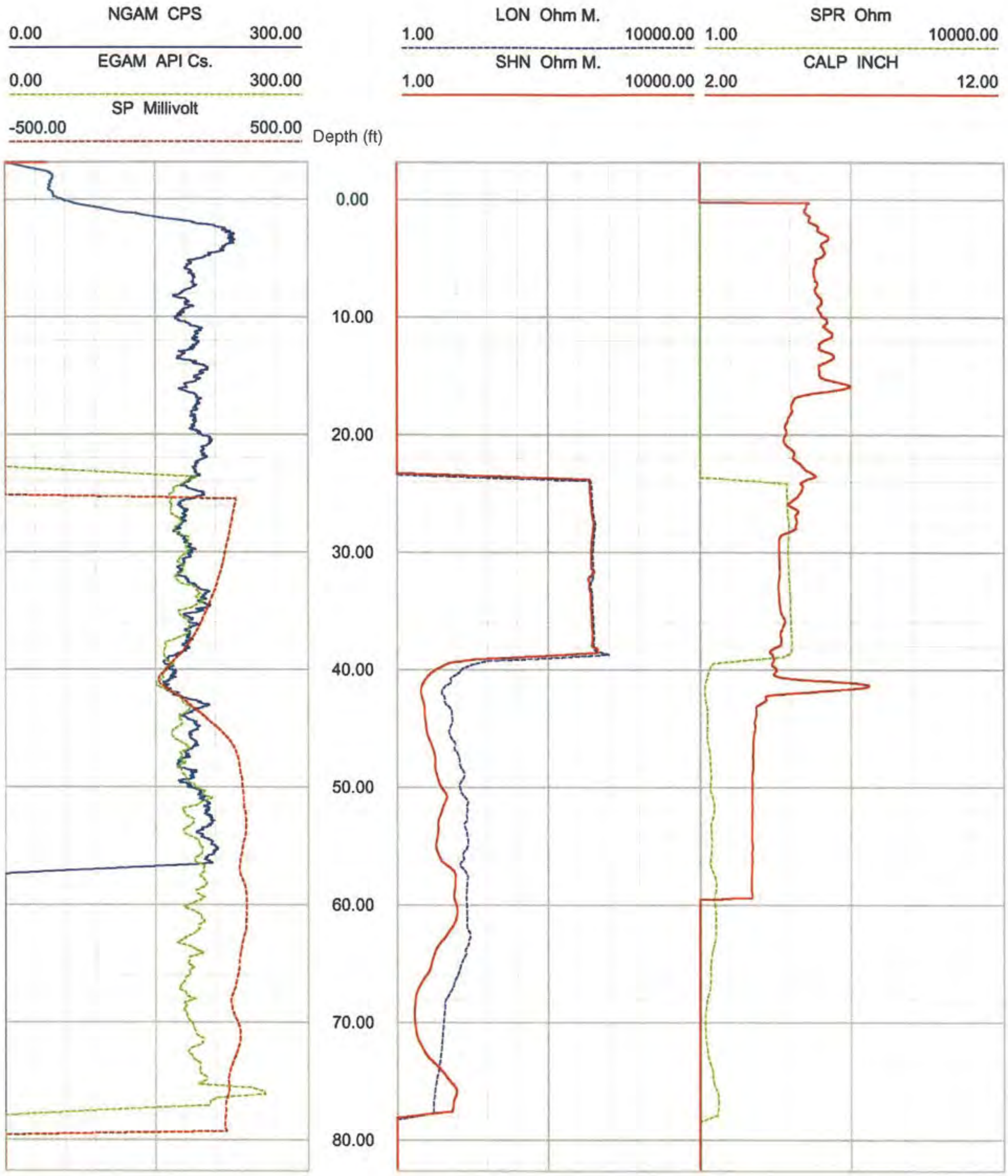


Figure 7: Boring B-901, Top Section, Caliper, Natural gamma, Resistivity and SP logs

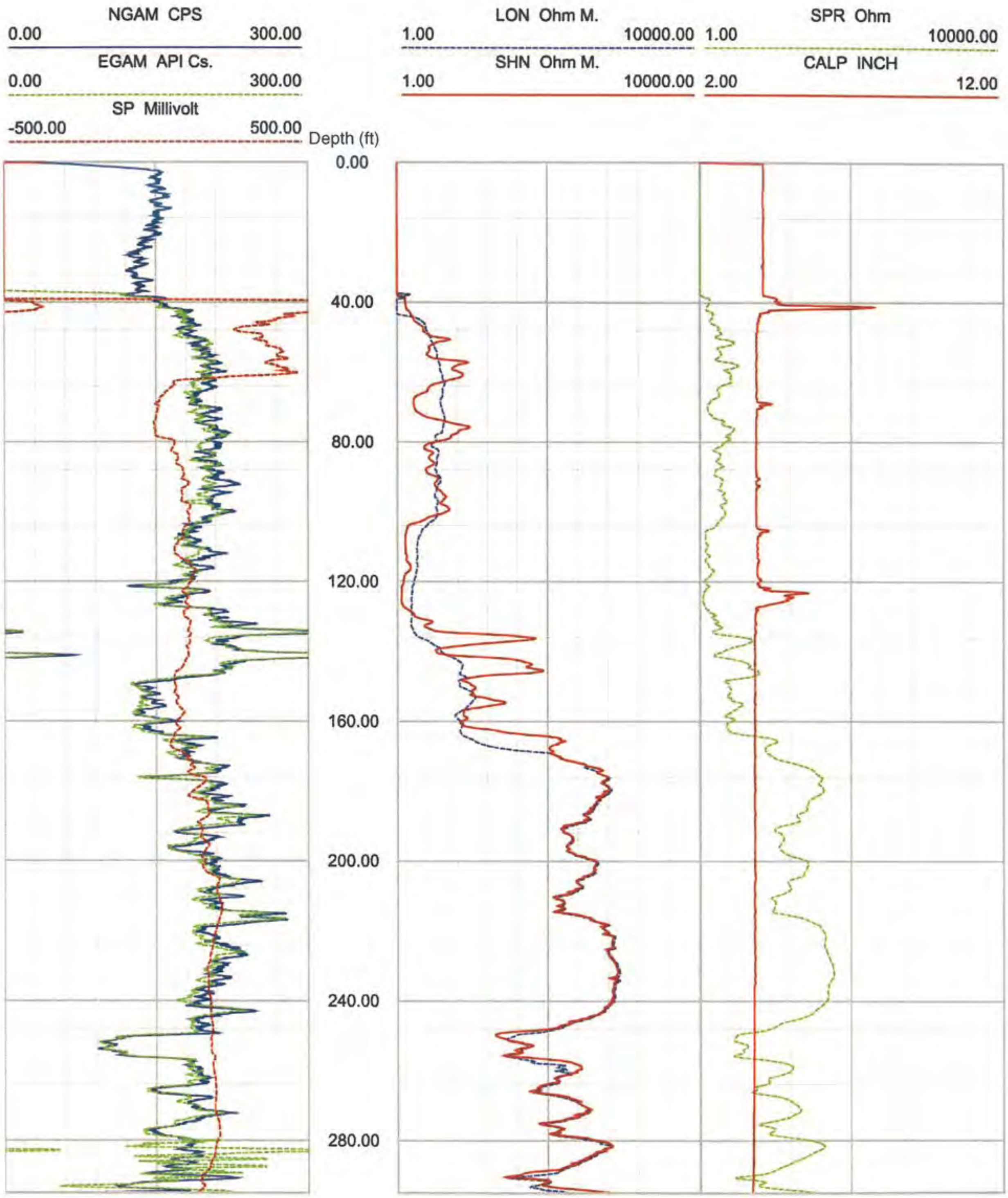
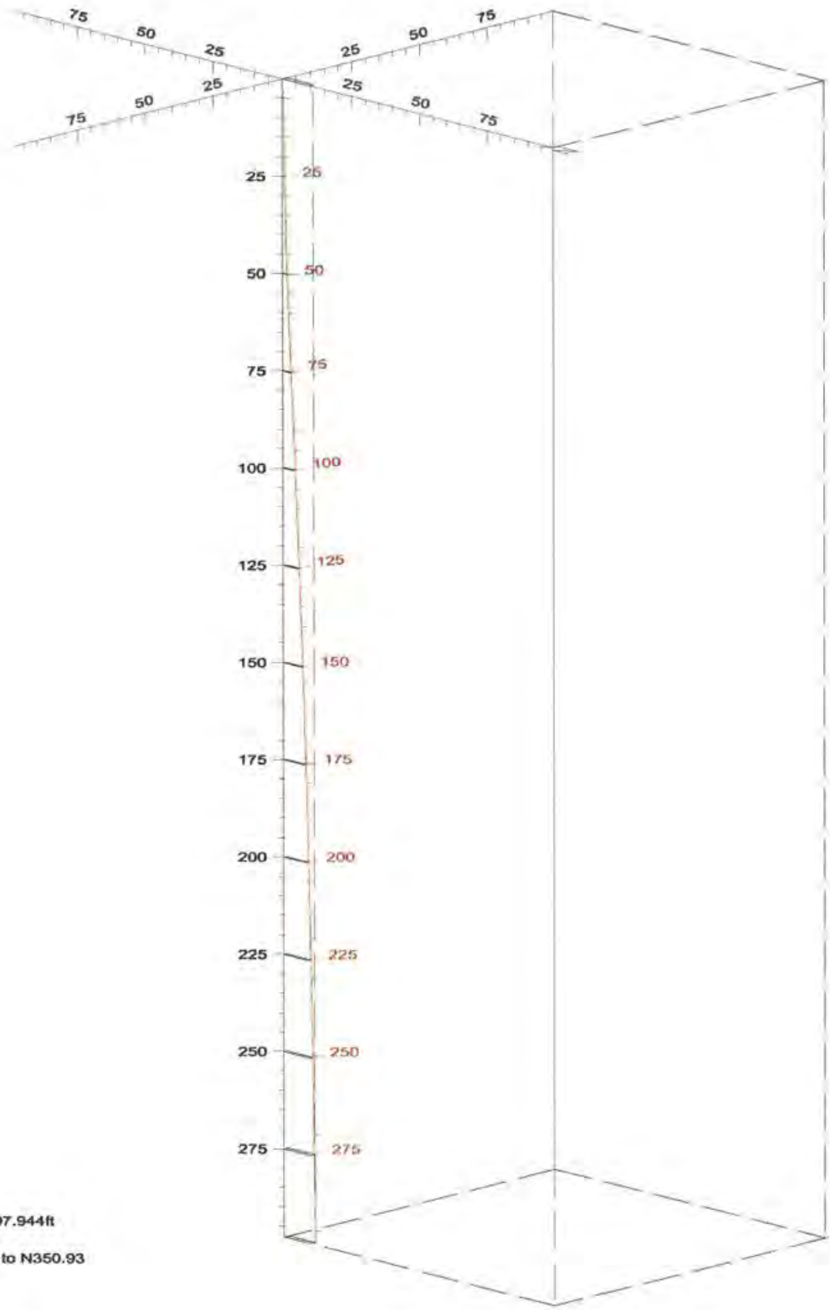


Figure 8: Boring B-901, Bottom Section, Caliper, Natural gamma, Resistivity and SP logs

Deviated borehole in orthographic projection, viewed from N45



Borehole: B-901
Zone from: 2.664 - 297.944ft
North ref is magnetic
Mean deviation: 1.86 to N350.93
End coordinates .....
North: 9.560
East : -1.527
Down : 297.747
Azimuth of end: N350.93
Distance start-end: 9.681ft
Viewpoint: N45
Data extrapolated to the surface from 2.664ft
15 Sep 2006

Figure 9. Boring B-901, Deviation Projection (dimensions in feet)

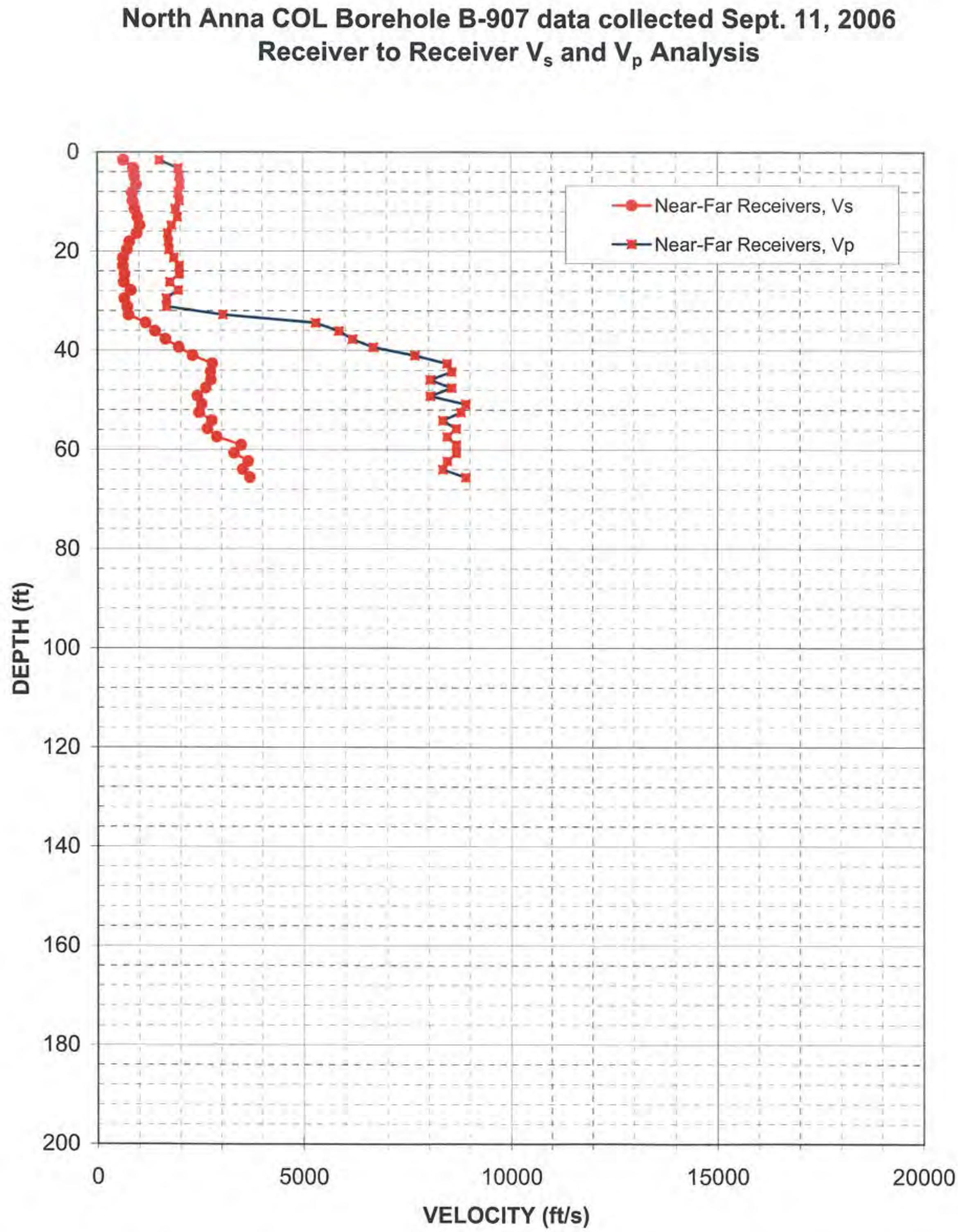


Figure 10: Boring B-907, Top Section, Suspension R1-R2 P- and S_H-wave velocities

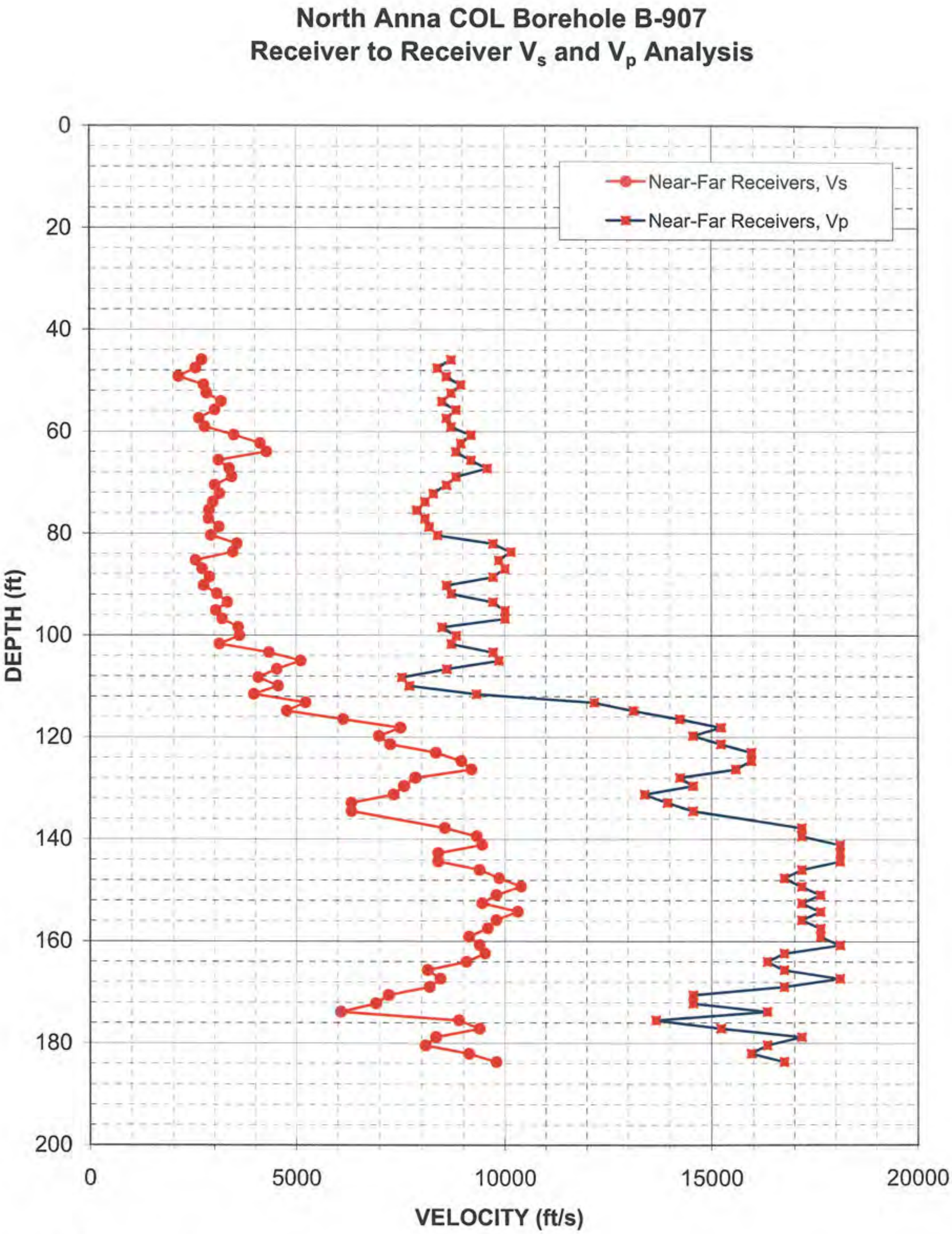


Figure 11: Boring B-907, Bottom Section, Suspension R1-R2 P- and S_H-wave velocities

Table 7. Boring B-907, Top Section, Suspension R1-R2 depths and P- and S_H-wave velocities

Summary of Compressional Wave Velocity, Shear Wave Velocity, and Poisson's Ratio Based on Receiver-to-Receiver Travel Time Data - Borehole B-907

American Units				Metric Units			
Depth at Midpoint Between Receivers	Velocity		Poisson's Ratio	Depth at Midpoint Between Receivers	Velocity		Poisson's Ratio
	V_s	V_p			V_s	V_p	
(ft)	(ft/s)	(ft/s)		(m)	(m/s)	(m/s)	
1.6	610	1480	0.40	0.5	190	450	0.40
3.3	850	1940	0.38	1.0	260	590	0.38
4.9	870	1960	0.38	1.5	270	600	0.38
6.6	920	1980	0.36	2.0	280	600	0.36
8.2	820	1940	0.39	2.5	250	590	0.39
9.8	830	1960	0.39	3.0	250	600	0.39
11.5	880	1870	0.36	3.5	270	570	0.36
13.1	950	1920	0.34	4.0	290	580	0.34
14.8	1000	1770	0.27	4.5	310	540	0.27
16.4	930	1680	0.28	5.0	280	510	0.28
18.0	760	1700	0.38	5.5	230	520	0.38
19.7	690	1720	0.40	6.0	210	520	0.40
21.3	600	1830	0.44	6.5	180	560	0.44
23.0	600	1960	0.45	7.0	180	600	0.45
24.6	640	1960	0.44	7.5	200	600	0.44
26.3	620	1740	0.43	8.0	190	530	0.43
27.9	780	1940	0.40	8.5	240	590	0.40
29.5	630	1650	0.41	9.0	190	500	0.41
31.2	710	1650	0.39	9.5	220	500	0.39
32.8	730	3030	0.47	10.0	220	920	0.47
34.5	1150	5290	0.48	10.5	350	1610	0.48
36.1	1370	5850	0.47	11.0	420	1780	0.47
37.7	1630	6170	0.46	11.5	500	1880	0.46
39.4	1950	6670	0.45	12.0	590	2030	0.45
41.0	2280	7660	0.45	12.5	700	2340	0.45
42.7	2770	8440	0.44	13.0	840	2570	0.44
44.3	2720	8550	0.44	13.5	830	2610	0.44
45.9	2730	8030	0.43	14.0	830	2450	0.43
47.6	2600	8550	0.45	14.5	790	2610	0.45
49.2	2400	8030	0.45	15.0	730	2450	0.45
50.9	2510	8890	0.46	15.5	760	2710	0.46
52.5	2440	8770	0.46	16.0	740	2670	0.46
54.1	2750	8330	0.44	16.5	840	2540	0.44
55.8	2650	8660	0.45	17.0	810	2640	0.45
57.4	2870	8440	0.43	17.5	880	2570	0.43
59.1	3470	8660	0.40	18.0	1060	2640	0.40

Summary of Compressional Wave Velocity, Shear Wave Velocity, and Poisson's Ratio Based on Receiver-to-Receiver Travel Time Data - Borehole B-907

American Units			
Depth at Midpoint Between Receivers	Velocity		Poisson's Ratio
	V_s	V_p	
(ft)	(ft/s)	(ft/s)	
60.7	3300	8660	0.41
62.3	3640	8440	0.39
64.0	3510	8330	0.39
65.6	3680	8890	0.40

Metric Units			
Depth at Midpoint Between Receivers	Velocity		Poisson's Ratio
	V_s	V_p	
(m)	(m/s)	(m/s)	
18.5	1010	2640	0.41
19.0	1110	2570	0.39
19.5	1070	2540	0.39
20.0	1120	2710	0.40

Notes: "-" means no data available at that particular interval of depth.

Table 8. Boring B-907, Bottom Section, Suspension R1-R2 depths and P- and S_H-wave velocities

Summary of Compressional Wave Velocity, Shear Wave Velocity, and Poisson's Ratio Based on Receiver-to-Receiver Travel Time Data - Borehole B-907

American Units				Metric Units			
Depth at Midpoint Between Receivers	Velocity		Poisson's Ratio	Depth at Midpoint Between Receivers	Velocity		Poisson's Ratio
	V_s	V_p			V_s	V_p	
(ft)	(ft/s)	(ft/s)		(m)	(m/s)	(m/s)	
45.9	2690	8690	0.45	14.0	820	2650	0.45
47.6	2540	8370	0.45	14.5	770	2550	0.45
49.2	2120	8580	0.47	15.0	650	2620	0.47
50.9	2730	8920	0.45	15.5	830	2720	0.45
52.5	2800	8690	0.44	16.0	850	2650	0.44
54.1	3160	8470	0.42	16.5	960	2580	0.42
55.8	3000	8810	0.43	17.0	910	2680	0.43
57.4	2610	8580	0.45	17.5	800	2620	0.45
59.1	2750	8690	0.44	18.0	840	2650	0.44
60.7	3470	9170	0.42	18.5	1060	2790	0.42
62.3	4110	8920	0.37	19.0	1250	2720	0.37
64.0	4260	8810	0.35	19.5	1300	2680	0.35
65.6	3090	9170	0.44	20.0	940	2790	0.44
67.3	3360	9560	0.43	20.5	1020	2910	0.43
68.9	3410	8810	0.41	21.0	1040	2680	0.41
70.5	3000	8580	0.43	21.5	910	2620	0.43
72.2	3110	8260	0.42	22.0	950	2520	0.42
73.8	2960	8060	0.42	22.5	900	2460	0.42
75.5	2850	7870	0.42	23.0	870	2400	0.42
77.1	2850	8060	0.43	23.5	870	2460	0.43
78.7	3100	8160	0.42	24.0	940	2490	0.42
80.4	2900	8370	0.43	24.5	890	2550	0.43
82.0	3540	9700	0.42	25.0	1080	2960	0.42
83.7	3440	10140	0.43	25.5	1050	3090	0.43
85.3	2530	9840	0.46	26.0	770	3000	0.46
86.9	2690	9990	0.46	26.5	820	3040	0.46
88.6	2870	9700	0.45	27.0	870	2960	0.45
90.2	2730	8580	0.44	27.5	830	2620	0.44
91.9	3050	8690	0.43	28.0	930	2650	0.43
93.5	3310	9700	0.43	28.5	1010	2960	0.43
95.1	3020	9990	0.45	29.0	920	3040	0.45
96.8	3180	9990	0.44	29.5	970	3040	0.44
98.4	3570	8470	0.39	30.0	1090	2580	0.39
100.1	3600	8810	0.40	30.5	1100	2680	0.40
101.7	3110	8690	0.43	31.0	950	2650	0.43
103.4	4320	9700	0.38	31.5	1320	2960	0.38

Summary of Compressional Wave Velocity, Shear Wave Velocity, and Poisson's Ratio Based on Receiver-to-Receiver Travel Time Data - Borehole B-907

American Units				Metric Units			
Depth at Midpoint Between Receivers	Velocity		Poisson's Ratio	Depth at Midpoint Between Receivers	Velocity		Poisson's Ratio
	V_s	V_p			V_s	V_p	
(ft)	(ft/s)	(ft/s)		(m)	(m/s)	(m/s)	
105.0	5090	9840	0.32	32.0	1550	3000	0.32
106.6	4510	8580	0.31	32.5	1370	2620	0.31
108.3	4060	7520	0.29	33.0	1240	2290	0.29
109.9	4540	7690	0.23	33.5	1380	2340	0.23
111.6	3950	9300	0.39	34.0	1200	2830	0.39
113.2	5210	12170	0.39	34.5	1590	3710	0.39
114.8	4750	13120	0.42	35.0	1450	4000	0.42
116.5	6110	14240	0.39	35.5	1860	4340	0.39
118.1	7480	15210	0.34	36.0	2280	4640	0.34
119.8	6970	14550	0.35	36.5	2130	4440	0.35
121.4	7240	15210	0.35	37.0	2210	4640	0.35
123.0	8310	15940	0.31	37.5	2530	4860	0.31
124.7	8920	15940	0.27	38.0	2720	4860	0.27
126.3	9170	15570	0.23	38.5	2790	4740	0.23
128.0	7830	14240	0.28	39.0	2390	4340	0.28
129.6	7560	14550	0.31	39.5	2310	4440	0.31
131.2	7320	13390	0.29	40.0	2230	4080	0.29
132.9	6310	13940	0.37	40.5	1920	4250	0.37
134.5	6310	14550	0.38	41.0	1920	4440	0.38
137.8	8530	17160	0.34	42.0	2600	5230	0.34
139.4	9300	17160	0.29	42.5	2830	5230	0.29
141.1	9430	18090	0.31	43.0	2870	5510	0.31
142.7	8370	18090	0.36	43.5	2550	5510	0.36
144.4	8370	18090	0.36	44.0	2550	5510	0.36
146.0	9360	17160	0.29	44.5	2850	5230	0.29
147.6	9840	16730	0.24	45.0	3000	5100	0.24
149.3	10380	17160	0.21	45.5	3160	5230	0.21
150.9	9770	17610	0.28	46.0	2980	5370	0.28
152.6	9430	17160	0.28	46.5	2870	5230	0.28
154.2	10300	17610	0.24	47.0	3140	5370	0.24
155.8	9770	17160	0.26	47.5	2980	5230	0.26
157.5	9560	17610	0.29	48.0	2910	5370	0.29
159.1	9110	17610	0.32	48.5	2780	5370	0.32
160.8	9360	18090	0.32	49.0	2850	5510	0.32
162.4	9490	16730	0.26	49.5	2890	5100	0.26
164.0	9050	16330	0.28	50.0	2760	4980	0.28
165.7	8110	16730	0.35	50.5	2470	5100	0.35
167.3	8420	18090	0.36	51.0	2570	5510	0.36
169.0	8160	16730	0.34	51.5	2490	5100	0.34

Summary of Compressional Wave Velocity, Shear Wave Velocity, and Poisson's Ratio Based on Receiver-to-Receiver Travel Time Data - Borehole B-907

American Units				Metric Units			
Depth at Midpoint Between Receivers	Velocity		Poisson's Ratio	Depth at Midpoint Between Receivers	Velocity		Poisson's Ratio
	V_s	V_p			V_s	V_p	
(ft)	(ft/s)	(ft/s)		(m)	(m/s)	(m/s)	
170.6	7200	14550	0.34	52.0	2190	4440	0.34
172.2	6900	14550	0.35	52.5	2100	4440	0.35
173.9	6060	16330	0.42	53.0	1850	4980	0.42
175.5	8870	13660	0.14	53.5	2700	4160	0.14
177.2	9360	15210	0.20	54.0	2850	4640	0.20
178.8	8310	17160	0.35	54.5	2530	5230	0.35
180.5	8060	16330	0.34	55.0	2460	4980	0.34
182.1	9110	15940	0.26	55.5	2780	4860	0.26
183.7	9770	16730	0.24	56.0	2980	5100	0.24

Notes: "-" means no data available at that particular interval of depth.

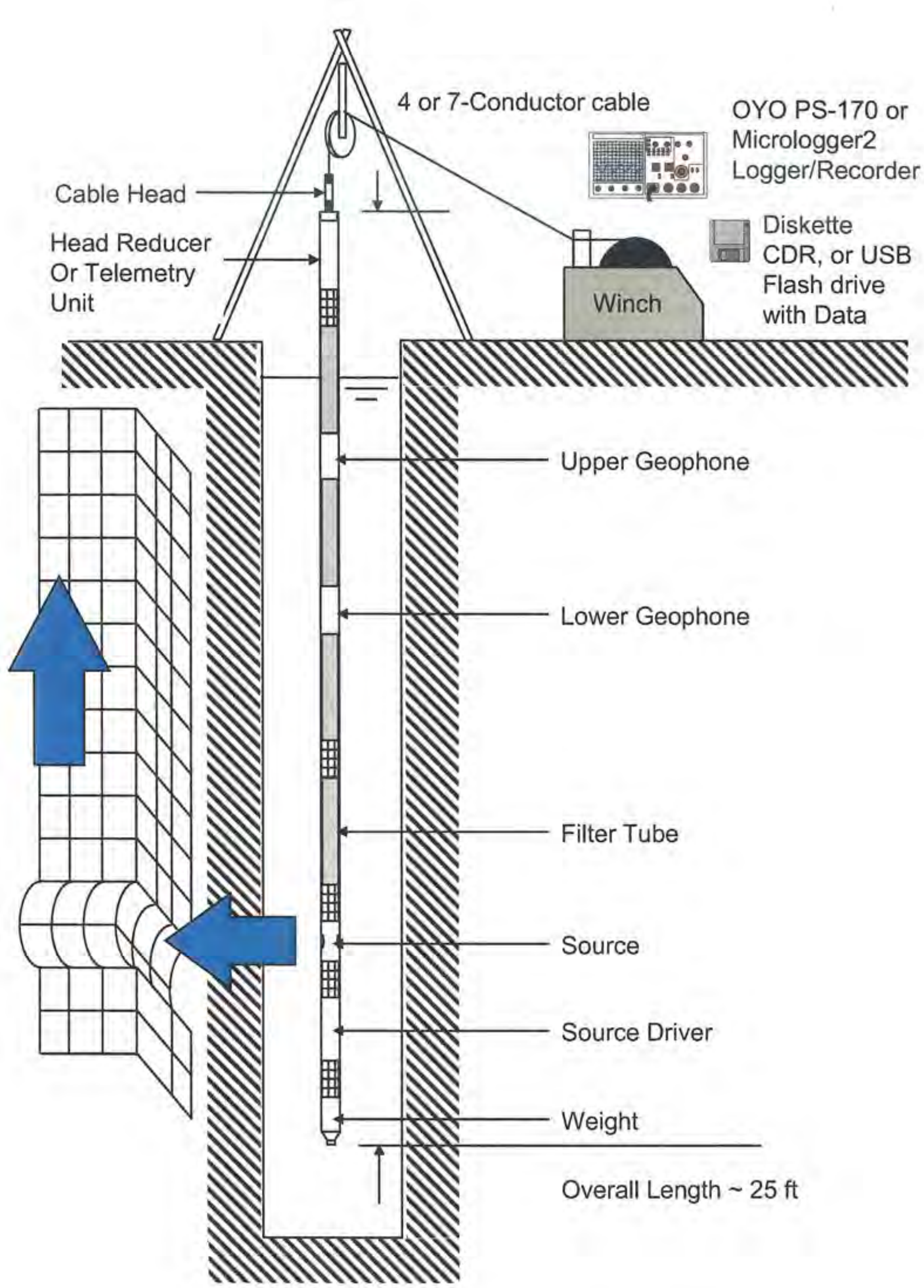


Figure 2: Concept illustration of P-S logging system

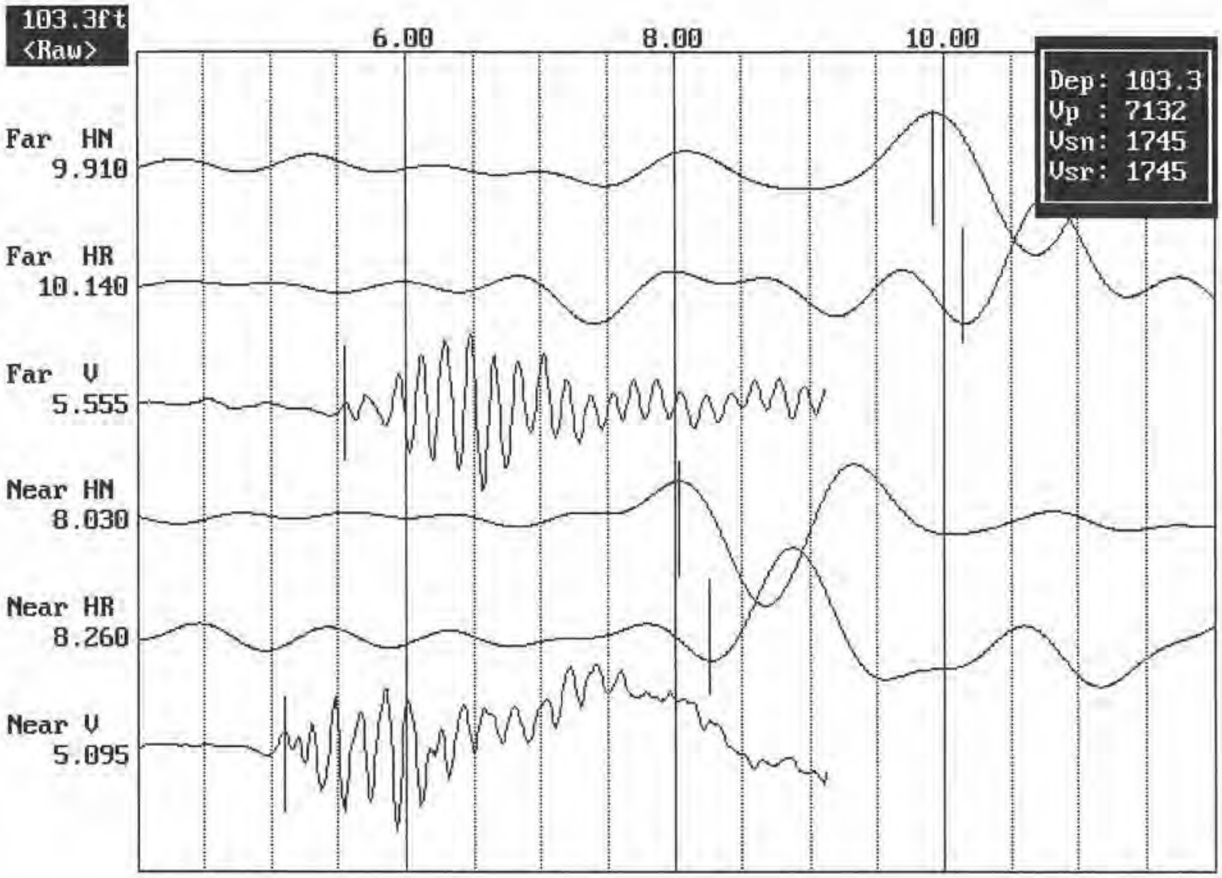


Figure 3: Example of filtered (1400 Hz lowpass) record

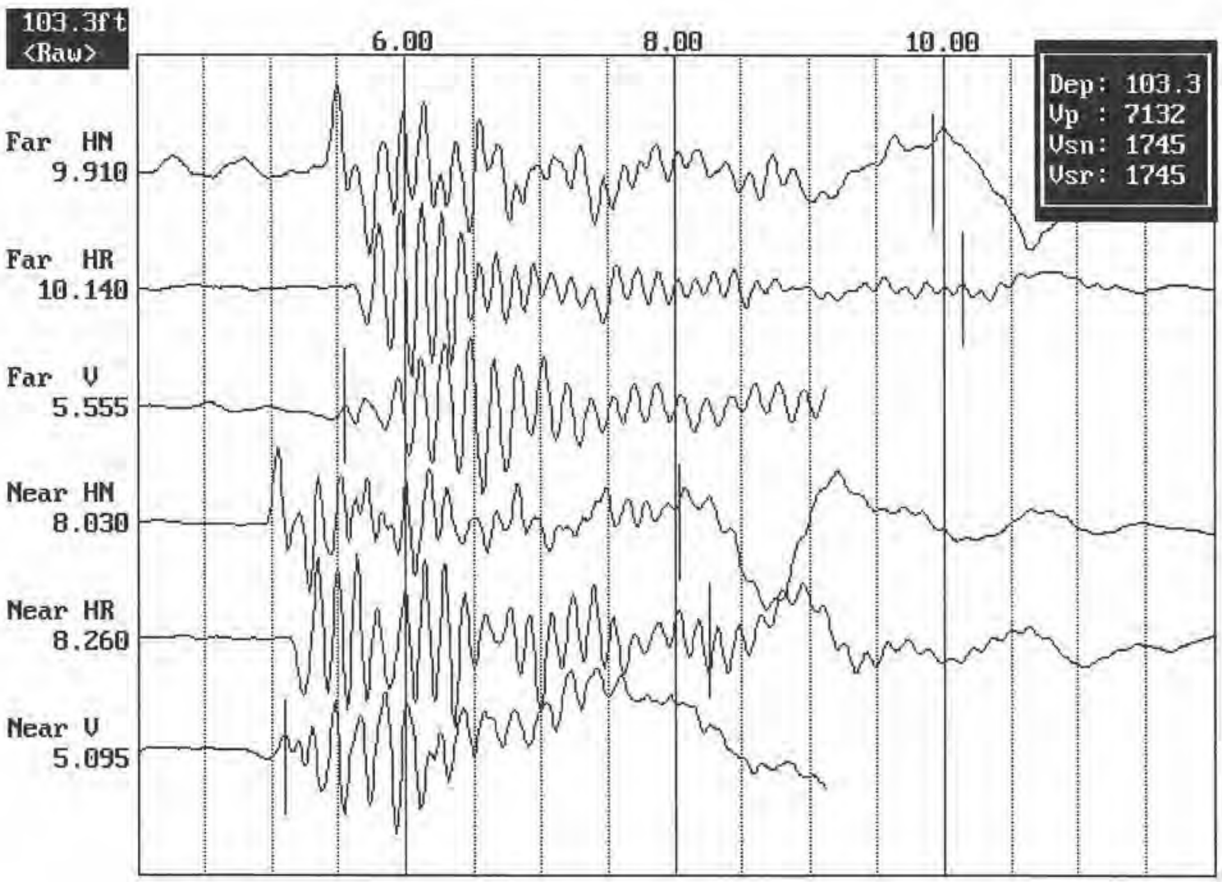


Figure 4. Example of unfiltered record

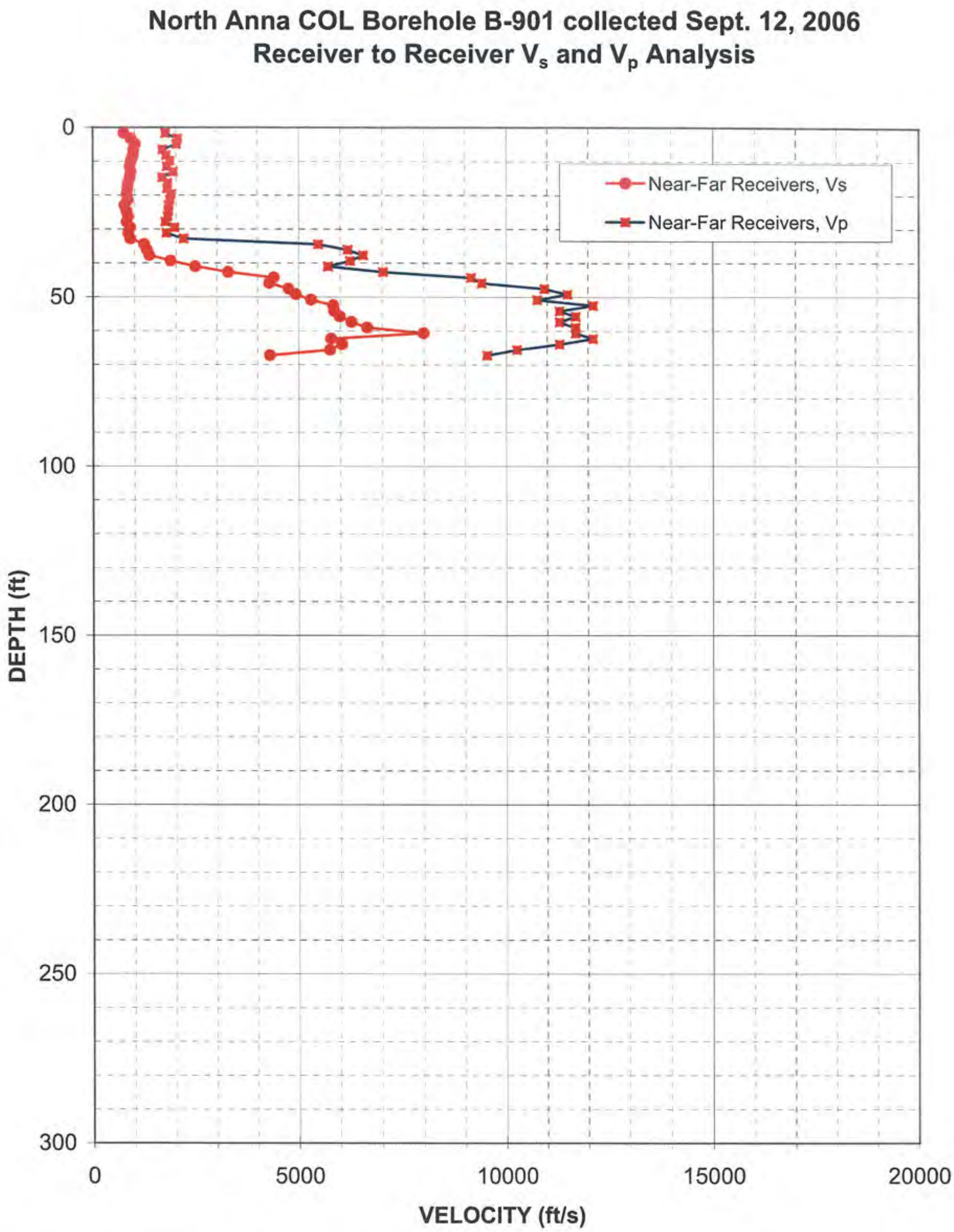


Figure 5: Boring B-901, Top Section, Suspension R1-R2 P- and S_H-wave velocities

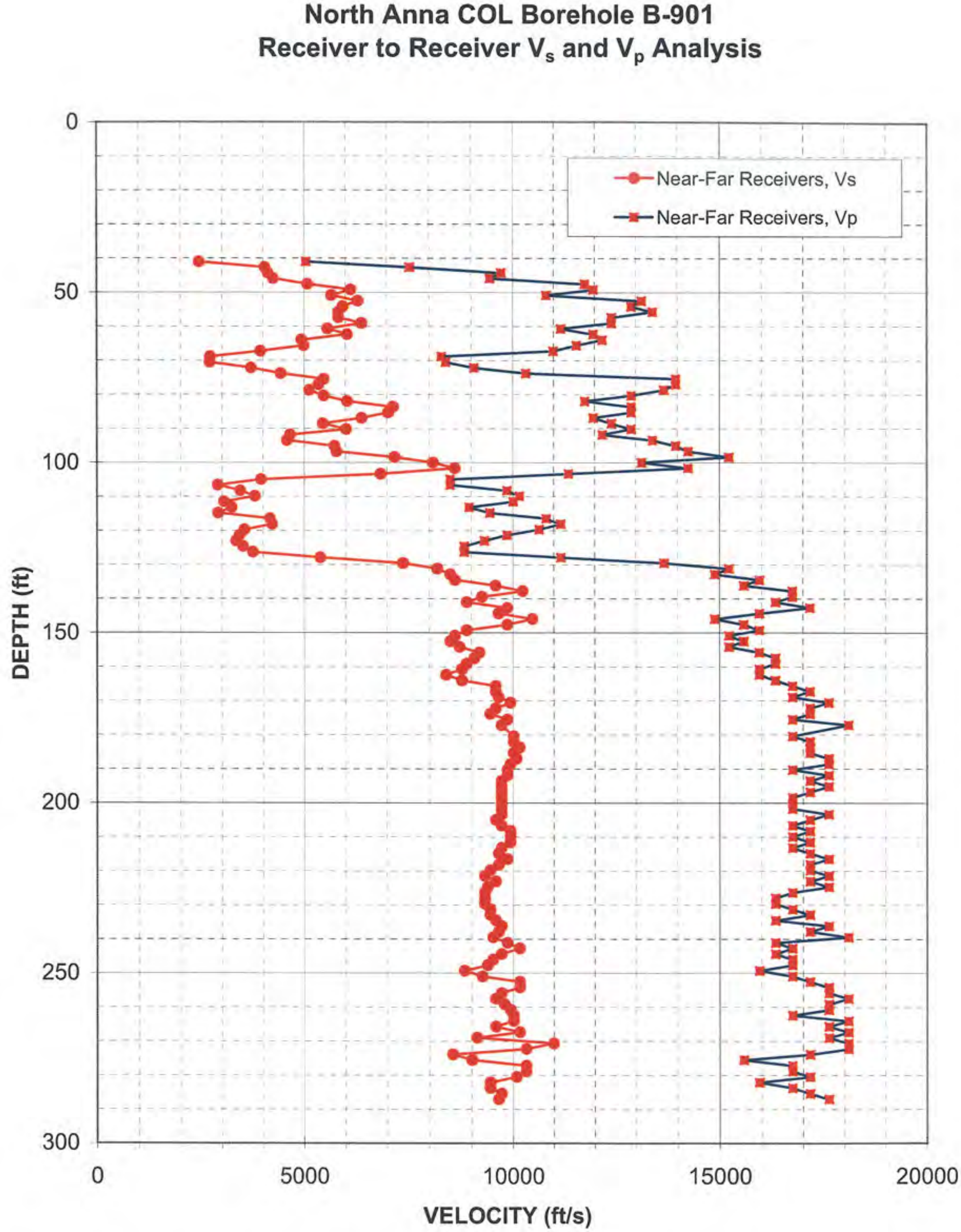


Figure 6: Boring B-901, Bottom Section, Suspension R1-R2 P- and SH-wave velocities

Table 5. Boring B-901, Top Section, Suspension R1-R2 depths and P- and SH-wave velocities

Summary of Compressional Wave Velocity, Shear Wave Velocity, and Poisson's Ratio Based on Receiver-to-Receiver Travel Time Data - Borehole B-901

American Units				Metric Units			
Depth at Midpoint Between Receivers	Velocity		Poisson's Ratio	Depth at Midpoint Between Receivers	Velocity		Poisson's Ratio
	V_s	V_p			V_s	V_p	
(ft)	(ft/s)	(ft/s)		(m)	(m/s)	(m/s)	
1.6	730	1740	0.39	0.5	220	530	0.39
3.3	900	2030	0.38	1.0	270	620	0.38
4.9	1000	2010	0.33	1.5	310	610	0.33
6.6	970	1670	0.25	2.0	290	510	0.25
8.2	950	1750	0.29	2.5	290	530	0.29
9.8	910	1840	0.34	3.0	280	560	0.34
11.5	870	1770	0.34	3.5	270	540	0.34
13.1	900	1930	0.36	4.0	270	590	0.36
14.8	870	1660	0.31	4.5	270	510	0.31
16.4	830	1790	0.36	5.0	250	550	0.36
18.0	820	1780	0.37	5.5	250	540	0.37
19.7	810	1870	0.39	6.0	250	570	0.39
21.3	830	1840	0.37	6.5	250	560	0.37
23.0	750	1810	0.40	7.0	230	550	0.40
24.6	800	1810	0.38	7.5	240	550	0.38
26.3	830	1790	0.36	8.0	250	550	0.36
27.9	800	1740	0.36	8.5	240	530	0.36
29.5	890	1960	0.37	9.0	270	600	0.37
31.2	840	1760	0.35	9.5	260	540	0.35
32.8	890	2180	0.40	10.0	270	660	0.40
34.5	1230	5460	0.47	10.5	370	1670	0.47
36.1	1290	6170	0.48	11.0	390	1880	0.48
37.7	1340	6540	0.48	11.5	410	1990	0.48
39.4	1860	6230	0.45	12.0	570	1900	0.45
41.0	2460	5700	0.39	12.5	750	1740	0.39
42.7	3270	7020	0.36	13.0	1000	2140	0.36
44.3	4390	9130	0.35	13.5	1340	2780	0.35
45.9	4270	9390	0.37	14.0	1300	2860	0.37
47.6	4740	10930	0.38	14.5	1450	3330	0.38
49.2	4920	11490	0.39	15.0	1500	3500	0.39
50.9	5290	10750	0.34	15.5	1610	3280	0.34
52.5	5820	12120	0.35	16.0	1770	3690	0.35
54.1	5850	11300	0.32	16.5	1780	3440	0.32
55.8	5980	11700	0.32	17.0	1820	3560	0.32

Summary of Compressional Wave Velocity, Shear Wave Velocity, and Poisson's Ratio Based on Receiver-to-Receiver Travel Time Data - Borehole B-901

American Units			
Depth at Midpoint Between Receivers	Velocity		Poisson's Ratio
	V_s	V_p	
(ft)	(ft/s)	(ft/s)	
57.4	6260	11300	0.28
59.1	6630	11700	0.26
60.7	7980	11700	0.06
62.3	5770	12120	0.35
64.0	6030	11300	0.30
65.6	5750	10260	0.27
67.3	4290	9520	0.37

Metric Units			
Depth at Midpoint Between Receivers	Velocity		Poisson's Ratio
	V_s	V_p	
(m)	(m/s)	(m/s)	
17.5	1910	3440	0.28
18.0	2020	3560	0.26
18.5	2430	3560	0.06
19.0	1760	3690	0.35
19.5	1840	3440	0.30
20.0	1750	3130	0.27
20.5	1310	2900	0.37

Table 6. Boring B-901, Bottom Section, Suspension R1-R2 depths and P- and S_H-wave velocities

Summary of Compressional Wave Velocity, Shear Wave Velocity, and Poisson's Ratio Based on Receiver-to-Receiver Travel Time Data - Borehole B-901

American Units				Metric Units			
Depth at Midpoint Between Receivers	Velocity		Poisson's Ratio	Depth at Midpoint Between Receivers	Velocity		Poisson's Ratio
	V_s	V_p			V_s	V_p	
(ft)	(ft/s)	(ft/s)		(m)	(m/s)	(m/s)	
41.0	2430	5030	0.35	12.5	740	1530	0.35
42.7	4030	7520	0.30	13.0	1230	2290	0.30
44.3	4110	9700	0.39	13.5	1250	2960	0.39
45.9	4240	9430	0.37	14.0	1290	2870	0.37
47.6	5070	11740	0.39	14.5	1550	3580	0.39
49.2	6110	11950	0.32	15.0	1860	3640	0.32
50.9	5650	10800	0.31	15.5	1720	3290	0.31
52.5	6280	13120	0.35	16.0	1920	4000	0.35
54.1	5920	12870	0.37	16.5	1810	3920	0.37
55.8	5820	13390	0.38	17.0	1770	4080	0.38
57.4	5820	12400	0.36	17.5	1770	3780	0.36
59.1	6370	12400	0.32	18.0	1940	3780	0.32
60.7	5550	11160	0.34	18.5	1690	3400	0.34
62.3	6030	11950	0.33	19.0	1840	3640	0.33
64.0	4920	12170	0.40	19.5	1500	3710	0.40
65.6	4980	11540	0.39	20.0	1520	3520	0.39
67.3	3930	10970	0.43	20.5	1200	3340	0.43
68.9	2700	8260	0.44	21.0	820	2520	0.44
70.5	2690	8370	0.44	21.5	820	2550	0.44
72.2	3700	9050	0.40	22.0	1130	2760	0.40
73.8	4420	10300	0.39	22.5	1350	3140	0.39
75.5	5460	13940	0.41	23.0	1670	4250	0.41
77.1	5330	13940	0.41	23.5	1630	4250	0.41
78.7	5110	13660	0.42	24.0	1560	4160	0.42
80.4	5460	12870	0.39	24.5	1670	3920	0.39
82.0	6030	11740	0.32	25.0	1840	3580	0.32
83.7	7120	12870	0.28	25.5	2170	3920	0.28
85.3	7010	12870	0.29	26.0	2140	3920	0.29
86.9	6370	11950	0.30	26.5	1940	3640	0.30
88.6	5440	12400	0.38	27.0	1660	3780	0.38
90.2	6000	12870	0.36	27.5	1830	3920	0.36
91.9	4650	12170	0.41	28.0	1420	3710	0.41
93.5	4570	13390	0.43	28.5	1390	4080	0.43
95.1	5720	13940	0.40	29.0	1740	4250	0.40
96.8	5770	14240	0.40	29.5	1760	4340	0.40
98.4	7160	15210	0.36	30.0	2180	4640	0.36

Summary of Compressional Wave Velocity, Shear Wave Velocity, and Poisson's Ratio Based on Receiver-to-Receiver Travel Time Data - Borehole B-901

American Units				Metric Units			
Depth at Midpoint Between Receivers	Velocity		Poisson's Ratio	Depth at Midpoint Between Receivers	Velocity		Poisson's Ratio
	V_s	V_p			V_s	V_p	
(ft)	(ft/s)	(ft/s)		(m)	(m/s)	(m/s)	
100.1	8060	13120	0.20	30.5	2460	4000	0.20
101.7	8580	14240	0.21	31.0	2620	4340	0.21
103.4	6830	11340	0.22	31.5	2080	3460	0.22
105.0	3940	8470	0.36	32.0	1200	2580	0.36
106.6	2890	8470	0.43	32.5	880	2580	0.43
108.3	3430	9840	0.43	33.0	1050	3000	0.43
109.9	3790	10140	0.42	33.5	1160	3090	0.42
111.6	3040	9990	0.45	34.0	930	3040	0.45
113.2	3230	8920	0.42	34.5	980	2720	0.42
114.8	2900	9430	0.45	35.0	880	2870	0.45
116.5	4160	10800	0.41	35.5	1270	3290	0.41
118.1	4210	11160	0.42	36.0	1280	3400	0.42
119.8	3530	10620	0.44	36.5	1080	3240	0.44
121.4	3410	9840	0.43	37.0	1040	3000	0.43
123.0	3330	9300	0.43	37.5	1010	2830	0.43
124.7	3500	8810	0.41	38.0	1070	2680	0.41
126.3	3740	8810	0.39	38.5	1140	2680	0.39
128.0	5380	11160	0.35	39.0	1640	3400	0.35
129.6	7360	13660	0.30	39.5	2240	4160	0.30
131.2	8160	15210	0.30	40.0	2490	4640	0.30
132.9	8470	14870	0.26	40.5	2580	4530	0.26
134.5	8580	15940	0.30	41.0	2620	4860	0.30
136.2	9560	15570	0.20	41.5	2910	4740	0.20
137.8	10220	16730	0.20	42.0	3110	5100	0.20
139.4	9230	16730	0.28	42.5	2810	5100	0.28
141.1	8870	16330	0.29	43.0	2700	4980	0.29
142.7	9840	17160	0.25	43.5	3000	5230	0.25
144.4	9630	15940	0.21	44.0	2940	4860	0.21
146.0	10460	14870	0.01	44.5	3190	4530	0.01
147.6	9840	15570	0.17	45.0	3000	4740	0.17
149.3	8870	15940	0.28	45.5	2700	4860	0.28
150.9	8580	15210	0.27	46.0	2620	4640	0.27
152.6	8470	15570	0.29	46.5	2580	4740	0.29
154.2	8690	15210	0.26	47.0	2650	4640	0.26
155.8	9170	15940	0.25	47.5	2790	4860	0.25
157.5	9050	16330	0.28	48.0	2760	4980	0.28
159.1	8870	16330	0.29	48.5	2700	4980	0.29
160.8	8750	15940	0.28	49.0	2670	4860	0.28
162.4	8370	15940	0.31	49.5	2550	4860	0.31

Summary of Compressional Wave Velocity, Shear Wave Velocity, and Poisson's Ratio Based on Receiver-to-Receiver Travel Time Data - Borehole B-901

American Units				Metric Units			
Depth at Midpoint Between Receivers	Velocity		Poisson's Ratio	Depth at Midpoint Between Receivers	Velocity		Poisson's Ratio
	V_s	V_p			V_s	V_p	
(ft)	(ft/s)	(ft/s)		(m)	(m/s)	(m/s)	
164.0	8750	16330	0.30	50.0	2670	4980	0.30
165.7	9560	16730	0.26	50.5	2910	5100	0.26
167.3	9560	17160	0.27	51.0	2910	5230	0.27
169.0	9630	16730	0.25	51.5	2940	5100	0.25
170.6	9920	17610	0.27	52.0	3020	5370	0.27
172.2	9560	17160	0.27	52.5	2910	5230	0.27
173.9	9430	17160	0.28	53.0	2870	5230	0.28
175.5	9840	16730	0.24	53.5	3000	5100	0.24
177.2	9700	18090	0.30	54.0	2960	5510	0.30
180.5	9990	16730	0.22	55.0	3040	5100	0.22
182.1	9990	17160	0.24	55.5	3040	5230	0.24
183.7	10140	17160	0.23	56.0	3090	5230	0.23
185.4	9990	17160	0.24	56.5	3040	5230	0.24
187.0	10070	17610	0.26	57.0	3070	5370	0.26
188.7	9920	17610	0.27	57.5	3020	5370	0.27
190.3	9840	16730	0.24	58.0	3000	5100	0.24
191.9	9840	17610	0.27	58.5	3000	5370	0.27
193.6	9700	17160	0.27	59.0	2960	5230	0.27
195.2	9700	17610	0.28	59.5	2960	5370	0.28
196.9	9700	17160	0.27	60.0	2960	5230	0.27
198.5	9700	16730	0.25	60.5	2960	5100	0.25
200.1	9700	16730	0.25	61.0	2960	5100	0.25
201.8	9700	16730	0.25	61.5	2960	5100	0.25
203.4	9700	17610	0.28	62.0	2960	5370	0.28
205.1	9560	17160	0.27	62.5	2910	5230	0.27
206.7	9700	16730	0.25	63.0	2960	5100	0.25
208.3	9920	17160	0.25	63.5	3020	5230	0.25
210.0	9920	16730	0.23	64.0	3020	5100	0.23
211.6	9920	17160	0.25	64.5	3020	5230	0.25
213.3	9700	16730	0.25	65.0	2960	5100	0.25
214.9	9630	17160	0.27	65.5	2940	5230	0.27
216.5	9840	17610	0.27	66.0	3000	5370	0.27
218.2	9630	17160	0.27	66.5	2940	5230	0.27
219.8	9430	17160	0.28	67.0	2870	5230	0.28
221.5	9300	17610	0.31	67.5	2830	5370	0.31
223.1	9560	17160	0.27	68.0	2910	5230	0.27
224.7	9360	17610	0.30	68.5	2850	5370	0.30
226.4	9300	16730	0.28	69.0	2830	5100	0.28
228.0	9300	16330	0.26	69.5	2830	4980	0.26

Summary of Compressional Wave Velocity, Shear Wave Velocity, and Poisson's Ratio Based on Receiver-to-Receiver Travel Time Data - Borehole B-901

American Units				Metric Units			
Depth at Midpoint Between Receivers	Velocity		Poisson's Ratio	Depth at Midpoint Between Receivers	Velocity		Poisson's Ratio
	V_s	V_p			V_s	V_p	
(ft)	(ft/s)	(ft/s)		(m)	(m/s)	(m/s)	
229.7	9300	16330	0.26	70.0	2830	4980	0.26
231.3	9430	16730	0.27	70.5	2870	5100	0.27
232.9	9430	17160	0.28	71.0	2870	5230	0.28
234.6	9560	16330	0.24	71.5	2910	4980	0.24
236.2	9700	17610	0.28	72.0	2960	5370	0.28
237.9	9630	17160	0.27	72.5	2940	5230	0.27
239.5	9490	18090	0.31	73.0	2890	5510	0.31
241.1	9840	16330	0.21	73.5	3000	4980	0.21
242.8	10140	16730	0.21	74.0	3090	5100	0.21
244.4	9700	16330	0.23	74.5	2960	4980	0.23
246.1	9490	16730	0.26	75.0	2890	5100	0.26
247.7	9360	16730	0.27	75.5	2850	5100	0.27
249.3	8810	15940	0.28	76.0	2680	4860	0.28
251.0	9230	16730	0.28	76.5	2810	5100	0.28
252.6	10140	17160	0.23	77.0	3090	5230	0.23
254.3	10140	17610	0.25	77.5	3090	5370	0.25
255.9	9700	17610	0.28	78.0	2960	5370	0.28
257.6	9560	18090	0.31	78.5	2910	5510	0.31
259.2	9770	17610	0.28	79.0	2980	5370	0.28
260.8	9920	17610	0.27	79.5	3020	5370	0.27
262.5	9990	16730	0.22	80.0	3040	5100	0.22
264.1	9990	18090	0.28	80.5	3040	5510	0.28
265.8	9560	17610	0.29	81.0	2910	5370	0.29
267.4	10140	18090	0.27	81.5	3090	5510	0.27
269.0	9110	17610	0.32	82.0	2780	5370	0.32
270.7	10970	18090	0.21	82.5	3340	5510	0.21
272.3	10300	18090	0.26	83.0	3140	5510	0.26
274.0	8530	17160	0.34	83.5	2600	5230	0.34
275.6	8980	15570	0.25	84.0	2740	4740	0.25
277.2	10300	16730	0.20	84.5	3140	5100	0.20
278.9	10300	16730	0.20	85.0	3140	5100	0.20
280.5	10070	17160	0.24	85.5	3070	5230	0.24
282.2	9430	15940	0.23	86.0	2870	4860	0.23
283.8	9430	16730	0.27	86.5	2870	5100	0.27
285.4	9700	17160	0.27	87.0	2960	5230	0.27
287.1	9630	17610	0.29	87.5	2940	5370	0.29

Notes: "-" means no data available at that particular interval of depth.

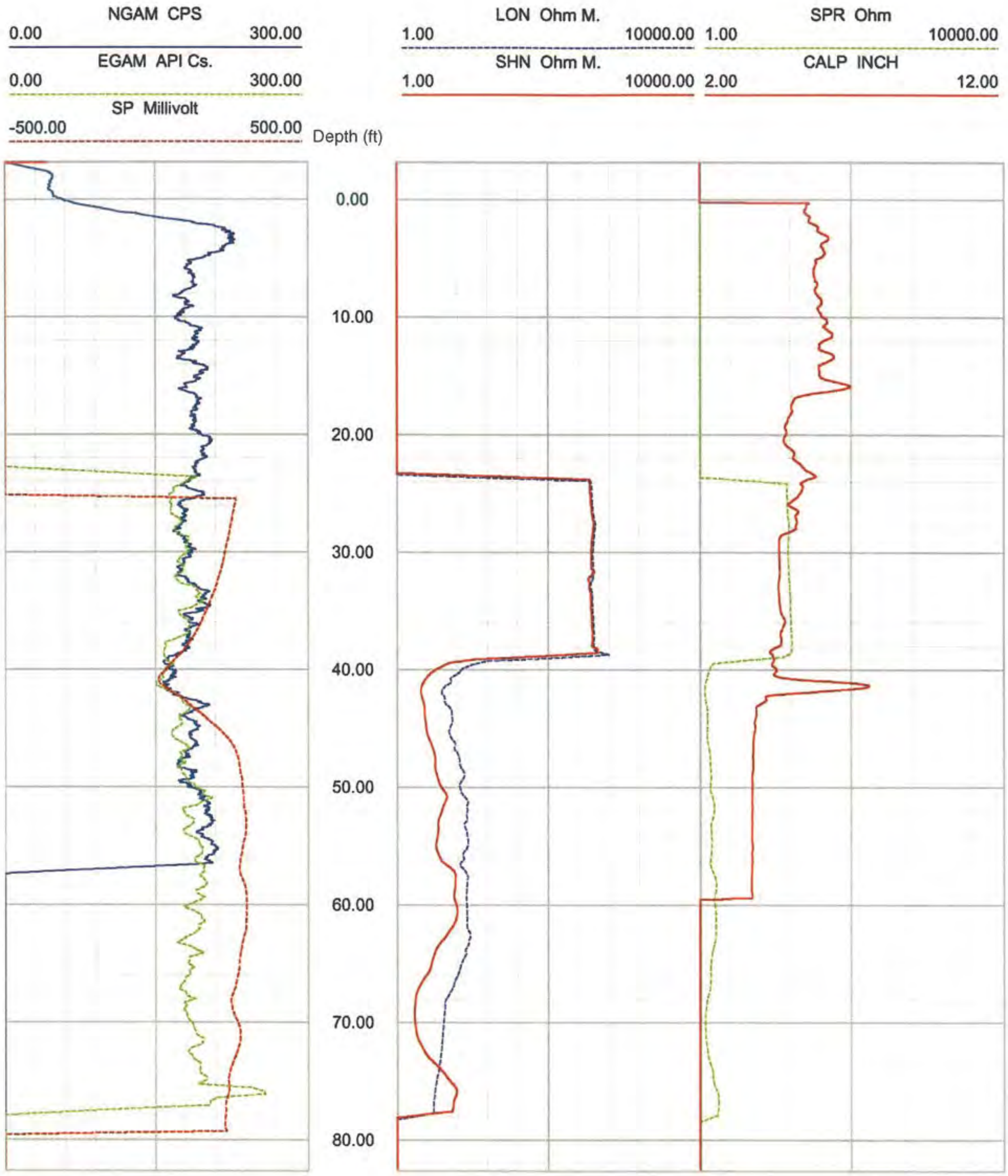


Figure 7: Boring B-901, Top Section, Caliper, Natural gamma, Resistivity and SP logs

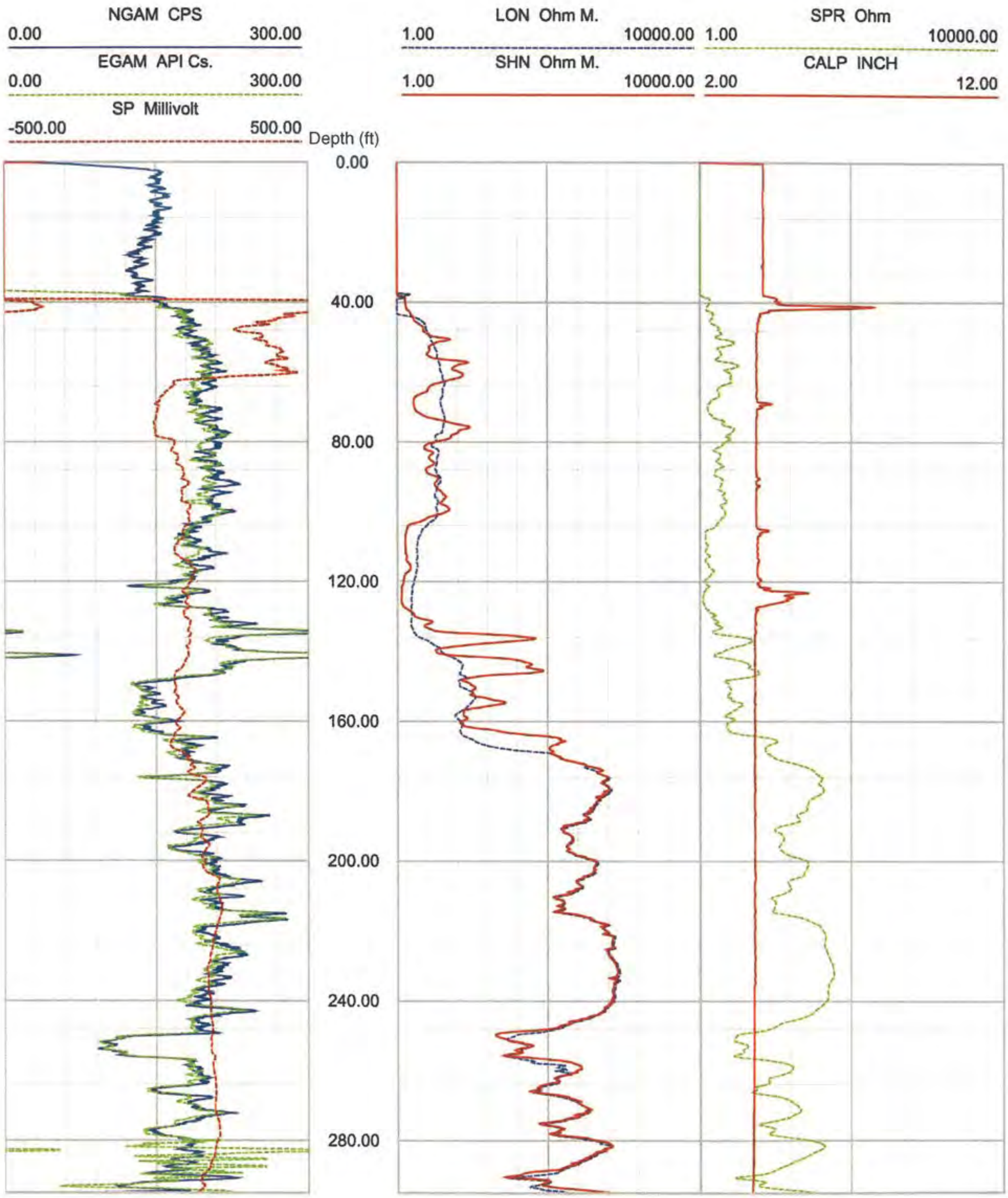
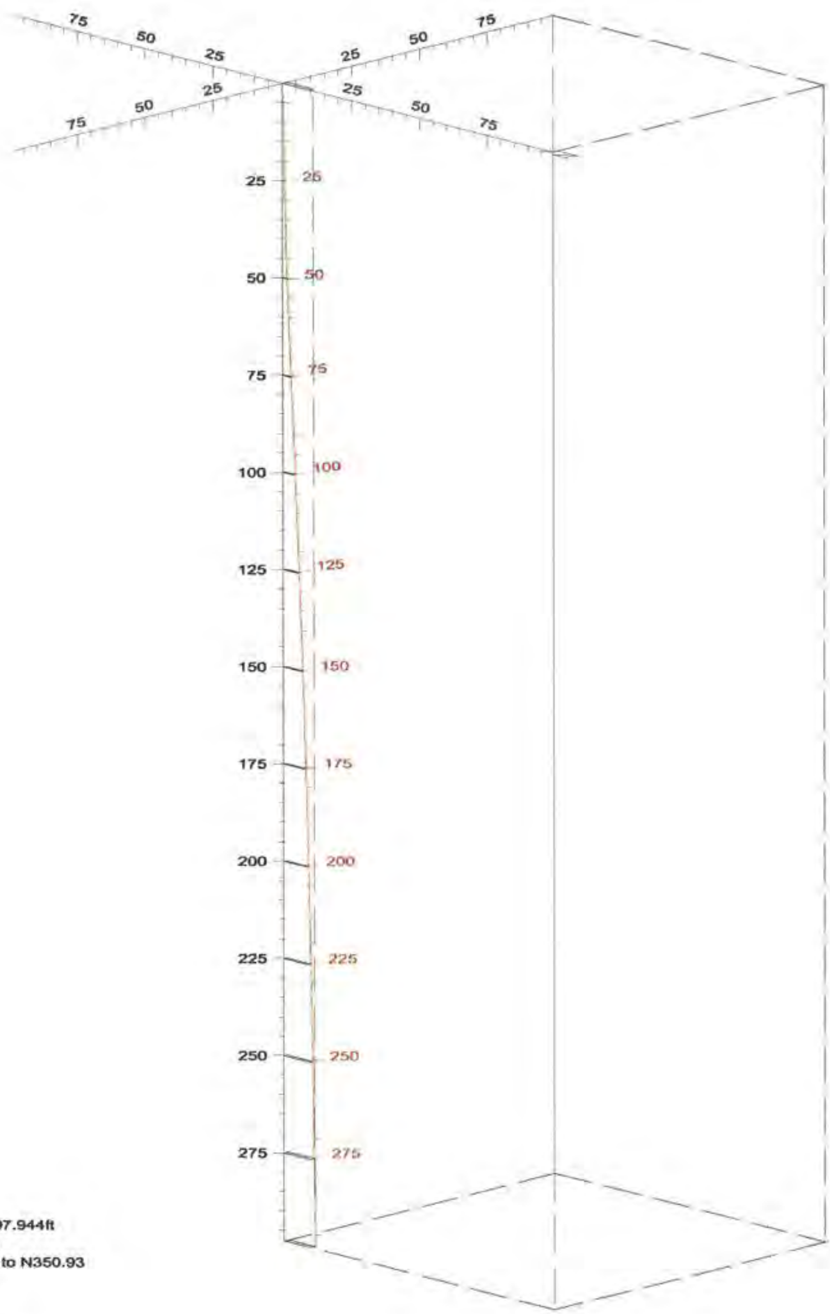


Figure 8: Boring B-901, Bottom Section, Caliper, Natural gamma, Resistivity and SP logs

Deviated borehole in orthographic projection, viewed from N45



Borehole: B-901
Zone from: 2.664 - 297.944ft
North ref is magnetic
Mean deviation: 1.86 to N350.93
End coordinates .....
North: 9.560
East : -1.527
Down : 297.747
Azimuth of end: N350.93
Distance start-end: 9.681ft
Viewpoint: N45
Data extrapolated to the surface from 2.664ft
15 Sep 2006

Figure 9. Boring B-901, Deviation Projection (dimensions in feet)

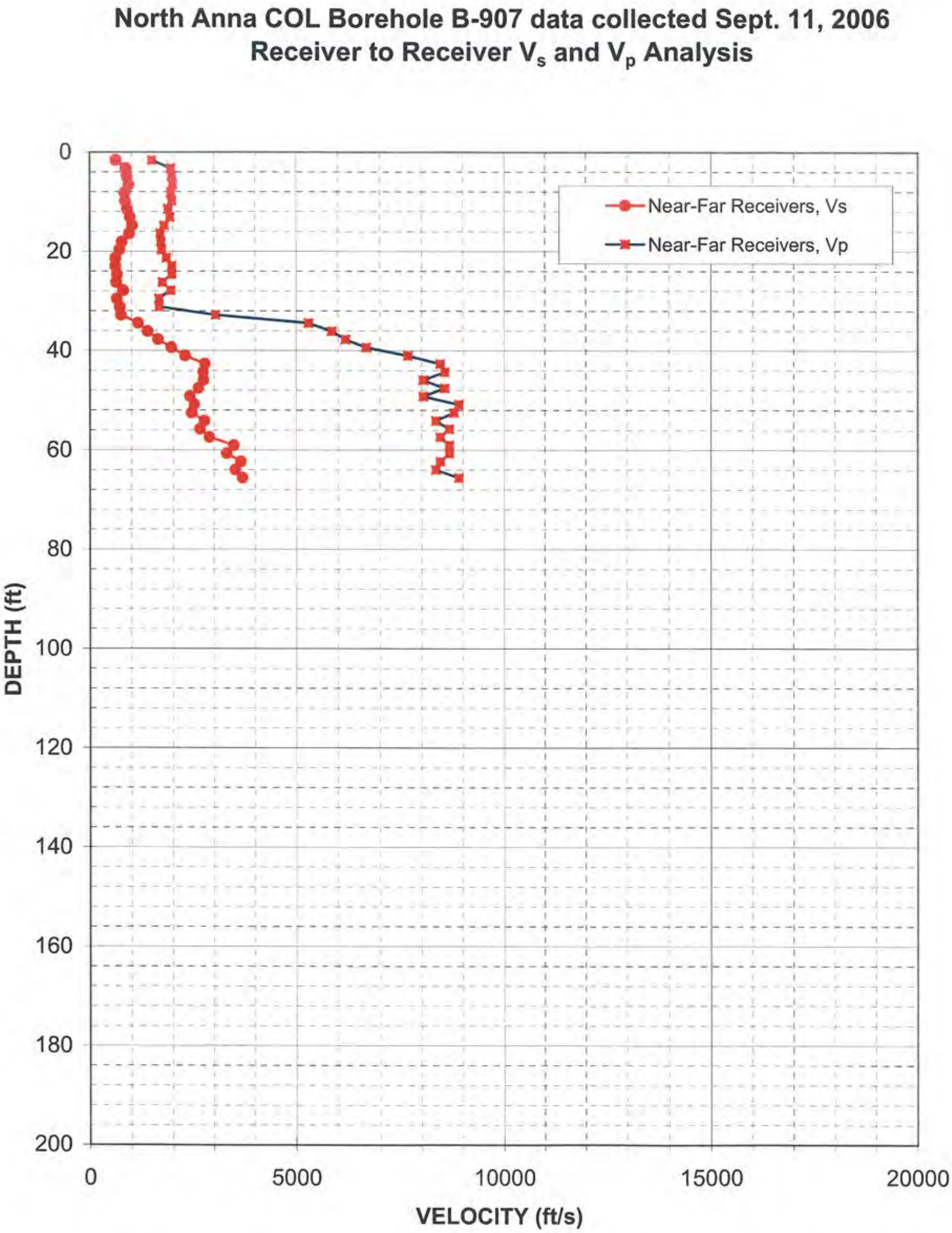


Figure 10: Boring B-907, Top Section, Suspension R1-R2 P- and S_H-wave velocities

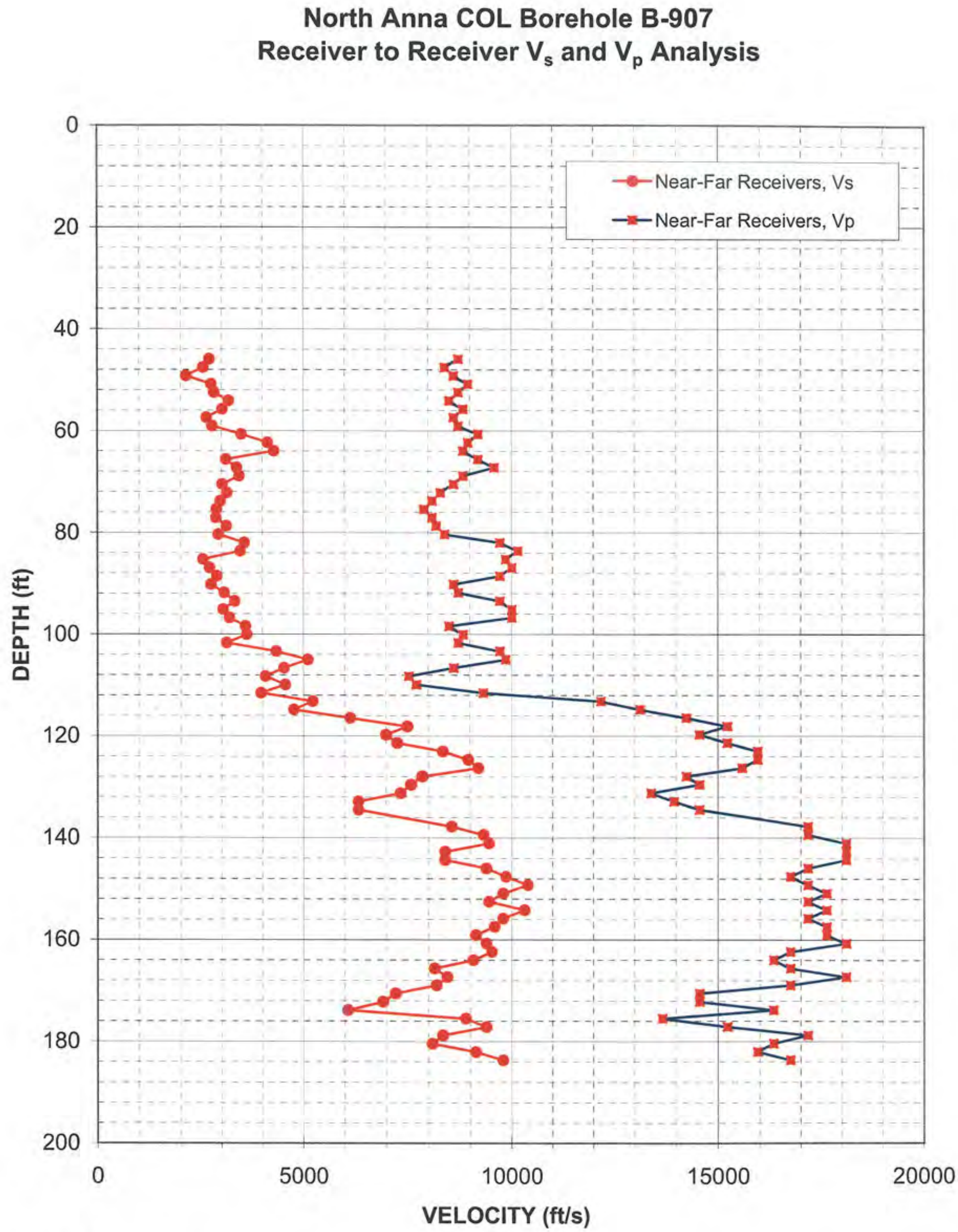


Figure 11: Boring B-907, Bottom Section, Suspension R1-R2 P- and S_H-wave velocities

Table 7. Boring B-907, Top Section, Suspension R1-R2 depths and P- and S_H-wave velocities

Summary of Compressional Wave Velocity, Shear Wave Velocity, and Poisson's Ratio Based on Receiver-to-Receiver Travel Time Data - Borehole B-907

American Units			
Depth at Midpoint Between Receivers	Velocity		Poisson's Ratio
	V_s	V_p	
(ft)	(ft/s)	(ft/s)	
1.6	610	1480	0.40
3.3	850	1940	0.38
4.9	870	1960	0.38
6.6	920	1980	0.36
8.2	820	1940	0.39
9.8	830	1960	0.39
11.5	880	1870	0.36
13.1	950	1920	0.34
14.8	1000	1770	0.27
16.4	930	1680	0.28
18.0	760	1700	0.38
19.7	690	1720	0.40
21.3	600	1830	0.44
23.0	600	1960	0.45
24.6	640	1960	0.44
26.3	620	1740	0.43
27.9	780	1940	0.40
29.5	630	1650	0.41
31.2	710	1650	0.39
32.8	730	3030	0.47
34.5	1150	5290	0.48
36.1	1370	5850	0.47
37.7	1630	6170	0.46
39.4	1950	6670	0.45
41.0	2280	7660	0.45
42.7	2770	8440	0.44
44.3	2720	8550	0.44
45.9	2730	8030	0.43
47.6	2600	8550	0.45
49.2	2400	8030	0.45
50.9	2510	8890	0.46
52.5	2440	8770	0.46
54.1	2750	8330	0.44
55.8	2650	8660	0.45
57.4	2870	8440	0.43
59.1	3470	8660	0.40

Metric Units			
Depth at Midpoint Between Receivers	Velocity		Poisson's Ratio
	V_s	V_p	
(m)	(m/s)	(m/s)	
0.5	190	450	0.40
1.0	260	590	0.38
1.5	270	600	0.38
2.0	280	600	0.36
2.5	250	590	0.39
3.0	250	600	0.39
3.5	270	570	0.36
4.0	290	580	0.34
4.5	310	540	0.27
5.0	280	510	0.28
5.5	230	520	0.38
6.0	210	520	0.40
6.5	180	560	0.44
7.0	180	600	0.45
7.5	200	600	0.44
8.0	190	530	0.43
8.5	240	590	0.40
9.0	190	500	0.41
9.5	220	500	0.39
10.0	220	920	0.47
10.5	350	1610	0.48
11.0	420	1780	0.47
11.5	500	1880	0.46
12.0	590	2030	0.45
12.5	700	2340	0.45
13.0	840	2570	0.44
13.5	830	2610	0.44
14.0	830	2450	0.43
14.5	790	2610	0.45
15.0	730	2450	0.45
15.5	760	2710	0.46
16.0	740	2670	0.46
16.5	840	2540	0.44
17.0	810	2640	0.45
17.5	880	2570	0.43
18.0	1060	2640	0.40

Summary of Compressional Wave Velocity, Shear Wave Velocity, and Poisson's Ratio Based on Receiver-to-Receiver Travel Time Data - Borehole B-907

American Units			
Depth at Midpoint Between Receivers	Velocity		Poisson's Ratio
	V_s	V_p	
(ft)	(ft/s)	(ft/s)	
60.7	3300	8660	0.41
62.3	3640	8440	0.39
64.0	3510	8330	0.39
65.6	3680	8890	0.40

Metric Units			
Depth at Midpoint Between Receivers	Velocity		Poisson's Ratio
	V_s	V_p	
(m)	(m/s)	(m/s)	
18.5	1010	2640	0.41
19.0	1110	2570	0.39
19.5	1070	2540	0.39
20.0	1120	2710	0.40

Notes: "-" means no data available at that particular interval of depth.

Table 8. Boring B-907, Bottom Section, Suspension R1-R2 depths and P- and S_H-wave velocities

Summary of Compressional Wave Velocity, Shear Wave Velocity, and Poisson's Ratio Based on Receiver-to-Receiver Travel Time Data - Borehole B-907

American Units			
Depth at Midpoint Between Receivers	Velocity		Poisson's Ratio
	V_s	V_p	
(ft)	(ft/s)	(ft/s)	
45.9	2690	8690	0.45
47.6	2540	8370	0.45
49.2	2120	8580	0.47
50.9	2730	8920	0.45
52.5	2800	8690	0.44
54.1	3160	8470	0.42
55.8	3000	8810	0.43
57.4	2610	8580	0.45
59.1	2750	8690	0.44
60.7	3470	9170	0.42
62.3	4110	8920	0.37
64.0	4260	8810	0.35
65.6	3090	9170	0.44
67.3	3360	9560	0.43
68.9	3410	8810	0.41
70.5	3000	8580	0.43
72.2	3110	8260	0.42
73.8	2960	8060	0.42
75.5	2850	7870	0.42
77.1	2850	8060	0.43
78.7	3100	8160	0.42
80.4	2900	8370	0.43
82.0	3540	9700	0.42
83.7	3440	10140	0.43
85.3	2530	9840	0.46
86.9	2690	9990	0.46
88.6	2870	9700	0.45
90.2	2730	8580	0.44
91.9	3050	8690	0.43
93.5	3310	9700	0.43
95.1	3020	9990	0.45
96.8	3180	9990	0.44
98.4	3570	8470	0.39
100.1	3600	8810	0.40
101.7	3110	8690	0.43
103.4	4320	9700	0.38

Metric Units			
Depth at Midpoint Between Receivers	Velocity		Poisson's Ratio
	V_s	V_p	
(m)	(m/s)	(m/s)	
14.0	820	2650	0.45
14.5	770	2550	0.45
15.0	650	2620	0.47
15.5	830	2720	0.45
16.0	850	2650	0.44
16.5	960	2580	0.42
17.0	910	2680	0.43
17.5	800	2620	0.45
18.0	840	2650	0.44
18.5	1060	2790	0.42
19.0	1250	2720	0.37
19.5	1300	2680	0.35
20.0	940	2790	0.44
20.5	1020	2910	0.43
21.0	1040	2680	0.41
21.5	910	2620	0.43
22.0	950	2520	0.42
22.5	900	2460	0.42
23.0	870	2400	0.42
23.5	870	2460	0.43
24.0	940	2490	0.42
24.5	890	2550	0.43
25.0	1080	2960	0.42
25.5	1050	3090	0.43
26.0	770	3000	0.46
26.5	820	3040	0.46
27.0	870	2960	0.45
27.5	830	2620	0.44
28.0	930	2650	0.43
28.5	1010	2960	0.43
29.0	920	3040	0.45
29.5	970	3040	0.44
30.0	1090	2580	0.39
30.5	1100	2680	0.40
31.0	950	2650	0.43
31.5	1320	2960	0.38

Summary of Compressional Wave Velocity, Shear Wave Velocity, and Poisson's Ratio Based on Receiver-to-Receiver Travel Time Data - Borehole B-907

American Units				Metric Units			
Depth at Midpoint Between Receivers	Velocity		Poisson's Ratio	Depth at Midpoint Between Receivers	Velocity		Poisson's Ratio
	V_s	V_p			V_s	V_p	
(ft)	(ft/s)	(ft/s)		(m)	(m/s)	(m/s)	
105.0	5090	9840	0.32	32.0	1550	3000	0.32
106.6	4510	8580	0.31	32.5	1370	2620	0.31
108.3	4060	7520	0.29	33.0	1240	2290	0.29
109.9	4540	7690	0.23	33.5	1380	2340	0.23
111.6	3950	9300	0.39	34.0	1200	2830	0.39
113.2	5210	12170	0.39	34.5	1590	3710	0.39
114.8	4750	13120	0.42	35.0	1450	4000	0.42
116.5	6110	14240	0.39	35.5	1860	4340	0.39
118.1	7480	15210	0.34	36.0	2280	4640	0.34
119.8	6970	14550	0.35	36.5	2130	4440	0.35
121.4	7240	15210	0.35	37.0	2210	4640	0.35
123.0	8310	15940	0.31	37.5	2530	4860	0.31
124.7	8920	15940	0.27	38.0	2720	4860	0.27
126.3	9170	15570	0.23	38.5	2790	4740	0.23
128.0	7830	14240	0.28	39.0	2390	4340	0.28
129.6	7560	14550	0.31	39.5	2310	4440	0.31
131.2	7320	13390	0.29	40.0	2230	4080	0.29
132.9	6310	13940	0.37	40.5	1920	4250	0.37
134.5	6310	14550	0.38	41.0	1920	4440	0.38
137.8	8530	17160	0.34	42.0	2600	5230	0.34
139.4	9300	17160	0.29	42.5	2830	5230	0.29
141.1	9430	18090	0.31	43.0	2870	5510	0.31
142.7	8370	18090	0.36	43.5	2550	5510	0.36
144.4	8370	18090	0.36	44.0	2550	5510	0.36
146.0	9360	17160	0.29	44.5	2850	5230	0.29
147.6	9840	16730	0.24	45.0	3000	5100	0.24
149.3	10380	17160	0.21	45.5	3160	5230	0.21
150.9	9770	17610	0.28	46.0	2980	5370	0.28
152.6	9430	17160	0.28	46.5	2870	5230	0.28
154.2	10300	17610	0.24	47.0	3140	5370	0.24
155.8	9770	17160	0.26	47.5	2980	5230	0.26
157.5	9560	17610	0.29	48.0	2910	5370	0.29
159.1	9110	17610	0.32	48.5	2780	5370	0.32
160.8	9360	18090	0.32	49.0	2850	5510	0.32
162.4	9490	16730	0.26	49.5	2890	5100	0.26
164.0	9050	16330	0.28	50.0	2760	4980	0.28
165.7	8110	16730	0.35	50.5	2470	5100	0.35
167.3	8420	18090	0.36	51.0	2570	5510	0.36
169.0	8160	16730	0.34	51.5	2490	5100	0.34

Summary of Compressional Wave Velocity, Shear Wave Velocity, and Poisson's Ratio Based on Receiver-to-Receiver Travel Time Data - Borehole B-907

American Units				Metric Units			
Depth at Midpoint Between Receivers	Velocity		Poisson's Ratio	Depth at Midpoint Between Receivers	Velocity		Poisson's Ratio
	V_s	V_p			V_s	V_p	
(ft)	(ft/s)	(ft/s)		(m)	(m/s)	(m/s)	
170.6	7200	14550	0.34	52.0	2190	4440	0.34
172.2	6900	14550	0.35	52.5	2100	4440	0.35
173.9	6060	16330	0.42	53.0	1850	4980	0.42
175.5	8870	13660	0.14	53.5	2700	4160	0.14
177.2	9360	15210	0.20	54.0	2850	4640	0.20
178.8	8310	17160	0.35	54.5	2530	5230	0.35
180.5	8060	16330	0.34	55.0	2460	4980	0.34
182.1	9110	15940	0.26	55.5	2780	4860	0.26
183.7	9770	16730	0.24	56.0	2980	5100	0.24

Notes: "-" means no data available at that particular interval of depth.

APPENDIX A

SUSPENSION VELOCITY MEASUREMENT QUALITY ASSURANCE SUSPENSION SOURCE TO RECEIVER ANALYSIS RESULTS

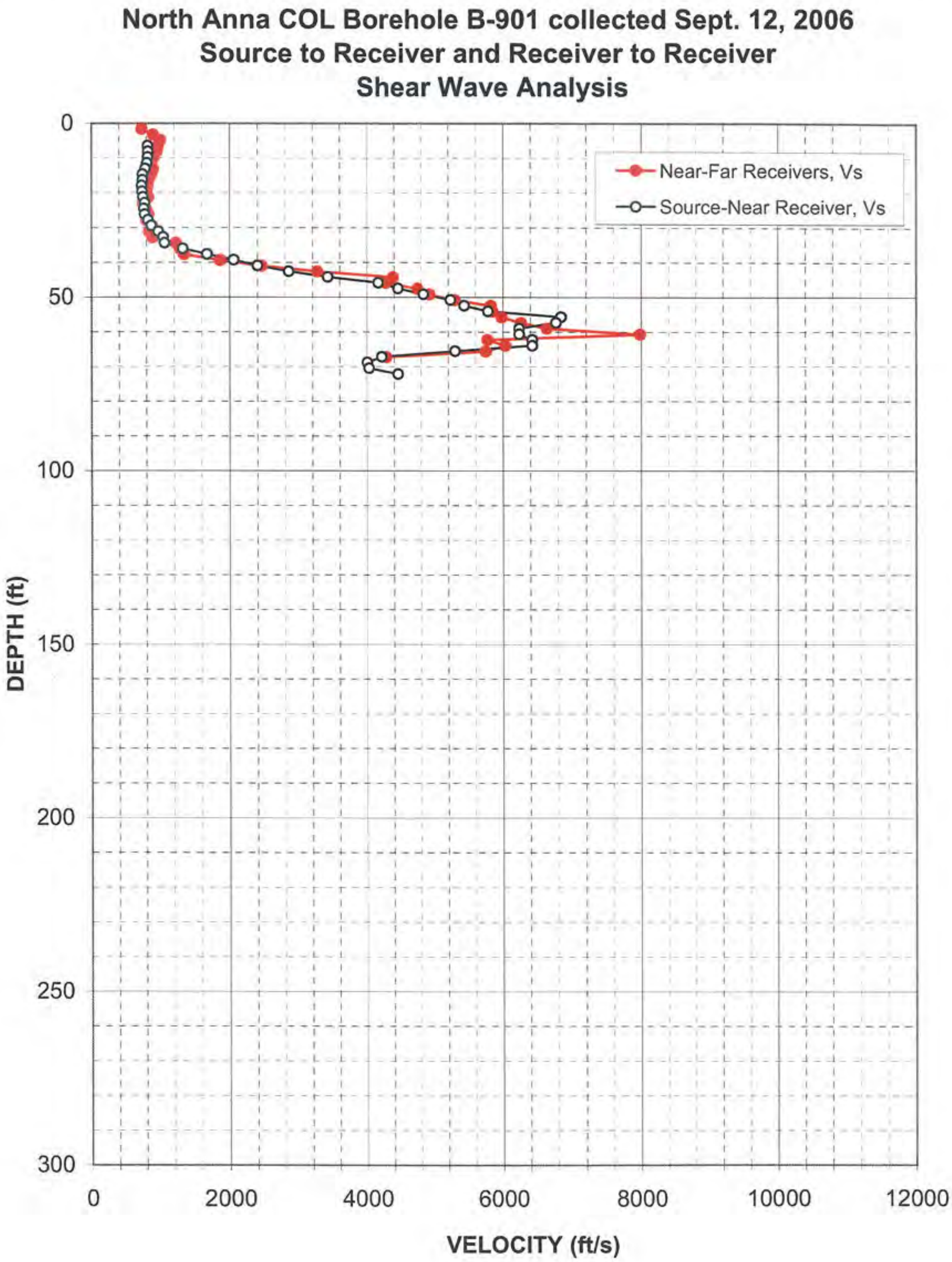


Figure A-1: Boring B-901, Top Section, Suspension S-R1 P- and S_H-wave velocities

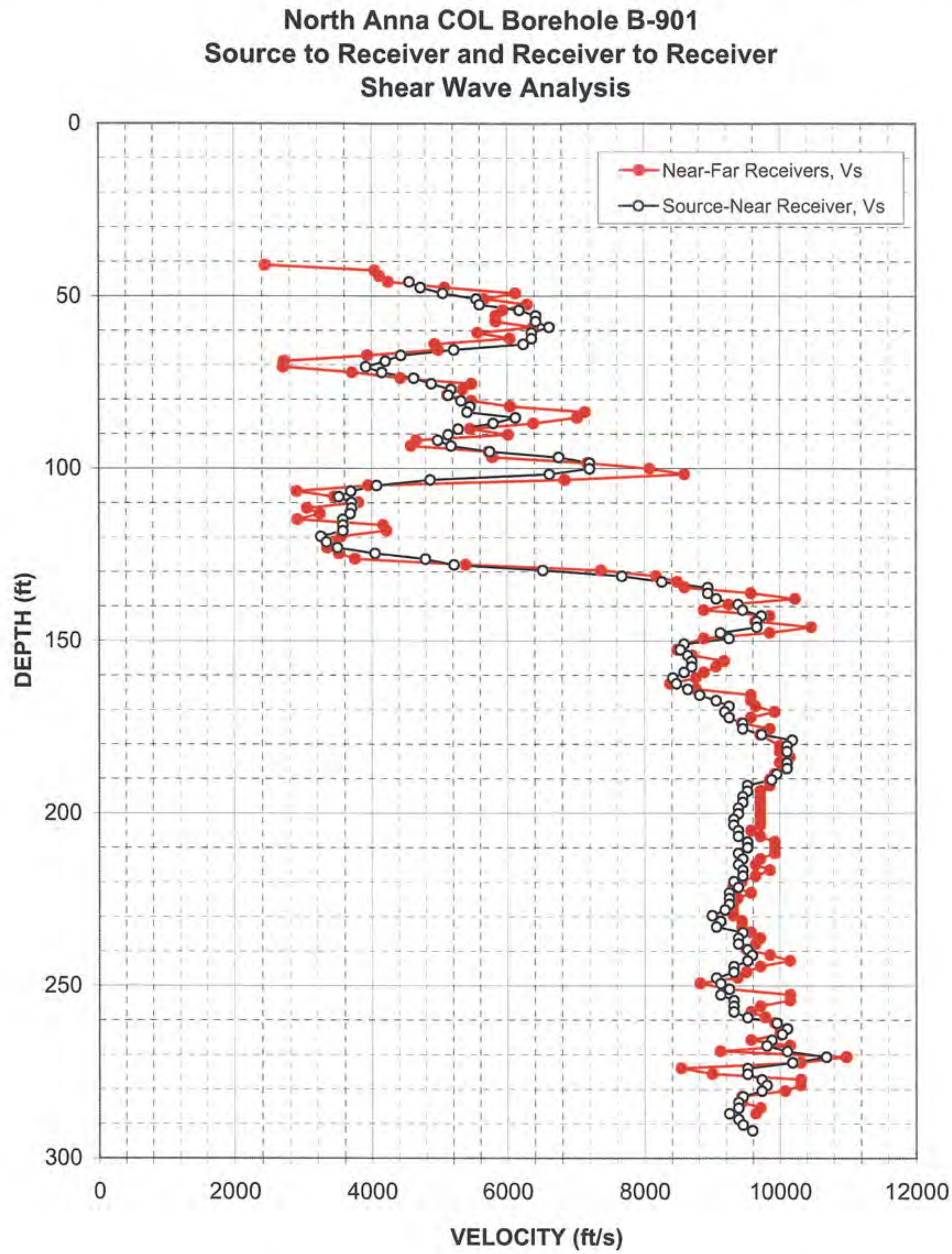


Figure A-2: Boring B-901, Bottom Section, Suspension S-R1 P- and S_H-wave velocities

Table A-1. Boring B-901, Top Section, Suspension S-R1 depths and P- and S_H-wave velocities

Summary of Compressional Wave Velocity, Shear Wave Velocity, and Poisson's Ratio Based on Source-to-Receiver Travel Time Data - Borehole B-901

American Units				Metric Units			
Depth at Midpoint Between Source and Near Receiver	Velocity		Poisson's Ratio	Depth at Midpoint Between Source and Near Receiver	Velocity		Poisson's Ratio
	V_s	V_p			V_s	V_p	
(ft)	(ft/s)	(ft/s)		(m)	(m/s)	(m/s)	
6.5	820	1710	0.35	2.0	250	520	0.35
8.1	820	1850	0.38	2.5	250	560	0.38
9.8	820	1990	0.40	3.0	250	610	0.40
11.4	810	2000	0.40	3.5	250	610	0.40
13.0	780	2120	0.42	4.0	240	650	0.42
14.7	740	2000	0.42	4.5	230	610	0.42
16.3	740	1880	0.41	5.0	230	570	0.41
18.0	730	1930	0.42	5.5	220	590	0.42
19.6	740	1800	0.40	6.0	220	550	0.40
21.2	750	1880	0.41	6.5	230	570	0.41
22.9	770	1770	0.38	7.0	240	540	0.38
24.5	760	1940	0.41	7.5	230	590	0.41
26.2	770	1970	0.41	8.0	240	600	0.41
27.8	820	1980	0.40	8.5	250	600	0.40
29.4	870	1880	0.36	9.0	270	570	0.36
31.1	970	2120	0.37	9.5	300	650	0.37
32.7	1040	2350	0.38	10.0	320	720	0.38
34.4	1060	3330	0.44	10.5	320	1020	0.44
36.0	1320	5190	0.47	11.0	400	1580	0.47
37.6	1670	5230	0.44	11.5	510	1590	0.44
39.3	2060	5550	0.42	12.0	630	1690	0.42
40.9	2400	6030	0.41	12.5	730	1840	0.41
42.6	2850	6810	0.39	13.0	870	2070	0.39
44.2	3420	7490	0.37	13.5	1040	2280	0.37
45.8	4160	9810	0.39	14.0	1270	2990	0.39
47.5	4460	9740	0.37	14.5	1360	2970	0.37
49.1	4830	10130	0.35	15.0	1470	3090	0.35
50.8	5230	10640	0.34	15.5	1590	3240	0.34
52.4	5430	11010	0.34	16.0	1660	3360	0.34
54.0	5780	10640	0.29	16.5	1760	3240	0.29
55.7	6840	10820	0.17	17.0	2090	3300	0.17
57.3	6770	11830	0.26	17.5	2060	3610	0.26
59.0	6240	11610	0.30	18.0	1900	3540	0.30
60.6	6240	11300	0.28	18.5	1900	3450	0.28
62.2	6430	11510	0.27	19.0	1960	3510	0.27

Summary of Compressional Wave Velocity, Shear Wave Velocity, and Poisson's Ratio Based on Source-to-Receiver Travel Time Data - Borehole B-901

American Units			
Depth at Midpoint Between Source and Near Receiver	Velocity		Poisson's Ratio
	V_s	V_p	
(ft)	(ft/s)	(ft/s)	
63.9	6430	10550	0.21
65.5	5300	9590	0.28
67.2	4220	8380	0.33
68.8	4010	8170	0.34
70.5	4030	8610	0.36
72.1	4460	9520	0.36

Metric Units			
Depth at Midpoint Between Source and Near Receiver	Velocity		Poisson's Ratio
	V_s	V_p	
(m)	(m/s)	(m/s)	
19.5	1960	3220	0.21
20.0	1610	2920	0.28
20.5	1290	2560	0.33
21.0	1220	2490	0.34
21.5	1230	2630	0.36
22.0	1360	2900	0.36

Notes: "-" means no data available at that particular interval of depth.

Table A-2. Boring B-901, Bottom Section, Suspension R1-R2 depths and P- and S_H-wave velocities

Summary of Compressional Wave Velocity, Shear Wave Velocity, and Poisson's Ratio Based on Source-to-Receiver Travel Time Data - Borehole B-901

American Units			
Depth at Midpoint Between Source and Near Receiver	Velocity		Poisson's Ratio
	V_s	V_p	
(ft)	(ft/s)	(ft/s)	
45.9	4560	11150	0.40
47.6	4720	11640	0.40
49.2	5050	12190	0.40
50.9	5550	12300	0.37
52.5	5600	12300	0.37
54.1	6180	12780	0.35
55.8	6420	12780	0.33
57.4	6420	12780	0.33
59.1	6620	12660	0.31
60.7	6360	12070	0.31
62.3	6360	11750	0.29
64.0	6240	11440	0.29
65.6	5220	10780	0.35
67.3	4440	9950	0.38
68.9	4210	9380	0.37
70.6	3920	8990	0.38
72.2	4150	9800	0.39
73.8	4620	11240	0.40
75.5	4880	12070	0.40
77.1	5170	12540	0.40
78.8	5130	13040	0.41
80.4	5320	12910	0.40
82.0	5460	12910	0.39
83.7	5410	12780	0.39
85.3	6120	12780	0.35
87.0	5800	13040	0.38
88.6	5280	12780	0.40
90.2	5130	13170	0.41
91.9	4980	12910	0.41
93.5	5170	12300	0.39
95.2	5740	13040	0.38
96.8	6760	13440	0.33
98.4	7200	14490	0.34
100.1	7200	14490	0.34
101.7	6620	13870	0.35

Metric Units			
Depth at Midpoint Between Source and Near Receiver	Velocity		Poisson's Ratio
	V_s	V_p	
(m)	(m/s)	(m/s)	
14.0	1390	3400	0.40
14.5	1440	3550	0.40
15.0	1540	3710	0.40
15.5	1690	3750	0.37
16.0	1710	3750	0.37
16.5	1880	3900	0.35
17.0	1960	3900	0.33
17.5	1960	3900	0.33
18.0	2020	3860	0.31
18.5	1940	3680	0.31
19.0	1940	3580	0.29
19.5	1900	3490	0.29
20.0	1590	3280	0.35
20.5	1350	3030	0.38
21.0	1280	2860	0.37
21.5	1190	2740	0.38
22.0	1270	2990	0.39
22.5	1410	3430	0.40
23.0	1490	3680	0.40
23.5	1580	3820	0.40
24.0	1560	3970	0.41
24.5	1620	3940	0.40
25.0	1660	3940	0.39
25.5	1650	3900	0.39
26.0	1870	3900	0.35
26.5	1770	3970	0.38
27.0	1610	3900	0.40
27.5	1560	4010	0.41
28.0	1520	3940	0.41
28.5	1580	3750	0.39
29.0	1750	3970	0.38
29.5	2060	4100	0.33
30.0	2200	4420	0.34
30.5	2200	4420	0.34
31.0	2020	4230	0.35

Summary of Compressional Wave Velocity, Shear Wave Velocity, and Poisson's Ratio Based on Source-to-Receiver Travel Time Data - Borehole B-901

American Units				Metric Units			
Depth at Midpoint Between Source and Near Receiver	Velocity		Poisson's Ratio	Depth at Midpoint Between Source and Near Receiver	Velocity		Poisson's Ratio
	V_s	V_p			V_s	V_p	
(ft)	(ft/s)	(ft/s)		(m)	(m/s)	(m/s)	
103.4	4870	11750	0.40	31.5	1480	3580	0.40
105.0	4080	11340	0.43	32.0	1240	3460	0.43
106.6	3690	10270	0.43	32.5	1130	3130	0.43
108.3	3510	9730	0.42	33.0	1070	2970	0.42
109.9	3700	9800	0.42	33.5	1130	2990	0.42
111.6	3700	10030	0.42	34.0	1130	3060	0.42
113.2	3680	10030	0.42	34.5	1120	3060	0.42
114.8	3570	10870	0.44	35.0	1090	3310	0.44
116.5	3570	10780	0.44	35.5	1090	3280	0.44
118.1	3570	10690	0.44	36.0	1090	3260	0.44
119.8	3250	9520	0.43	36.5	990	2900	0.43
121.4	3340	9120	0.42	37.0	1020	2780	0.42
123.0	3500	8750	0.41	37.5	1070	2670	0.41
124.7	4050	9250	0.38	38.0	1230	2820	0.38
126.3	4790	10030	0.35	38.5	1460	3060	0.35
128.0	5220	12070	0.39	39.0	1590	3680	0.39
129.6	6520	13870	0.36	39.5	1990	4230	0.36
131.2	7670	14490	0.31	40.0	2340	4420	0.31
132.9	8250	15900	0.32	40.5	2520	4850	0.32
134.5	8930	16100	0.28	41.0	2720	4910	0.28
136.2	8930	15520	0.25	41.5	2720	4730	0.25
137.8	9060	15900	0.26	42.0	2760	4850	0.26
139.4	9380	16720	0.27	42.5	2860	5100	0.27
141.1	9450	16300	0.25	43.0	2880	4970	0.25
142.7	9730	16510	0.23	43.5	2970	5030	0.23
144.4	9660	16720	0.25	44.0	2940	5100	0.25
146.0	9660	16510	0.24	44.5	2940	5030	0.24
147.7	9120	15710	0.25	45.0	2780	4790	0.25
149.3	9250	15340	0.21	45.5	2820	4680	0.21
150.9	8580	15160	0.26	46.0	2610	4620	0.26
152.6	8520	15340	0.28	46.5	2600	4680	0.28
154.2	8640	15710	0.28	47.0	2630	4790	0.28
155.9	8690	15520	0.27	47.5	2650	4730	0.27
157.5	8690	15160	0.26	48.0	2650	4620	0.26
159.1	8580	15520	0.28	48.5	2610	4730	0.28
160.8	8410	15520	0.29	49.0	2560	4730	0.29
162.4	8470	15710	0.30	49.5	2580	4790	0.30
164.1	8640	16300	0.30	50.0	2630	4970	0.30
165.7	8810	16510	0.30	50.5	2690	5030	0.30

Summary of Compressional Wave Velocity, Shear Wave Velocity, and Poisson's Ratio Based on Source-to-Receiver Travel Time Data - Borehole B-901

American Units				Metric Units			
Depth at Midpoint Between Source and Near Receiver	Velocity		Poisson's Ratio	Depth at Midpoint Between Source and Near Receiver	Velocity		Poisson's Ratio
	V_s	V_p			V_s	V_p	
(ft)	(ft/s)	(ft/s)		(m)	(m/s)	(m/s)	
167.3	9060	16510	0.28	51.0	2760	5030	0.28
169.0	9250	16510	0.27	51.5	2820	5030	0.27
170.6	9180	16300	0.27	52.0	2800	4970	0.27
172.3	9250	16510	0.27	52.5	2820	5030	0.27
173.9	9450	17160	0.28	53.0	2880	5230	0.28
175.5	9450	17390	0.29	53.5	2880	5300	0.29
177.2	9730	17390	0.27	54.0	2970	5300	0.27
178.8	10190	17620	0.25	54.5	3110	5370	0.25
180.5	10110	17860	0.26	55.0	3080	5440	0.26
182.1	10110	17860	0.26	55.5	3080	5440	0.26
185.4	10110	17860	0.26	56.5	3080	5440	0.26
187.0	10110	17860	0.26	57.0	3080	5440	0.26
188.7	9950	17390	0.26	57.5	3030	5300	0.26
190.3	9880	17160	0.25	58.0	3010	5230	0.25
191.9	9520	17160	0.28	58.5	2900	5230	0.28
193.6	9520	17390	0.29	59.0	2900	5300	0.29
195.2	9450	17390	0.29	59.5	2880	5300	0.29
196.9	9450	17390	0.29	60.0	2880	5300	0.29
198.5	9380	17160	0.29	60.5	2860	5230	0.29
200.1	9380	17390	0.29	61.0	2860	5300	0.29
201.8	9310	16940	0.28	61.5	2840	5160	0.28
203.4	9310	16720	0.27	62.0	2840	5100	0.27
205.1	9380	16720	0.27	62.5	2860	5100	0.27
206.7	9380	17160	0.29	63.0	2860	5230	0.29
208.3	9520	17160	0.28	63.5	2900	5230	0.28
210.0	9520	16720	0.26	64.0	2900	5100	0.26
211.6	9380	17160	0.29	64.5	2860	5230	0.29
213.3	9450	17160	0.28	65.0	2880	5230	0.28
214.9	9380	16940	0.28	65.5	2860	5160	0.28
216.5	9450	17620	0.30	66.0	2880	5370	0.30
218.2	9450	17620	0.30	66.5	2880	5370	0.30
219.8	9310	17160	0.29	67.0	2840	5230	0.29
221.5	9380	17620	0.30	67.5	2860	5370	0.30
223.1	9250	17390	0.30	68.0	2820	5300	0.30
224.8	9250	17160	0.30	68.5	2820	5230	0.30
226.4	9250	17160	0.30	69.0	2820	5230	0.30
228.0	9180	16720	0.28	69.5	2800	5100	0.28
229.7	8990	16510	0.29	70.0	2740	5030	0.29
231.3	9120	16720	0.29	70.5	2780	5100	0.29

Summary of Compressional Wave Velocity, Shear Wave Velocity, and Poisson's Ratio Based on Source-to-Receiver Travel Time Data - Borehole B-901

American Units				Metric Units			
Depth at Midpoint Between Source and Near Receiver	Velocity		Poisson's Ratio	Depth at Midpoint Between Source and Near Receiver	Velocity		Poisson's Ratio
	V_s	V_p			V_s	V_p	
(ft)	(ft/s)	(ft/s)		(m)	(m/s)	(m/s)	
233.0	9060	16720	0.29	71.0	2760	5100	0.29
234.6	9450	16720	0.27	71.5	2880	5100	0.27
236.2	9380	16720	0.27	72.0	2860	5100	0.27
237.9	9380	16940	0.28	72.5	2860	5160	0.28
239.5	9520	17160	0.28	73.0	2900	5230	0.28
241.2	9590	17160	0.27	73.5	2920	5230	0.27
242.8	9520	17160	0.28	74.0	2900	5230	0.28
244.4	9310	16720	0.27	74.5	2840	5100	0.27
246.1	9310	16720	0.27	75.0	2840	5100	0.27
247.7	9060	16300	0.28	75.5	2760	4970	0.28
249.4	9120	16300	0.27	76.0	2780	4970	0.27
251.0	9250	16720	0.28	76.5	2820	5100	0.28
252.6	9120	16510	0.28	77.0	2780	5030	0.28
254.3	9310	16940	0.28	77.5	2840	5160	0.28
255.9	9310	16940	0.28	78.0	2840	5160	0.28
257.6	9310	16940	0.28	78.5	2840	5160	0.28
259.2	9520	16940	0.27	79.0	2900	5160	0.27
260.8	9950	16940	0.24	79.5	3030	5160	0.24
262.5	10110	17390	0.24	80.0	3080	5300	0.24
264.1	10030	16940	0.23	80.5	3060	5160	0.23
265.8	9880	16510	0.22	81.0	3010	5030	0.22
267.4	9800	16720	0.24	81.5	2990	5100	0.24
269.0	10110	17620	0.25	82.0	3080	5370	0.25
270.7	10690	17390	0.20	82.5	3260	5300	0.20
272.3	10190	17390	0.24	83.0	3110	5300	0.24
274.0	9520	16940	0.27	83.5	2900	5160	0.27
275.6	9520	16940	0.27	84.0	2900	5160	0.27
277.2	9730	16940	0.25	84.5	2970	5160	0.25
278.9	9800	17390	0.27	85.0	2990	5300	0.27
280.5	9730	17620	0.28	85.5	2970	5370	0.28
282.2	9450	16940	0.27	86.0	2880	5160	0.27
283.8	9380	16940	0.28	86.5	2860	5160	0.28
285.4	9380	16720	0.27	87.0	2860	5100	0.27
287.1	9250	16940	0.29	87.5	2820	5160	0.29
288.7	9380	17160	0.29	88.0	2860	5230	0.29
290.4	9450	16940	0.27	88.5	2880	5160	0.27
292.0	9590	16720	0.25	89.0	2920	5100	0.25

Summary of Compressional Wave Velocity, Shear Wave Velocity, and Poisson's Ratio Based on Source-to-Receiver Travel Time Data - Borehole B-901

American Units				Metric Units			
Depth at Midpoint Between Source and Near Receiver	Velocity		Poisson's Ratio	Depth at Midpoint Between Source and Near Receiver	Velocity		Poisson's Ratio
	V_s	V_p			V_s	V_p	
(ft)	(ft/s)	(ft/s)		(m)	(m/s)	(m/s)	

Notes: "-" means no data available at that particular interval of depth.

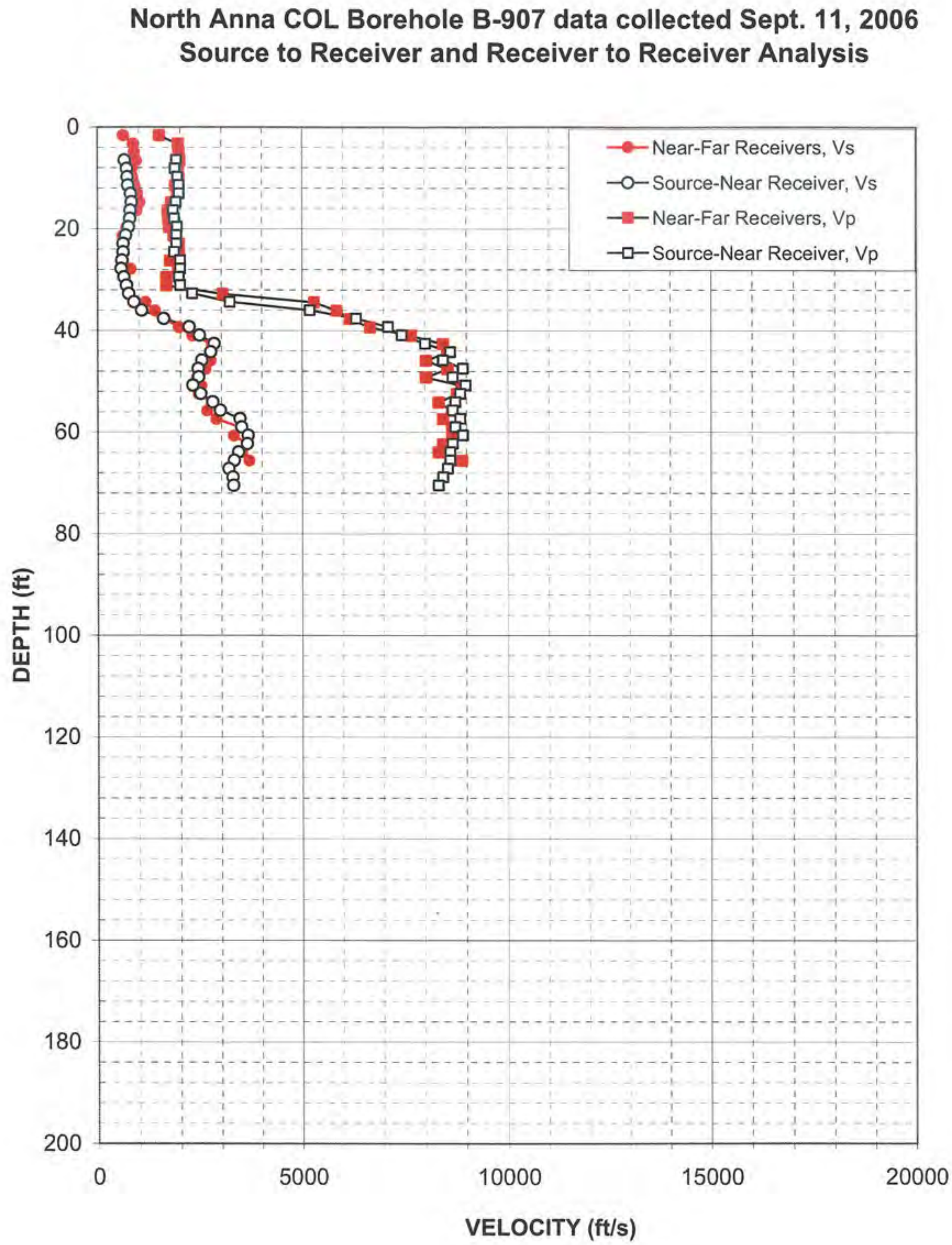


Figure A-3: Boring B-907, Top Section, Suspension S-R1 P- and S_H-wave velocities

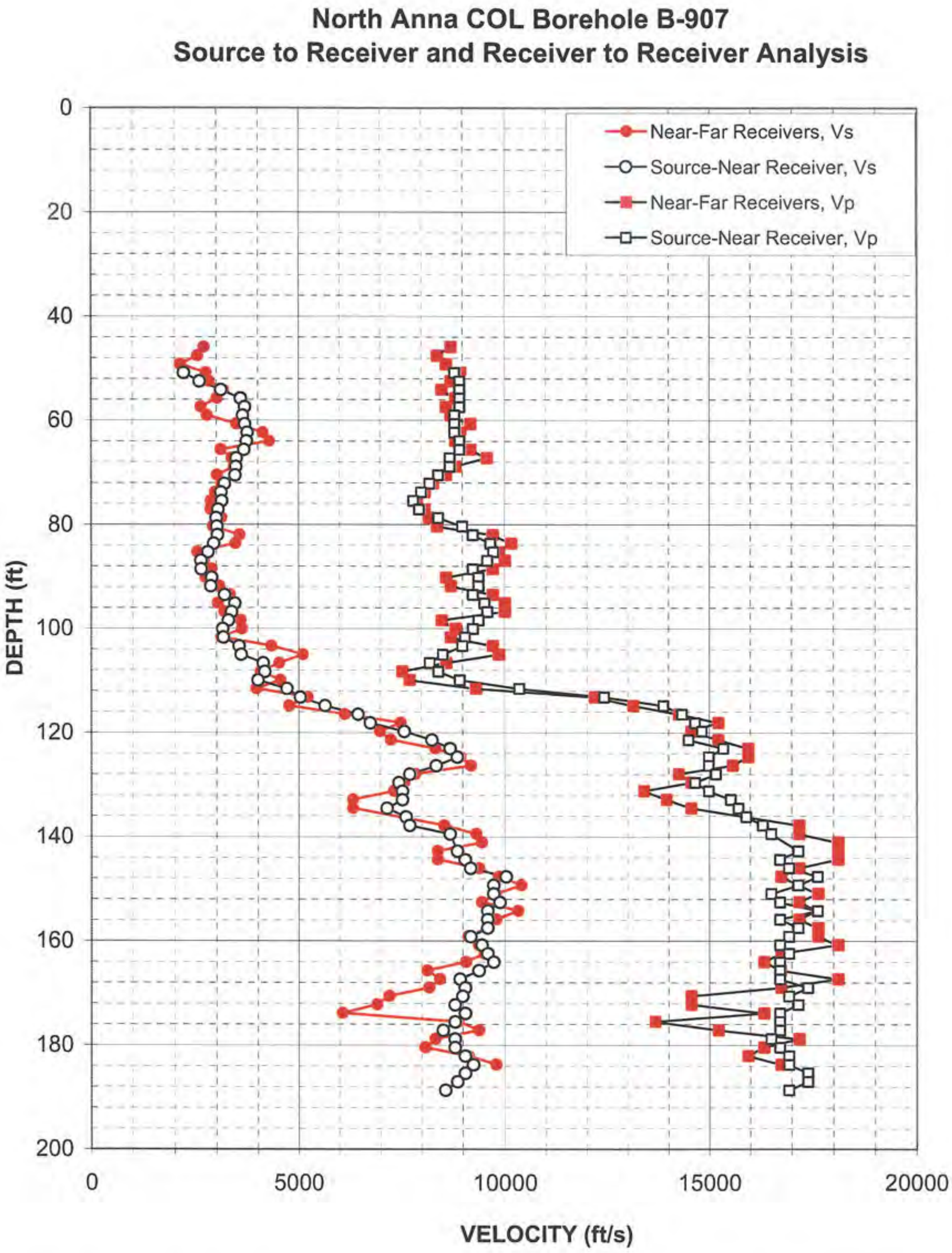


Figure A-4: Boring B-907, Bottom Section, Suspension S-R1 P- and S_H-wave velocities

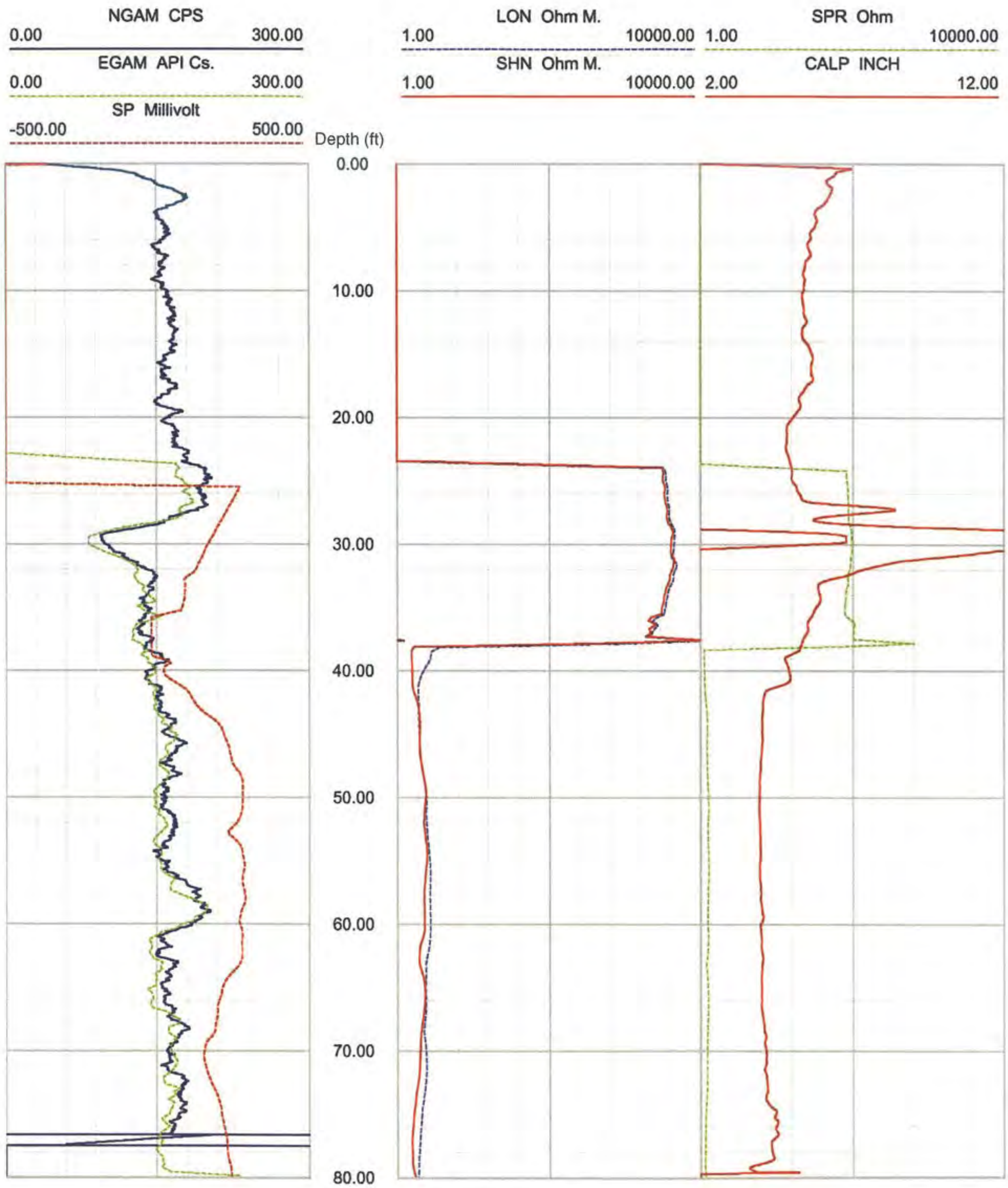


Figure 12. Boring B-907, Top Section, Caliper, Natural gamma, Resistivity and SP logs

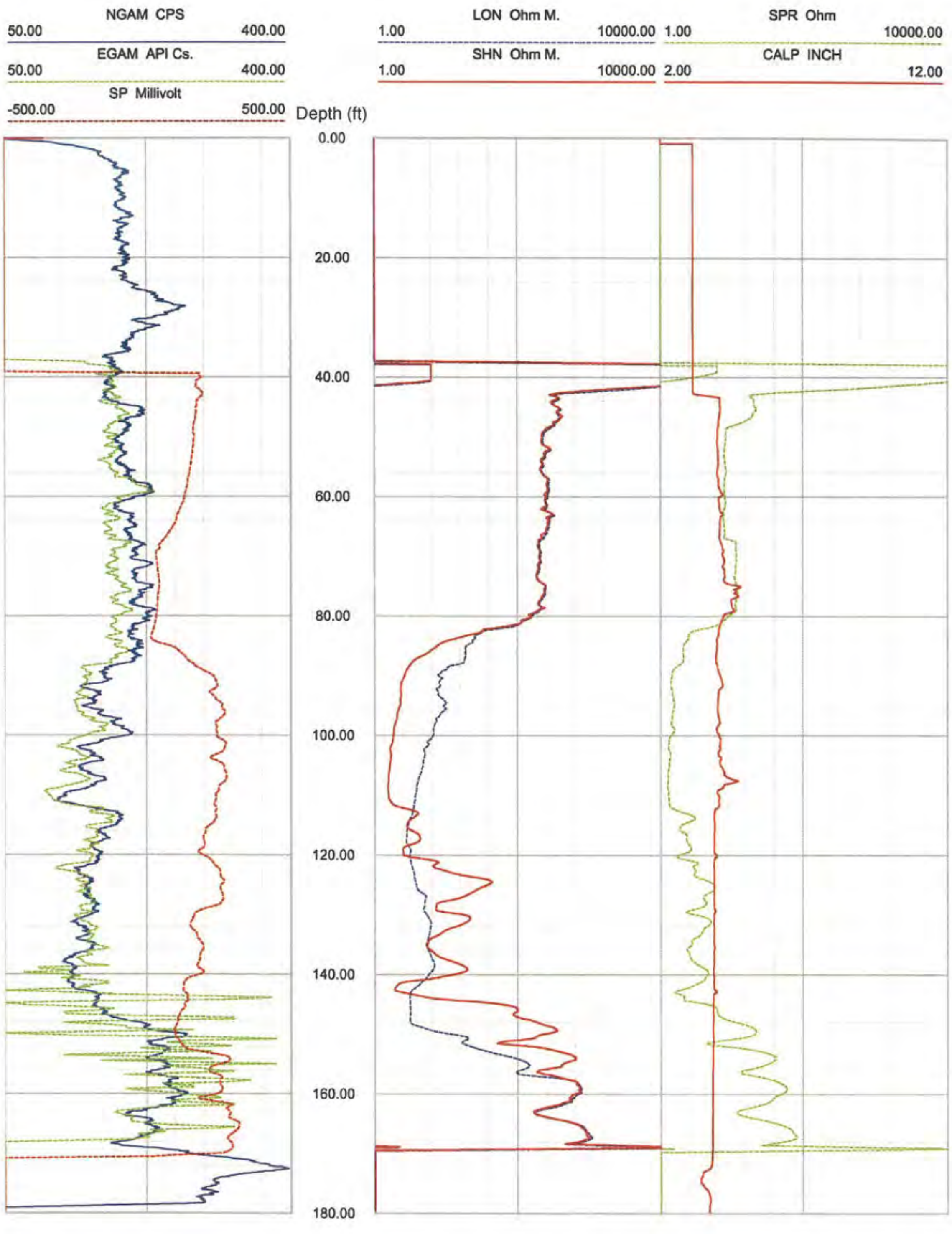
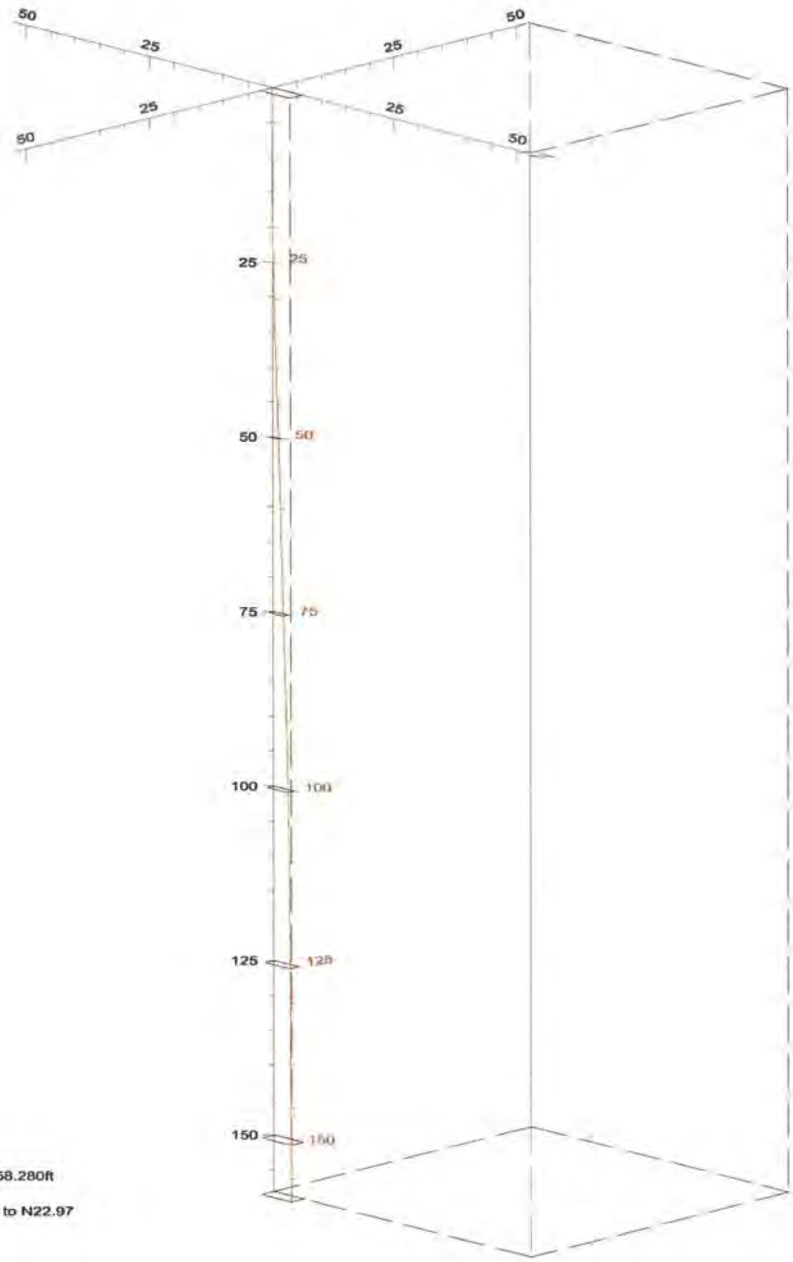


Figure 13. Boring B-907, Bottom Section, Caliper, Natural gamma, Resistivity and SP logs

Deviated borehole in orthographic projection, viewed from N45



Borehole: B-907
Zone from: 1.528 - 158.280ft
North ref is true
Mean deviation: 2.40 to N22.97
End coordinates .....
North: 6.106
East : 2.588
Down : 158.115
Azimuth of end: N22.97
Distance start-end: 6.632ft
Viewpoint: N45
Data extrapolated to the surface from 1.528ft
29 Sep 2006

Figure 14. Boring B-907, Deviation Projection (dimensions in feet)

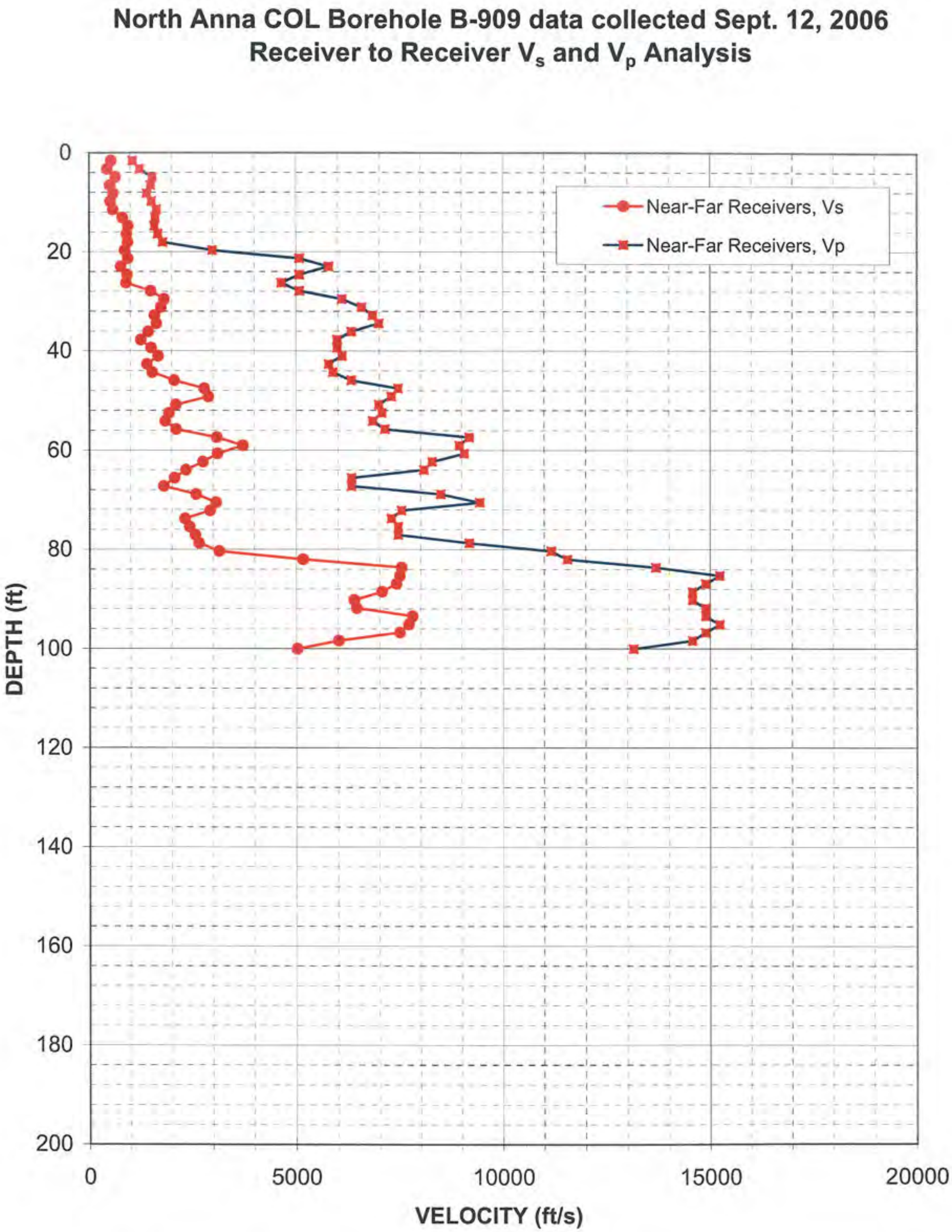


Figure 15. Boring B-909, Top Section, Suspension R1-R2 P- and S_H-wave velocities

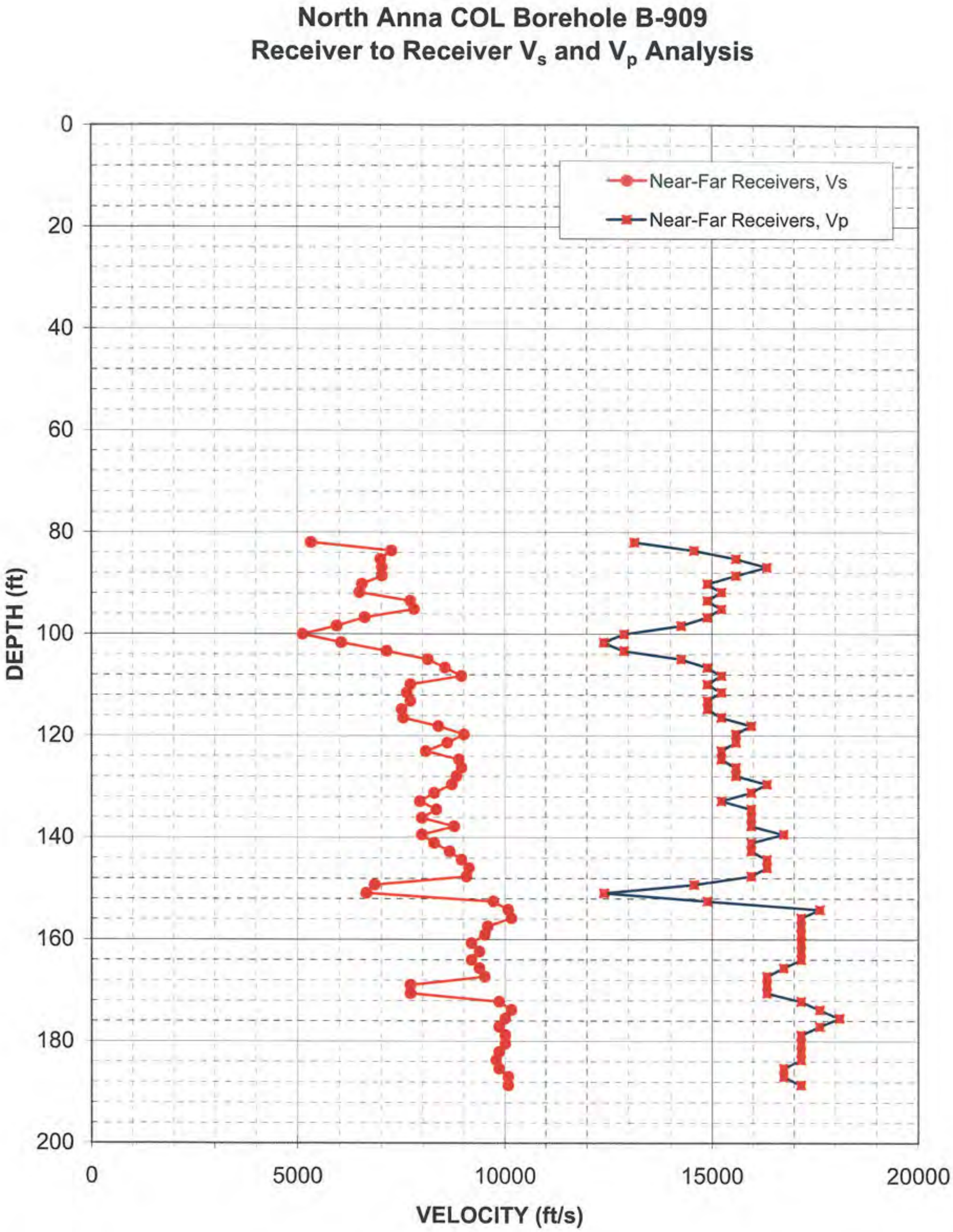


Figure 16. Boring B-909, Bottom Section, Suspension R1-R2 P- and S_H-wave velocities

Table 9. Boring B-909, Top Section, Suspension R1-R2 depths and P- and S_H-wave velocities

Summary of Compressional Wave Velocity, Shear Wave Velocity, and Poisson's Ratio Based on Receiver-to-Receiver Travel Time Data - Borehole B-909

American Units				Metric Units			
Depth at Midpoint Between Receivers	Velocity		Poisson's Ratio	Depth at Midpoint Between Receivers	Velocity		Poisson's Ratio
	V_s	V_p			V_s	V_p	
(ft)	(ft/s)	(ft/s)		(m)	(m/s)	(m/s)	
1.6	520	1050	0.33	0.5	160	320	0.33
3.3	430	1220	0.43	1.0	130	370	0.43
4.9	630	1520	0.40	1.5	190	460	0.40
6.6	490	1490	0.44	2.0	150	450	0.44
8.2	570	1400	0.40	2.5	170	430	0.40
9.8	500	1510	0.44	3.0	150	460	0.44
11.5	570	1630	0.43	3.5	170	500	0.43
13.1	800	1600	0.33	4.0	240	490	0.33
14.8	940	1580	0.23	4.5	290	480	0.23
16.4	900	1660	0.29	5.0	270	510	0.29
18.0	920	1780	0.32	5.5	280	540	0.32
19.7	850	2990	0.46	6.0	260	910	0.46
21.3	930	5080	0.48	6.5	280	1550	0.48
23.0	760	5780	0.49	7.0	230	1760	0.49
24.6	910	5080	0.48	7.5	280	1550	0.48
26.3	890	4650	0.48	8.0	270	1420	0.48
27.9	1490	5080	0.45	8.5	450	1550	0.45
29.5	1810	6090	0.45	9.0	550	1860	0.45
31.2	1740	6570	0.46	9.5	530	2000	0.46
32.8	1580	6840	0.47	10.0	480	2080	0.47
34.5	1630	6980	0.47	10.5	500	2130	0.47
36.1	1430	6320	0.47	11.0	430	1930	0.47
37.7	1250	5980	0.48	11.5	380	1820	0.48
39.4	1500	5980	0.47	12.0	460	1820	0.47
41.0	1670	6090	0.46	12.5	510	1860	0.46
42.7	1400	5780	0.47	13.0	430	1760	0.47
44.3	1520	5880	0.46	13.5	460	1790	0.46
45.9	2060	6320	0.44	14.0	630	1930	0.44
47.6	2790	7440	0.42	14.5	850	2270	0.42
49.2	2890	7280	0.41	15.0	880	2220	0.41
50.9	2090	6980	0.45	15.5	640	2130	0.45
52.5	1930	7050	0.46	16.0	590	2150	0.46
54.1	1840	6840	0.46	16.5	560	2080	0.46
55.8	2100	7130	0.45	17.0	640	2170	0.45
57.4	3090	9180	0.44	17.5	940	2800	0.44

Summary of Compressional Wave Velocity, Shear Wave Velocity, and Poisson's Ratio Based on Receiver-to-Receiver Travel Time Data - Borehole B-909

American Units				Metric Units			
Depth at Midpoint Between Receivers	Velocity		Poisson's Ratio	Depth at Midpoint Between Receivers	Velocity		Poisson's Ratio
	V_s	V_p			V_s	V_p	
(ft)	(ft/s)	(ft/s)		(m)	(m/s)	(m/s)	
59.1	3720	8930	0.39	18.0	1130	2720	0.39
60.7	3110	9050	0.43	18.5	950	2760	0.43
62.3	2760	8270	0.44	19.0	840	2520	0.44
64.0	2340	8070	0.45	19.5	710	2460	0.45
65.6	2060	6320	0.44	20.0	630	1930	0.44
67.3	1800	6320	0.46	20.5	550	1930	0.46
68.9	2590	8480	0.45	21.0	790	2590	0.45
70.5	3070	9440	0.44	21.5	940	2880	0.44
72.2	2930	7530	0.41	22.0	890	2290	0.41
73.8	2320	7280	0.44	22.5	710	2220	0.44
75.5	2430	7440	0.44	23.0	740	2270	0.44
77.1	2570	7440	0.43	23.5	780	2270	0.43
78.7	2660	9180	0.45	24.0	810	2800	0.45
80.4	3150	11170	0.46	24.5	960	3400	0.46
82.0	5150	11550	0.38	25.0	1570	3520	0.38
83.7	7530	13670	0.28	25.5	2290	4170	0.28
85.3	7490	15230	0.34	26.0	2280	4640	0.34
86.9	7400	14890	0.34	26.5	2260	4540	0.34
88.6	7050	14570	0.35	27.0	2150	4440	0.35
90.2	6380	14570	0.38	27.5	1940	4440	0.38
91.9	6440	14890	0.38	28.0	1960	4540	0.38
93.5	7790	14890	0.31	28.5	2370	4540	0.31
95.1	7700	15230	0.33	29.0	2350	4640	0.33
96.8	7490	14890	0.33	29.5	2280	4540	0.33
98.4	6010	14570	0.40	30.0	1830	4440	0.40
100.1	5020	13140	0.41	30.5	1530	4000	0.41

Notes: "-" means no data available at that particular interval of depth.

Table 10. Boring B-909, Bottom Section, Suspension R1-R2 depths and P- and S_H-wave velocities

Summary of Compressional Wave Velocity, Shear Wave Velocity, and Poisson's Ratio Based on Receiver-to-Receiver Travel Time Data - Borehole B-909

American Units				Metric Units			
Depth at Midpoint Between Receivers	Velocity		Poisson's Ratio	Depth at Midpoint Between Receivers	Velocity		Poisson's Ratio
	V_s	V_p			V_s	V_p	
(ft)	(ft/s)	(ft/s)		(m)	(m/s)	(m/s)	
82.0	5310	13120	0.40	25.0	1620	4000	0.40
83.7	7240	14550	0.34	25.5	2210	4440	0.34
85.3	6970	15570	0.37	26.0	2130	4740	0.37
86.9	7010	16330	0.39	26.5	2140	4980	0.39
88.6	7010	15570	0.37	27.0	2140	4740	0.37
90.2	6530	14870	0.38	27.5	1990	4530	0.38
91.9	6470	15210	0.39	28.0	1970	4640	0.39
93.5	7690	14870	0.32	28.5	2340	4530	0.32
95.1	7780	15210	0.32	29.0	2370	4640	0.32
96.8	6590	14870	0.38	29.5	2010	4530	0.38
98.4	5920	14240	0.40	30.0	1810	4340	0.40
100.1	5110	12870	0.41	30.5	1560	3920	0.41
101.7	6030	12400	0.34	31.0	1840	3780	0.34
103.4	7120	12870	0.28	31.5	2170	3920	0.28
105.0	8110	14240	0.26	32.0	2470	4340	0.26
106.6	8530	14870	0.26	32.5	2600	4530	0.26
108.3	8920	15210	0.24	33.0	2720	4640	0.24
109.9	7690	14870	0.32	33.5	2340	4530	0.32
111.6	7610	15210	0.33	34.0	2320	4640	0.33
113.2	7690	14870	0.32	34.5	2340	4530	0.32
114.8	7480	14870	0.33	35.0	2280	4530	0.33
116.5	7520	15210	0.34	35.5	2290	4640	0.34
118.1	8370	15940	0.31	36.0	2550	4860	0.31
119.8	8980	15570	0.25	36.5	2740	4740	0.25
121.4	8580	15570	0.28	37.0	2620	4740	0.28
123.0	8060	15210	0.30	37.5	2460	4640	0.30
124.7	8870	15210	0.24	38.0	2700	4640	0.24
126.3	8920	15570	0.26	38.5	2720	4740	0.26
128.0	8810	15570	0.26	39.0	2680	4740	0.26
129.6	8690	16330	0.30	39.5	2650	4980	0.30
131.2	8260	15940	0.32	40.0	2520	4860	0.32
132.9	7920	15210	0.31	40.5	2410	4640	0.31
134.5	8310	15940	0.31	41.0	2530	4860	0.31
136.2	7970	15940	0.33	41.5	2430	4860	0.33
137.8	8750	15940	0.28	42.0	2670	4860	0.28

Summary of Compressional Wave Velocity, Shear Wave Velocity, and Poisson's Ratio Based on Receiver-to-Receiver Travel Time Data - Borehole B-909

American Units				Metric Units			
Depth at Midpoint Between Receivers	Velocity		Poisson's Ratio	Depth at Midpoint Between Receivers	Velocity		Poisson's Ratio
	V_s	V_p			V_s	V_p	
(ft)	(ft/s)	(ft/s)		(m)	(m/s)	(m/s)	
139.4	7970	16730	0.35	42.5	2430	5100	0.35
141.1	8260	15940	0.32	43.0	2520	4860	0.32
142.7	8640	15940	0.29	43.5	2630	4860	0.29
144.4	8920	16330	0.29	44.0	2720	4980	0.29
146.0	9110	16330	0.27	44.5	2780	4980	0.27
147.6	9050	15940	0.26	45.0	2760	4860	0.26
149.3	6830	14550	0.36	45.5	2080	4440	0.36
150.9	6630	12400	0.30	46.0	2020	3780	0.30
152.6	9700	14870	0.13	46.5	2960	4530	0.13
154.2	10070	17610	0.26	47.0	3070	5370	0.26
155.8	10140	17160	0.23	47.5	3090	5230	0.23
157.5	9560	17160	0.27	48.0	2910	5230	0.27
159.1	9490	17160	0.28	48.5	2890	5230	0.28
160.8	9170	17160	0.30	49.0	2790	5230	0.30
162.4	9360	17160	0.29	49.5	2850	5230	0.29
164.0	9170	17160	0.30	50.0	2790	5230	0.30
165.7	9360	16730	0.27	50.5	2850	5100	0.27
167.3	9490	16330	0.24	51.0	2890	4980	0.24
169.0	7690	16330	0.36	51.5	2340	4980	0.36
170.6	7690	16330	0.36	52.0	2340	4980	0.36
172.2	9840	17160	0.25	52.5	3000	5230	0.25
173.9	10140	17610	0.25	53.0	3090	5370	0.25
175.5	9990	18090	0.28	53.5	3040	5510	0.28
177.2	9840	17610	0.27	54.0	3000	5370	0.27
178.8	9990	17160	0.24	54.5	3040	5230	0.24
180.5	9990	17160	0.24	55.0	3040	5230	0.24
182.1	9840	17160	0.25	55.5	3000	5230	0.25
183.7	9770	17160	0.26	56.0	2980	5230	0.26
185.4	9840	16730	0.24	56.5	3000	5100	0.24
187.0	10070	16730	0.22	57.0	3070	5100	0.22
188.7	10070	17160	0.24	57.5	3070	5230	0.24

Notes: "-" means no data available at that particular interval of depth.

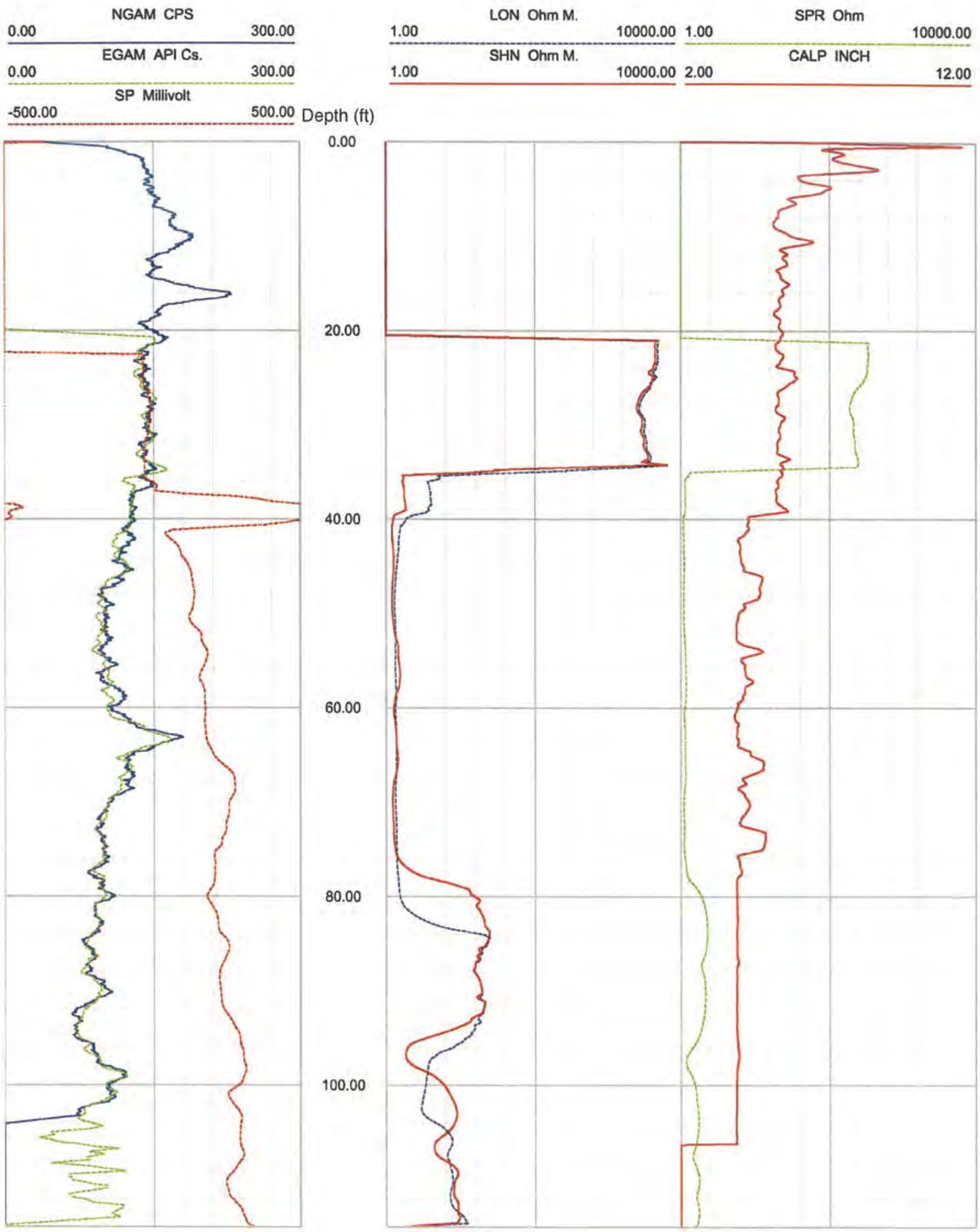


Figure 17. Boring B-909, Top Section, Caliper, Natural gamma, Resistivity and SP logs

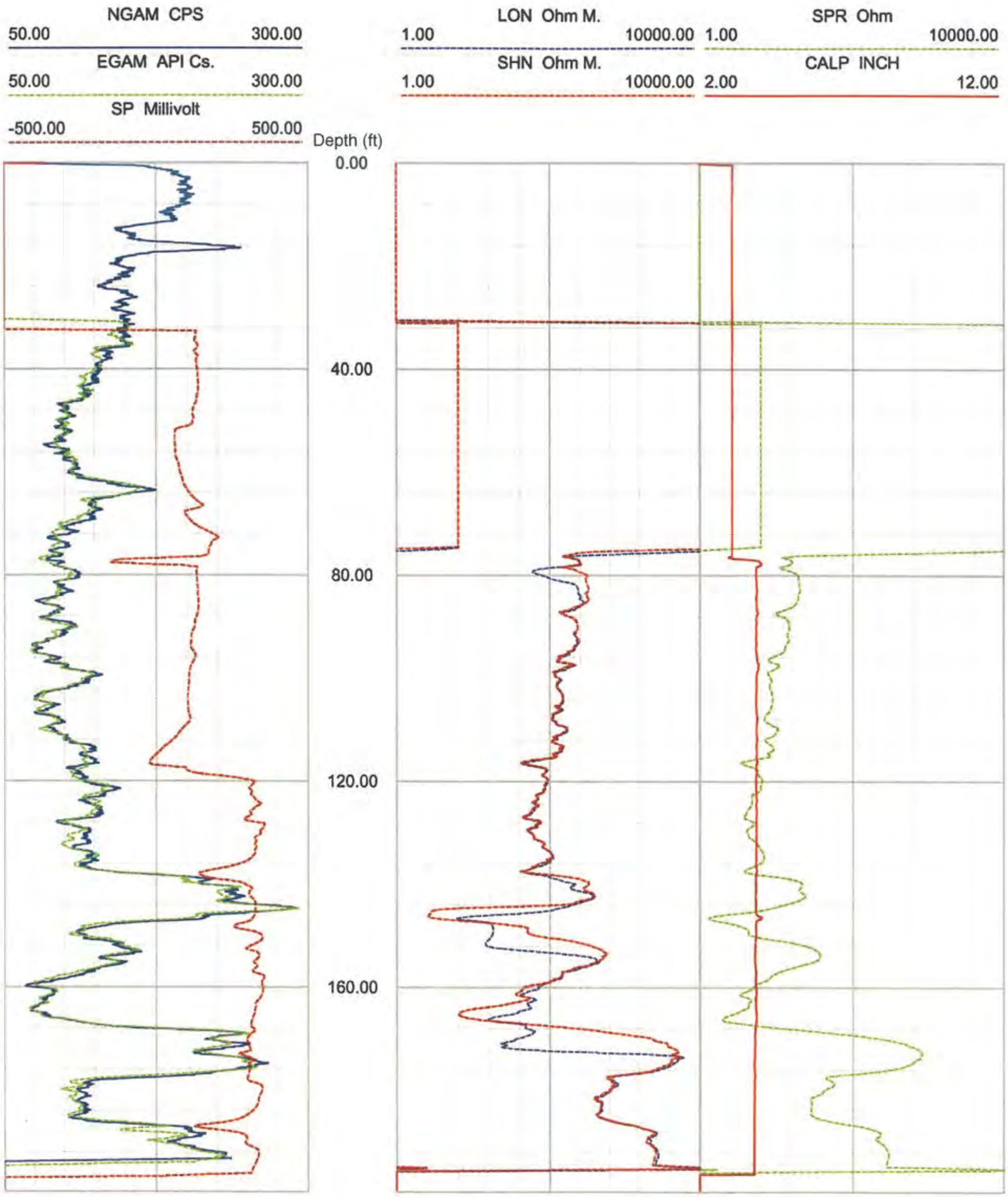
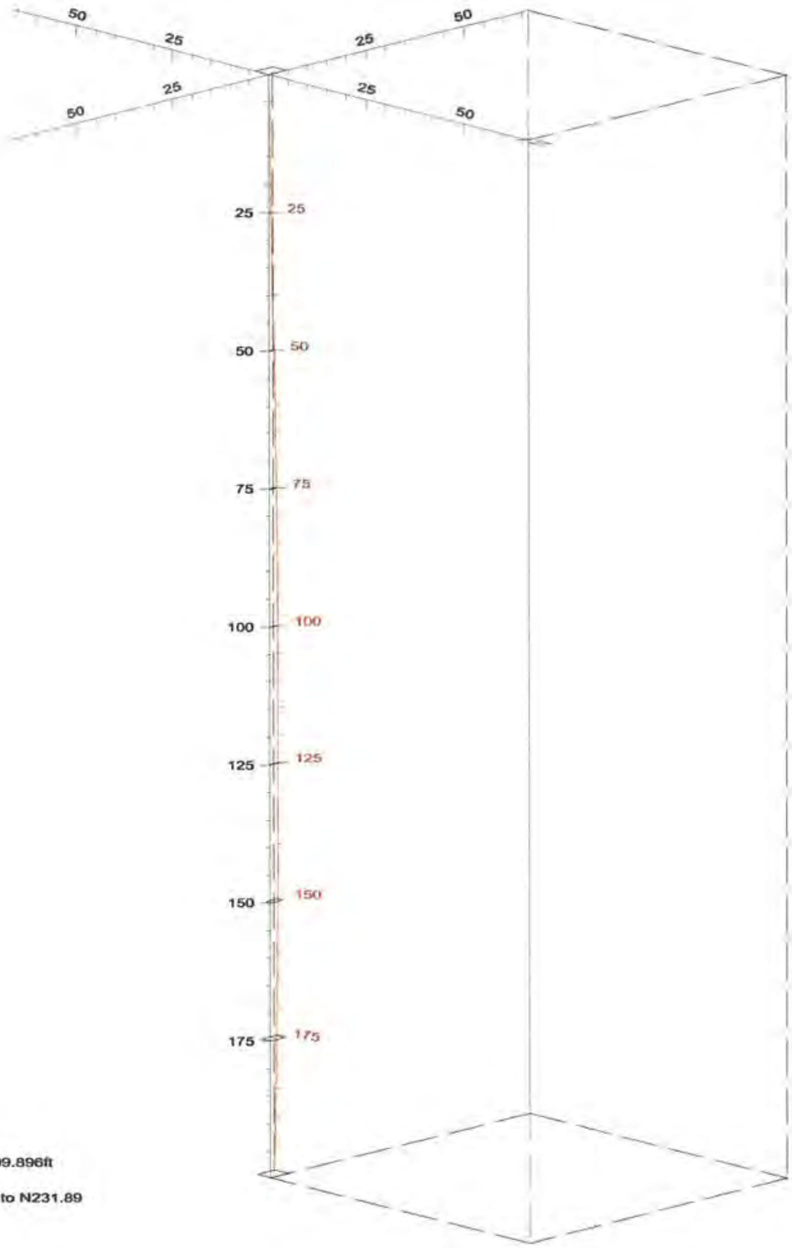


Figure 18. Boring B-909, Bottom Section, Caliper, Natural gamma, Resistivity and SP logs

Deviated borehole in orthographic projection, viewed from N45



Borehole: B-909
Zone from: 3.224 - 199.896ft
North ref is true
Mean deviation: 1.63 to N231.89
End coordinates .....
North: -3.509
East : -4.472
Down : 199.767
Azimuth of end: N231.88
Distance start-end: 5.684ft
Viewpoint: N45
Data extrapolated to the surface from 3.224ft
29 Sep 2006

Figure 19. Boring B-909, Deviation Projection (dimensions in feet)

Table A-3. Boring B-907, Top Section, Suspension S-R1 depths and P- and S_H-wave velocities

Summary of Compressional Wave Velocity, Shear Wave Velocity, and Poisson's Ratio Based on Source-to-Receiver Travel Time Data - Borehole B-907

American Units				Metric Units			
Depth at Midpoint Between Source and Near Receiver	Velocity		Poisson's Ratio	Depth at Midpoint Between Source and Near Receiver	Velocity		Poisson's Ratio
	V_s	V_p			V_s	V_p	
(ft)	(ft/s)	(ft/s)		(m)	(m/s)	(m/s)	
6.5	650	1910	0.43	2.0	200	580	0.43
8.1	710	1870	0.42	2.5	220	570	0.42
9.8	720	1940	0.42	3.0	220	590	0.42
11.4	730	1970	0.42	3.5	220	600	0.42
13.0	800	1970	0.40	4.0	240	600	0.40
14.7	820	1900	0.38	4.5	250	580	0.38
16.3	790	1820	0.38	5.0	240	560	0.38
18.0	780	1850	0.39	5.5	240	560	0.39
19.6	750	1920	0.41	6.0	230	580	0.41
21.2	680	1910	0.43	6.5	210	580	0.43
22.9	620	1910	0.44	7.0	190	580	0.44
24.5	620	1850	0.44	7.5	190	560	0.44
26.2	590	2000	0.45	8.0	180	610	0.45
27.8	570	2000	0.46	8.5	170	610	0.46
29.4	630	1970	0.44	9.0	190	600	0.44
31.1	700	2000	0.43	9.5	210	610	0.43
32.7	750	2290	0.44	10.0	230	700	0.44
34.4	880	3210	0.46	10.5	270	980	0.46
36.0	1060	5190	0.48	11.0	320	1580	0.48
37.6	1590	6330	0.47	11.5	490	1930	0.47
39.3	2210	7110	0.45	12.0	670	2170	0.45
40.9	2460	7450	0.44	12.5	750	2270	0.44
42.6	2830	8010	0.43	13.0	860	2440	0.43
44.2	2740	8610	0.44	13.5	840	2630	0.44
45.8	2520	8440	0.45	14.0	770	2570	0.45
47.5	2430	8920	0.46	14.5	740	2720	0.46
49.1	2440	8670	0.46	15.0	740	2640	0.46
50.8	2300	8980	0.46	15.5	700	2740	0.46
52.4	2490	8850	0.46	16.0	760	2700	0.46
54.0	2790	8730	0.44	16.5	850	2660	0.44
55.7	2970	8670	0.43	17.0	910	2640	0.43
57.3	3460	8850	0.41	17.5	1050	2700	0.41
59.0	3500	8730	0.40	18.0	1070	2660	0.40
60.6	3660	8920	0.40	18.5	1120	2720	0.40
62.2	3640	8670	0.39	19.0	1110	2640	0.39

Summary of Compressional Wave Velocity, Shear Wave Velocity, and Poisson's Ratio Based on Source-to-Receiver Travel Time Data - Borehole B-907

American Units			
Depth at Midpoint Between Source and Near Receiver	Velocity		Poisson's Ratio
	V_s	V_p	
(ft)	(ft/s)	(ft/s)	
63.9	3420	8610	0.41
65.5	3310	8610	0.41
67.2	3180	8550	0.42
68.8	3280	8440	0.41
70.5	3300	8330	0.41

Metric Units			
Depth at Midpoint Between Source and Near Receiver	Velocity		Poisson's Ratio
	V_s	V_p	
(m)	(m/s)	(m/s)	
19.5	1040	2630	0.41
20.0	1010	2630	0.41
20.5	970	2610	0.42
21.0	1000	2570	0.41
21.5	1000	2540	0.41

Notes: "-" means no data available at that particular interval of depth.

Table A-4. Boring B-907, Bottom Section, Suspension S-R1 depths and P- and S_H-wave velocities

Summary of Compressional Wave Velocity, Shear Wave Velocity, and Poisson's Ratio Based on Source-to-Receiver Travel Time Data - Borehole B-907

American Units				Metric Units			
Depth at Midpoint Between Source and Near Receiver	Velocity		Poisson's Ratio	Depth at Midpoint Between Source and Near Receiver	Velocity		Poisson's Ratio
	V_s	V_p			V_s	V_p	
(ft)	(ft/s)	(ft/s)		(m)	(m/s)	(m/s)	
50.9	2220	8810	0.47	15.5	680	2690	0.47
52.5	2600	8930	0.45	16.0	790	2720	0.45
54.1	3110	8930	0.43	16.5	950	2720	0.43
55.8	3580	8930	0.40	17.0	1090	2720	0.40
57.4	3680	8930	0.40	17.5	1120	2720	0.40
59.1	3630	8810	0.40	18.0	1110	2690	0.40
60.7	3680	8810	0.39	18.5	1120	2690	0.39
62.3	3750	8810	0.39	19.0	1140	2690	0.39
64.0	3730	8930	0.39	19.5	1140	2720	0.39
65.6	3660	8930	0.40	20.0	1120	2720	0.40
67.3	3480	8690	0.40	20.5	1060	2650	0.40
68.9	3470	8690	0.41	21.0	1060	2650	0.41
70.6	3450	8410	0.40	21.5	1050	2560	0.40
72.2	3200	8200	0.41	22.0	970	2500	0.41
73.8	3110	8000	0.41	22.5	950	2440	0.41
75.5	3130	7810	0.40	23.0	950	2380	0.40
77.1	3040	7950	0.41	23.5	930	2420	0.41
78.8	3000	8410	0.43	24.0	910	2560	0.43
80.4	3010	8990	0.44	24.5	920	2740	0.44
82.0	3030	9250	0.44	25.0	920	2820	0.44
83.7	2940	9660	0.45	25.5	900	2940	0.45
85.3	2800	9730	0.45	26.0	850	2970	0.45
87.0	2630	9590	0.46	26.5	800	2920	0.46
88.6	2630	9250	0.46	27.0	800	2820	0.46
90.2	2880	9380	0.45	27.5	880	2860	0.45
91.9	2870	9380	0.45	28.0	870	2860	0.45
93.5	3200	9250	0.43	28.5	970	2820	0.43
95.2	3440	9520	0.42	29.0	1050	2900	0.42
96.8	3360	9590	0.43	29.5	1020	2920	0.43
98.4	3280	9380	0.43	30.0	1000	2860	0.43
100.1	3150	9250	0.43	30.5	960	2820	0.43
101.7	3170	9060	0.43	31.0	960	2760	0.43
103.4	3540	8990	0.41	31.5	1080	2740	0.41
105.0	3590	8520	0.39	32.0	1090	2600	0.39
106.6	4130	8200	0.33	32.5	1260	2500	0.33

Summary of Compressional Wave Velocity, Shear Wave Velocity, and Poisson's Ratio Based on Source-to-Receiver Travel Time Data - Borehole B-907

American Units				Metric Units			
Depth at Midpoint Between Source and Near Receiver	Velocity		Poisson's Ratio	Depth at Midpoint Between Source and Near Receiver	Velocity		Poisson's Ratio
	V_s	V_p			V_s	V_p	
(ft)	(ft/s)	(ft/s)		(m)	(m/s)	(m/s)	
108.3	4170	8410	0.34	33.0	1270	2560	0.34
109.9	4000	8930	0.37	33.5	1220	2720	0.37
111.6	4710	10350	0.37	34.0	1430	3150	0.37
113.2	5030	12420	0.40	34.5	1530	3790	0.40
114.8	5650	13870	0.40	35.0	1720	4230	0.40
116.5	6460	14330	0.37	35.5	1970	4370	0.37
118.1	6760	14650	0.36	36.0	2060	4470	0.36
119.8	7580	14820	0.32	36.5	2310	4520	0.32
121.4	8250	14490	0.26	37.0	2520	4420	0.26
123.0	8690	15340	0.26	37.5	2650	4680	0.26
124.7	8870	14990	0.23	38.0	2700	4570	0.23
126.3	8360	14990	0.27	38.5	2550	4570	0.27
128.0	7720	15160	0.33	39.0	2350	4620	0.33
129.6	7450	14650	0.33	39.5	2270	4470	0.33
131.2	7540	14990	0.33	40.0	2300	4570	0.33
132.9	7540	15520	0.35	40.5	2300	4730	0.35
134.5	7160	15710	0.37	41.0	2180	4790	0.37
136.2	7630	15900	0.35	41.5	2320	4850	0.35
137.8	7720	16300	0.36	42.0	2350	4970	0.36
139.4	8690	16510	0.31	42.5	2650	5030	0.31
142.7	8870	17160	0.32	43.5	2700	5230	0.32
144.4	9060	16720	0.29	44.0	2760	5100	0.29
146.0	9180	16940	0.29	44.5	2800	5160	0.29
147.7	10030	17620	0.26	45.0	3060	5370	0.26
149.3	9730	17160	0.26	45.5	2970	5230	0.26
150.9	9730	16510	0.23	46.0	2970	5030	0.23
152.6	9880	16720	0.23	46.5	3010	5100	0.23
154.2	9590	17620	0.29	47.0	2920	5370	0.29
155.9	9590	16720	0.25	47.5	2920	5100	0.25
157.5	9590	17160	0.27	48.0	2920	5230	0.27
159.1	9180	16940	0.29	48.5	2800	5160	0.29
160.8	9450	16720	0.27	49.0	2880	5100	0.27
162.4	9590	16940	0.26	49.5	2920	5160	0.26
164.1	9730	16720	0.24	50.0	2970	5100	0.24
165.7	9380	16720	0.27	50.5	2860	5100	0.27
167.3	8930	16720	0.30	51.0	2720	5100	0.30
169.0	9060	17390	0.31	51.5	2760	5300	0.31
170.6	8990	16940	0.30	52.0	2740	5160	0.30
172.3	8810	17160	0.32	52.5	2690	5230	0.32

Summary of Compressional Wave Velocity, Shear Wave Velocity, and Poisson's Ratio Based on Source-to-Receiver Travel Time Data - Borehole B-907

American Units				Metric Units			
Depth at Midpoint Between Source and Near Receiver	Velocity		Poisson's Ratio	Depth at Midpoint Between Source and Near Receiver	Velocity		Poisson's Ratio
	V_s	V_p			V_s	V_p	
(ft)	(ft/s)	(ft/s)		(m)	(m/s)	(m/s)	
173.9	9060	16720	0.29	53.0	2760	5100	0.29
175.5	8810	16720	0.31	53.5	2690	5100	0.31
177.2	8520	16720	0.32	54.0	2600	5100	0.32
178.8	8810	16510	0.30	54.5	2690	5030	0.30
180.5	8810	16720	0.31	55.0	2690	5100	0.31
182.1	9060	16940	0.30	55.5	2760	5160	0.30
183.7	9250	16940	0.29	56.0	2820	5160	0.29
185.4	9060	17390	0.31	56.5	2760	5300	0.31
187.0	8870	17390	0.32	57.0	2700	5300	0.32
188.7	8580	16940	0.33	57.5	2610	5160	0.33

Notes: "-" means no data available at that particular interval of depth.

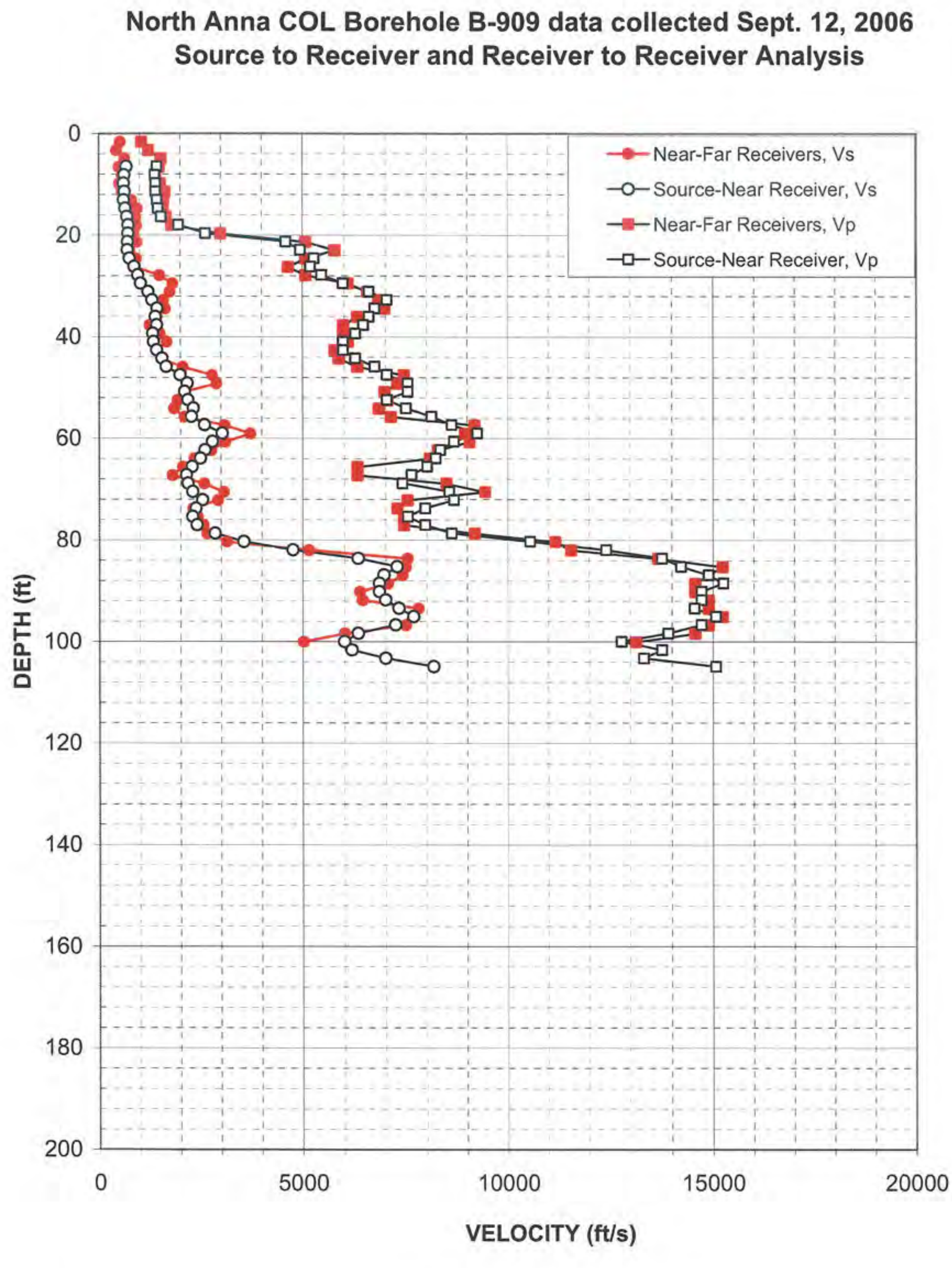


Figure A-5. Boring B-909, Top Section, Suspension S-R1 P- and S_H-wave velocities

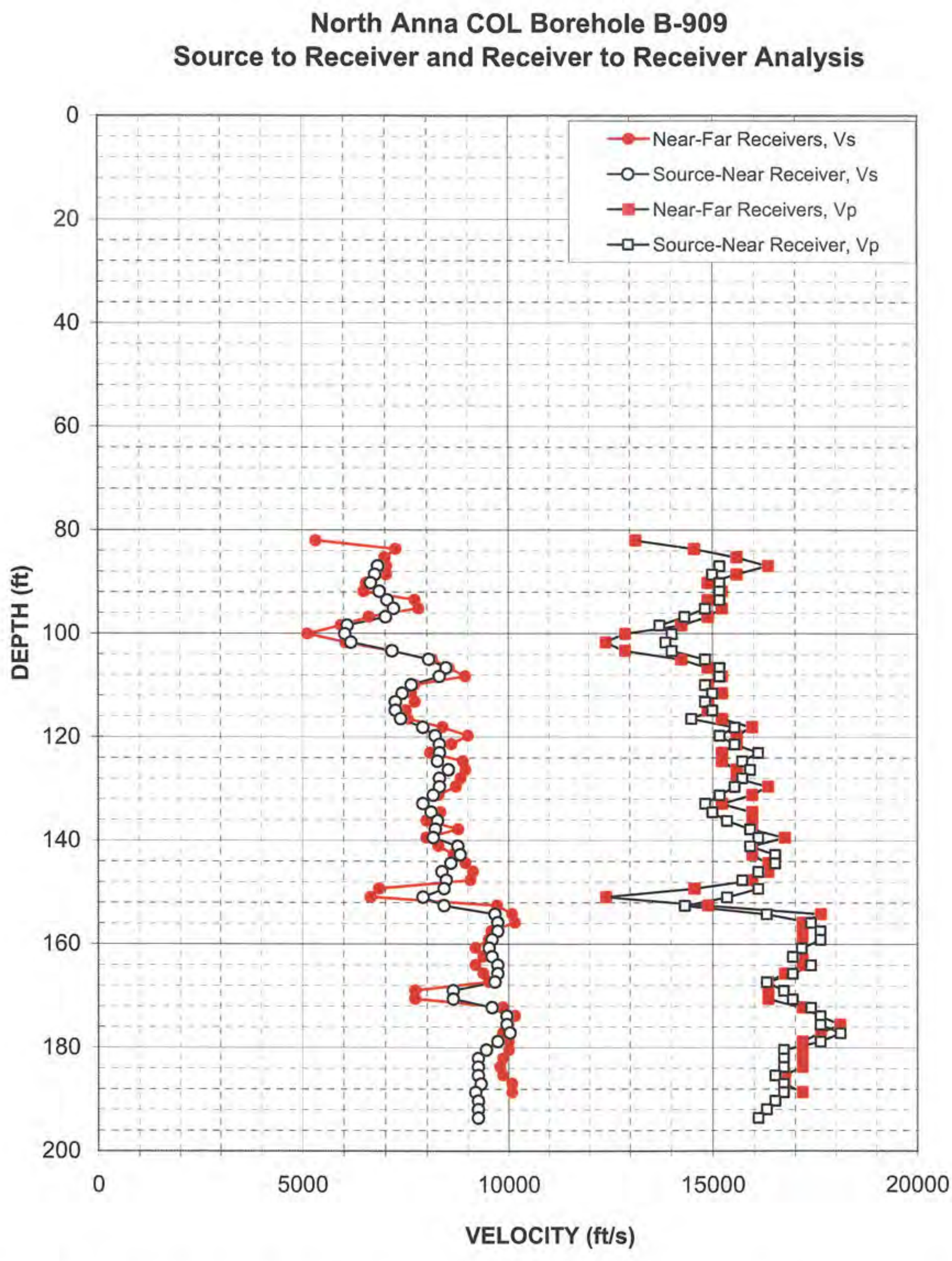


Figure A-6. Boring B-909, Bottom Section, Suspension S-R1 P- and S_H-wave velocities

Table A-5. Boring B-909, Top Section, Suspension S-R1 depths and P- and S_H-wave velocities

Summary of Compressional Wave Velocity, Shear Wave Velocity, and Poisson's Ratio Based on Source-to-Receiver Travel Time Data - Borehole B-909

American Units				Metric Units			
Depth at Midpoint Between Source and Near Receiver	Velocity		Poisson's Ratio	Depth at Midpoint Between Source and Near Receiver	Velocity		Poisson's Ratio
	V_s	V_p			V_s	V_p	
(ft)	(ft/s)	(ft/s)		(m)	(m/s)	(m/s)	
6.5	670	1420	0.36	2.0	200	430	0.36
8.1	620	1370	0.37	2.5	190	420	0.37
9.8	610	1390	0.38	3.0	180	420	0.38
11.4	620	1390	0.37	3.5	190	420	0.37
13.0	610	1420	0.39	4.0	180	430	0.39
14.7	640	1450	0.38	4.5	200	440	0.38
16.3	690	1520	0.37	5.0	210	460	0.37
18.0	710	1950	0.42	5.5	220	600	0.42
19.6	710	2620	0.46	6.0	220	800	0.46
21.2	700	4590	0.49	6.5	210	1400	0.49
22.9	700	4950	0.49	7.0	210	1510	0.49
24.5	740	5280	0.49	7.5	230	1610	0.49
26.2	860	5190	0.49	8.0	260	1580	0.49
27.8	950	5460	0.48	8.5	290	1660	0.48
29.5	1020	5970	0.48	9.0	310	1820	0.48
31.1	1200	6590	0.48	9.5	370	2010	0.48
32.7	1300	7030	0.48	10.0	400	2140	0.48
34.4	1430	6730	0.48	10.5	430	2050	0.48
36.0	1380	6590	0.48	11.0	420	2010	0.48
37.7	1410	6460	0.47	11.5	430	1970	0.47
39.3	1320	6270	0.48	12.0	400	1910	0.48
40.9	1340	5970	0.47	12.5	410	1820	0.47
42.6	1410	5970	0.47	13.0	430	1820	0.47
44.2	1540	6270	0.47	13.5	470	1910	0.47
45.9	1650	6730	0.47	14.0	500	2050	0.47
47.5	1990	7030	0.46	14.5	610	2140	0.46
49.1	2170	7540	0.45	15.0	660	2300	0.45
50.8	2100	7540	0.46	15.5	640	2300	0.46
52.4	2180	7030	0.45	16.0	670	2140	0.45
54.1	2320	7490	0.45	16.5	710	2280	0.45
55.7	2270	8120	0.46	17.0	690	2470	0.46
57.3	2590	8610	0.45	17.5	790	2630	0.45
59.0	3030	9240	0.44	18.0	920	2820	0.44
60.6	2790	8670	0.44	18.5	850	2640	0.44
62.3	2600	8330	0.45	19.0	790	2540	0.45

Summary of Compressional Wave Velocity, Shear Wave Velocity, and Poisson's Ratio Based on Source-to-Receiver Travel Time Data - Borehole B-909

American Units				Metric Units			
Depth at Midpoint Between Source and Near Receiver	Velocity		Poisson's Ratio	Depth at Midpoint Between Source and Near Receiver	Velocity		Poisson's Ratio
	V_s	V_p			V_s	V_p	
(ft)	(ft/s)	(ft/s)		(m)	(m/s)	(m/s)	
63.9	2490	8220	0.45	19.5	760	2510	0.45
65.5	2290	8010	0.46	20.0	700	2440	0.46
67.2	2150	7630	0.46	20.5	650	2320	0.46
68.8	2180	7400	0.45	21.0	670	2260	0.45
70.5	2300	8550	0.46	21.5	700	2610	0.46
72.1	2540	8670	0.45	22.0	770	2640	0.45
73.7	2380	7960	0.45	22.5	730	2430	0.45
75.4	2300	7540	0.45	23.0	700	2300	0.45
77.0	2410	7960	0.45	23.5	730	2430	0.45
78.7	2850	8610	0.44	24.0	870	2630	0.44
80.3	3560	10550	0.44	24.5	1080	3220	0.44
81.9	4760	12410	0.41	25.0	1450	3780	0.41
83.6	6330	13760	0.37	25.5	1930	4190	0.37
85.2	7280	14220	0.32	26.0	2220	4340	0.32
86.9	6960	14890	0.36	26.5	2120	4540	0.36
88.5	6840	15250	0.37	27.0	2090	4650	0.37
90.1	6840	14720	0.36	27.5	2090	4490	0.36
91.8	6990	14720	0.35	28.0	2130	4490	0.35
93.4	7320	14550	0.33	28.5	2230	4440	0.33
95.1	7670	15070	0.33	29.0	2340	4590	0.33
96.7	7230	14720	0.34	29.5	2210	4490	0.34
98.3	6330	13910	0.37	30.0	1930	4240	0.37
100.0	6000	12790	0.36	30.5	1830	3900	0.36
101.6	6180	13760	0.37	31.0	1880	4190	0.37
103.3	6990	13330	0.31	31.5	2130	4060	0.31
104.9	8170	15070	0.29	32.0	2490	4590	0.29

Notes: "-" means no data available at that particular interval of depth.

Table A-6. Boring B-909, Bottom Section, Suspension S-R1 depths and P- and S_H-wave velocities

Summary of Compressional Wave Velocity, Shear Wave Velocity, and Poisson's Ratio Based on Source-to-Receiver Travel Time Data - Borehole B-909

American Units				Metric Units			
Depth at Midpoint Between Source and Near Receiver	Velocity		Poisson's Ratio	Depth at Midpoint Between Source and Near Receiver	Velocity		Poisson's Ratio
	V_s	V_p			V_s	V_p	
(ft)	(ft/s)	(ft/s)		(m)	(m/s)	(m/s)	
87.0	6830	15160	0.37	26.5	2080	4620	0.37
88.6	6760	14990	0.37	27.0	2060	4570	0.37
90.2	6650	15160	0.38	27.5	2030	4620	0.38
91.9	6860	15160	0.37	28.0	2090	4620	0.37
93.5	7050	15160	0.36	28.5	2150	4620	0.36
95.2	7200	14820	0.35	29.0	2200	4520	0.35
96.8	7010	14330	0.34	29.5	2140	4370	0.34
98.4	6090	13730	0.38	30.0	1860	4180	0.38
100.1	6040	14020	0.39	30.5	1840	4270	0.39
101.7	6180	13870	0.38	31.0	1880	4230	0.38
103.4	7160	14020	0.32	31.5	2180	4270	0.32
105.0	8050	14820	0.29	32.0	2450	4520	0.29
106.6	8470	15160	0.27	32.5	2580	4620	0.27
108.3	8310	15160	0.29	33.0	2530	4620	0.29
109.9	7630	14820	0.32	33.5	2320	4520	0.32
111.6	7410	14990	0.34	34.0	2260	4570	0.34
113.2	7240	14820	0.34	34.5	2210	4520	0.34
114.8	7240	14990	0.35	35.0	2210	4570	0.35
116.5	7370	14490	0.33	35.5	2250	4420	0.33
118.1	7900	15520	0.33	36.0	2410	4730	0.33
119.8	8200	15160	0.29	36.5	2500	4620	0.29
121.4	8310	15520	0.30	37.0	2530	4730	0.30
123.0	8310	16100	0.32	37.5	2530	4910	0.32
124.7	8250	15710	0.31	38.0	2520	4790	0.31
126.3	8520	15900	0.30	38.5	2600	4850	0.30
128.0	8310	15710	0.31	39.0	2530	4790	0.31
129.6	8310	15520	0.30	39.5	2530	4730	0.30
131.2	8150	15160	0.30	40.0	2480	4620	0.30
132.9	7900	14820	0.30	40.5	2410	4520	0.30
134.5	8100	14990	0.29	41.0	2470	4570	0.29
136.2	8250	15340	0.30	41.5	2520	4680	0.30
137.8	8200	15900	0.32	42.0	2500	4850	0.32
139.4	8150	16100	0.33	42.5	2480	4910	0.33
141.1	8750	15900	0.28	43.0	2670	4850	0.28
142.7	8810	16510	0.30	43.5	2690	5030	0.30

Summary of Compressional Wave Velocity, Shear Wave Velocity, and Poisson's Ratio Based on Source-to-Receiver Travel Time Data - Borehole B-909

American Units				Metric Units			
Depth at Midpoint Between Source and Near Receiver	Velocity		Poisson's Ratio	Depth at Midpoint Between Source and Near Receiver	Velocity		Poisson's Ratio
	V_s	V_p			V_s	V_p	
(ft)	(ft/s)	(ft/s)		(m)	(m/s)	(m/s)	
144.4	8580	16510	0.31	44.0	2610	5030	0.31
146.0	8360	16100	0.32	44.5	2550	4910	0.32
147.7	8470	15710	0.30	45.0	2580	4790	0.30
149.3	8410	16100	0.31	45.5	2560	4910	0.31
150.9	7900	15340	0.32	46.0	2410	4680	0.32
152.6	8410	14330	0.24	46.5	2560	4370	0.24
154.2	9660	16300	0.23	47.0	2940	4970	0.23
155.9	9730	17390	0.27	47.5	2970	5300	0.27
157.5	9730	17620	0.28	48.0	2970	5370	0.28
159.1	9590	17620	0.29	48.5	2920	5370	0.29
160.8	9520	17160	0.28	49.0	2900	5230	0.28
162.4	9590	16940	0.26	49.5	2920	5160	0.26
164.1	9730	17390	0.27	50.0	2970	5300	0.27
165.7	9730	16940	0.25	50.5	2970	5160	0.25
167.3	9660	16300	0.23	51.0	2940	4970	0.23
169.0	8640	16720	0.32	51.5	2630	5100	0.32
170.6	8640	16940	0.32	52.0	2630	5160	0.32
172.3	9590	17390	0.28	52.5	2920	5300	0.28
173.9	9950	17620	0.27	53.0	3030	5370	0.27
175.5	9950	17620	0.27	53.5	3030	5370	0.27
177.2	10030	18110	0.28	54.0	3060	5520	0.28
178.8	9730	17620	0.28	54.5	2970	5370	0.28
180.5	9450	16720	0.27	55.0	2880	5100	0.27
182.1	9250	16720	0.28	55.5	2820	5100	0.28
183.7	9250	16720	0.28	56.0	2820	5100	0.28
185.4	9250	16510	0.27	56.5	2820	5030	0.27
187.0	9310	16720	0.27	57.0	2840	5100	0.27
188.7	9180	16720	0.28	57.5	2800	5100	0.28
190.3	9250	16510	0.27	58.0	2820	5030	0.27
191.9	9250	16300	0.26	58.5	2820	4970	0.26
193.6	9250	16100	0.25	59.0	2820	4910	0.25

Notes: "-" means no data available at that particular interval of depth.

APPENDIX B

CALIPER, NATURAL GAMMA, RESISTIVITY, AND SPONTANEOUS POTENTIAL LOGS

ROBERTSON GEOLOGGING LIMITED

NORTH ANNA COL

B901CALUP02

COMPANY	GEOVision
WELL	B-901
FIELD	
COUNTRY	
STATE	
COUNTY	
LAT.:	
LONG.:	

OTHER SERVICES

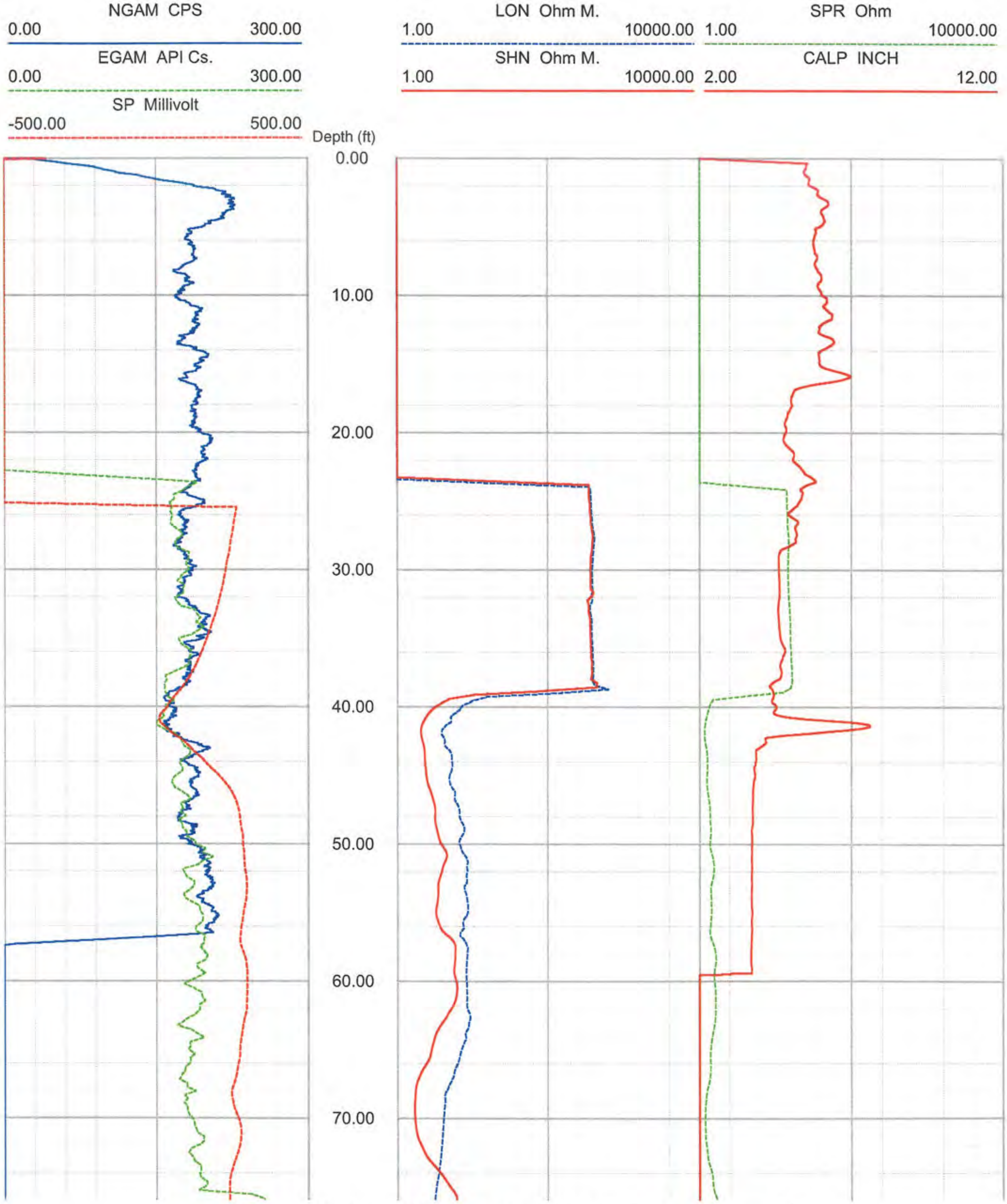
Perm. Da..	Elev	KB	0.00
Log. Da..		DF	0.00
Drill Datum		GL	0.00

DATE	12 Sep 06	21 Oct 05	21 Oct 05
RUN#	3	0	0
TYPE OF LOG	CALIPER		
DEPTH DRILLER	300.00	0.00	0.00
DEPTH LOGGER	300.00	0.00	0.00
LOG DEEPEST	60.00	0.00	0.00
LOG SHALLOW	0.00	0.00	0.00
FLUID IN HOLE	DRILLING MUD		
SALINITY			
DENSITY			
LEVEL			
MAX TEMP °C	0.00	0.00	0.00
RIG TIME			
RECORDED BY	R. STELLER		
WITNESSED BY			

RUN#	BIT RECORD			CASING RECORD			
	SIZE	FROM	TO	SIZE	WEIGHT	FROM	TO
3	5.00	0.00	38.60	0.00	0.00	0.00	0.00
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00

ROBERTSON GEOLOGGING TECHNOLOGY

REMARKS (C:\Data\PS\North Anna\B-901 11-12 Septemb..



North Anna COL Boring B-901 upper section ELOG, Caliper and Gamma Sheet 2 of 3

NGAM CPS		Depth (ft)	LON Ohm M.		SPR Ohm	
0.00	300.00		1.00	10000.00	1.00	10000.00
EGAM API Cs.			SHN Ohm M.		CALP INCH	
0.00	300.00		1.00	10000.00	2.00	12.00
SP Millivolt						
-500.00	500.00					

North Anna COL Boring B-901 upper section ELOG, Caliper and Gamma Sheet 3 of 3

ROBERTSON GEOLOGGING LIMITED

NORTH ANNA COL

B901CALUP01

COMPANY	GEOVision	OTHER SERVICES
WELL	B-901	
FIELD		
COUNTRY		
STATE		
COUNTY		
LAT.:		
LONG.:		

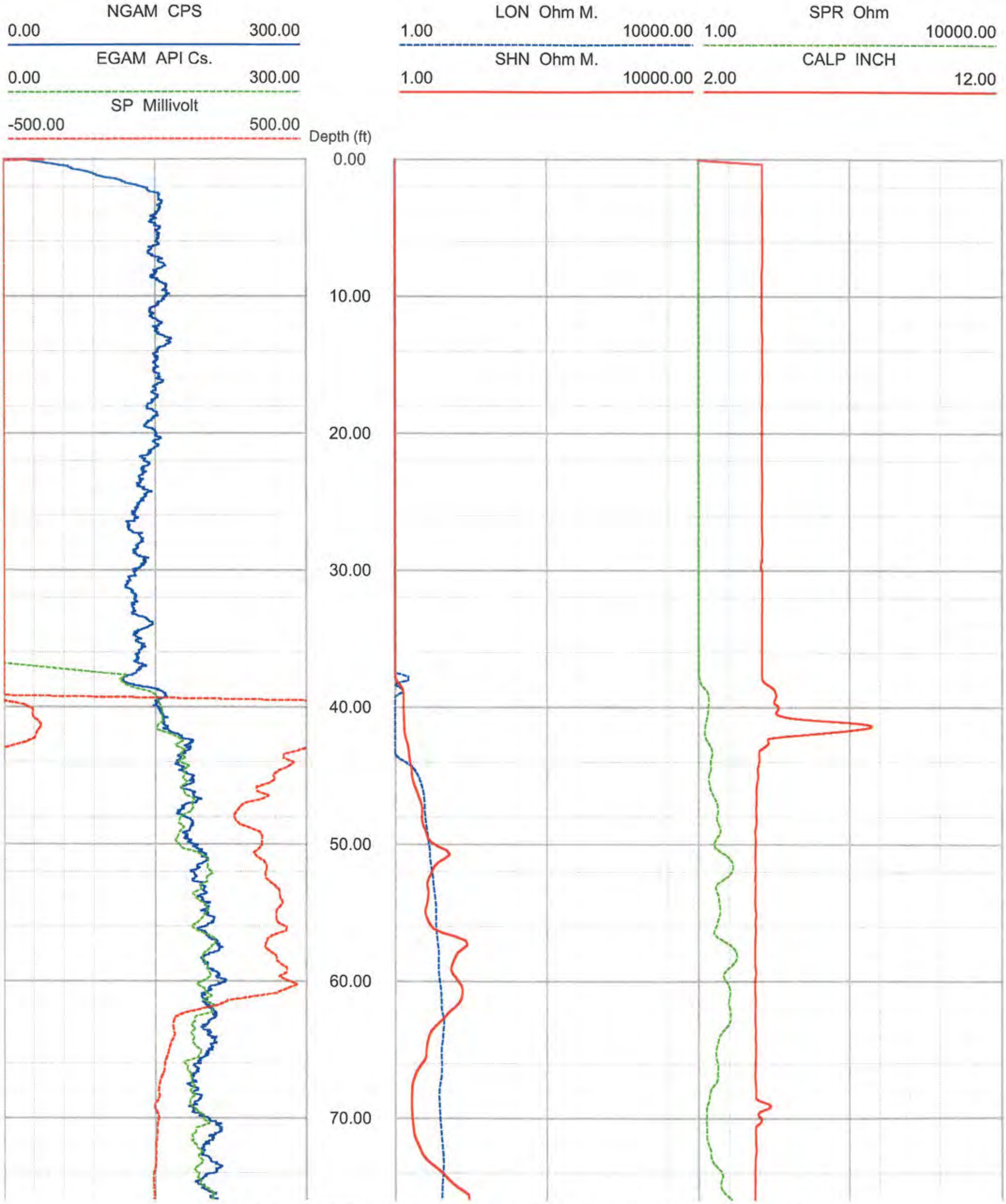
Perm. Da..	Elev	KB	0.00
Log. Da..		DF	0.00
Drill Datum		GL	0.00

DATE	29 Aug 06	21 Oct 05	21 Oct 05
RUN#	2	0	0
TYPE OF LOG	CALIPER		
DEPTH DRILLER	300.00	0.00	0.00
DEPTH LOGGER	300.00	0.00	0.00
LOG DEEPEST	298.00	0.00	0.00
LOG SHALLOW	0.00	0.00	0.00
FLUID IN HOLE	WATER		
SALINITY			
DENSITY			
LEVEL			
MAX TEMP °C	0.00	0.00	0.00
RIG TIME			
RECORDED BY	R. STELLER		
WITNESSED BY			

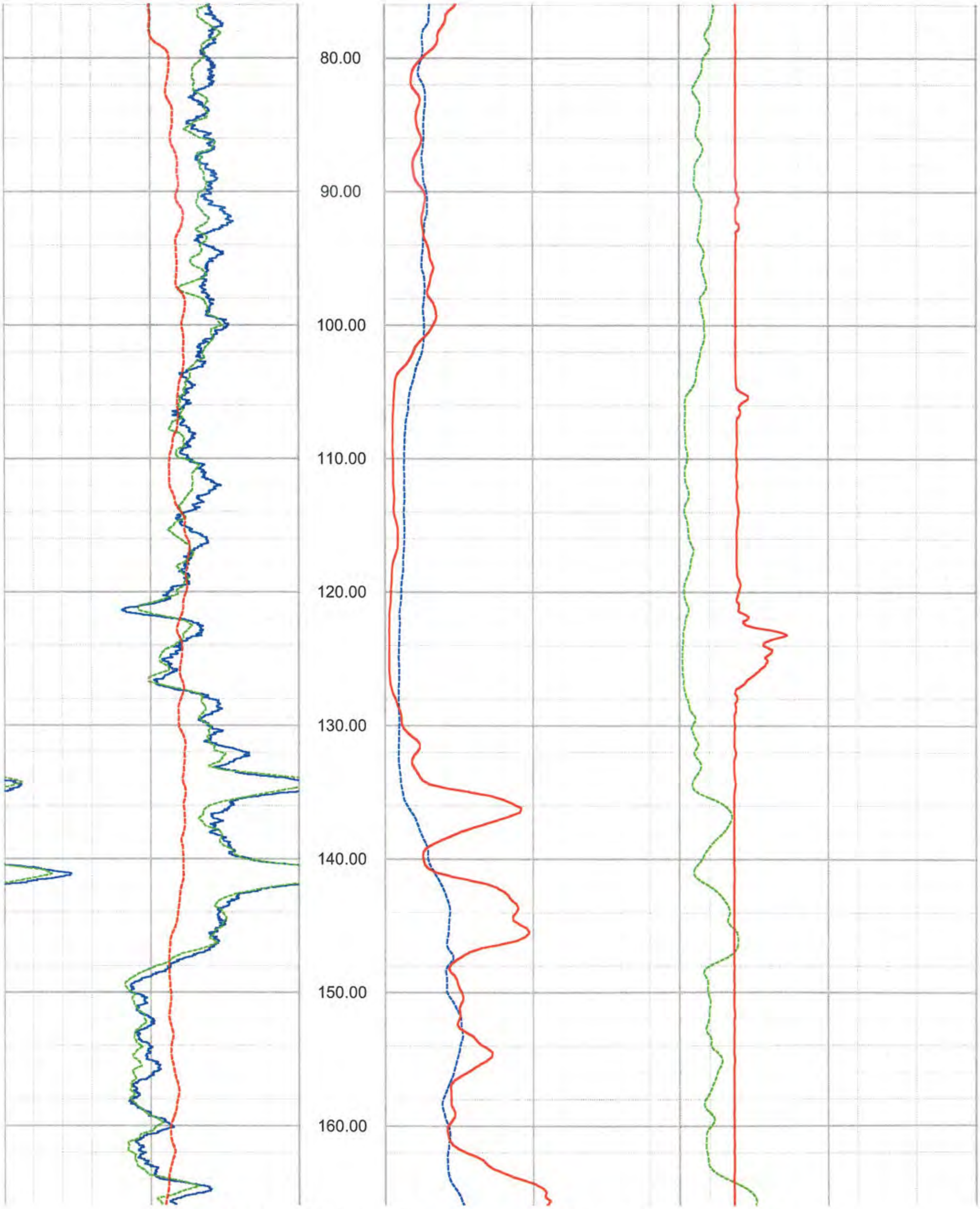
RUN#	BIT RECORD			CASING RECORD			
	SIZE	FROM	TO	SIZE	WEIGHT	FROM	TO
2	3.70	40.00	300.00	4.00	0.00	0.00	40.00
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00

ROBERTSON GEOLOGGING TECHNOLOGY

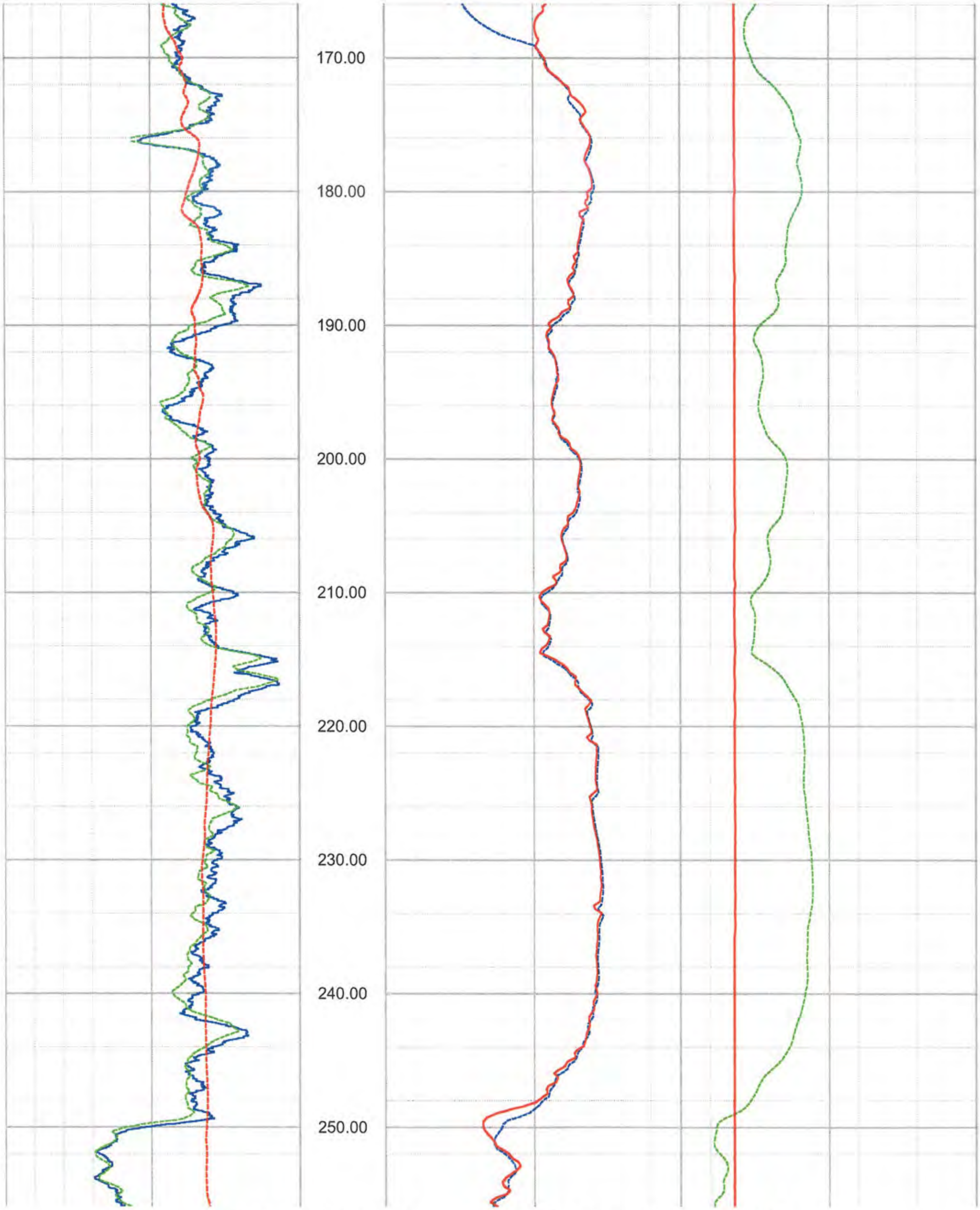
REMARKS (C:\Data\PS\North Anna\B-901 28-29 August 2..



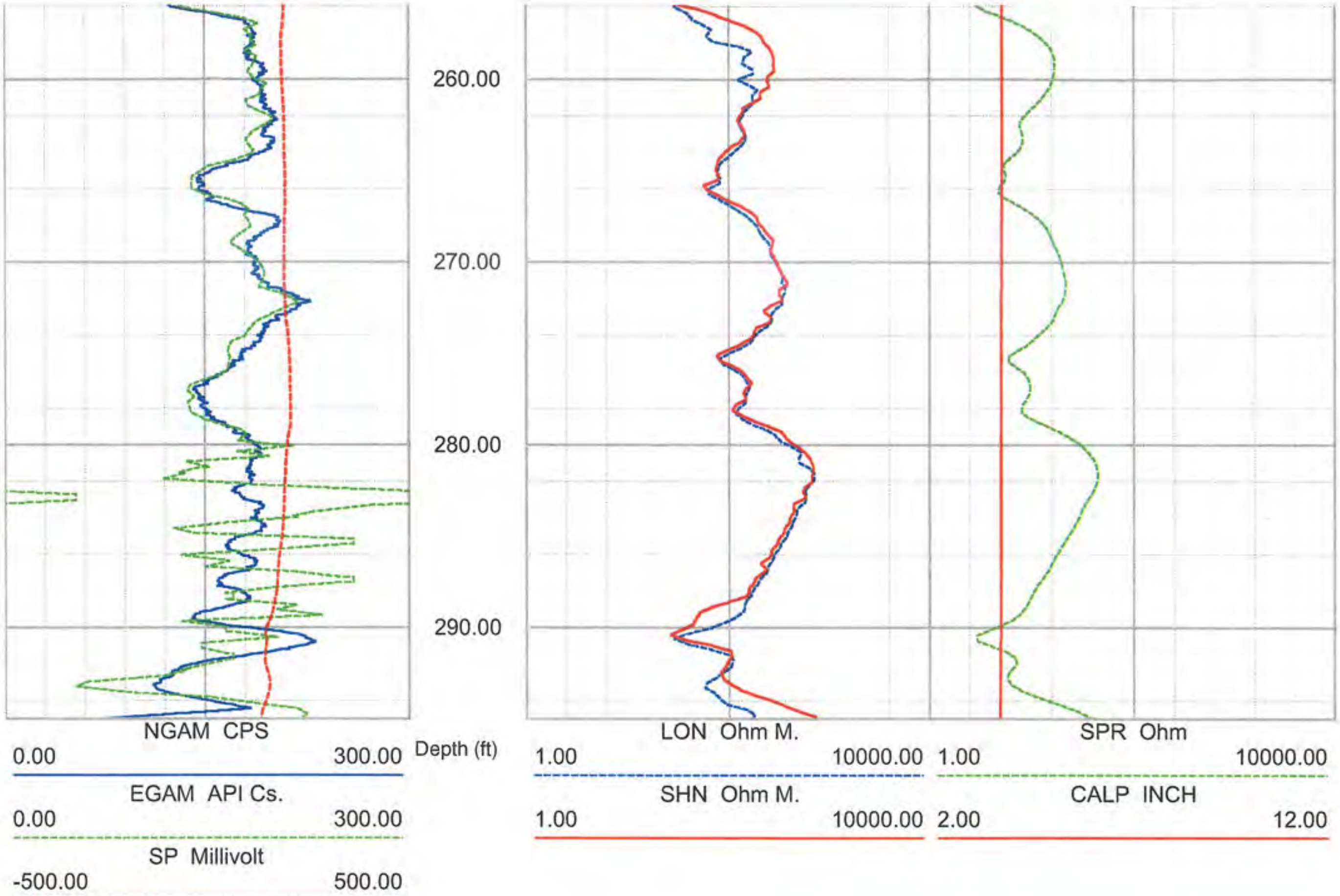
North Anna COL Boring B-901 lower section ELOG, Caliper and Gamma Sheet 2 of 5



North Anna COL Boring B-901 lower section ELOG, Caliper and Gamma Sheet 3 of 5



North Anna COL Boring B-901 lower section ELOG, Caliper and Gamma Sheet 4 of 5



North Anna COL Boring B-901 lower section ELOG, Caliper and Gamma Sheet 5 of 5

ROBERTSON
GEOLOGGING
LIMITED

NORTH ANNA COL

B907CALUP03

COMPANY	GEOVision
WELL	B-907
FIELD	
COUNTRY	
STATE	
COUNTY	
LAT.:	
LONG.:	

OTHER SERVICES

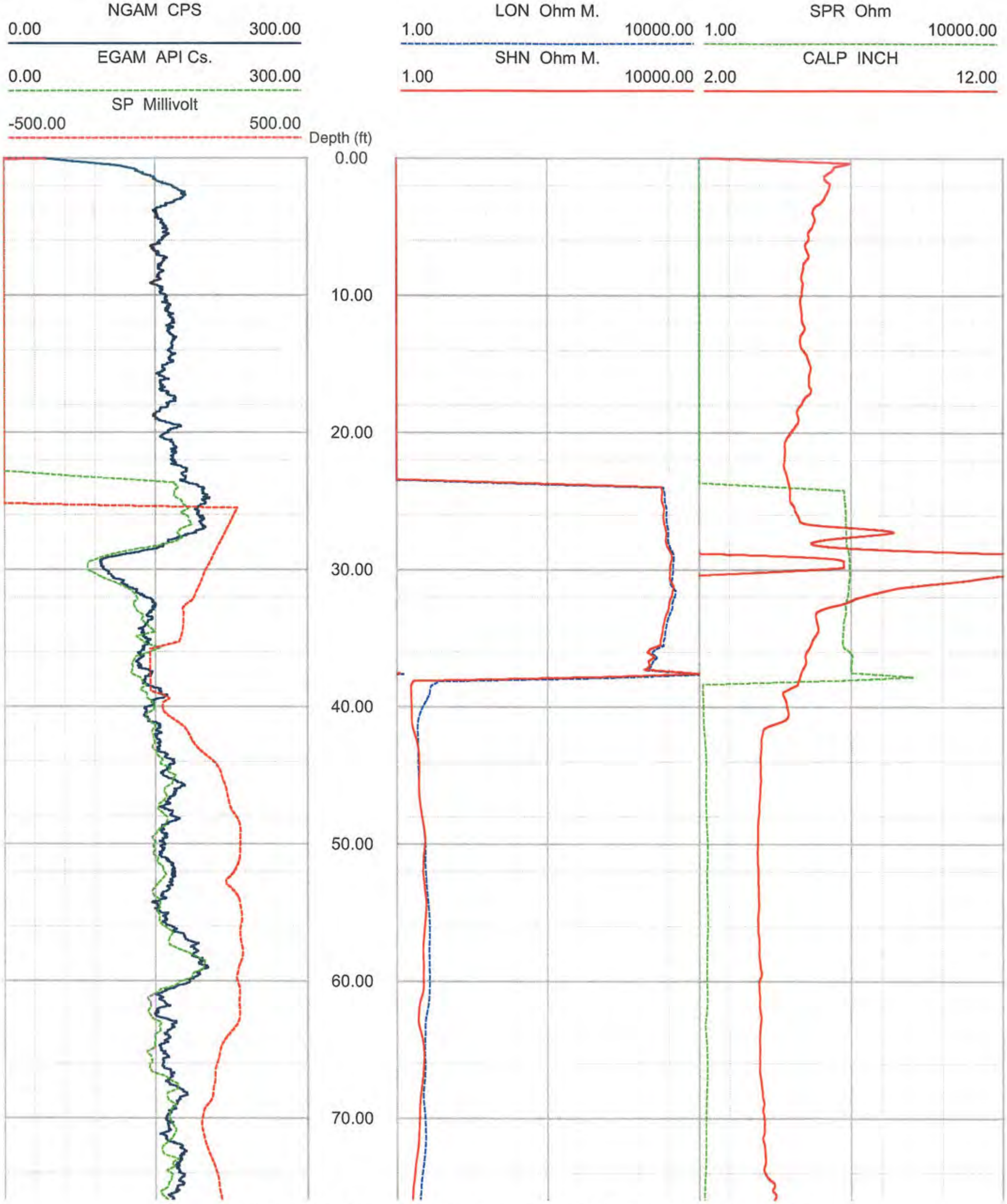
Perm. Da..	Elev	KB 0.00
Log. Da..		DF 0.00
Drill Datum		GL 0.00

DATE	11 Sep 06	21 Oct 05	21 Oct 05
RUN#	3	0	0
TYPE OF LOG	CALIPER		
DEPTH DRILLER	200.00	0.00	0.00
DEPTH LOGGER	170.70	0.00	0.00
LOG DEEPEST	80.00	0.00	0.00
LOG SHALLOW	0.00	0.00	0.00
FLUID IN HOLE	DRILLING MUD		
SALINITY			
DENSITY			
LEVEL			
MAX TEMP °C	0.00	0.00	0.00
RIG TIME			
RECORDED BY	R. STELLER		
WITNESSED BY			

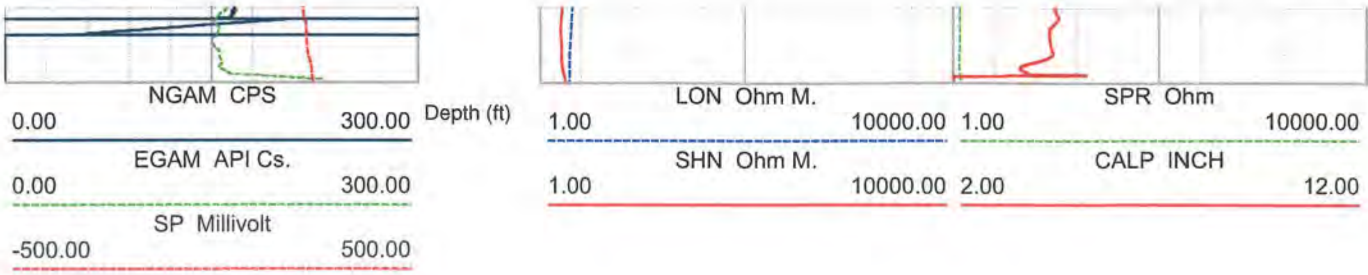
RUN#	BIT RECORD			CASING RECORD			
	SIZE	FROM	TO	SIZE	WEIGHT	FROM	TO
3	5.00	0.00	38.50	0.00	0.00	0.00	0.00
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00

ROBERTSON GEOLOGGING TECHNOLOGY

REMARKS (C:\Data\PS\North Anna\B-907 11 September 2..



North Anna COL Boring B-907 upper section ELOG, Caliper and Gamma Sheet 2 of 3



North Anna COL Boring B-907 upper section ELOG, Caliper and Gamma Sheet 3 of 3

ROBERTSON GEOLOGGING LIMITED

NORTH ANNA COL

B907CALUP02

COMPANY	GEOVision
WELL	B-907
FIELD	
COUNTRY	
STATE	
COUNTY	
LAT.:	
LONG.:	

OTHER SERVICES

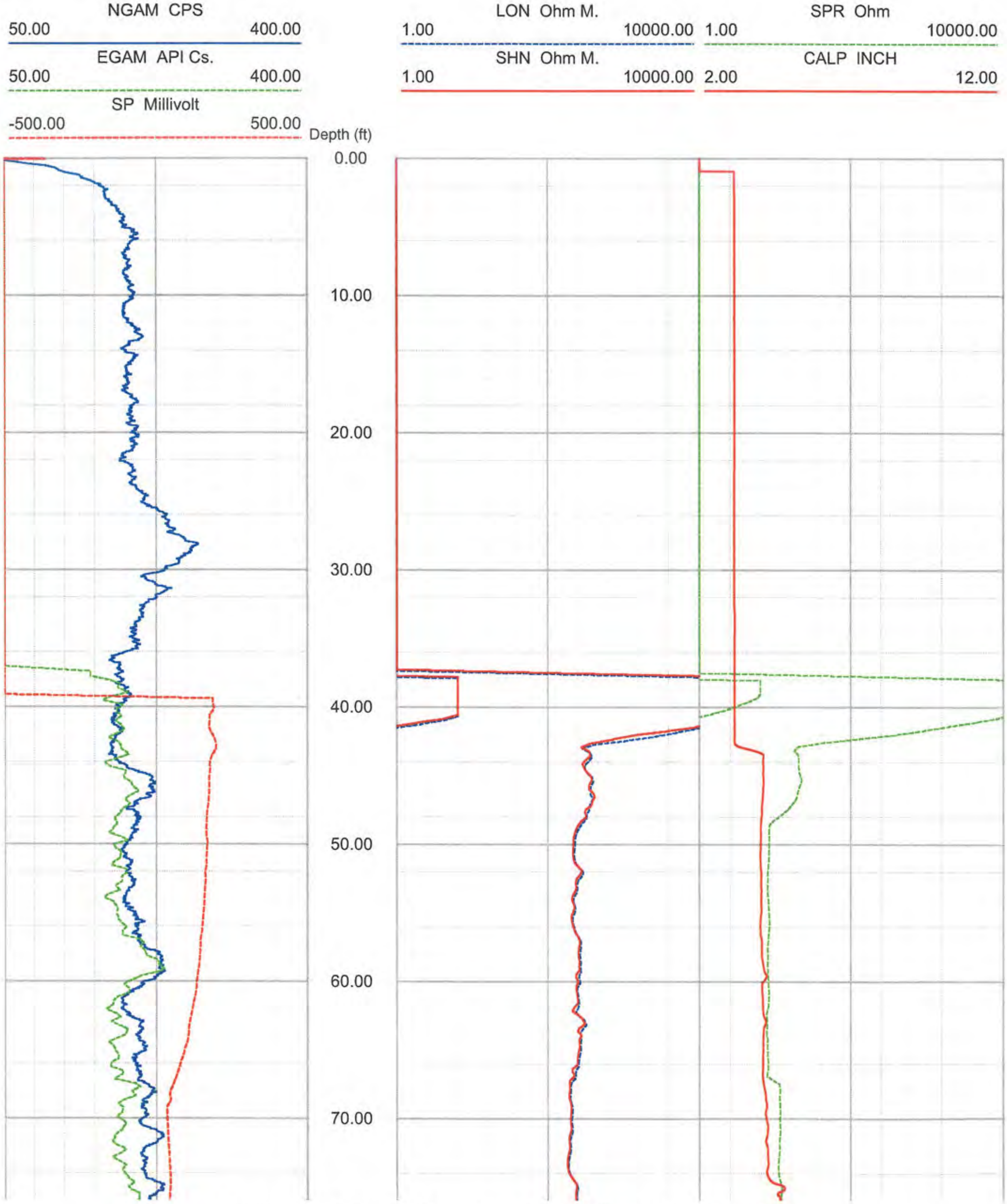
Perm. Da..	Elev	KB	0.00
Log. Da..		DF	0.00
Drill Datum		GL	0.00

DATE	30 Aug 06	21 Oct 05	21 Oct 05
RUN#	5	0	0
TYPE OF LOG	CALIPER		
DEPTH DRILLER	200.00	0.00	0.00
DEPTH LOGGER	195.00	0.00	0.00
LOG DEEPEST	182.00	0.00	0.00
LOG SHALLOW	1.00	0.00	0.00
FLUID IN HOLE	WATER		
SALINITY			
DENSITY			
LEVEL			
MAX TEMP °C	0.00	0.00	0.00
RIG TIME			
RECORDED BY	R. STELLER		
WITNESSED BY			

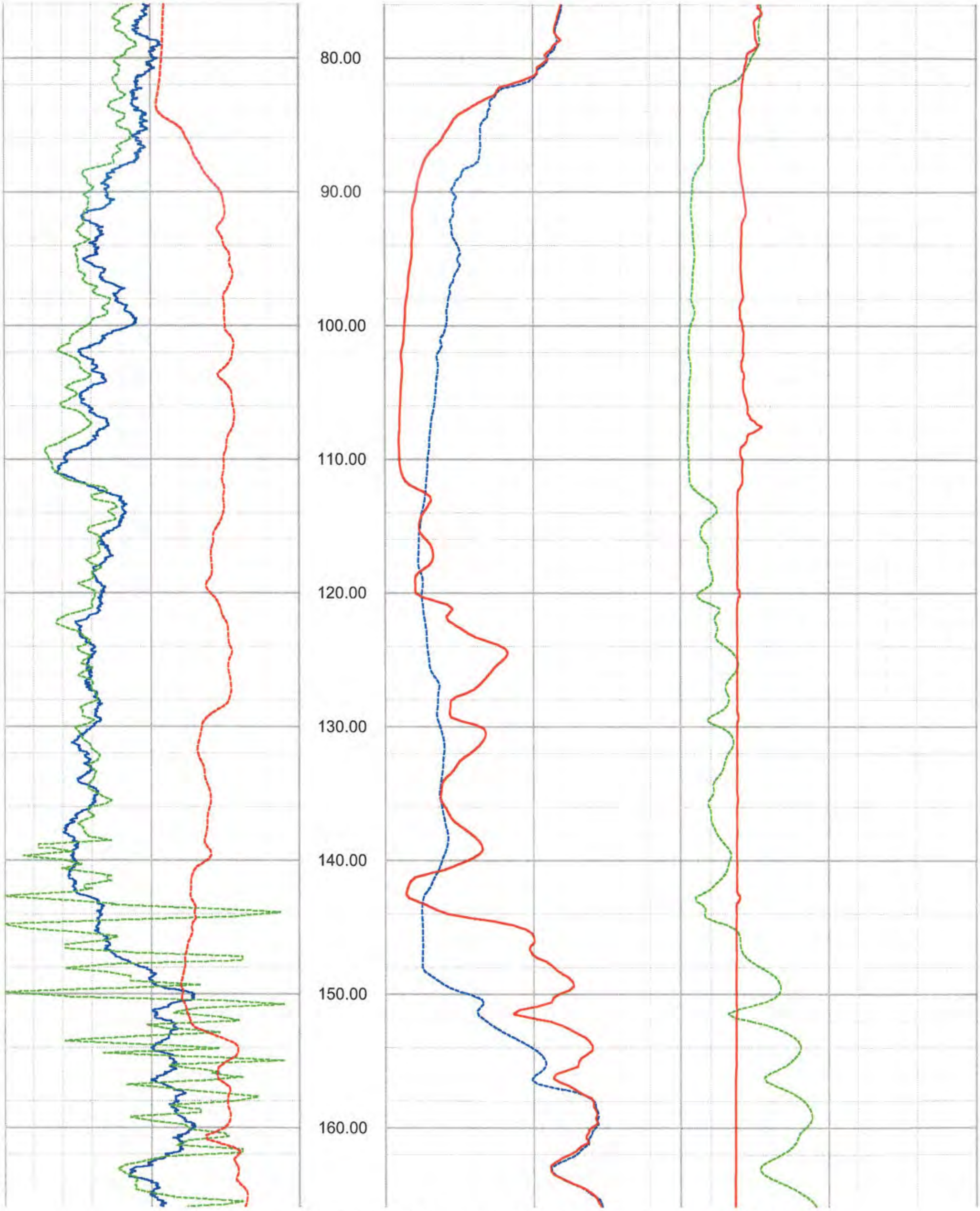
RUN#	BIT RECORD			CASING RECORD			
	SIZE	FROM	TO	SIZE	WEIGHT	FROM	TO
5	3.70	40.00	200.00	3.00	0.00	0.00	40.00
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00

ROBERTSON GEOLOGGING TECHNOLOGY

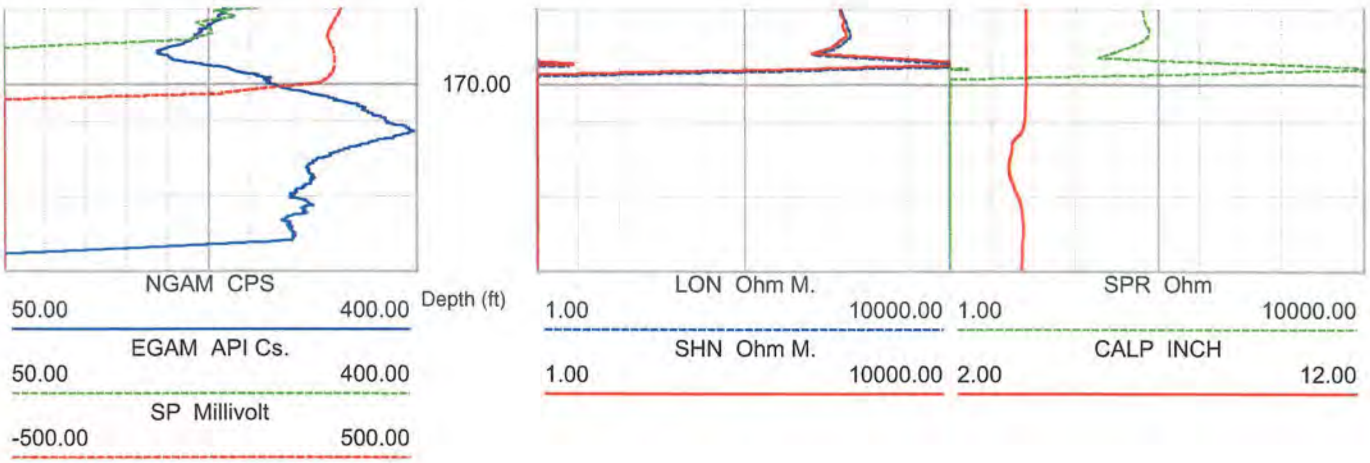
REMARKS (C:\Data\PS\North Anna\B-907 30-31 August 2..



North Anna COL Boring B-907 lower section ELOG, Caliper and Gamma Sheet 2 of 4



North Anna COL Boring B-907 lower section ELOG, Caliper and Gamma Sheet 3 of 4



North Anna COL Boring B-907 lower section ELOG, Caliper and Gamma Sheet 4 of 4

ROBERTSON GEOLOGGING LIMITED

NORTH ANNA COL

B909ECALUP02

COMPANY	GEOVision	OTHER SERVICES
WELL	B-909	
FIELD		
COUNTRY		
STATE		
COUNTY		
LAT.:		
LONG.:		

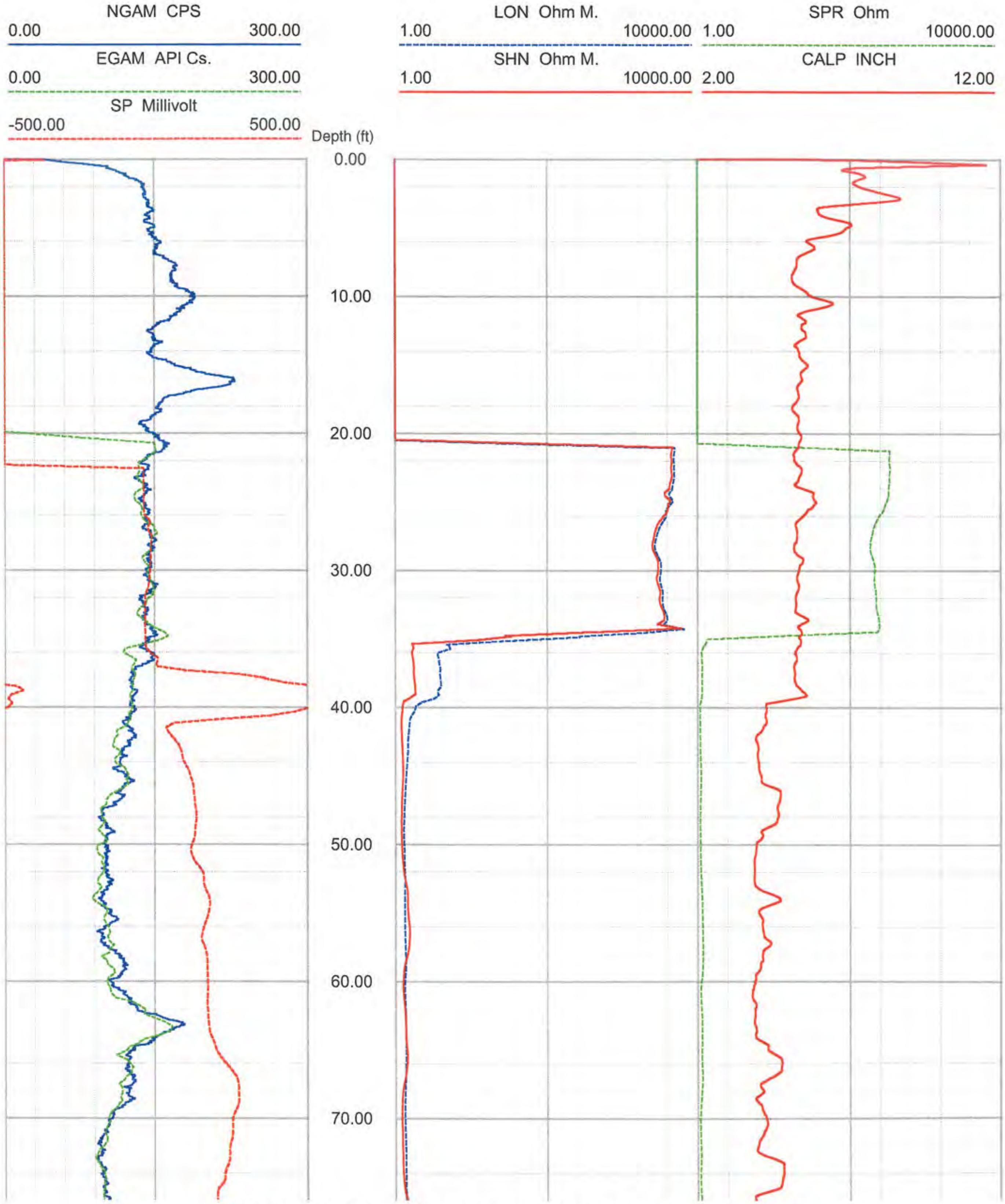
Perm. Da..	Elev	KB	0.00
Log. Da..		DF	0.00
Drill Datum		GL	0.00

DATE	12 Sep 06	21 Oct 05	21 Oct 05
RUN#	3	0	0
TYPE OF LOG	ELOG		
DEPTH DRILLER	200.00	0.00	0.00
DEPTH LOGGER	200.00	0.00	0.00
LOG DEEPEST	110.00	0.00	0.00
LOG SHALLOW	0.00	0.00	0.00
FLUID IN HOLE	DRILLING MUD		
SALINITY			
DENSITY			
LEVEL			
MAX TEMP °C	0.00	0.00	0.00
RIG TIME			
RECORDED BY	R. STELLER		
WITNESSED BY			

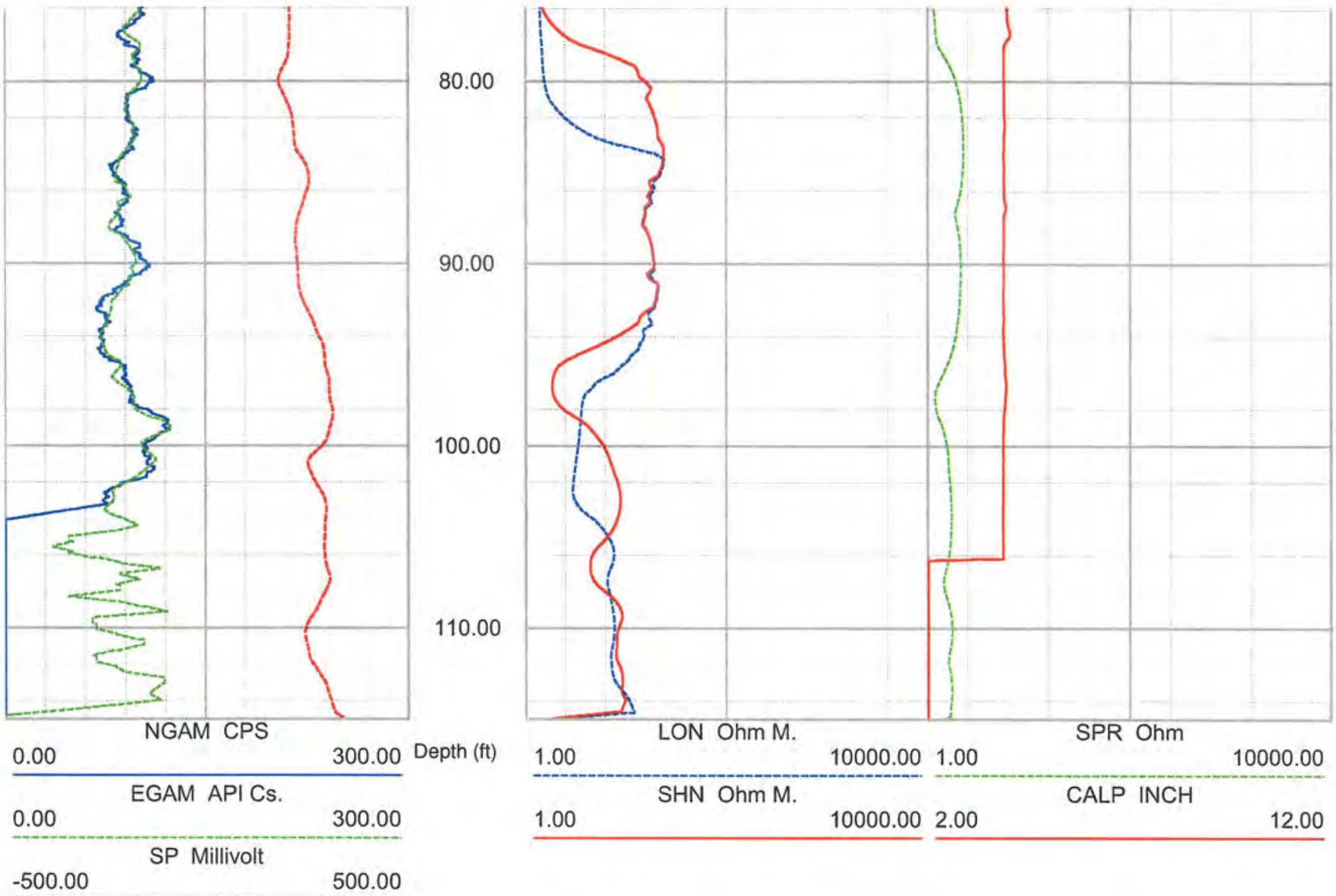
RUN#	BIT RECORD			CASING RECORD			
	SIZE	FROM	TO	SIZE	WEIGHT	FROM	TO
3	5.00	0.00	40.00	0.00	0.00	0.00	0.00
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00

ROBERTSON GEOLOGGING TECHNOLOGY

REMARKS (C:\Data\PS\North Anna\B-909 12 September 2..



North Anna COL Boring B-909 upper section ELOG, Caliper and Gamma Sheet 2 of 3



North Anna COL Boring B-909 upper section ELOG, Caliper and Gamma Sheet 3 of 3

ROBERTSON GEOLOGGING LIMITED

NORTH ANNA COL

B909CALUP01

COMPANY	GEOVision	OTHER SERVICES
WELL	B-909	
FIELD		
COUNTRY		
STATE		
COUNTY		
LAT.:		
LONG.:		

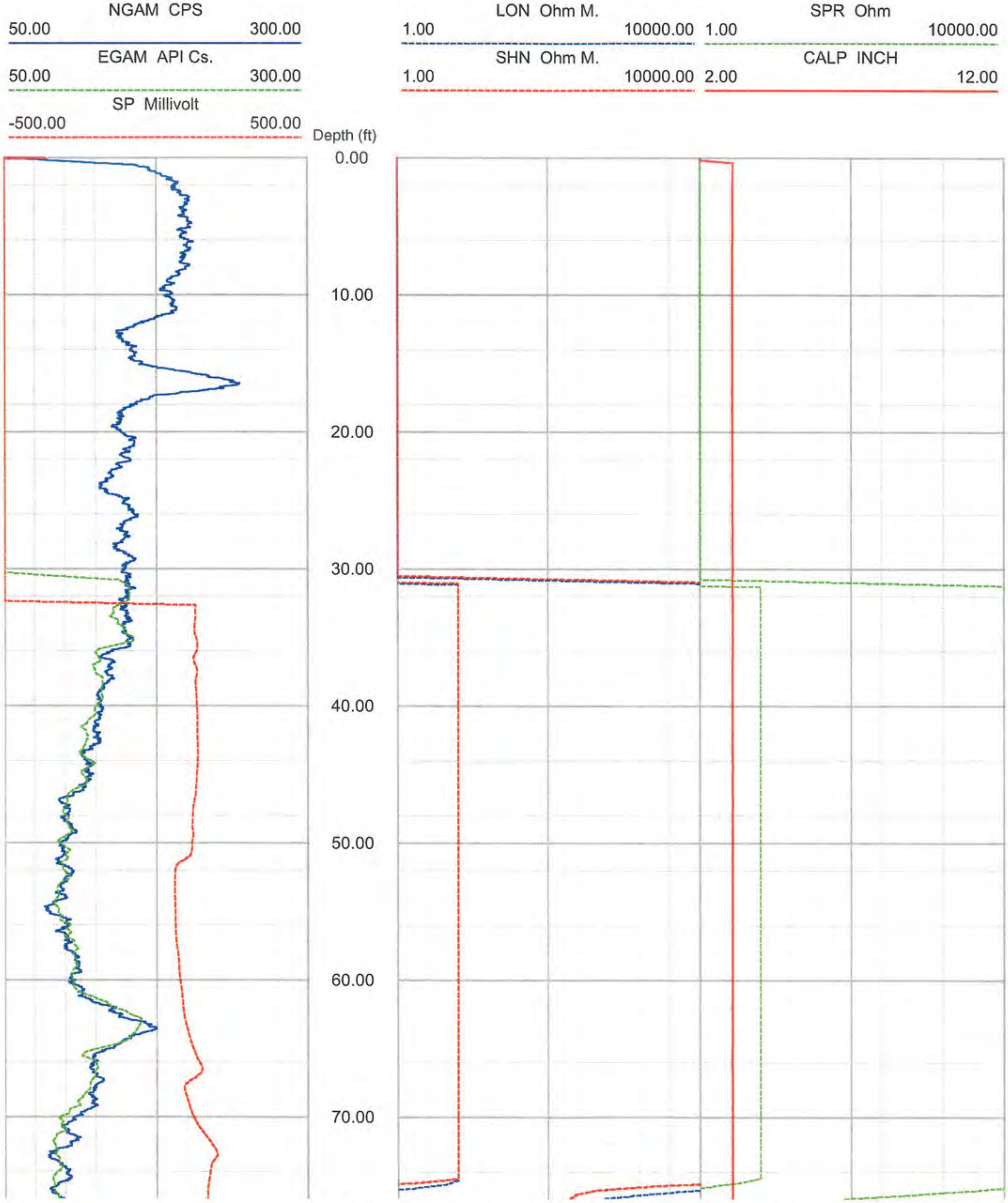
Perm. Da..	Elev	KB	0.00
Log. Da..		DF	0.00
Drill Datum		GL	0.00

DATE	30 Aug 06	21 Oct 05	21 Oct 05
RUN#	4	0	0
TYPE OF LOG	CALIPER		
DEPTH DRILLER	200.00	0.00	0.00
DEPTH LOGGER	200.00	0.00	0.00
LOG DEEPEST	200.00	0.00	0.00
LOG SHALLOW	0.00	0.00	0.00
FLUID IN HOLE	WATER		
SALINITY			
DENSITY			
LEVEL			
MAX TEMP °C	0.00	0.00	0.00
RIG TIME			
RECORDED BY	R. STELLER		
WITNESSED BY			

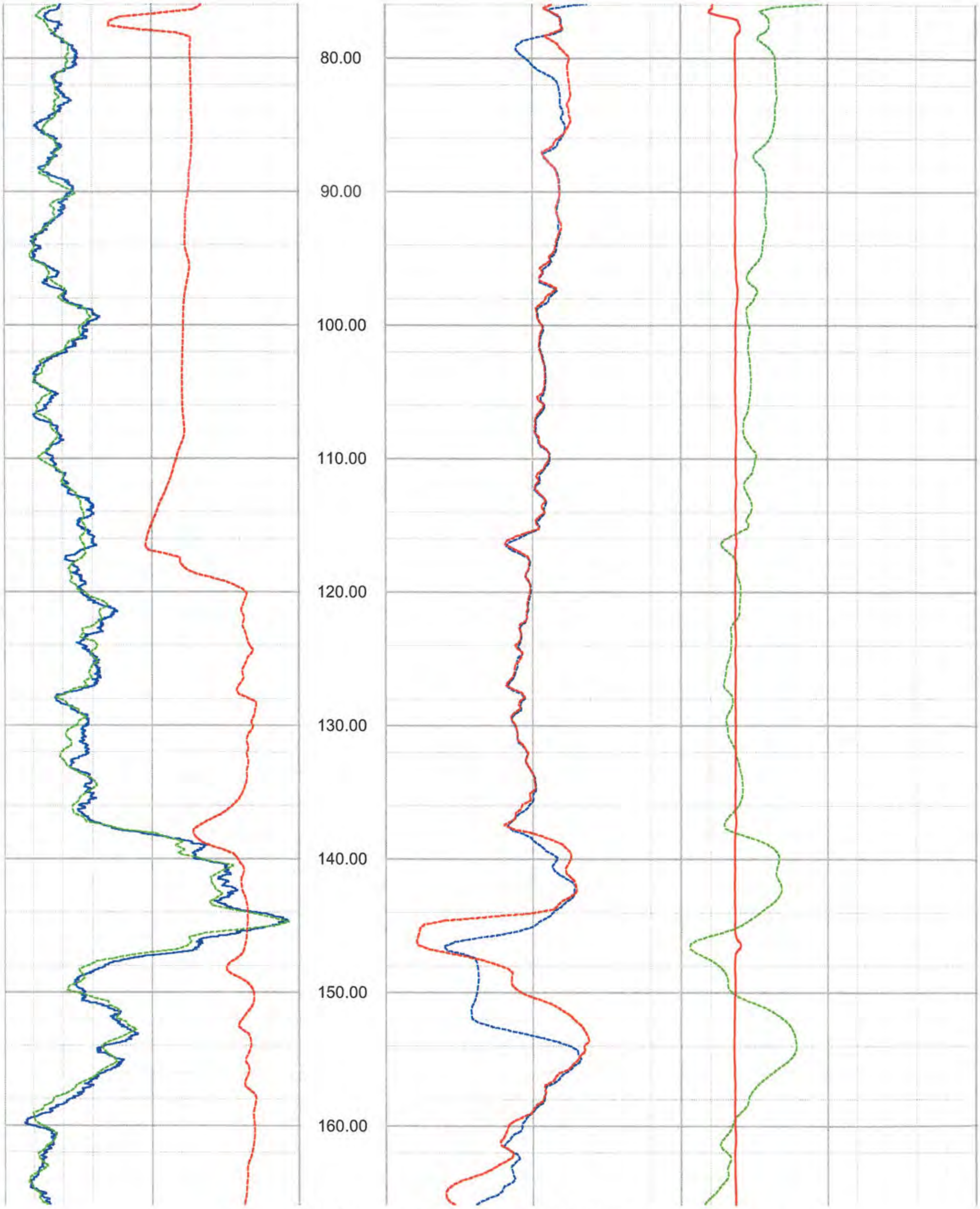
RUN#	BIT RECORD			CASING RECORD			
	SIZE	FROM	TO	SIZE	WEIGHT	FROM	TO
4	3.70	78.00	200.00	3.00	0.00	0.00	78.00
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00

ROBERTSON GEOLOGGING TECHNOLOGY

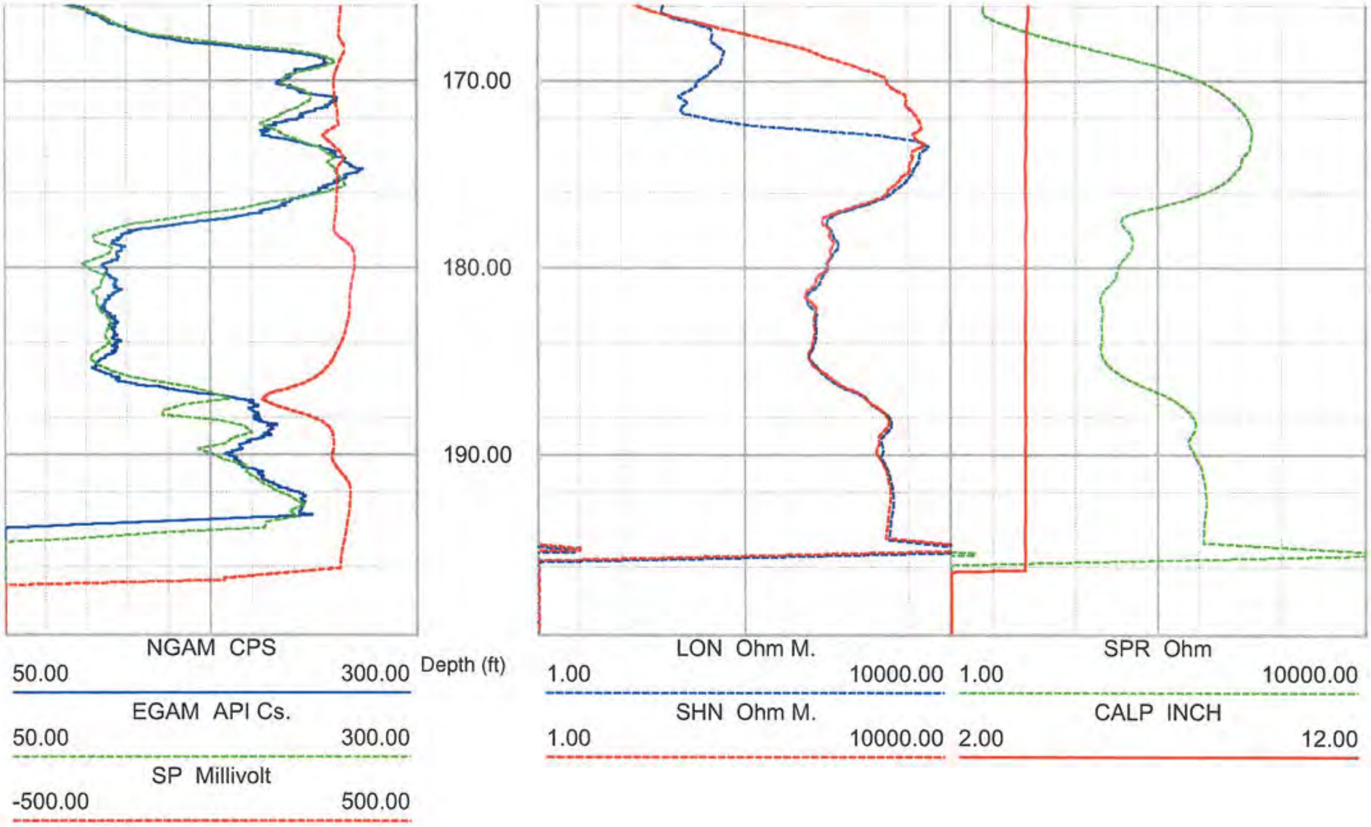
REMARKS (C:\Data\PS\North Anna\B-909 30 August 2006 ..



North Anna COL Boring B-909 lower section ELOG, Caliper and Gamma Sheet 2 of 4



North Anna COL Boring B-909 lower section ELOG, Caliper and Gamma Sheet 3 of 4



North Anna COL Boring B-909 lower section ELOG, Caliper and Gamma Sheet 4 of 4

APPENDIX C

ACOUSTIC TELEVIEWER DIP LOGS

BHTV DATA PROCESSING
RGLDIP vsn 6.2
INTERPRETED BHTV DIPS LOG

22 Dec 2006

ROBERTSON GEOLOGGING TECHNOLOGY

Borehole: B-901

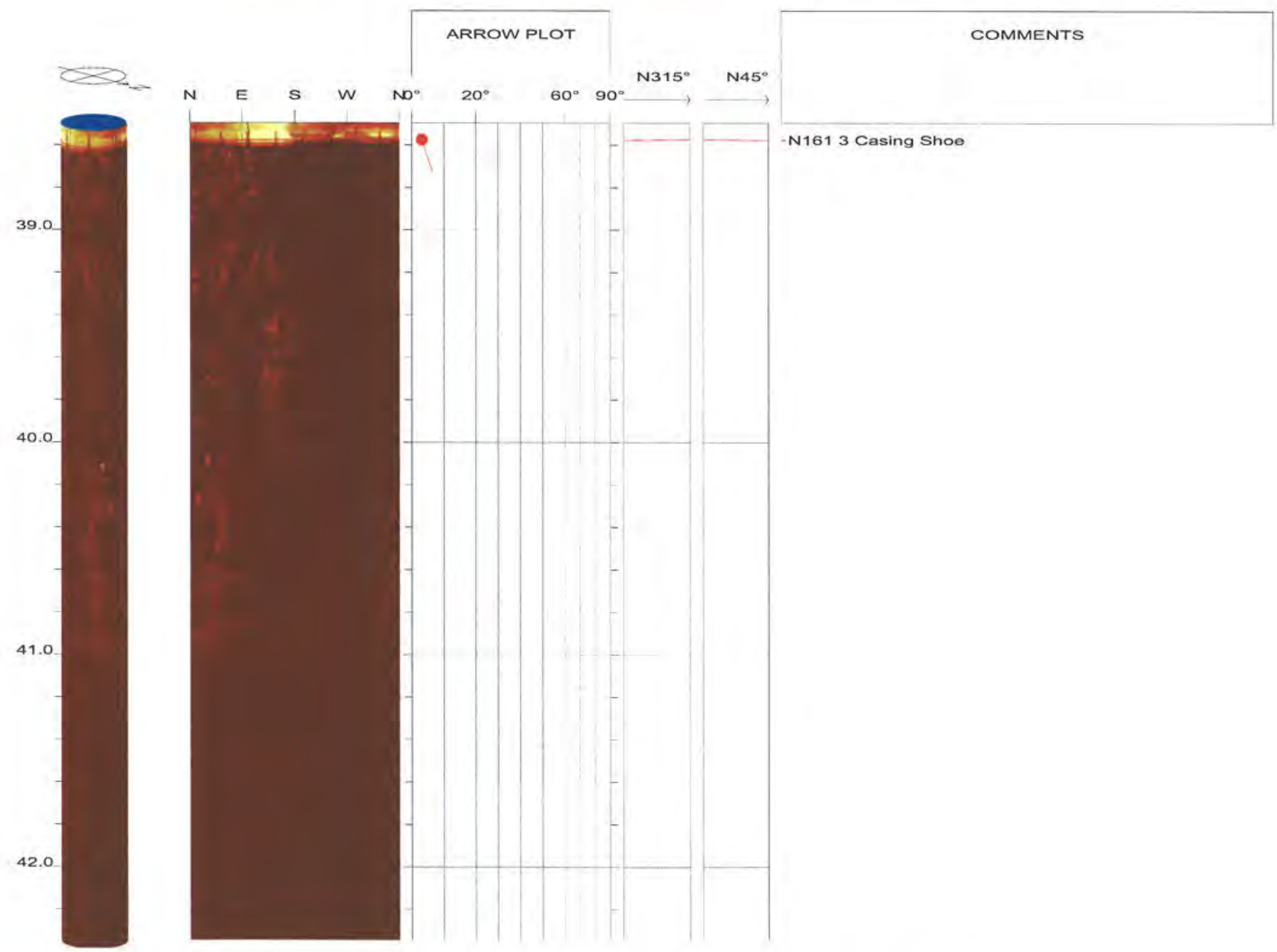
top of borehole.....
East: _
North: _
Elev: _

North ref. is true
Depth units are feet
Vertical scale: 1/10
Horiz scale = 1.00x Vert scale

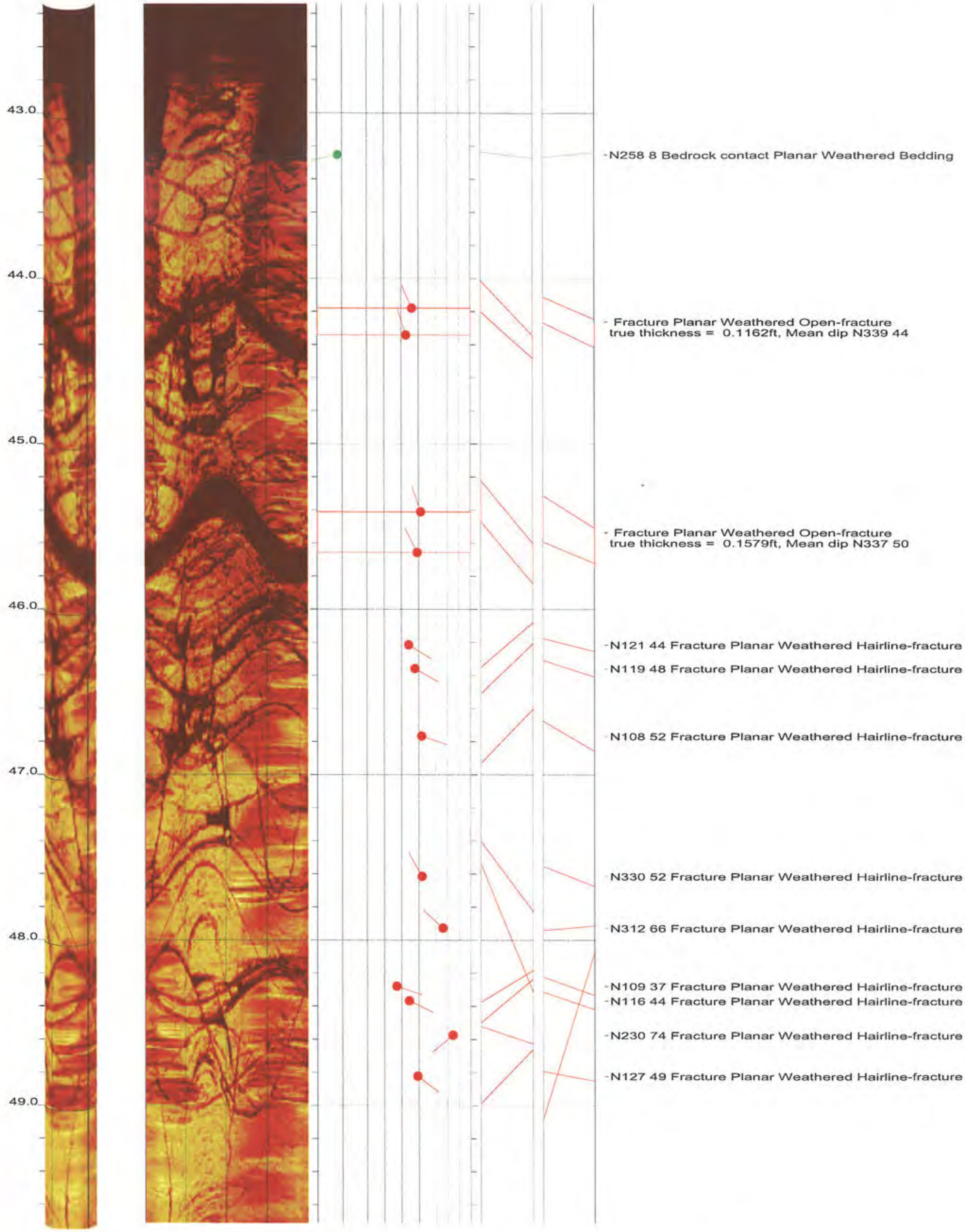
Zone from 297.936 to 38.496ft
Format: BHTV-NESWN

Borehole diam: 3.750inch
Vertical = borehole-axis
Image: Amplitude

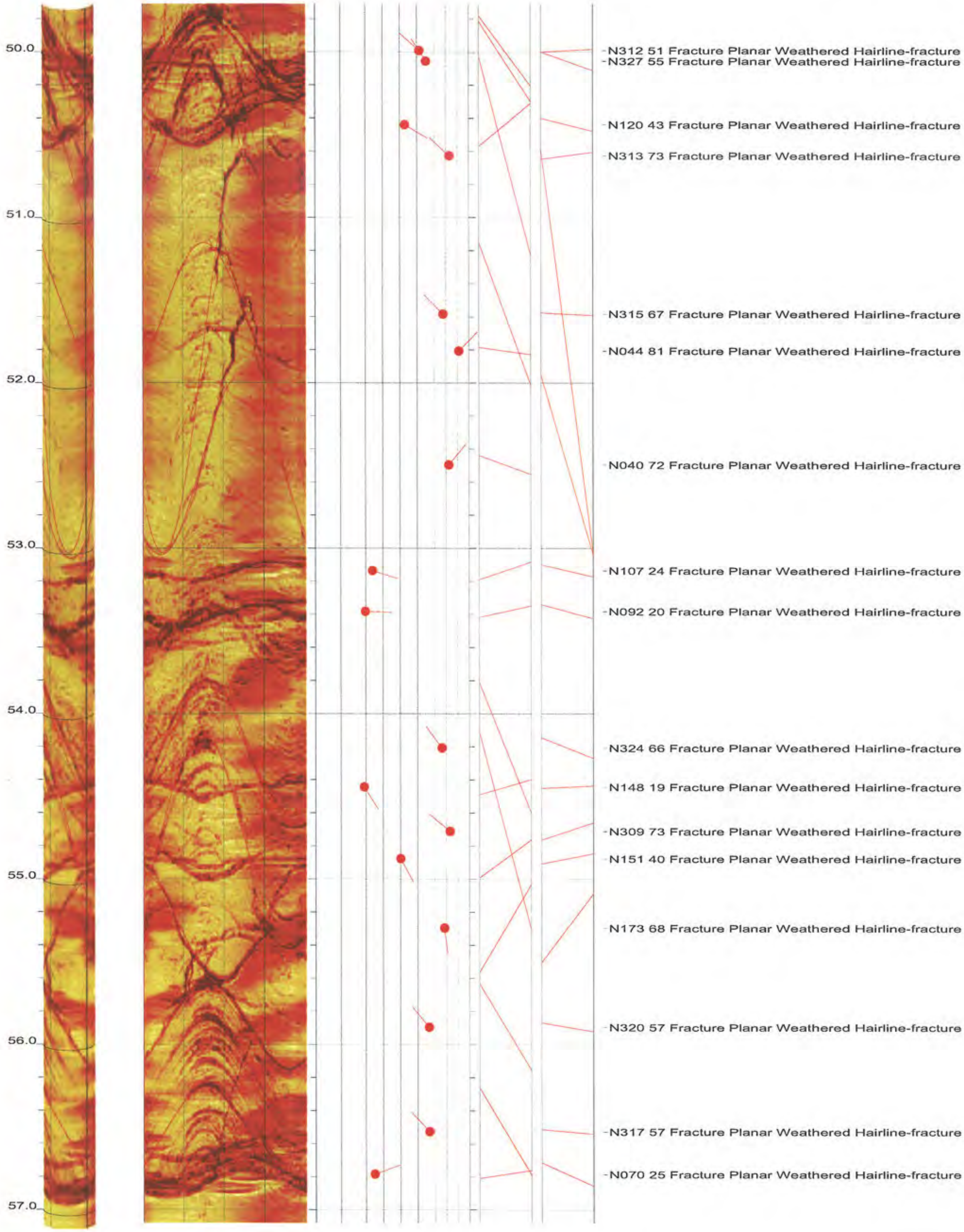
Stratigraphic dips
Non-stratigraphic dips
Identified units



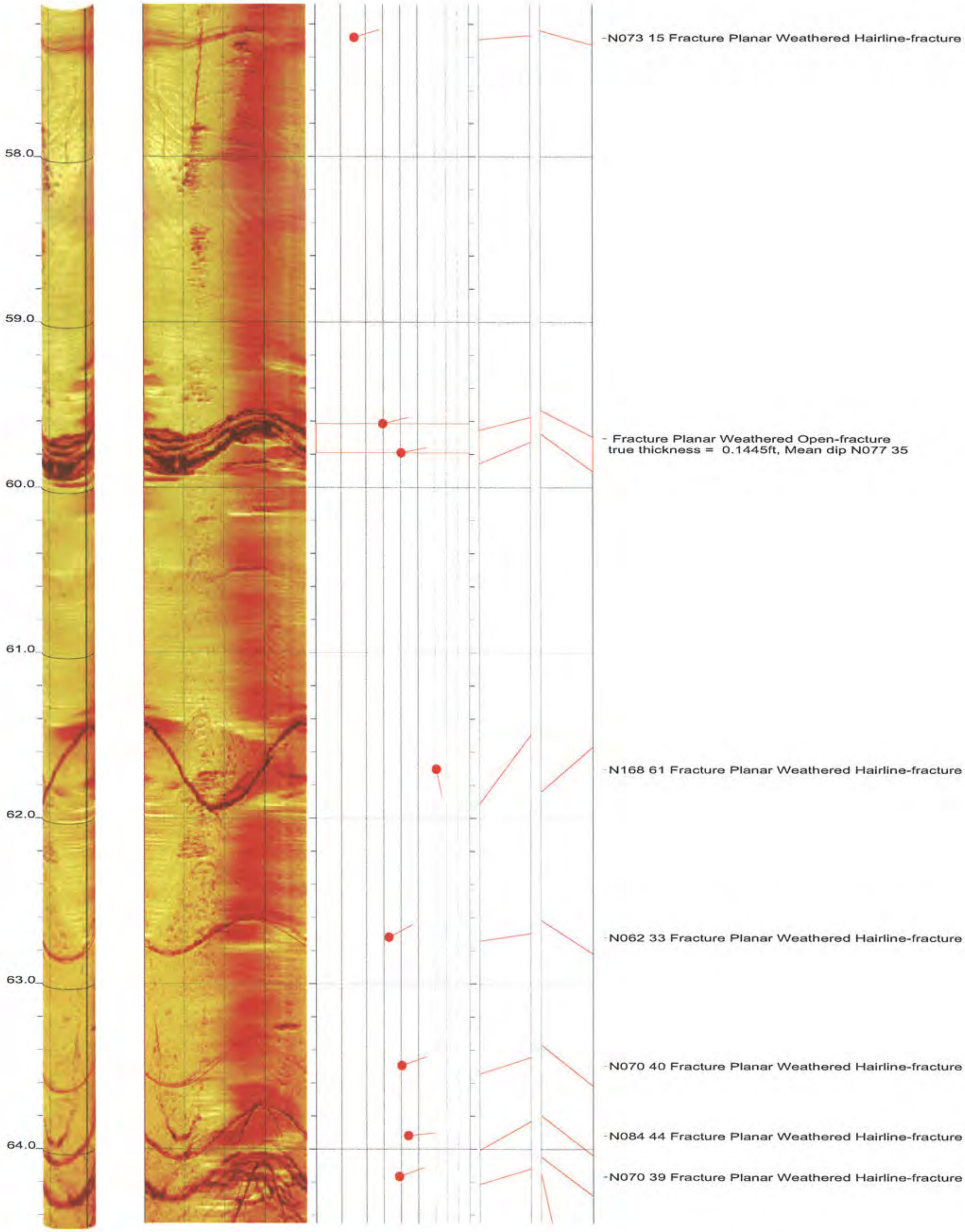
North Anna COL Boring B-901 Acoustic Televiewer Dips Sheet 1 of 36



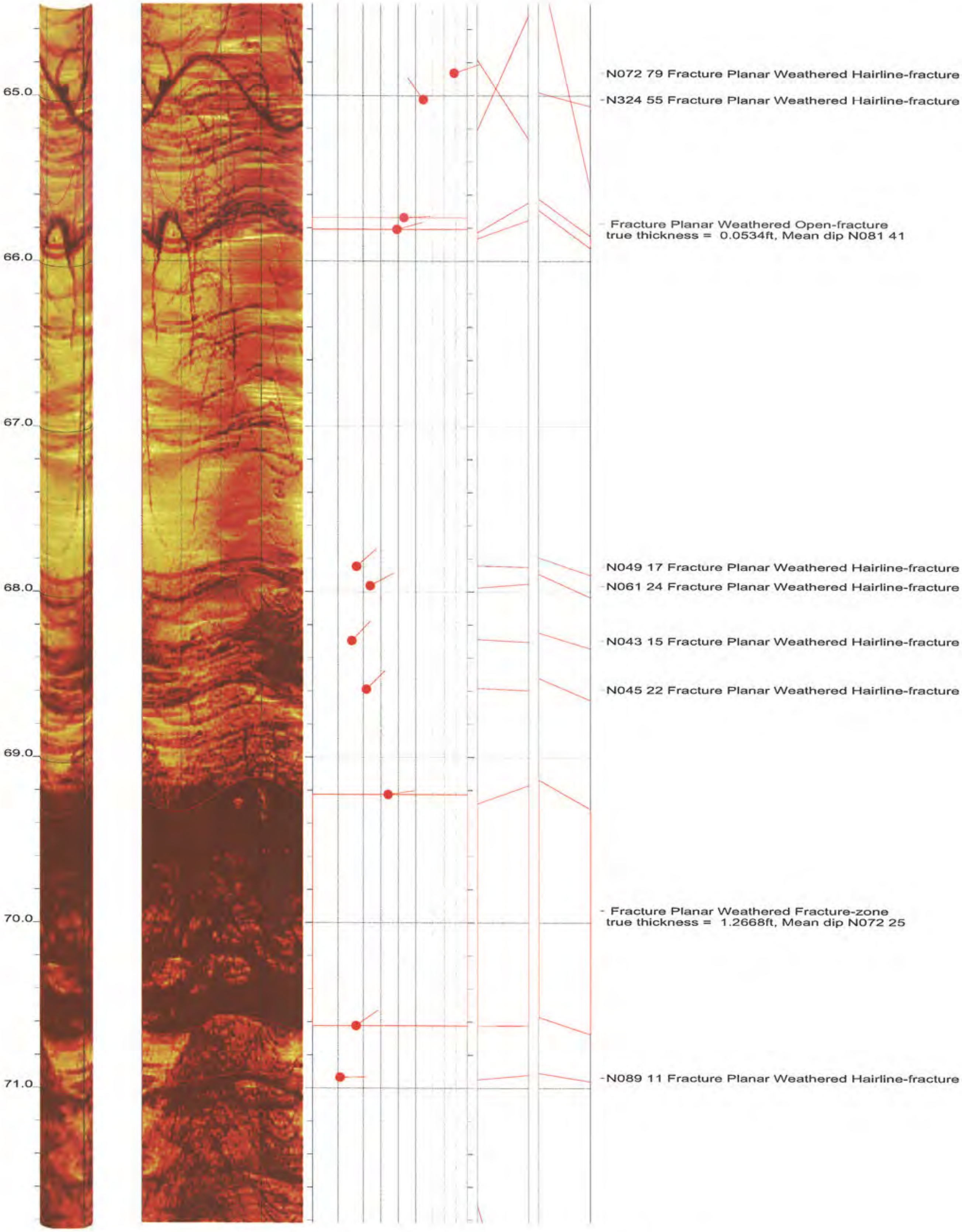
North Anna COL Boring B-901 Acoustic Televiewer Dips Sheet 2 of 36



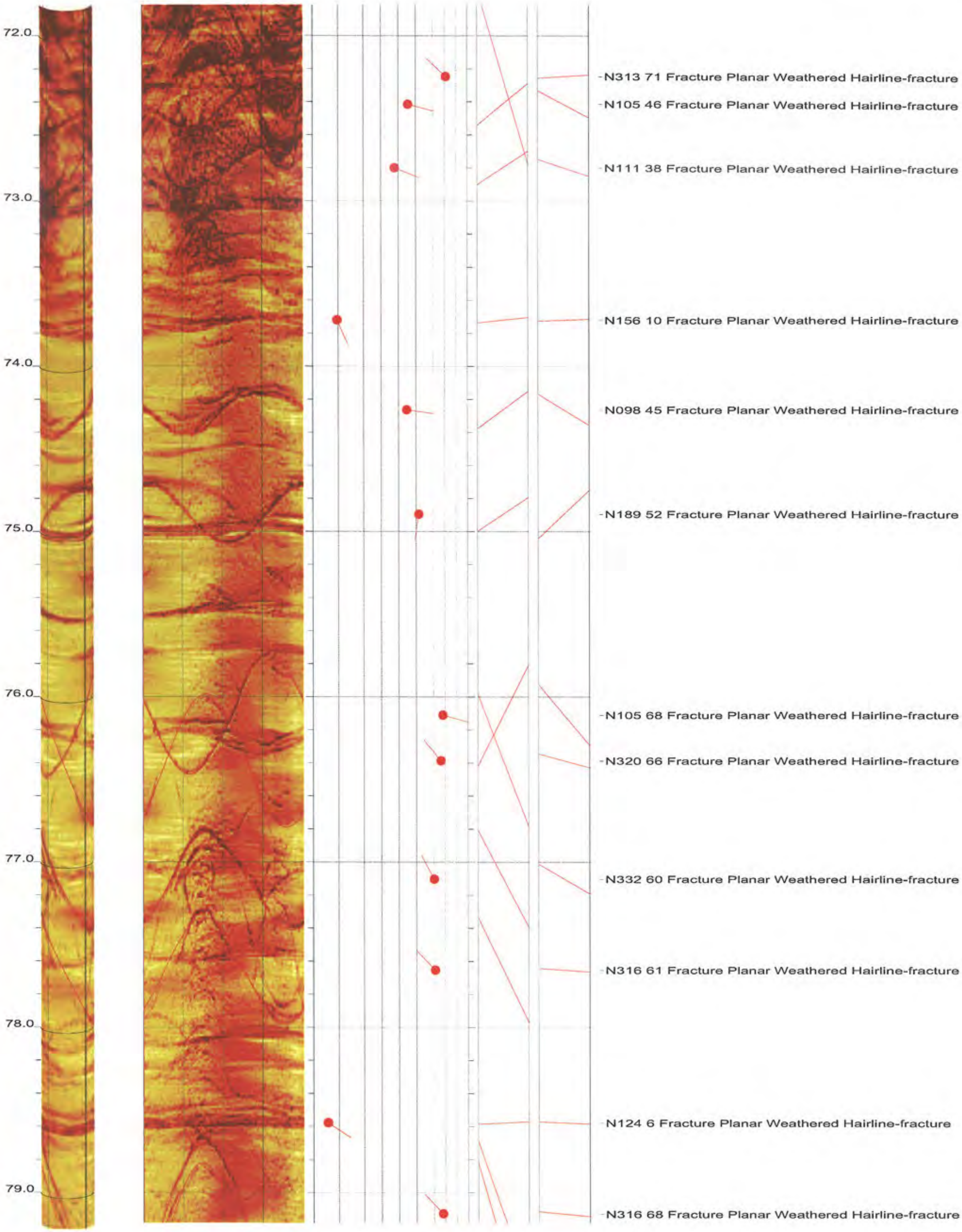
North Anna COL Boring B-901 Acoustic Televiewer Dips Sheet 3 of 36



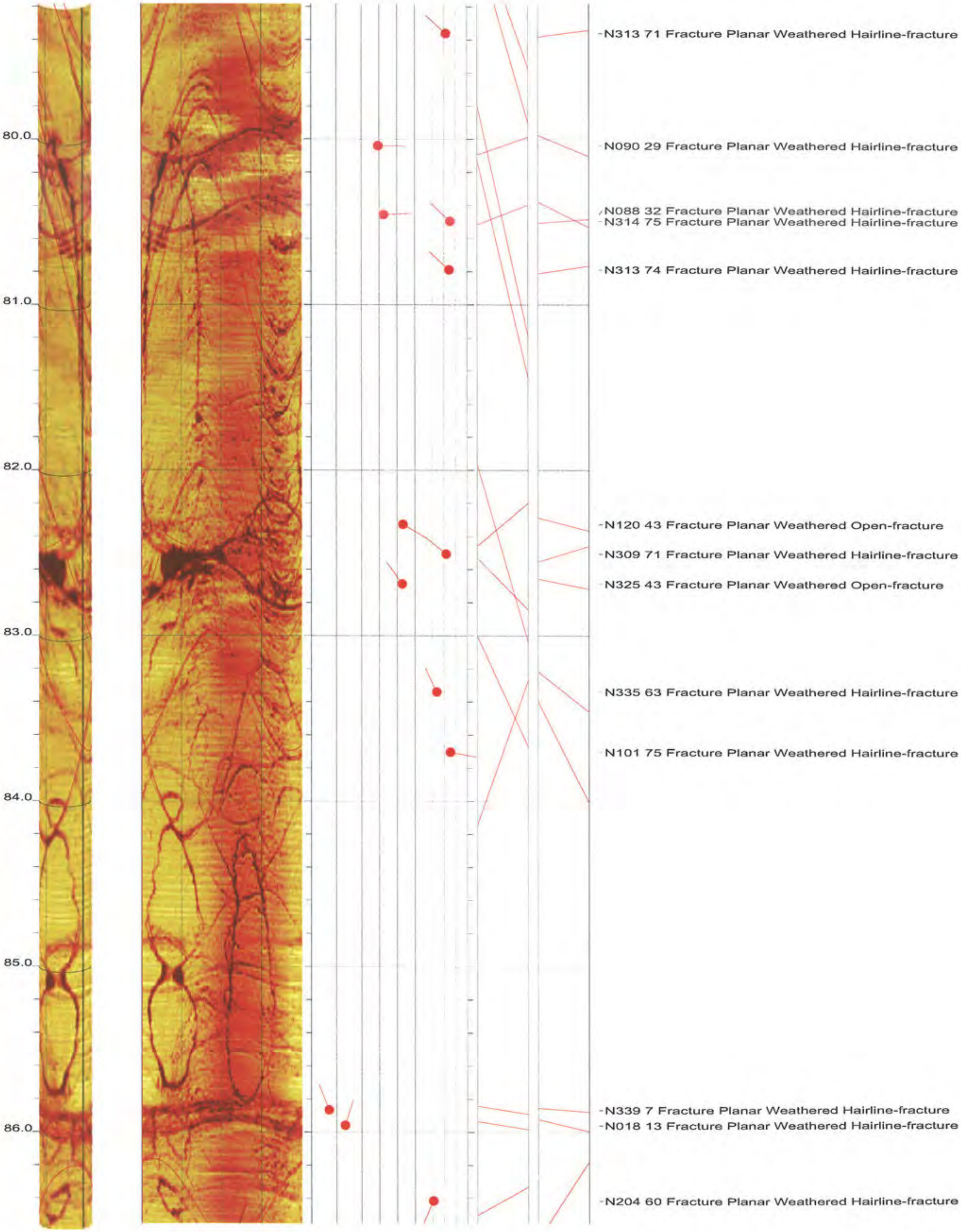
North Anna COL Boring B-901 Acoustic Televiewer Dips Sheet 4 of 36



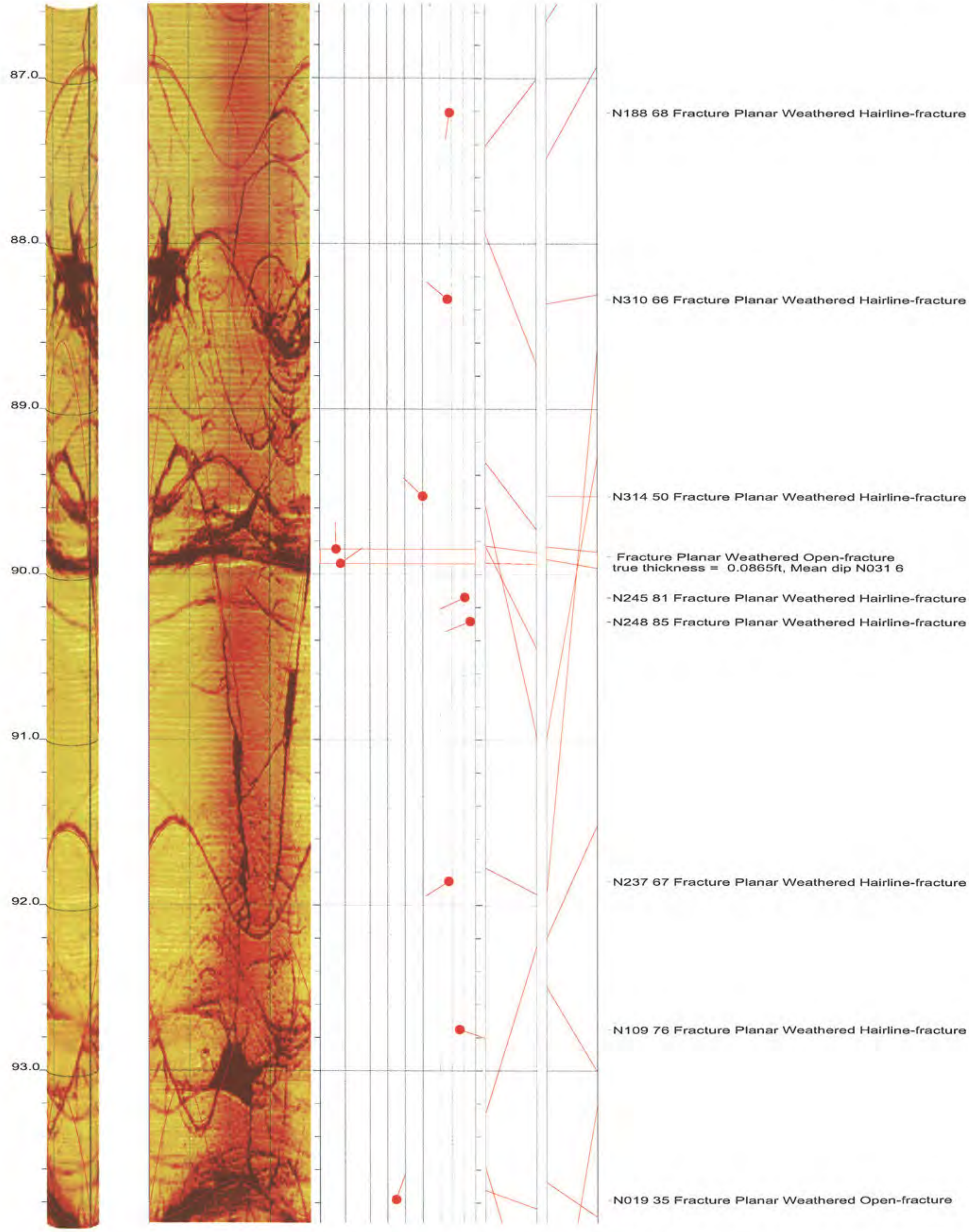
North Anna COL Boring B-901 Acoustic Televiewer Dips Sheet 5 of 36



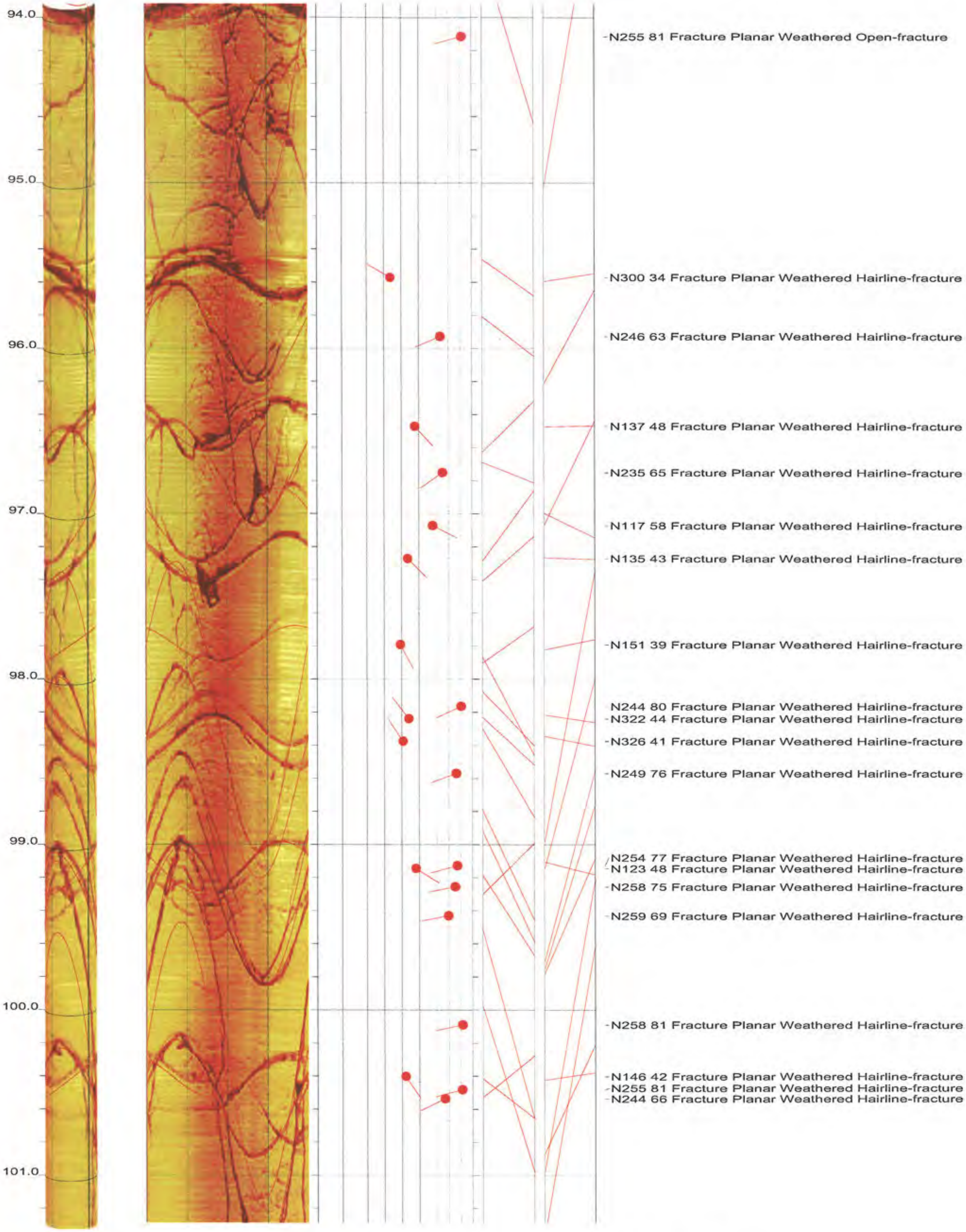
North Anna COL Boring B-901 Acoustic Televiewer Dips Sheet 6 of 36



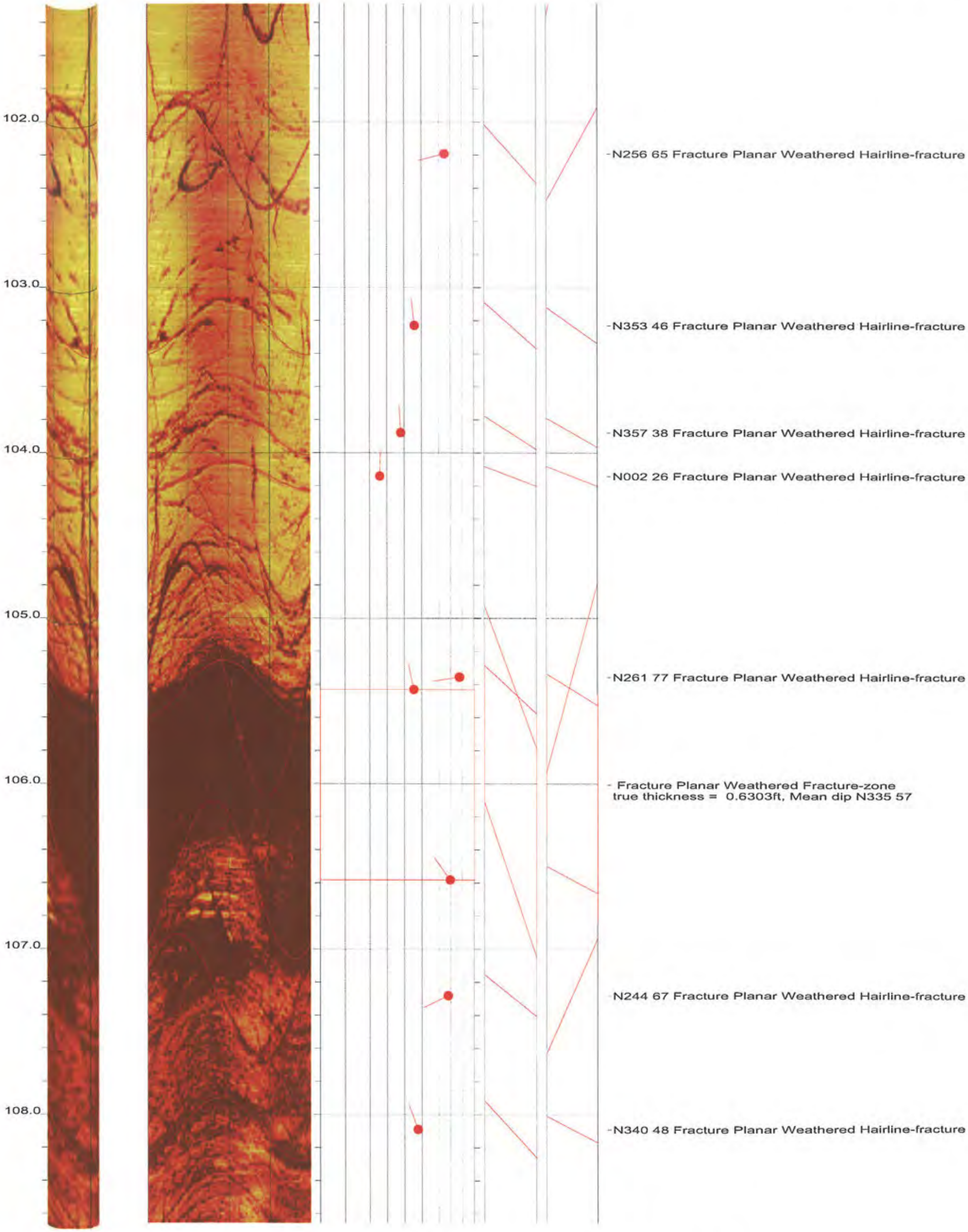
North Anna COL Boring B-901 Acoustic Televiewer Dips Sheet 7 of 36



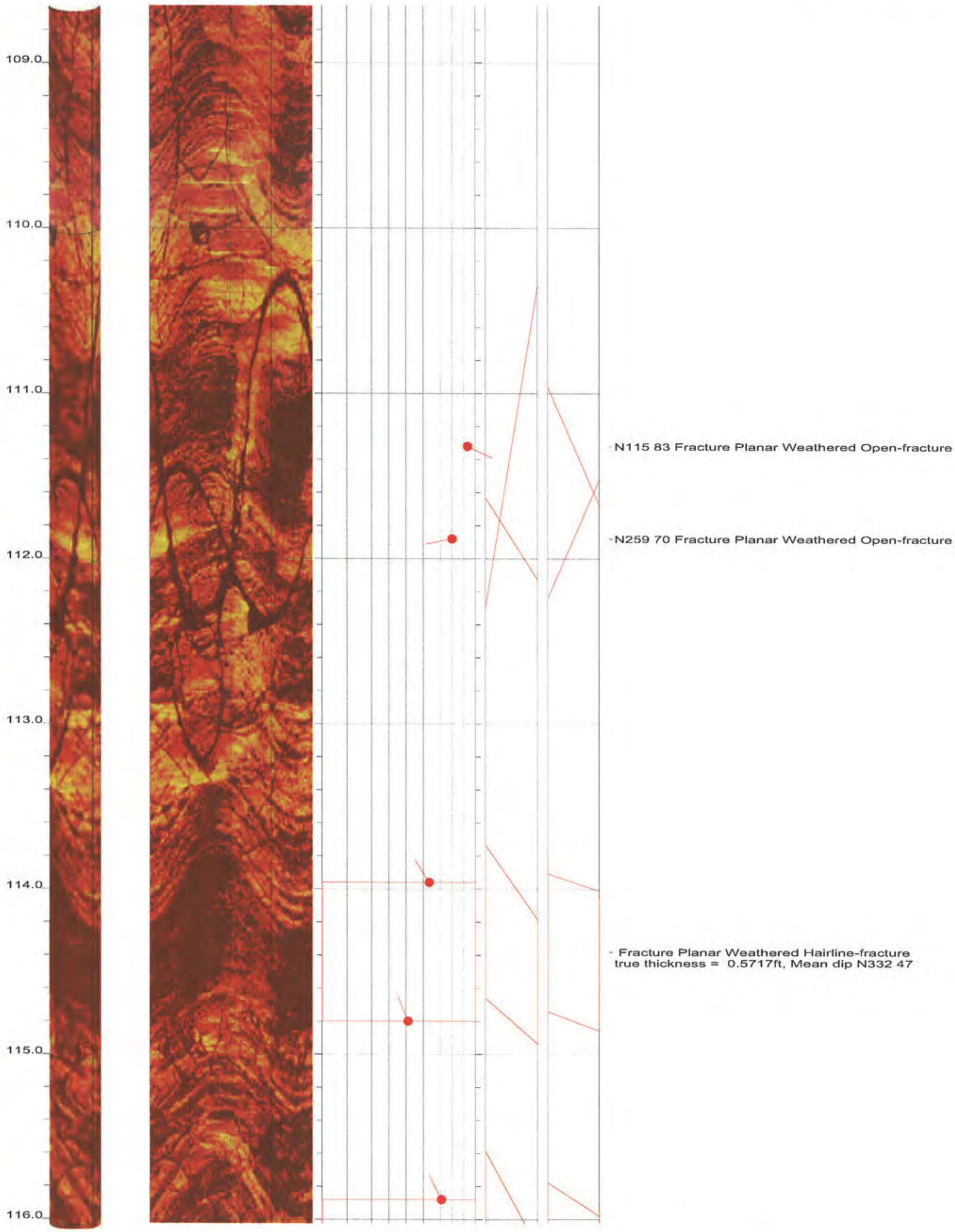
North Anna COL Boring B-901 Acoustic Televiewer Dips Sheet 8 of 36



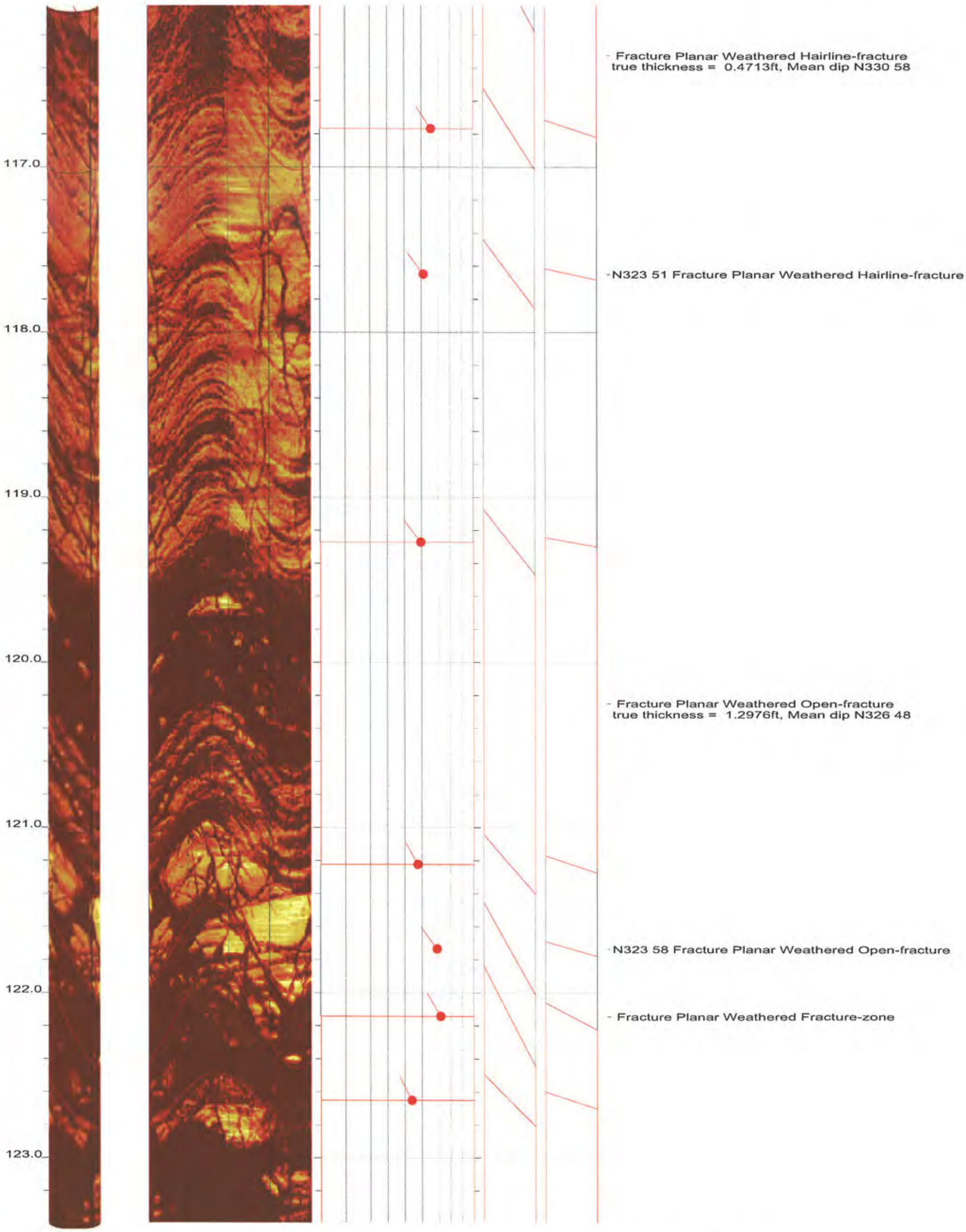
North Anna COL Boring B-901 Acoustic Televiewer Dips Sheet 9 of 36



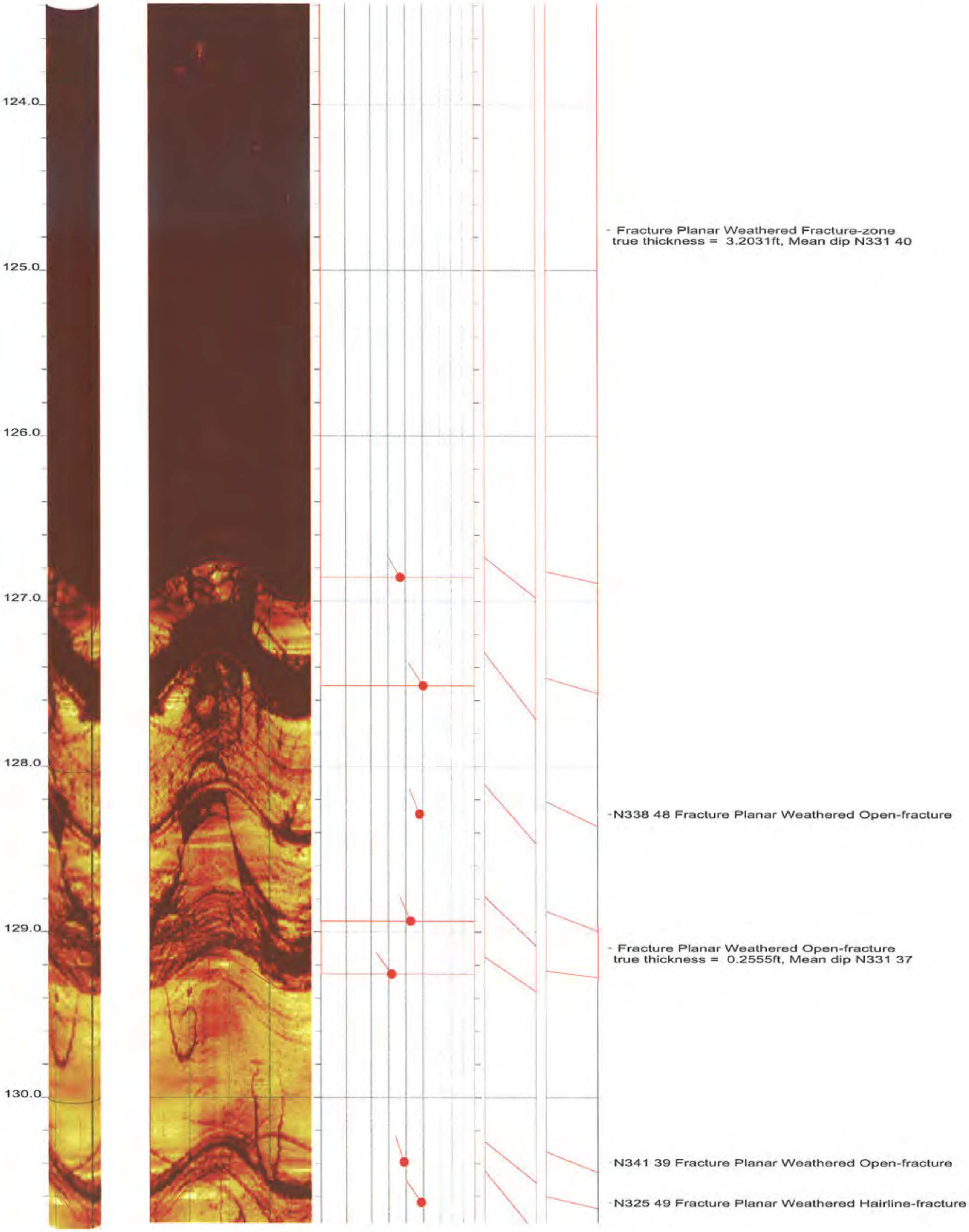
North Anna COL Boring B-901 Acoustic Televiewer Dips Sheet 10 of 36



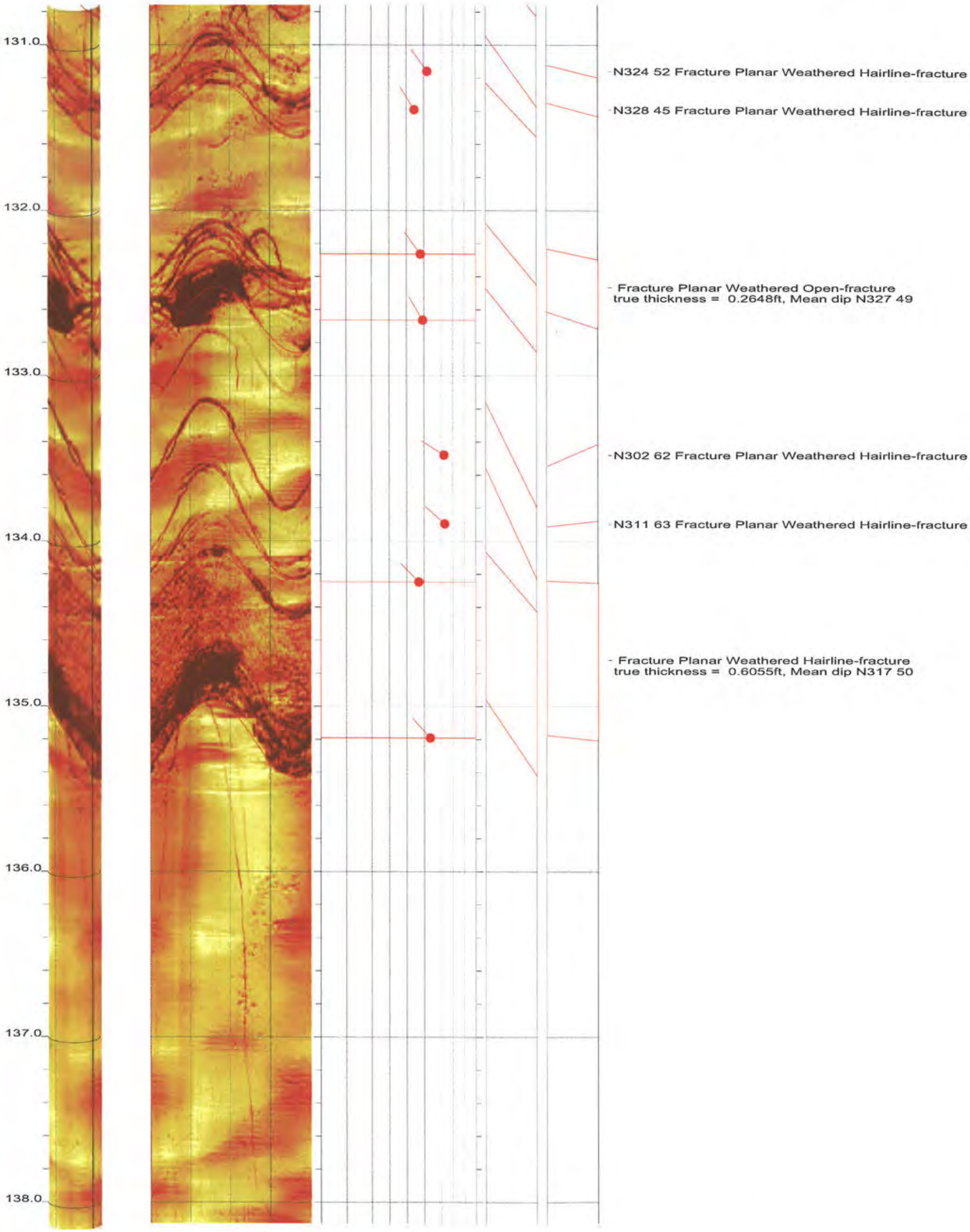
North Anna COL Boring B-901 Acoustic Televiewer Dips Sheet 11 of 36



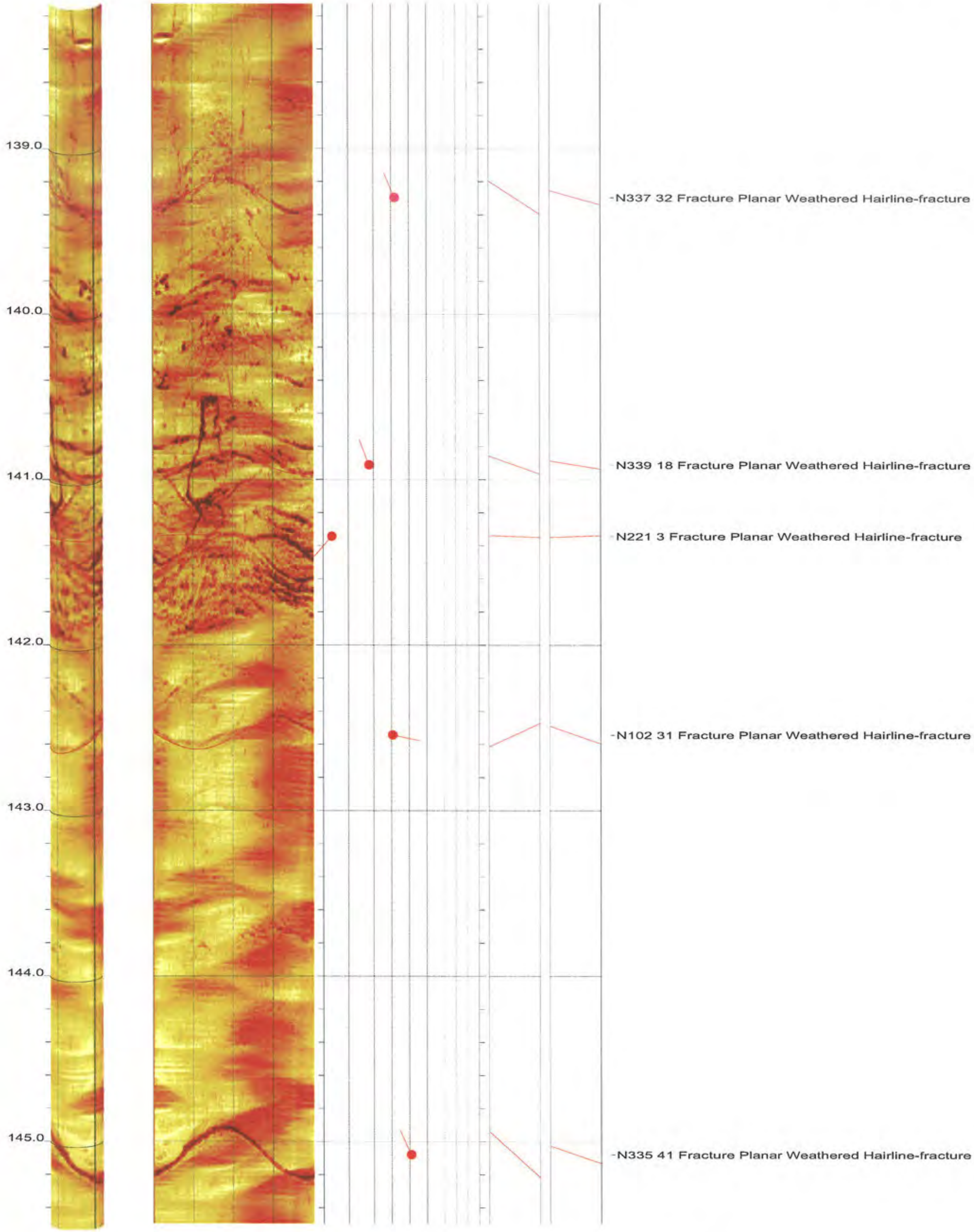
North Anna COL Boring B-901 Acoustic Televiewer Dips Sheet 12 of 36



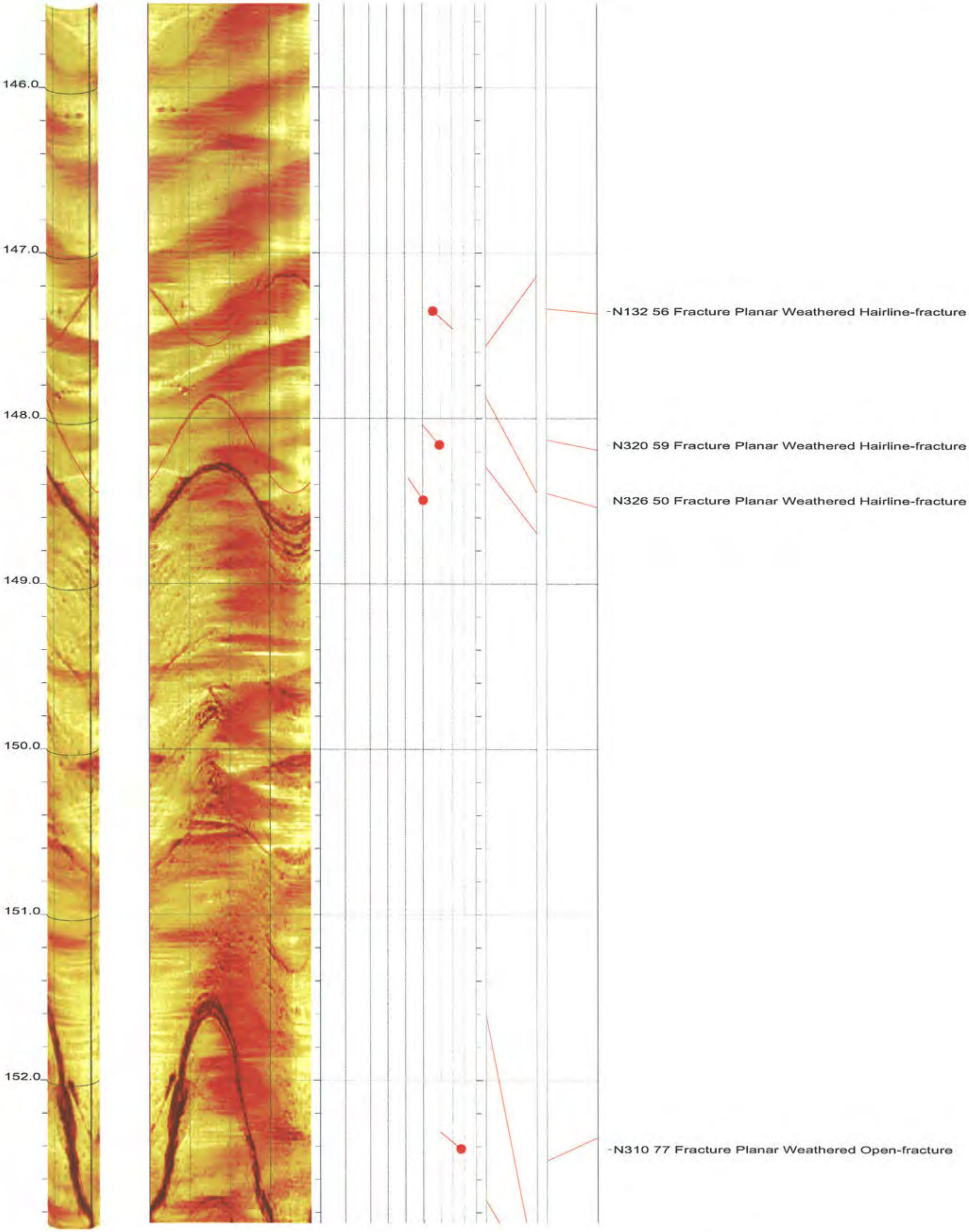
North Anna COL Boring B-901 Acoustic Televiewer Dips Sheet 13 of 36



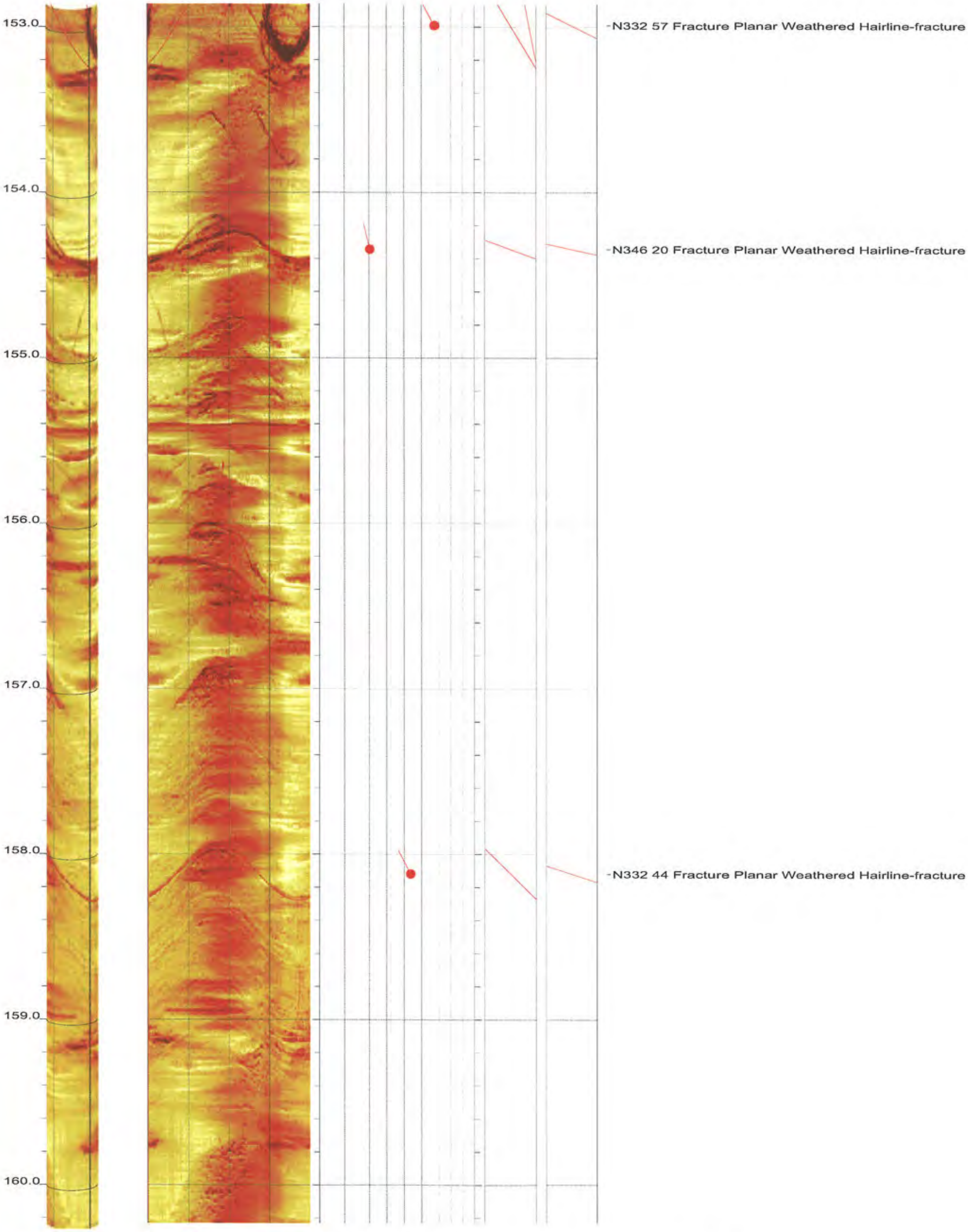
North Anna COL Boring B-901 Acoustic Televiewer Dips Sheet 14 of 36



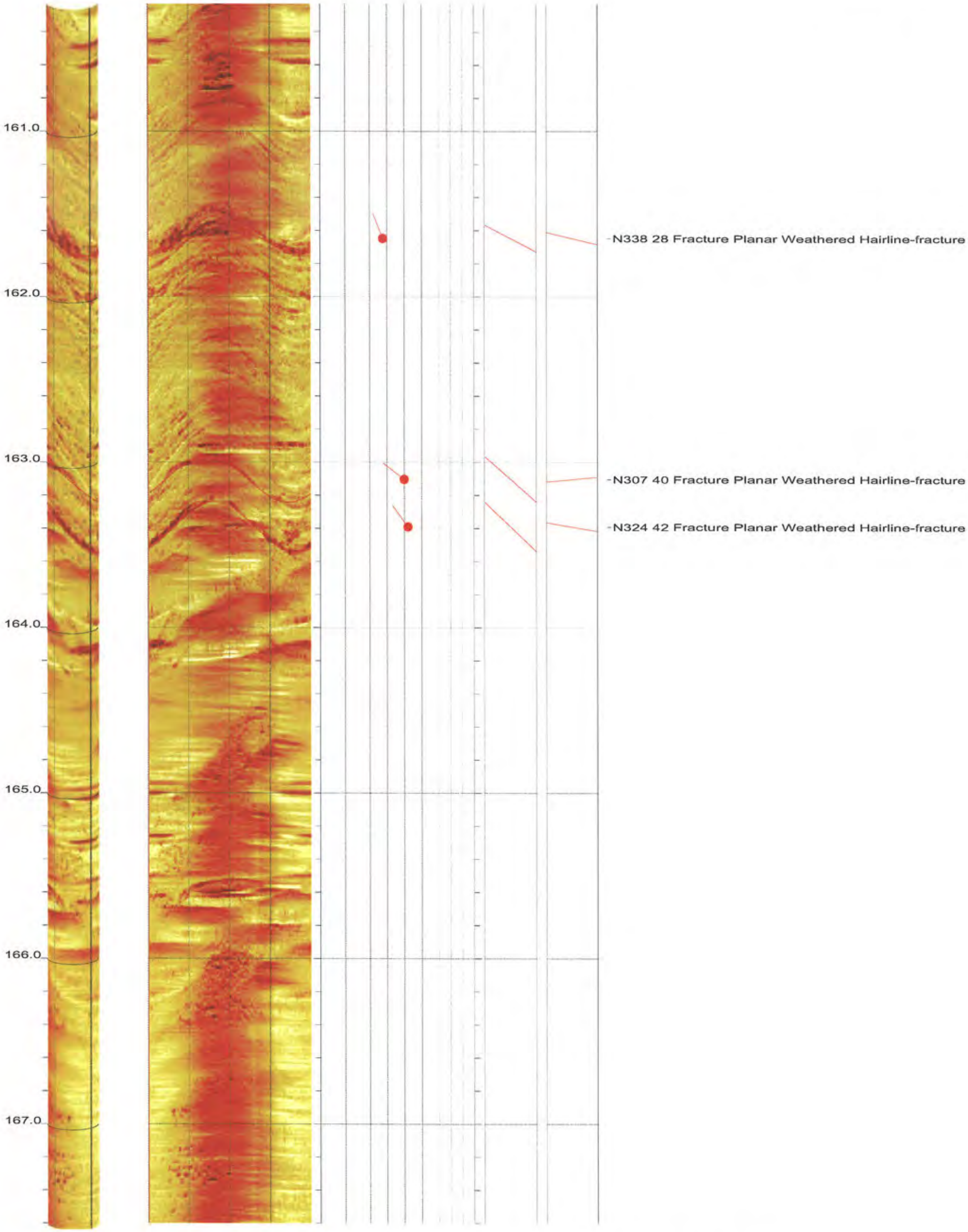
North Anna COL Boring B-901 Acoustic Televiewer Dips Sheet 15 of 36



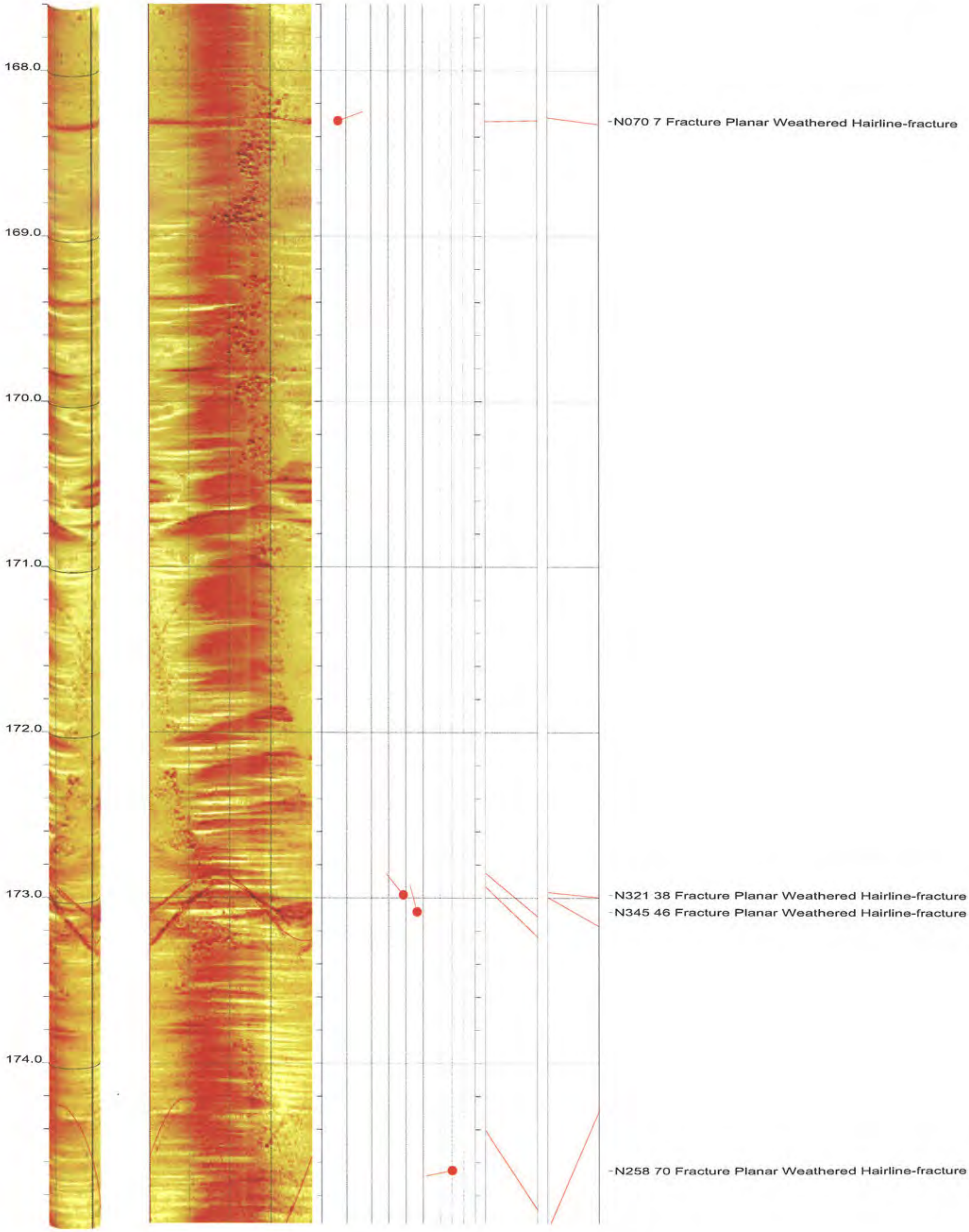
North Anna COL Boring B-901 Acoustic Televiewer Dips Sheet 16 of 36



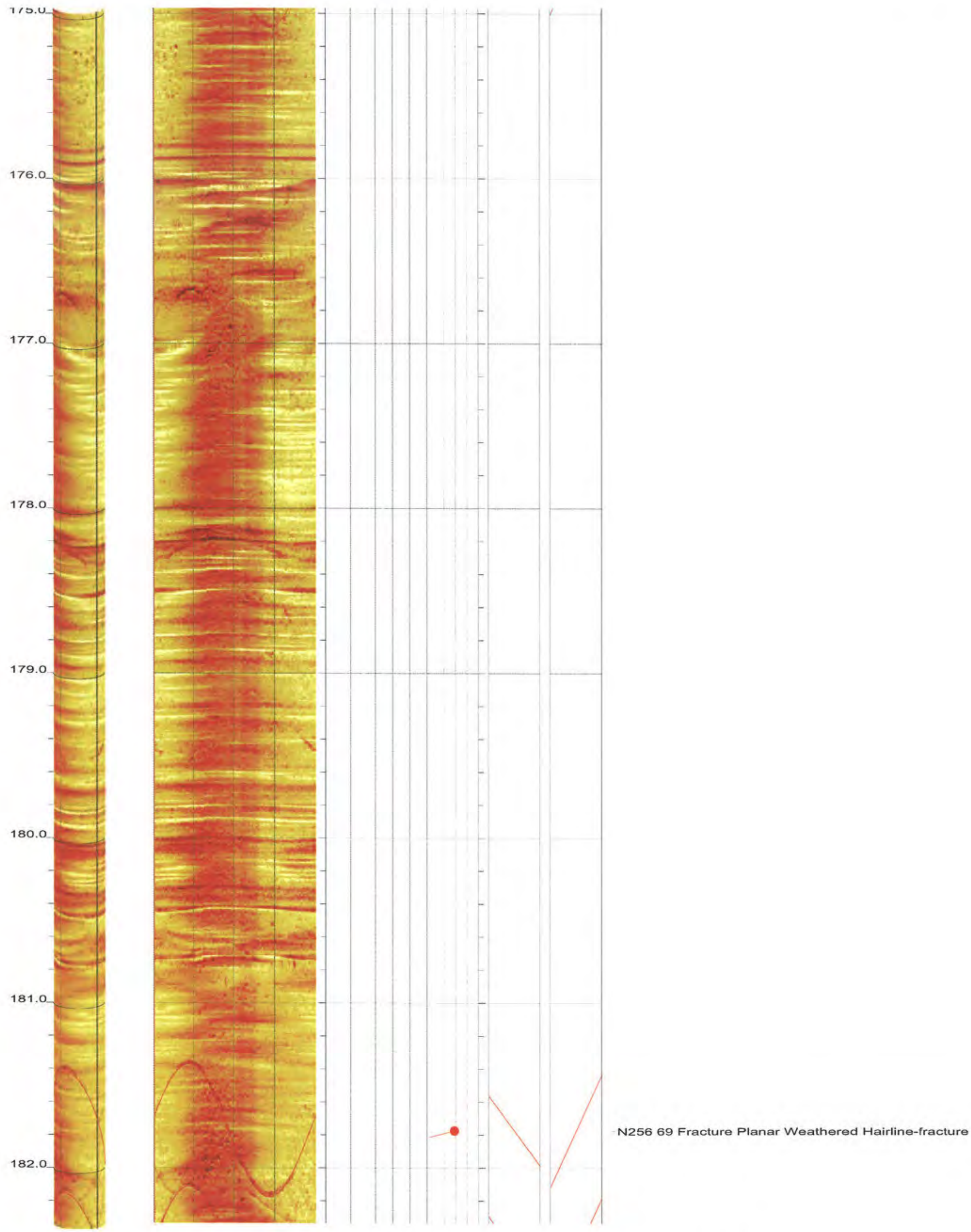
North Anna COL Boring B-901 Acoustic Televiewer Dips Sheet 17 of 36



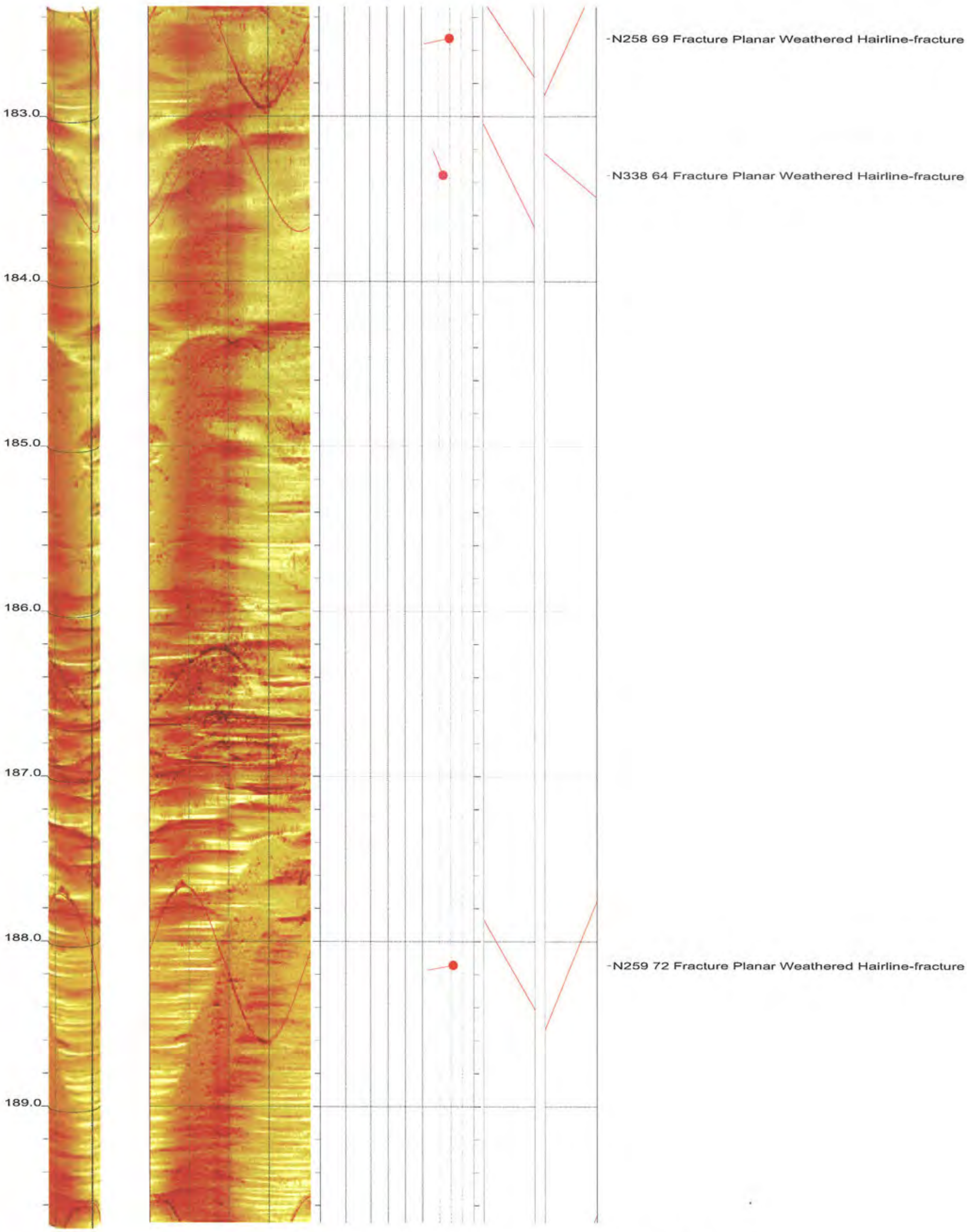
North Anna COL Boring B-901 Acoustic Televiewer Dips Sheet 18 of 36



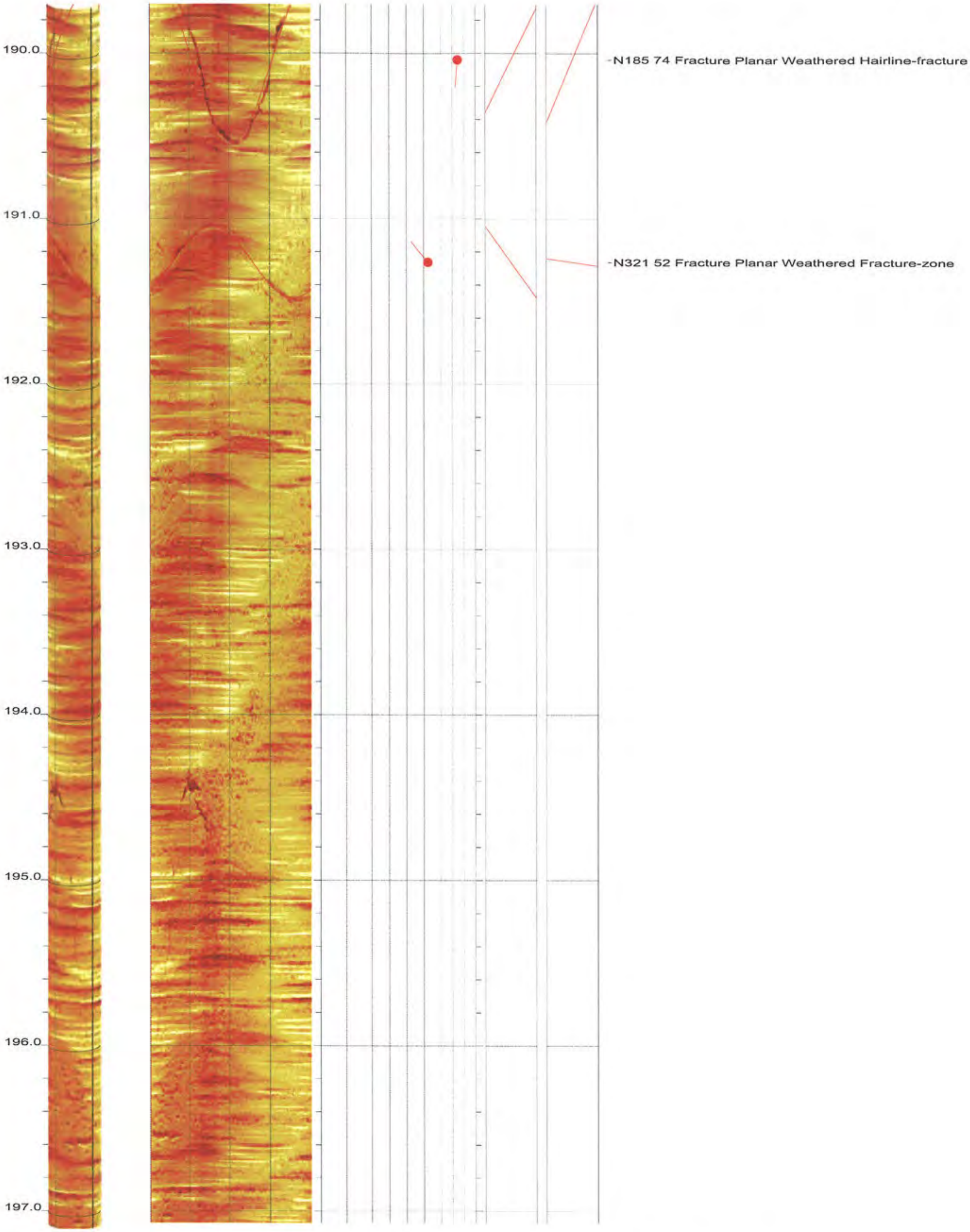
North Anna COL Boring B-901 Acoustic Televiewer Dips Sheet 19 of 36



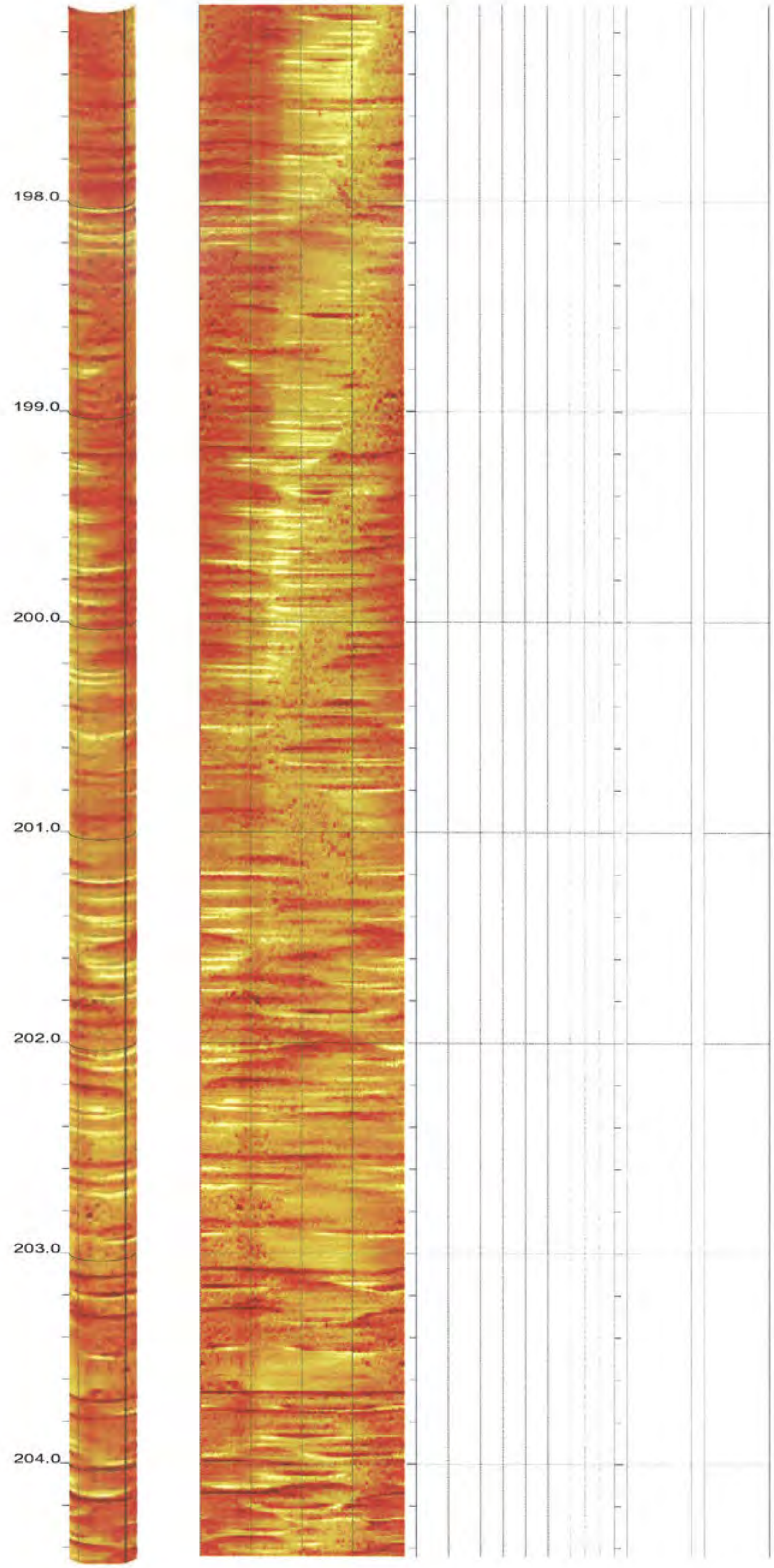
North Anna COL Boring B-901 Acoustic Televiewer Dips Sheet 20 of 36



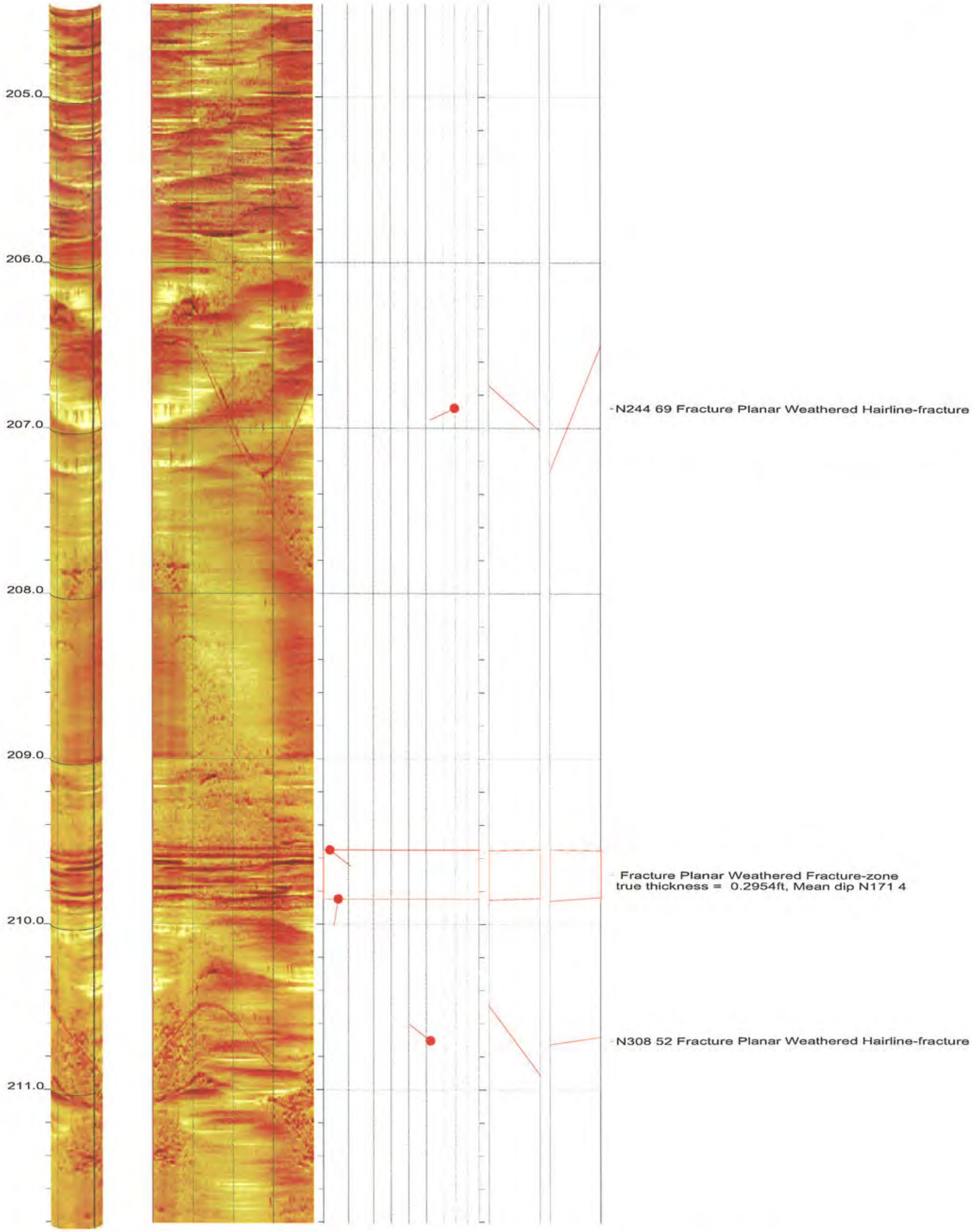
North Anna COL Boring B-901 Acoustic Televiewer Dips Sheet 21 of 36



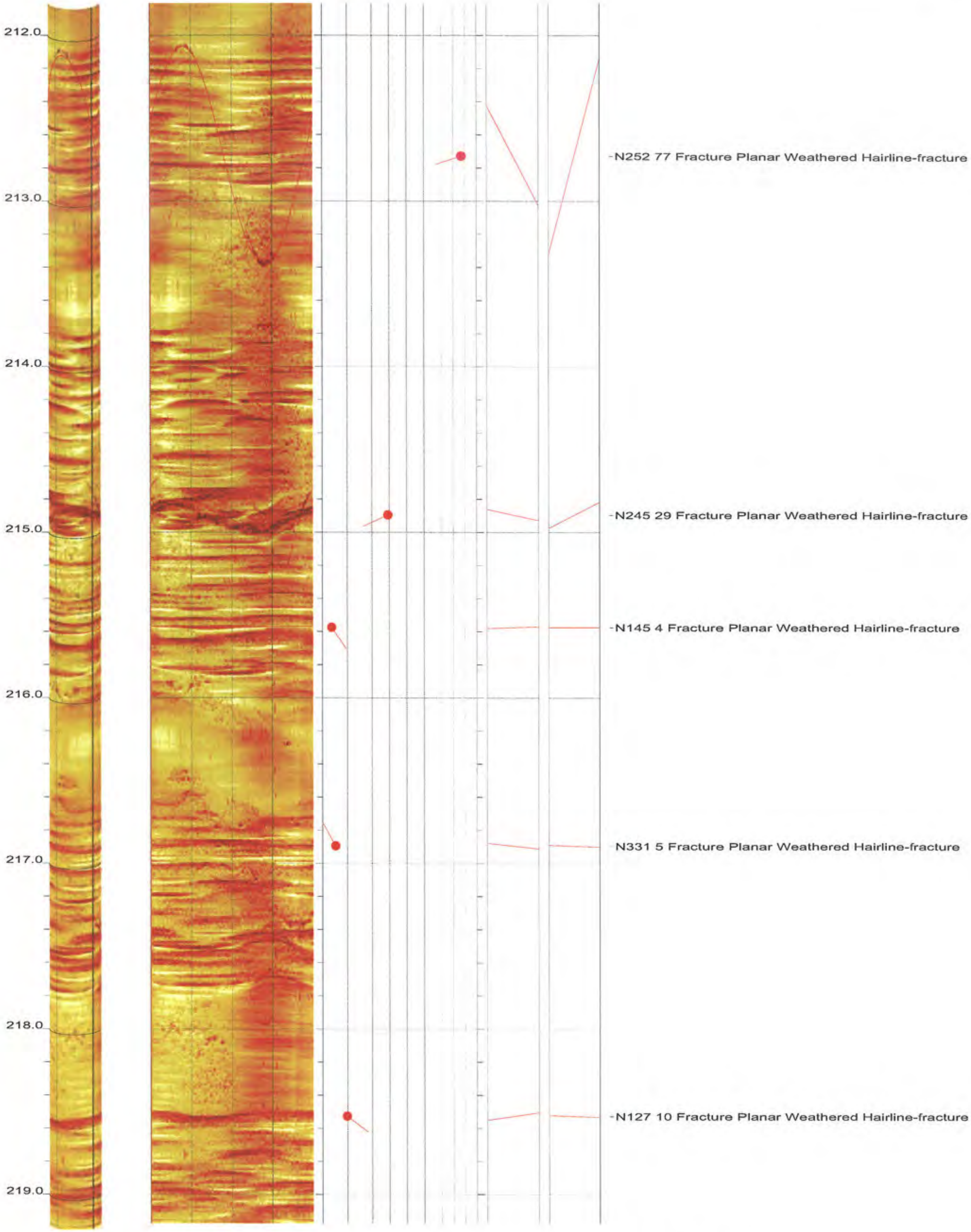
North Anna COL Boring B-901 Acoustic Televiewer Dips Sheet 22 of 36



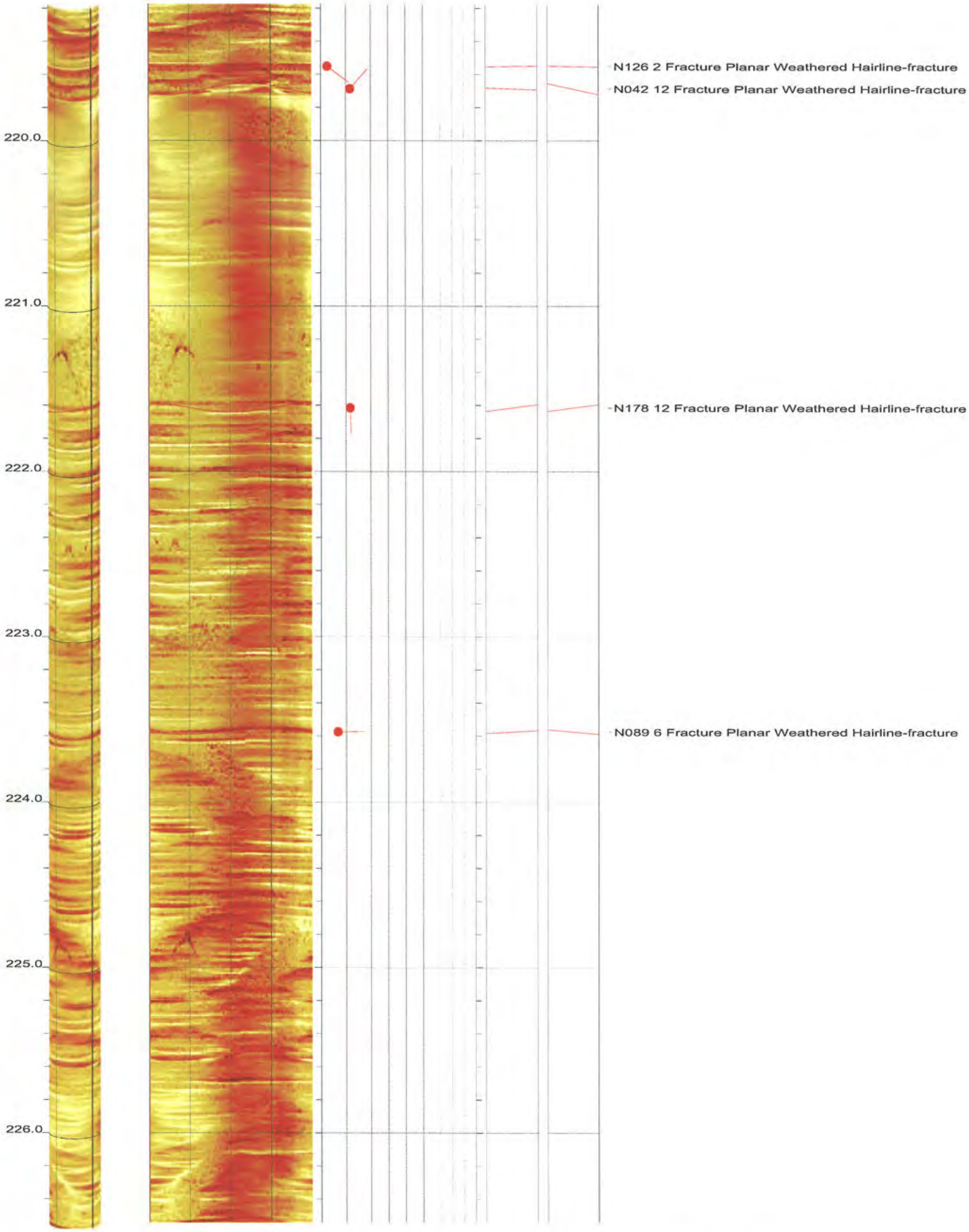
North Anna COL Boring B-901 Acoustic Televiewer Dips Sheet 23 of 36



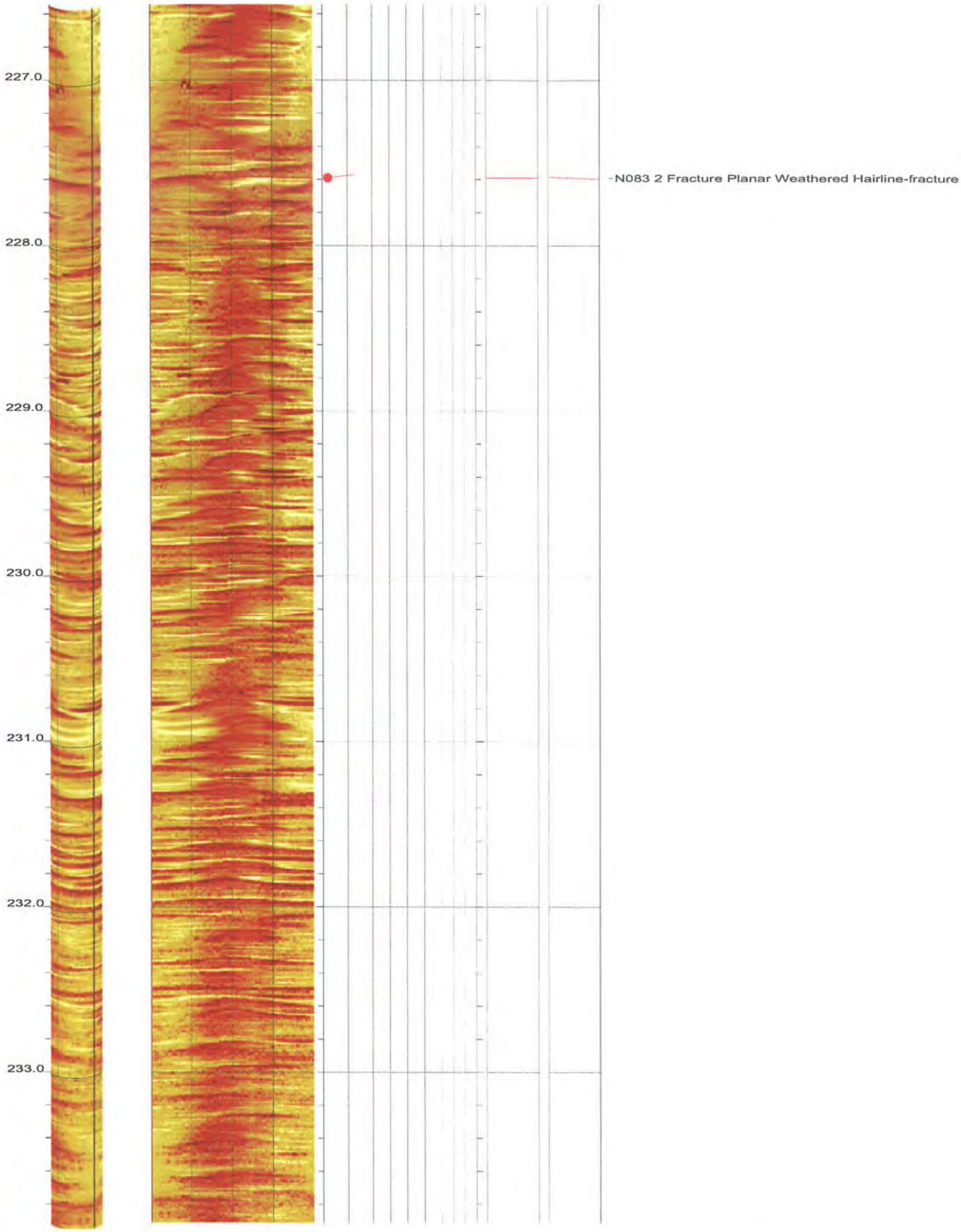
North Anna COL Boring B-901 Acoustic Televiewer Dips Sheet 24 of 36



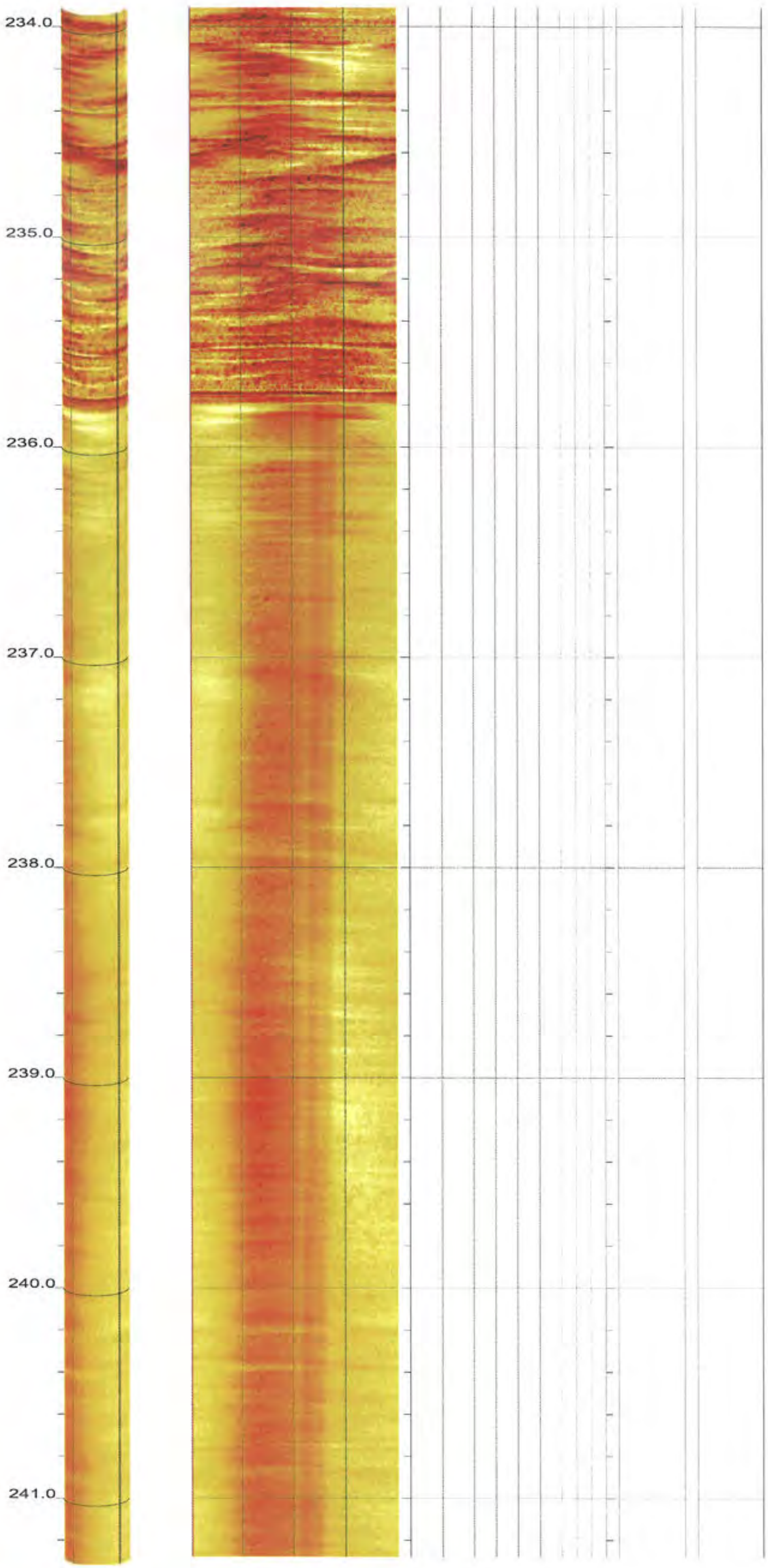
North Anna COL Boring B-901 Acoustic Televiewer Dips Sheet 25 of 36



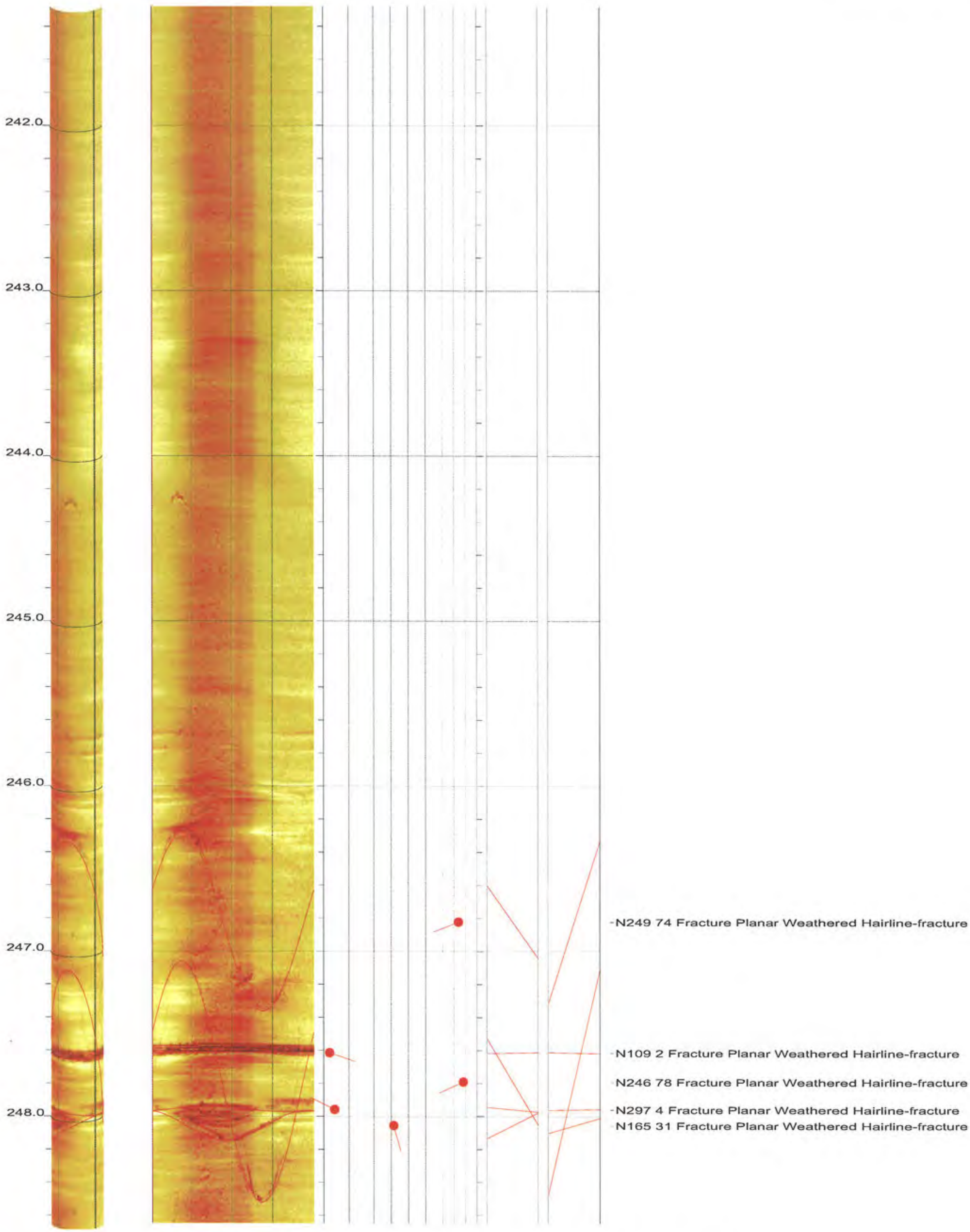
North Anna COL Boring B-901 Acoustic Televiewer Dips Sheet 26 of 36



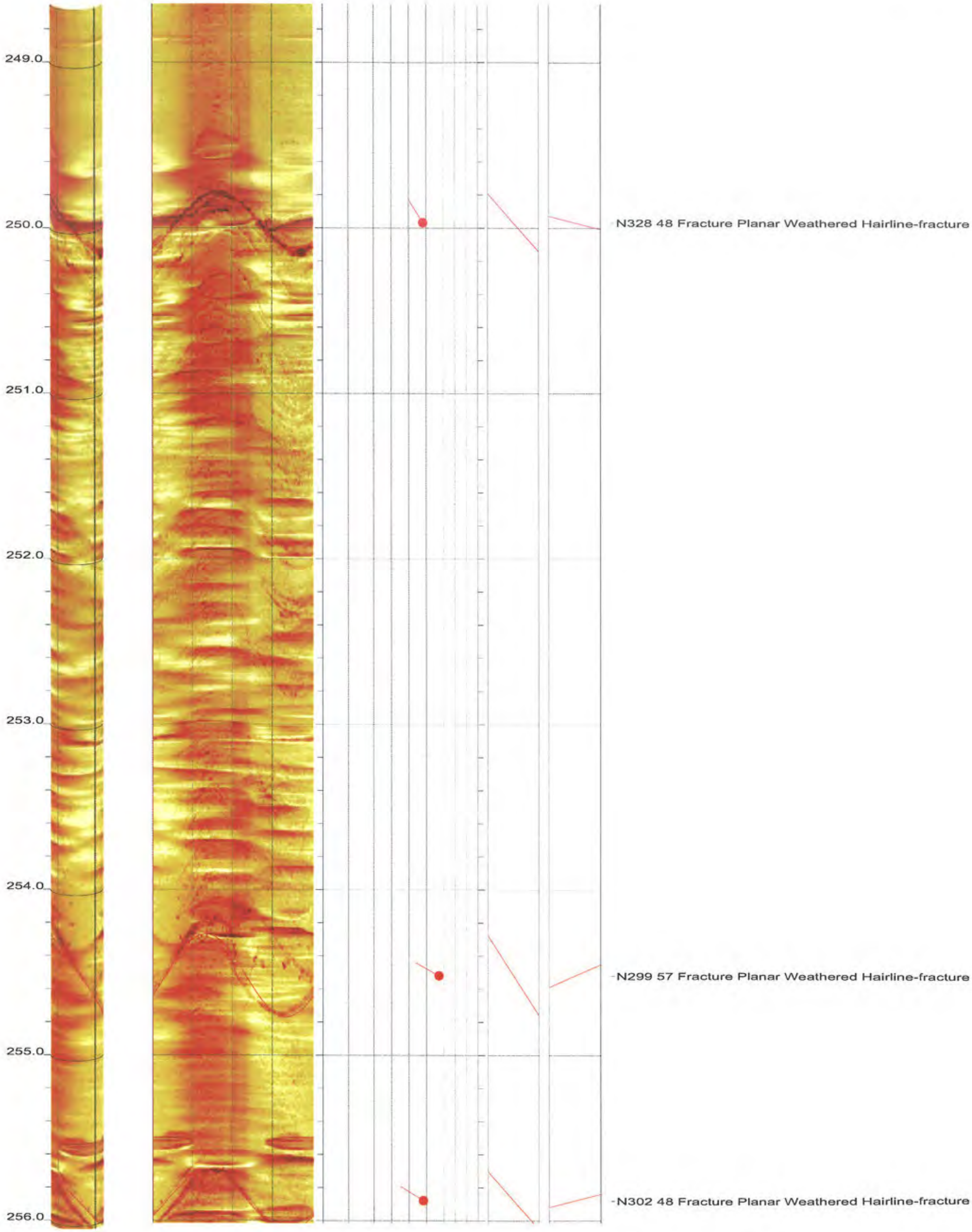
North Anna COL Boring B-901 Acoustic Televiewer Dips Sheet 27 of 36



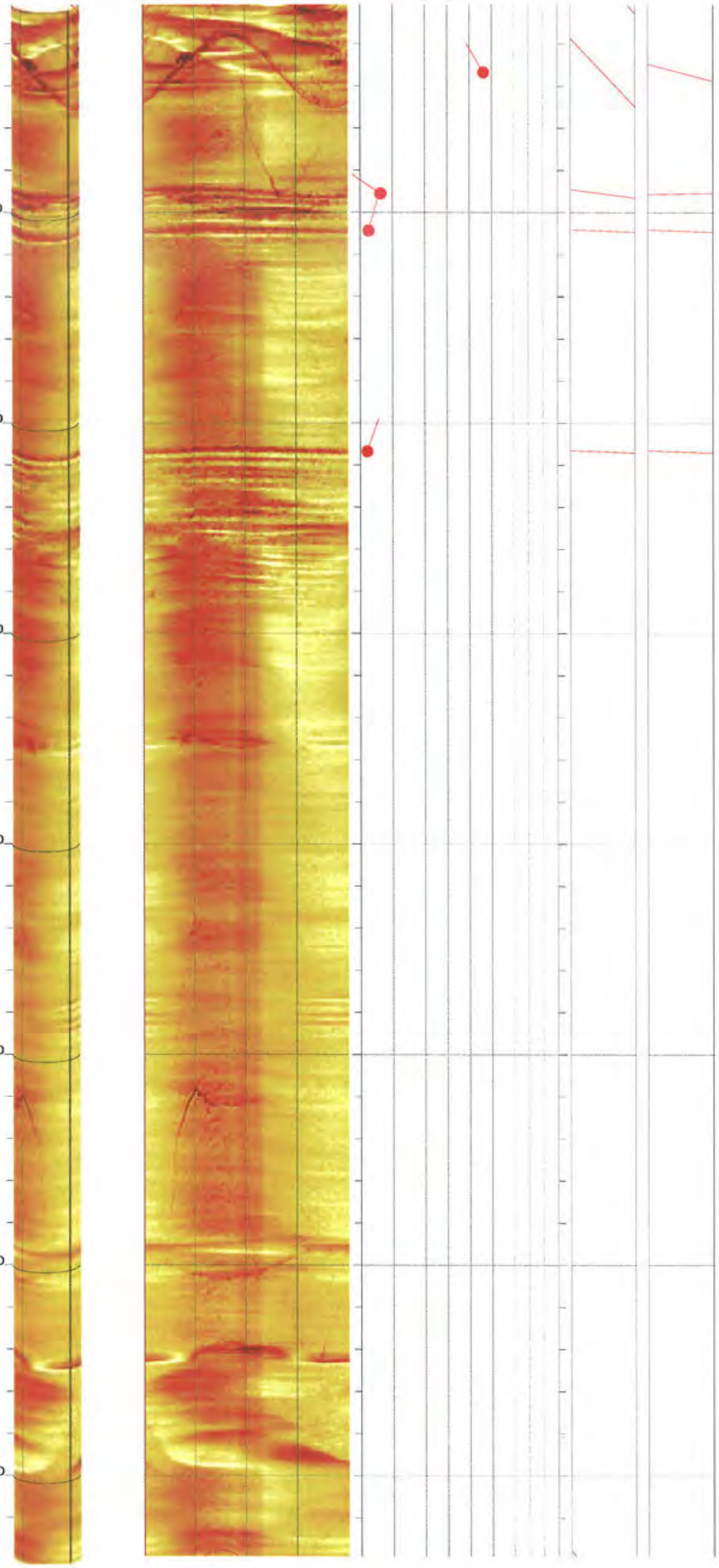
North Anna COL Boring B-901 Acoustic Televiewer Dips Sheet 28 of 36



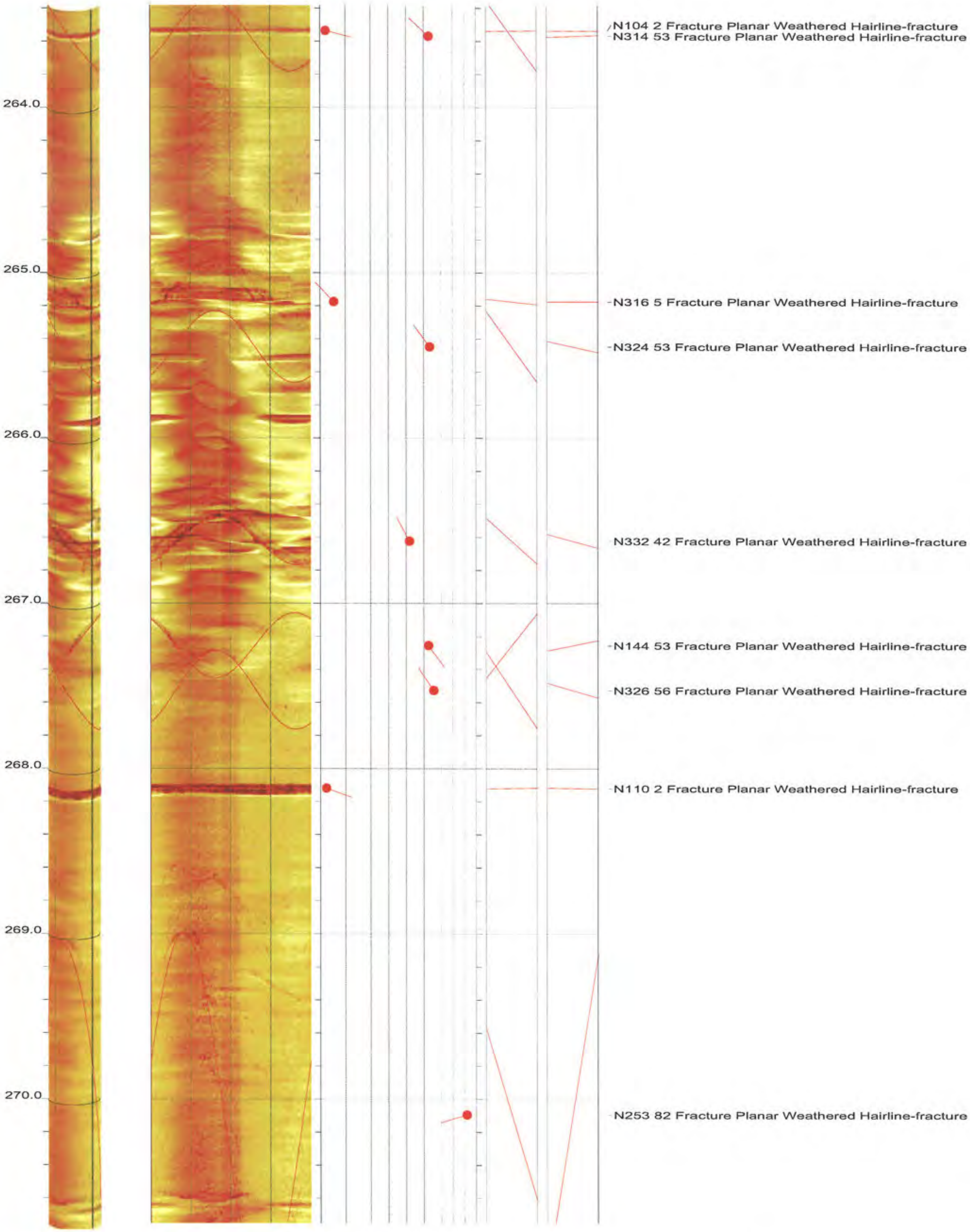
North Anna COL Boring B-901 Acoustic Televiewer Dips Sheet 29 of 36



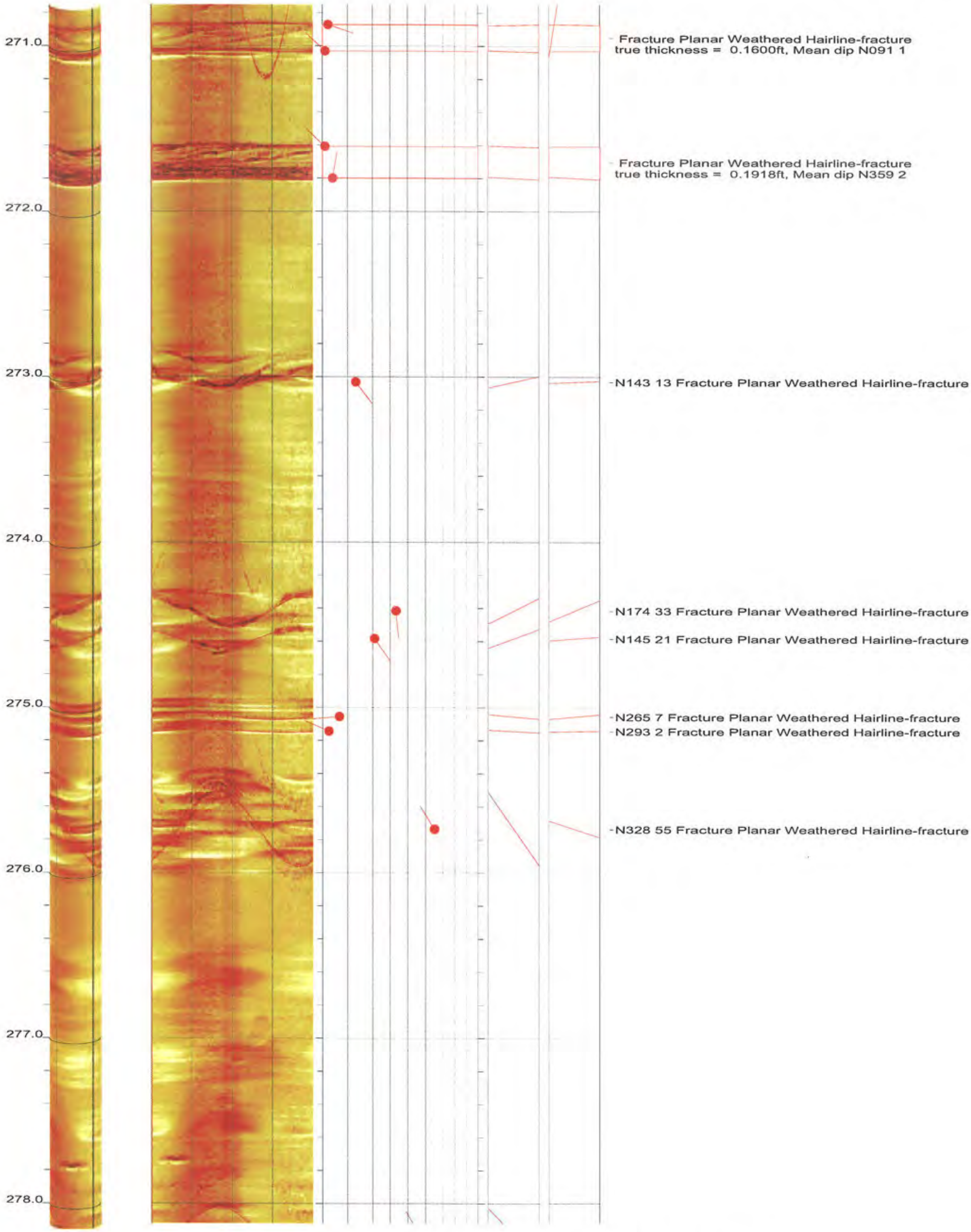
North Anna COL Boring B-901 Acoustic Televiewer Dips Sheet 30 of 36



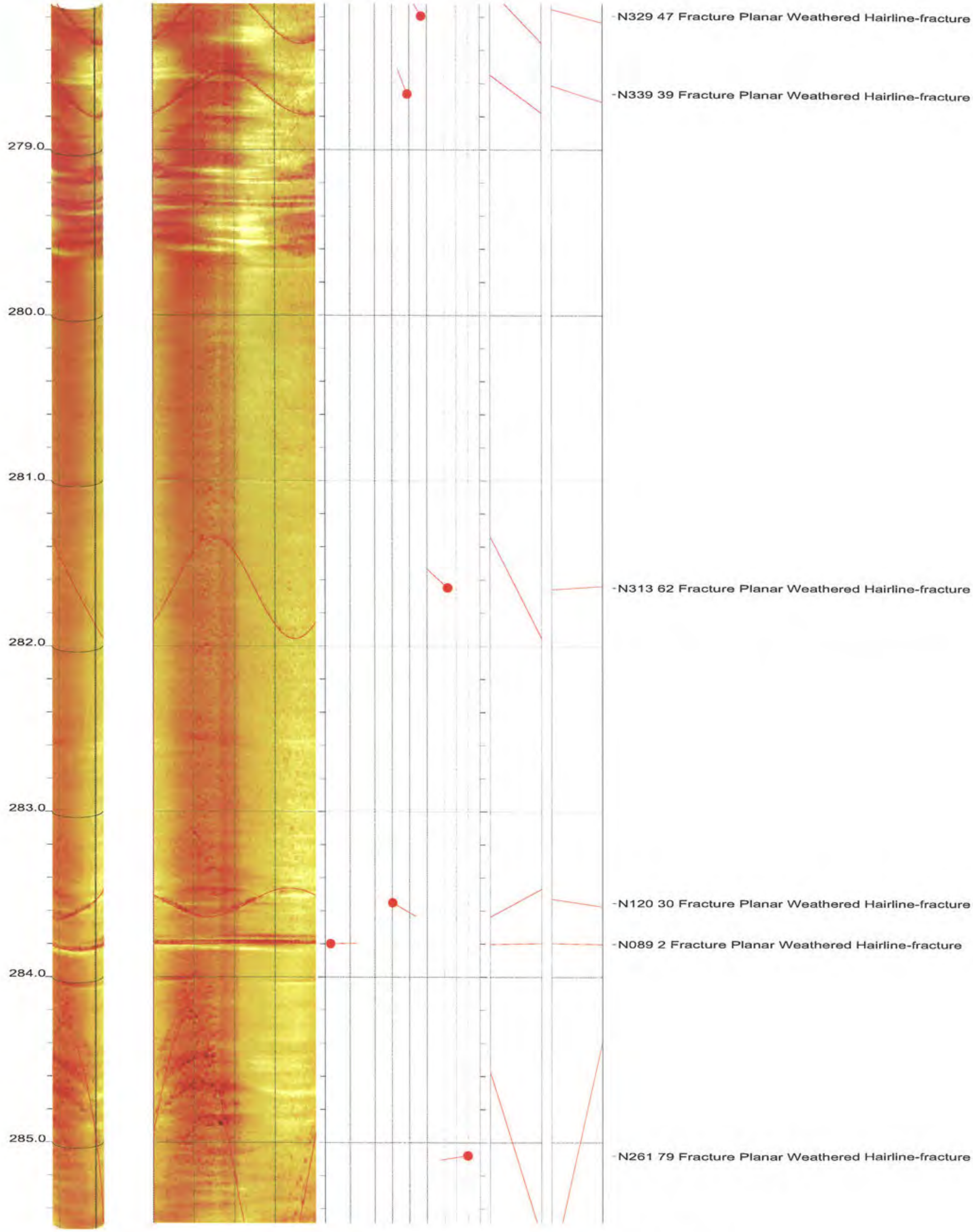
North Anna COL Boring B-901 Acoustic Televiewer Dips Sheet 31 of 36



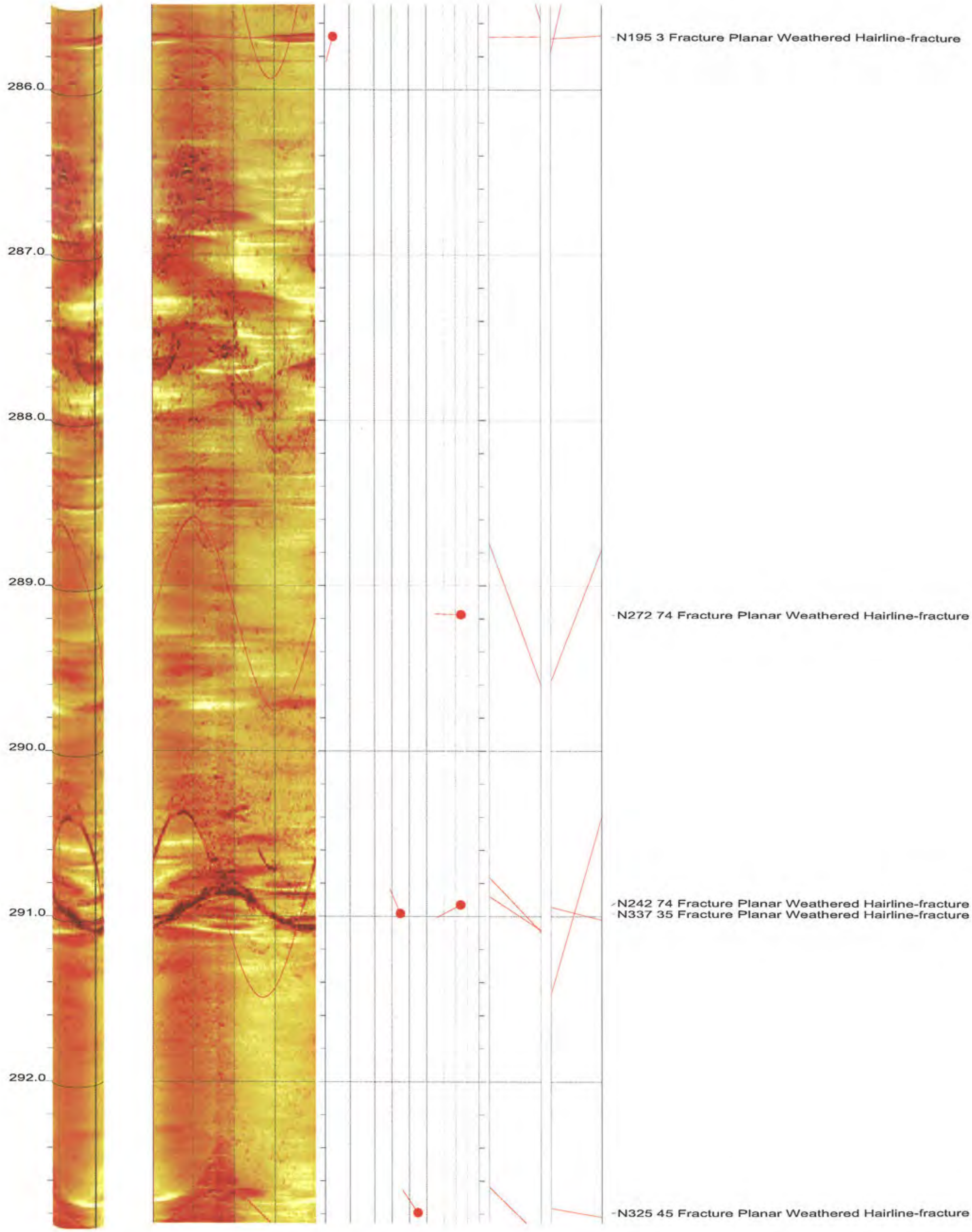
North Anna COL Boring B-901 Acoustic Televiewer Dips Sheet 32 of 36



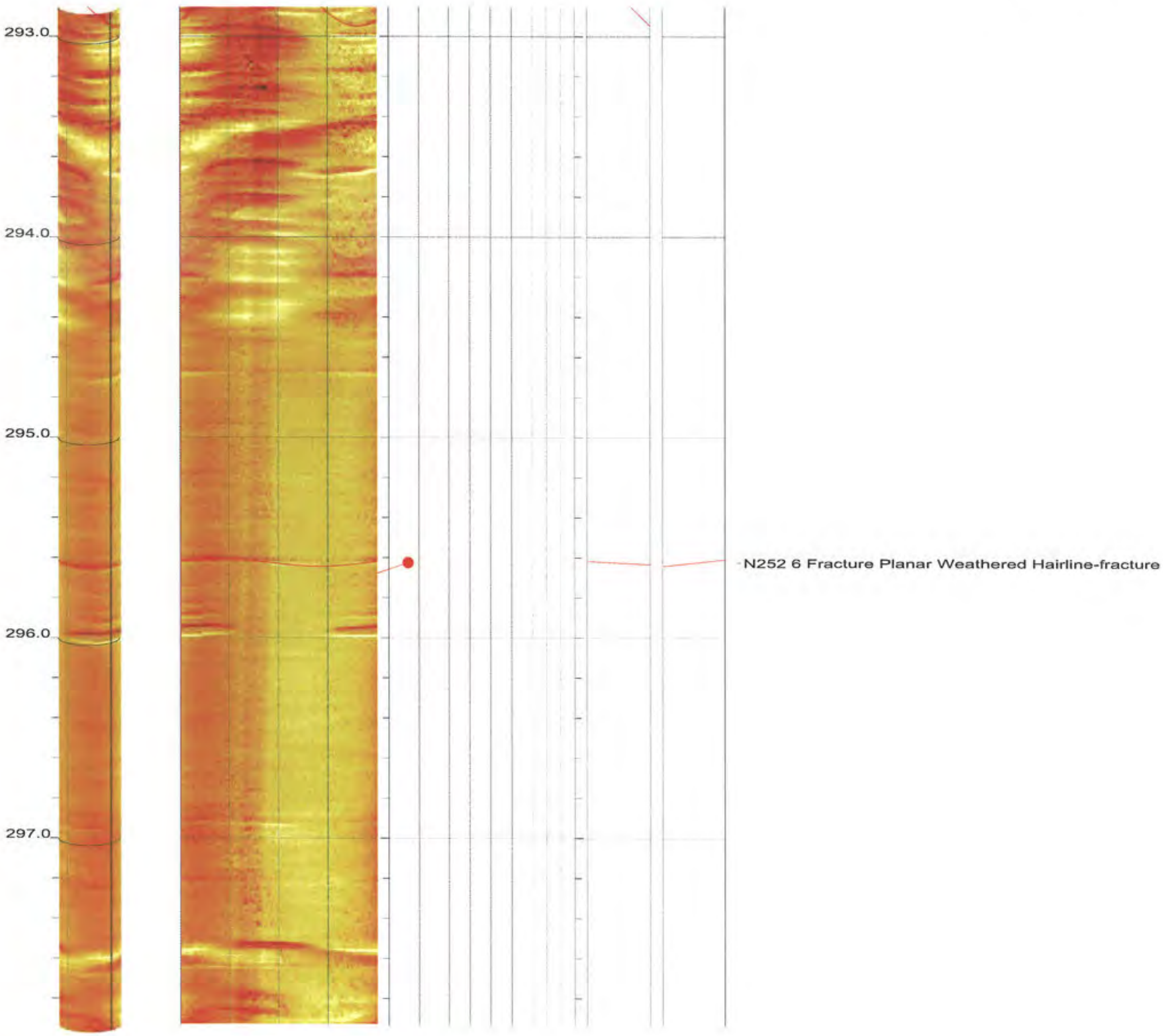
North Anna COL Boring B-901 Acoustic Televiewer Dips Sheet 33 of 36



North Anna COL Boring B-901 Acoustic Televiewer Dips Sheet 34 of 36



North Anna COL Boring B-901 Acoustic Televiewer Dips Sheet 35 of 36



North Anna COL Boring B-901 Acoustic Televiewer Dips Sheet 36 of 36

BHTV DATA PROCESSING
RGLDIP vsn 6.2
INTERPRETED BHTV DIPS LOG

24 Dec 2006

GEOVISION

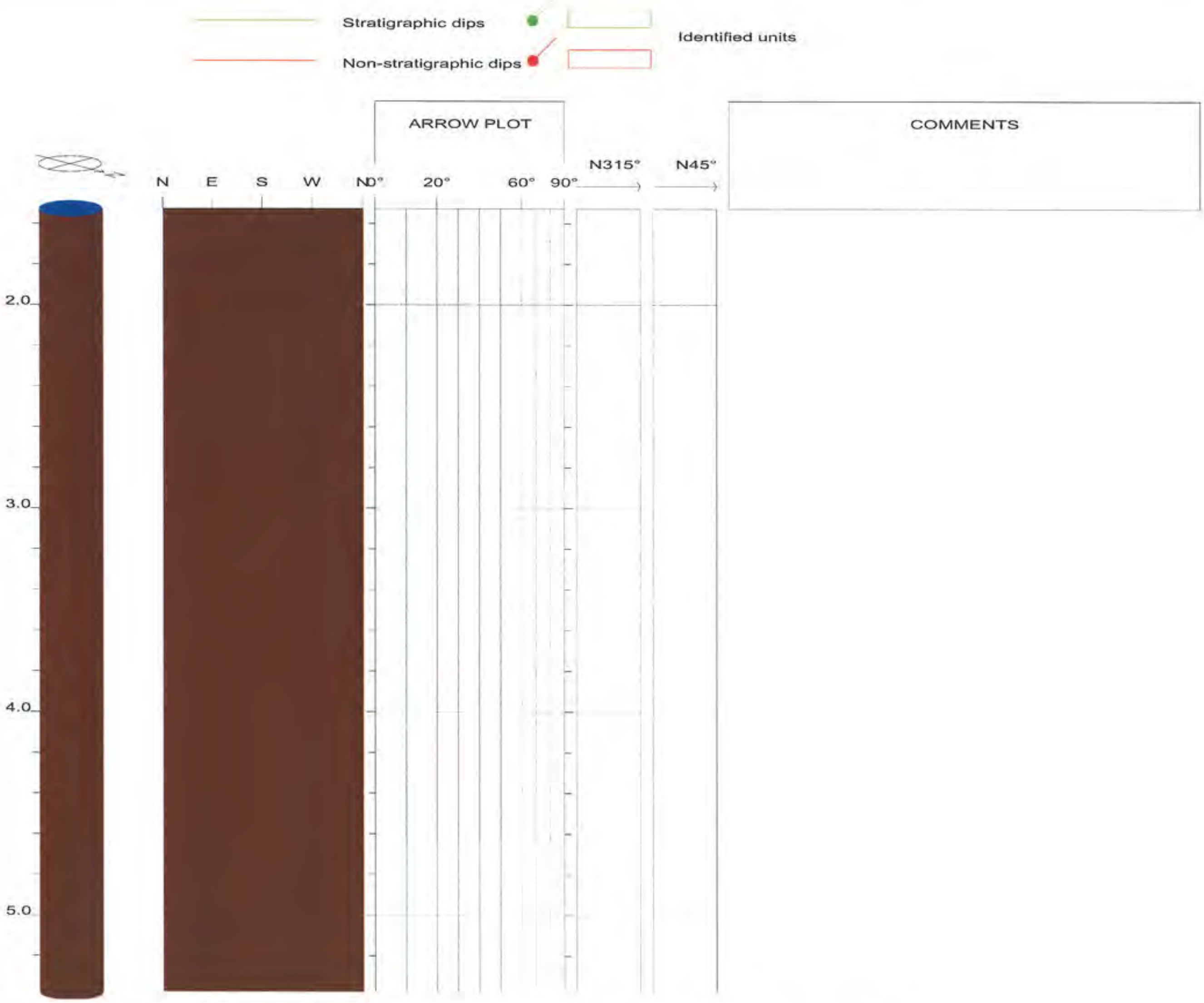
Borehole: B-907

top of borehole.....
East: _
North: _
Elev: _

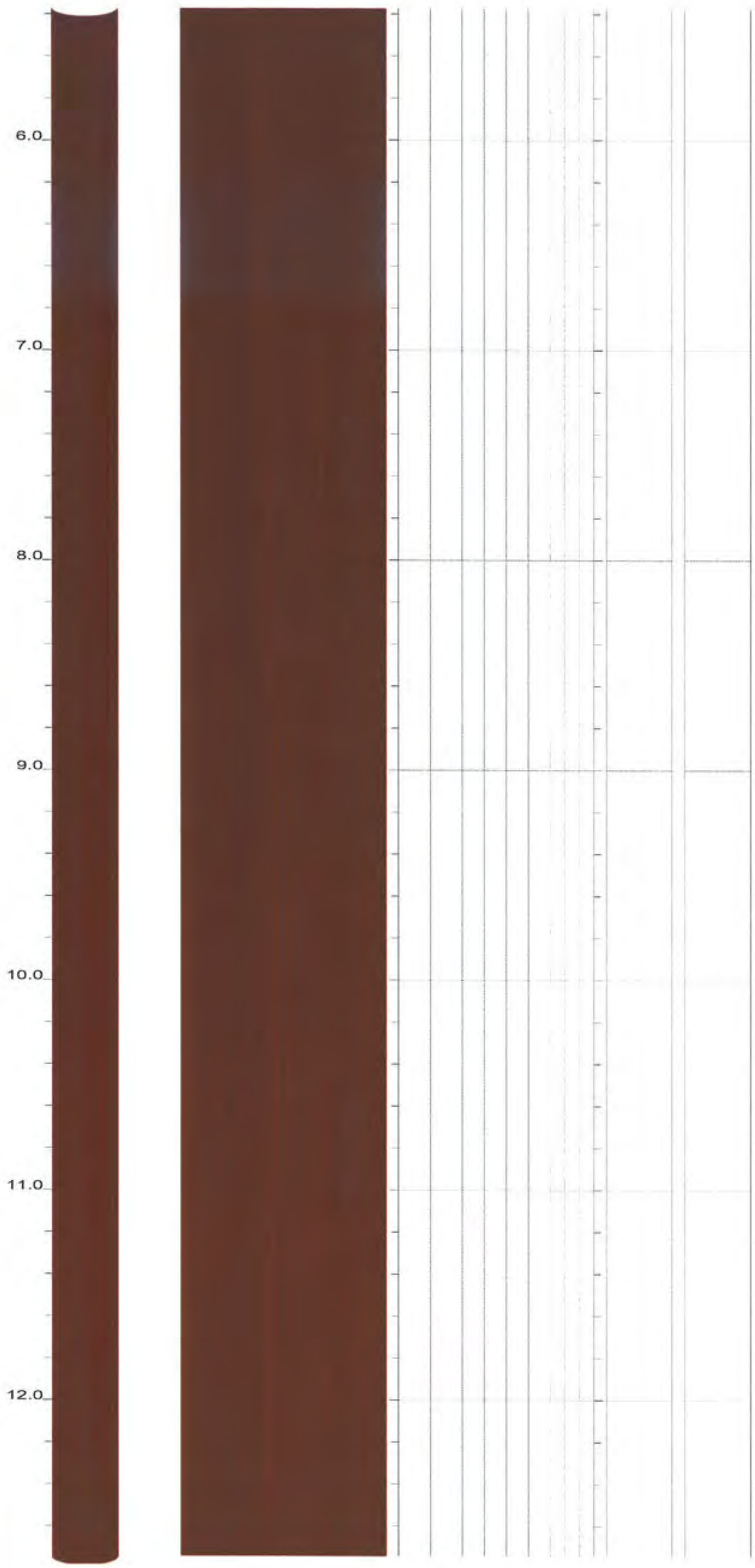
North ref. is true
Depth units are feet
Vertical scale: 1/10
Horiz scale = 1.00x Vert scale

Zone from 158.272 to 1.528ft
Format: BHTV-NESWN

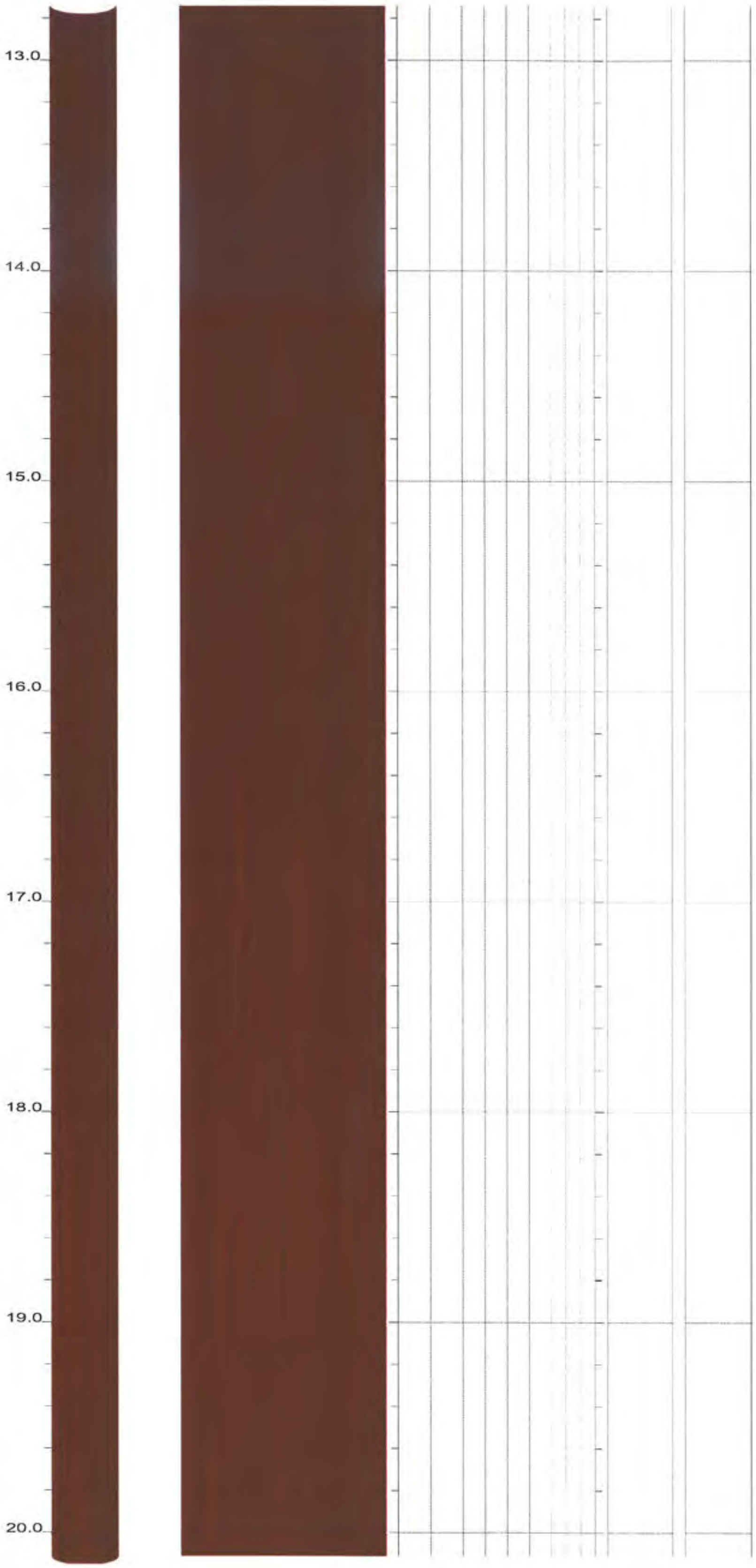
Borehole diam: 3.750inch
Vertical = borehole-axis
Image: Amplitude



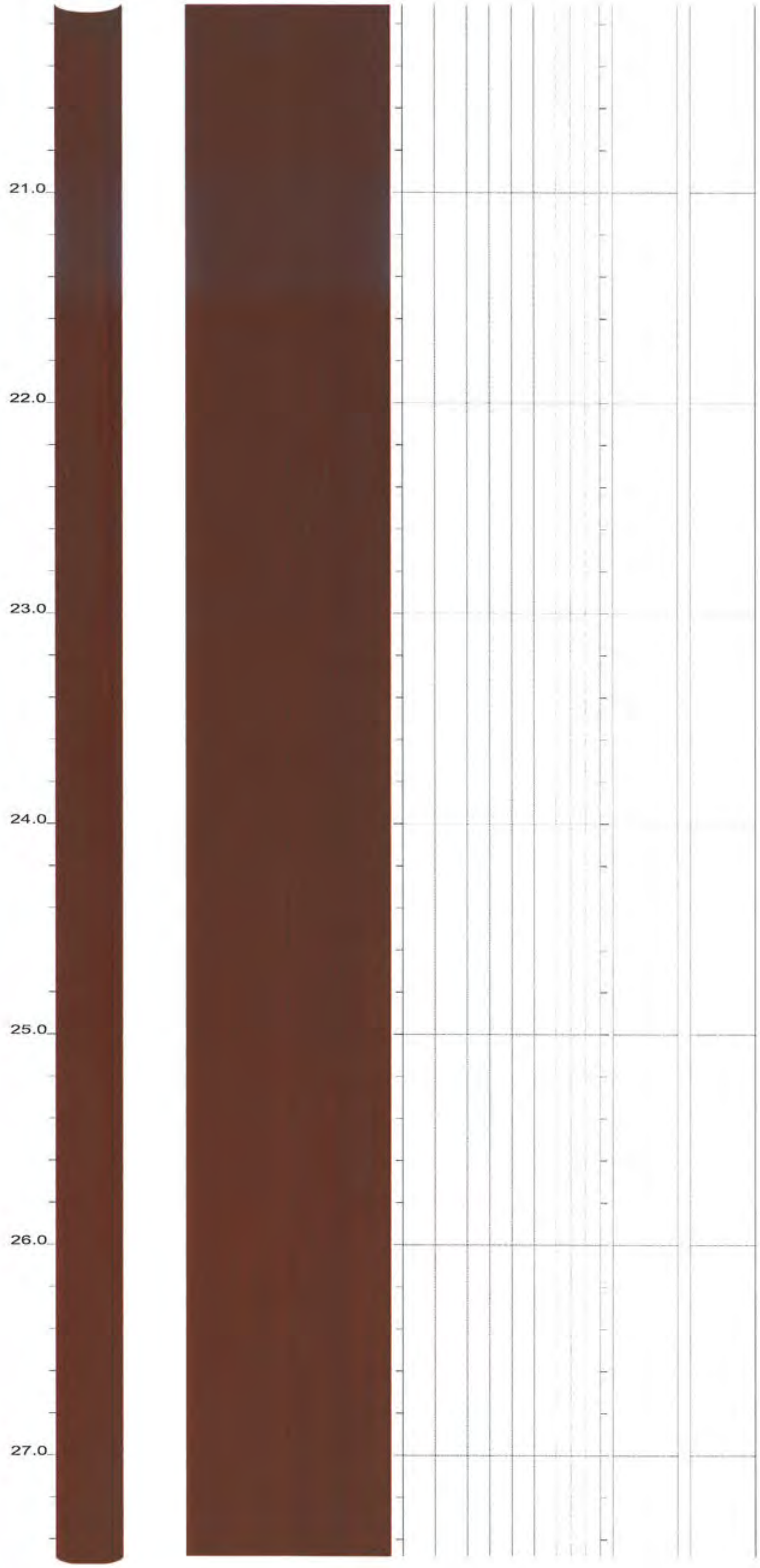
North Anna COL Boring B-907 Acoustic Televiewer Dips Sheet 1 of 22



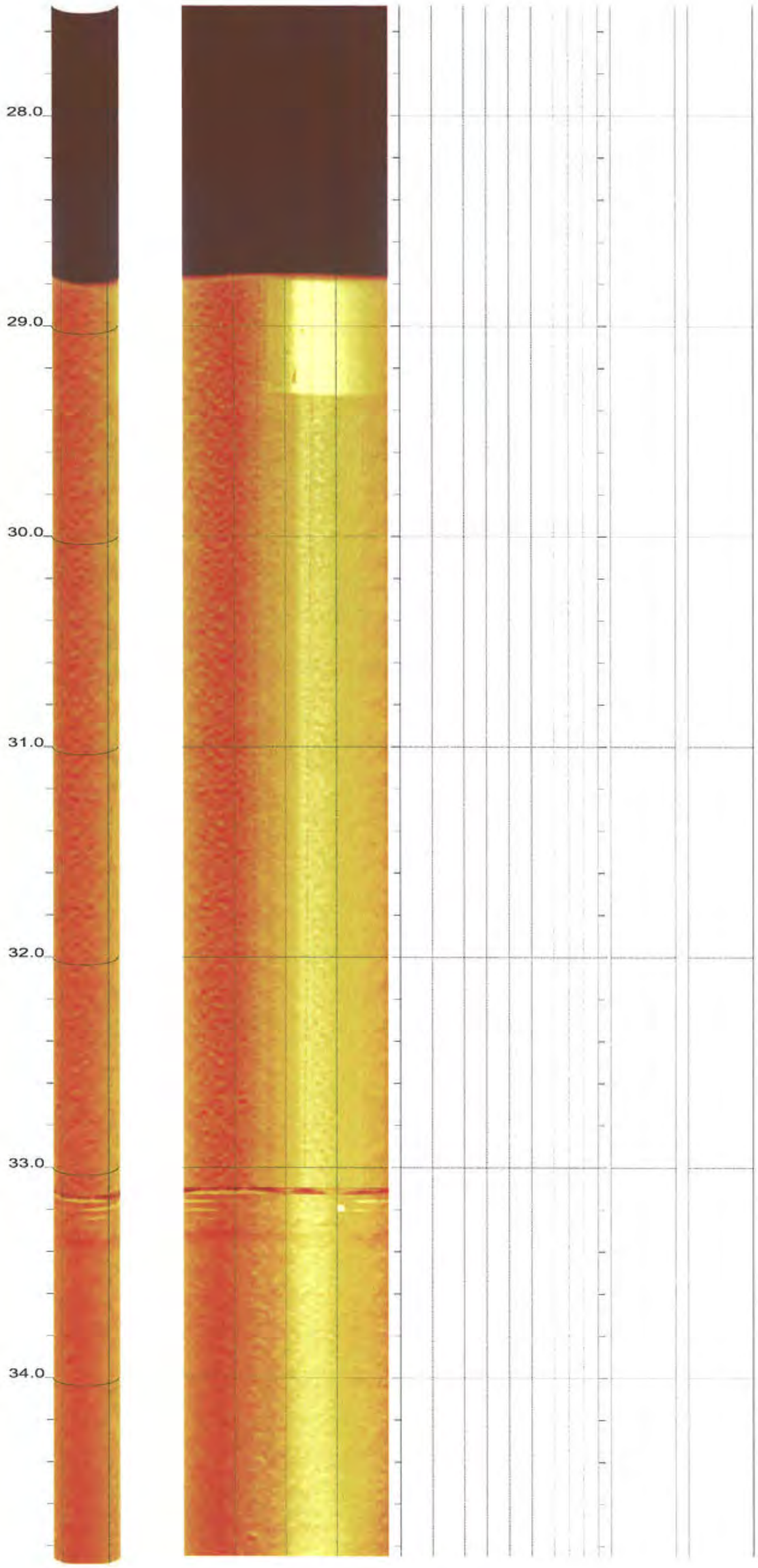
North Anna COL Boring B-907 Acoustic Televiewer Dips Sheet 2 of 22



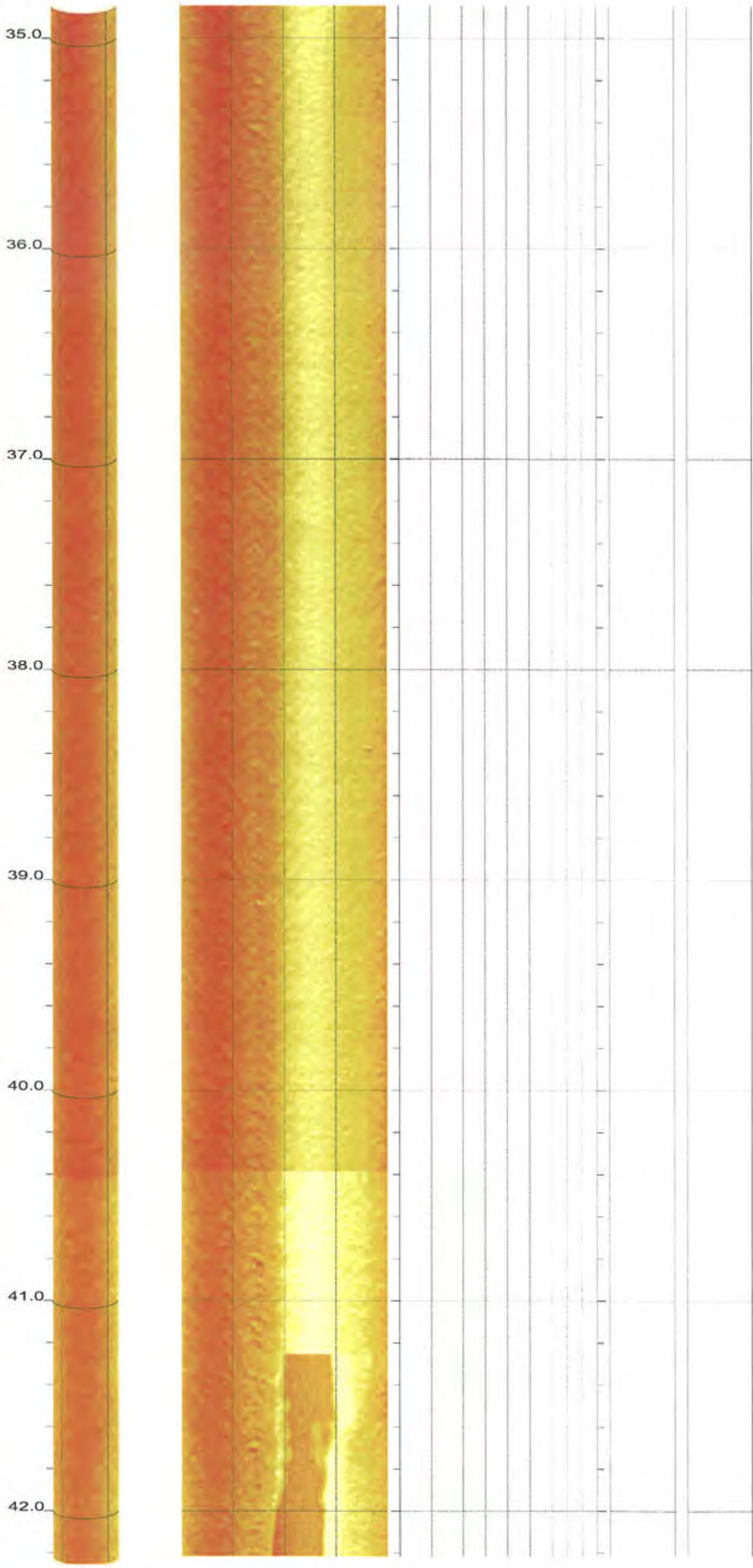
North Anna COL Boring B-907 Acoustic Televiewer Dips Sheet 3 of 22



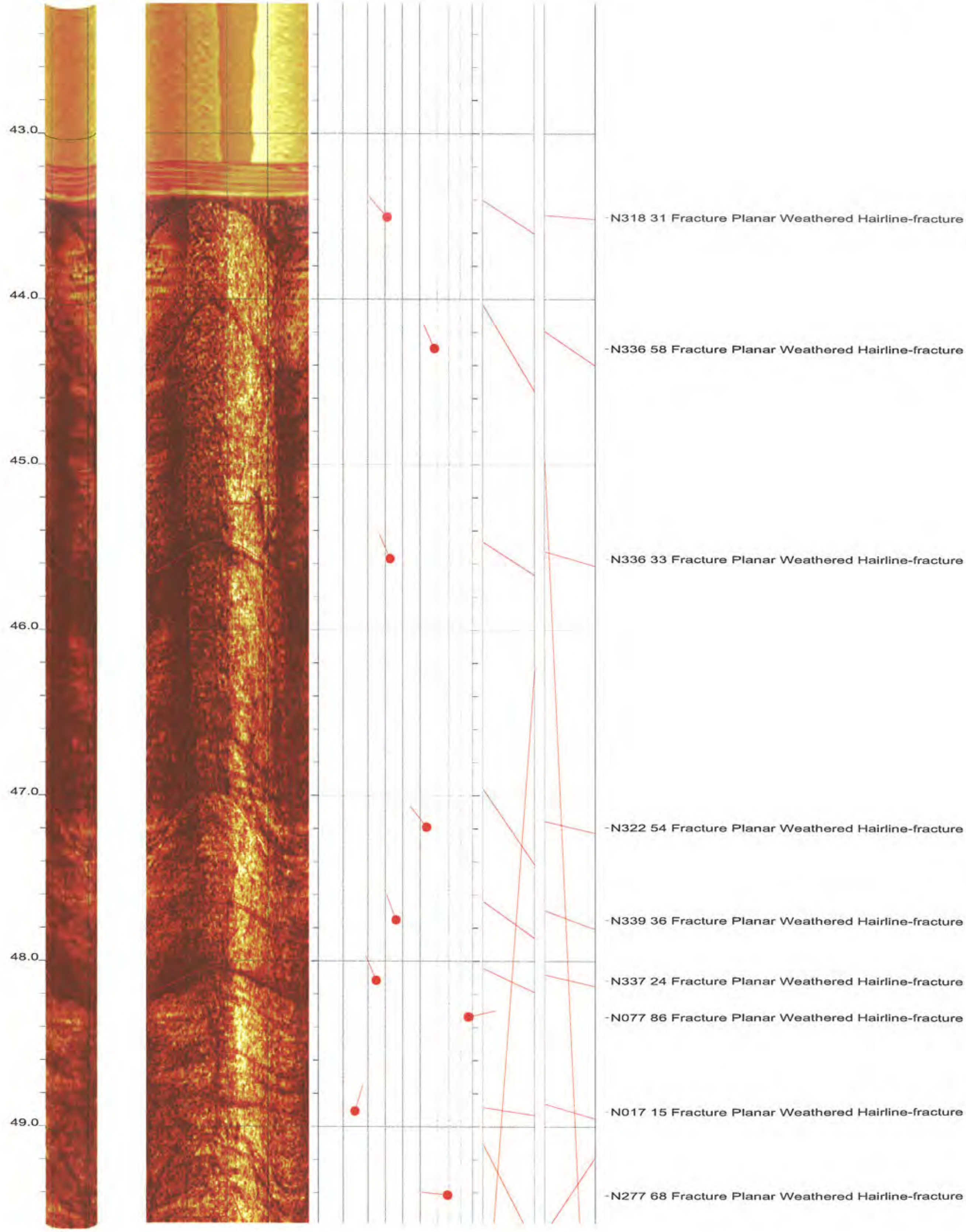
North Anna COL Boring B-907 Acoustic Televiewer Dips Sheet 4 of 22



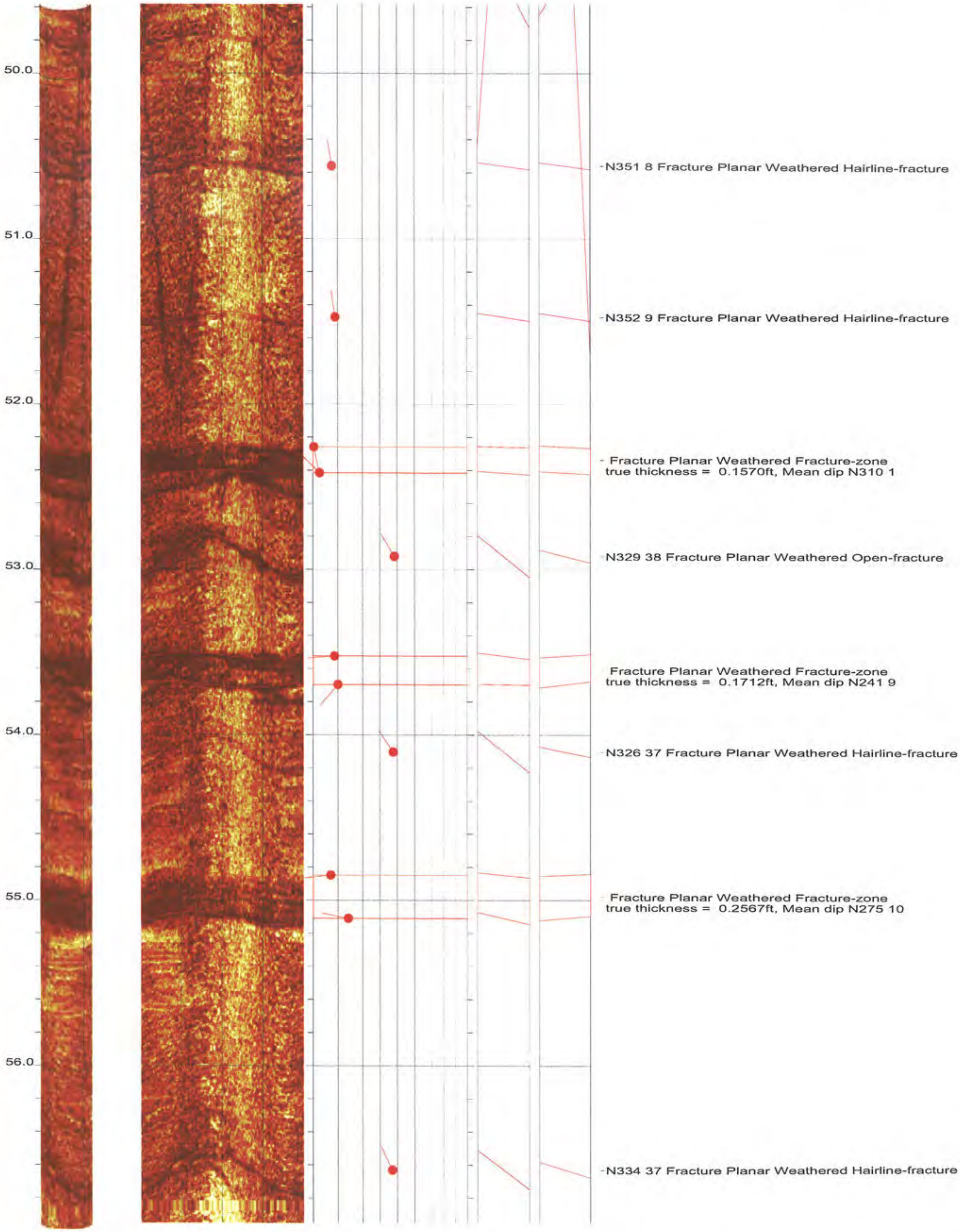
North Anna COL Boring B-907 Acoustic Televiewer Dips Sheet 5 of 22



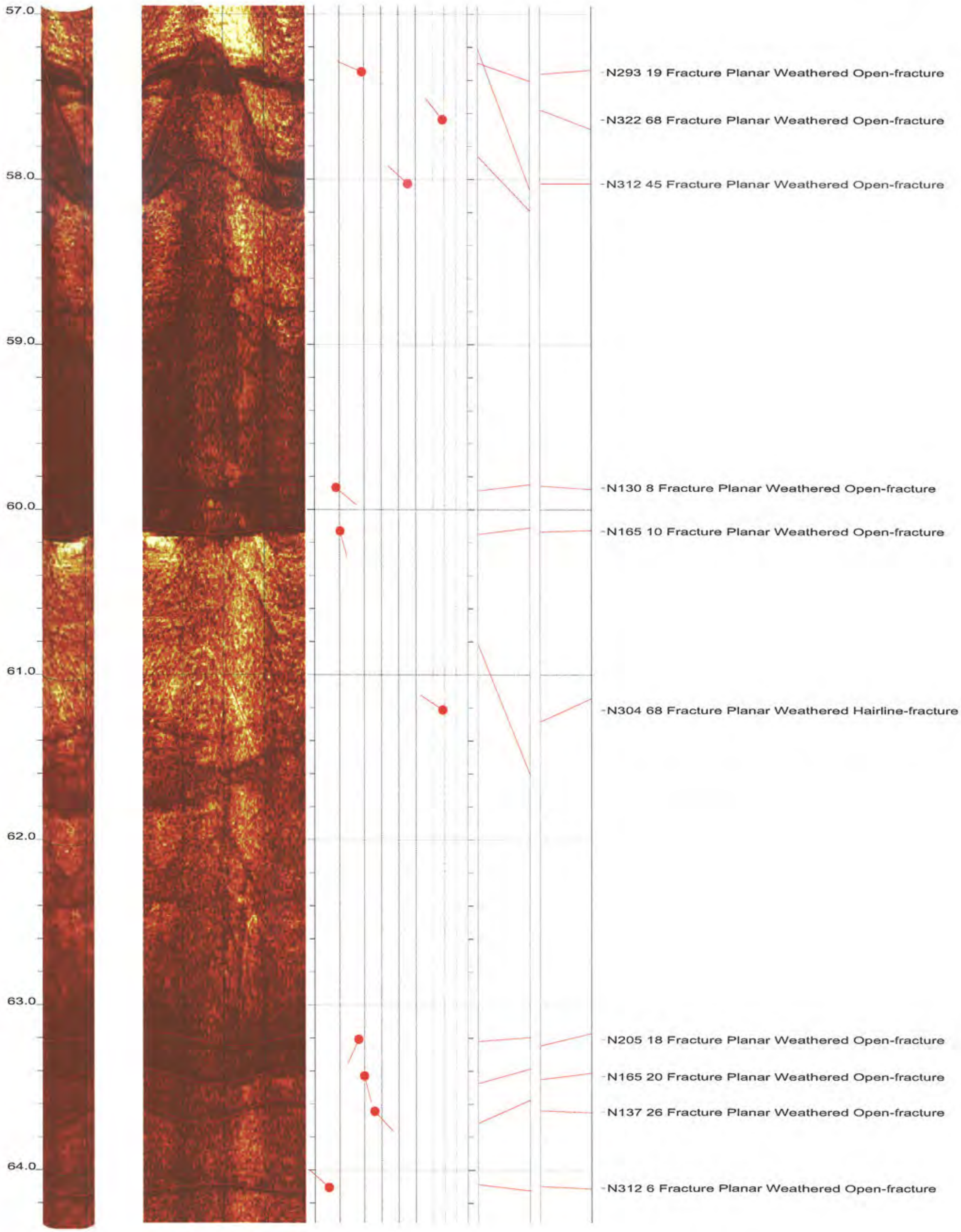
North Anna COL Boring B-907 Acoustic Televiewer Dips Sheet 6 of 22



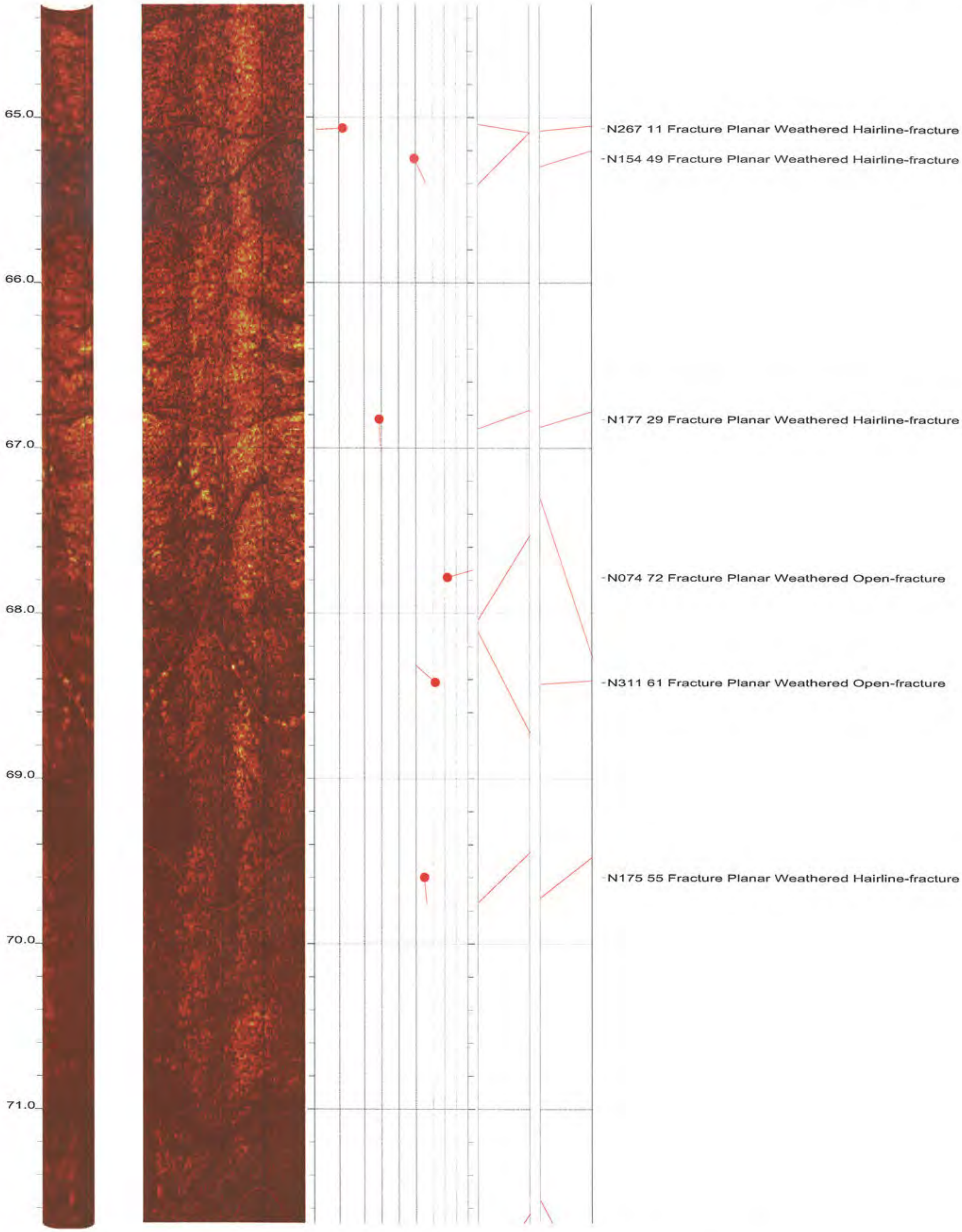
North Anna COL Boring B-907 Acoustic Televiewer Dips Sheet 7 of 22



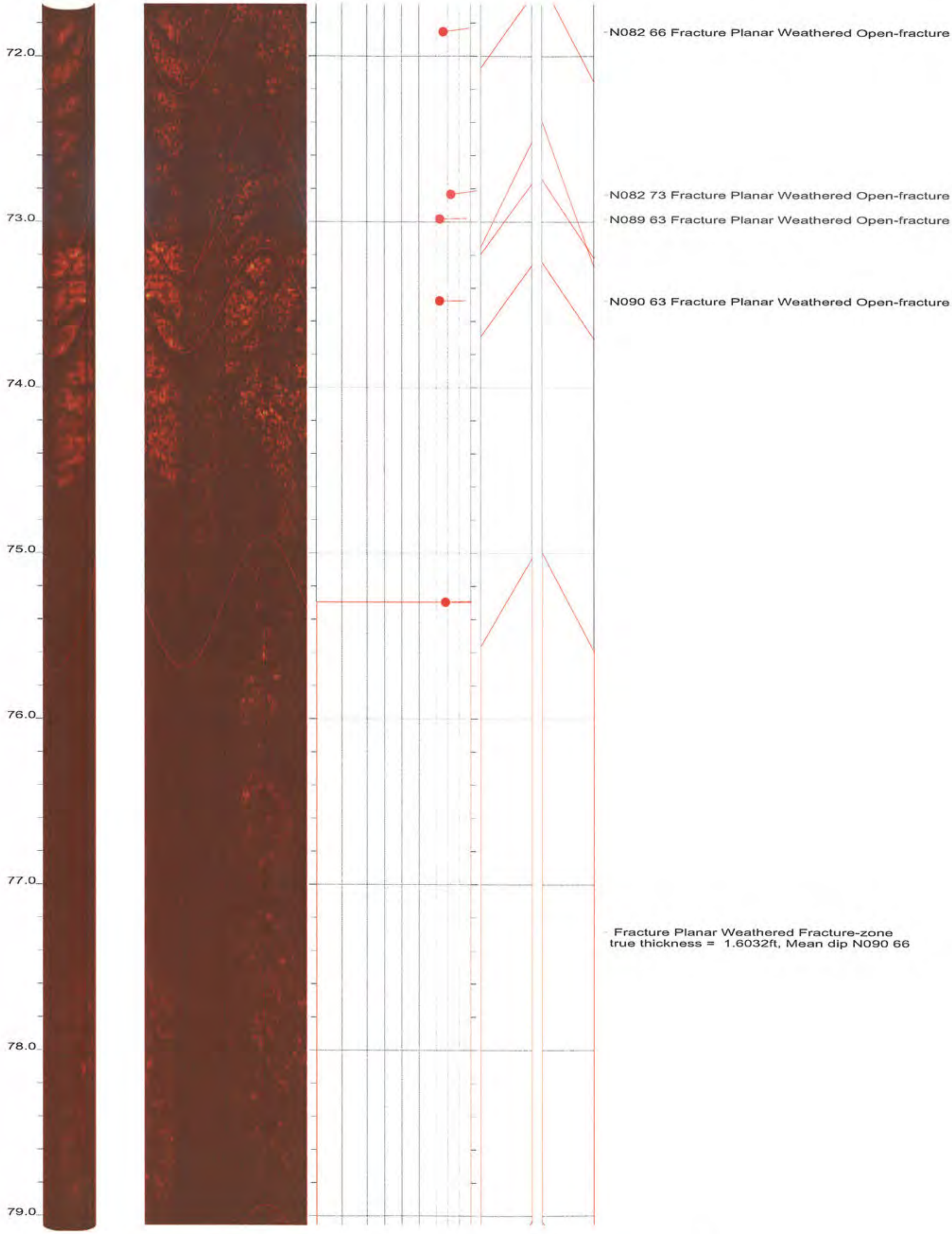
North Anna COL Boring B-907 Acoustic Televiewer Dips Sheet 8 of 22



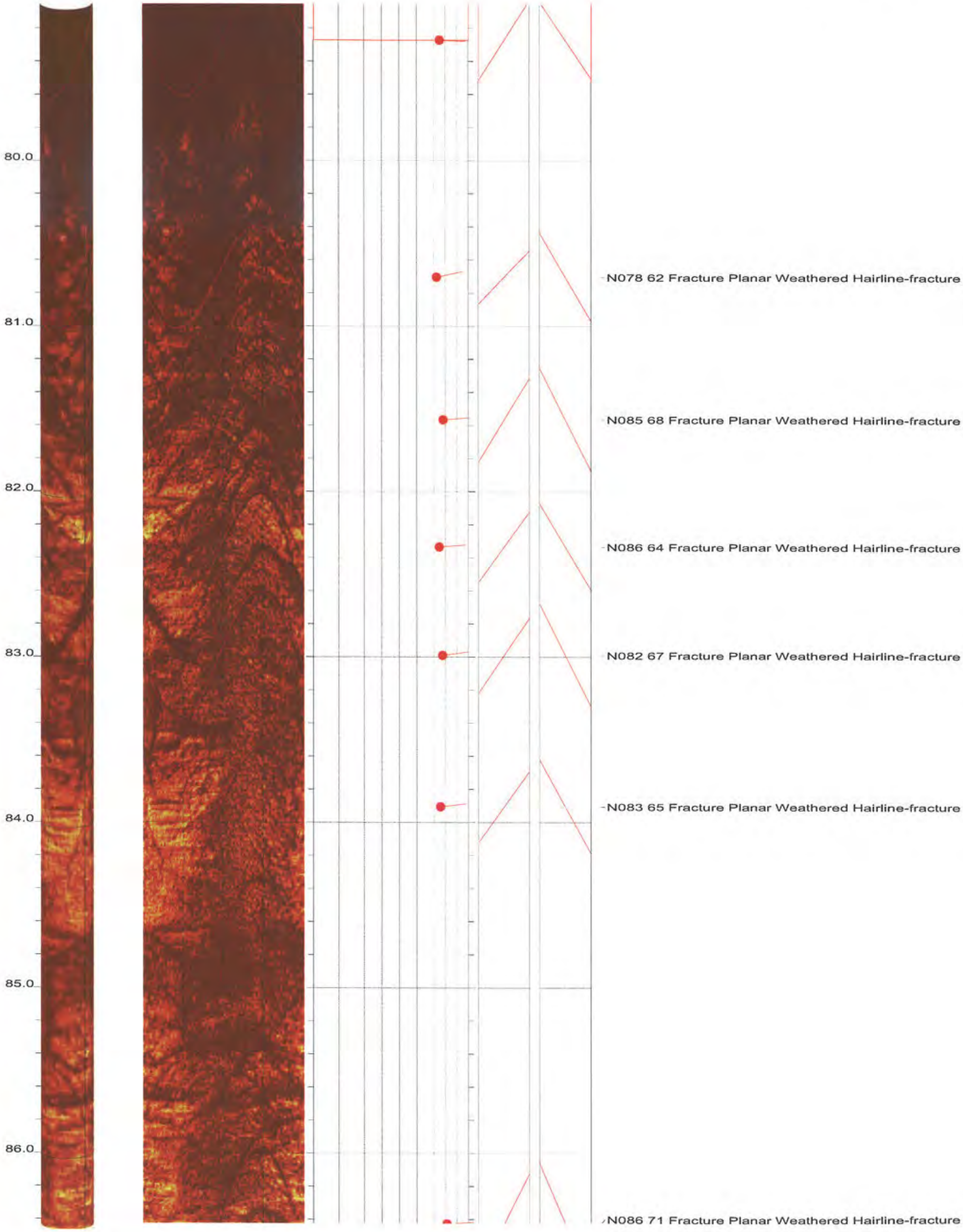
North Anna COL Boring B-907 Acoustic Televiewer Dips Sheet 9 of 22



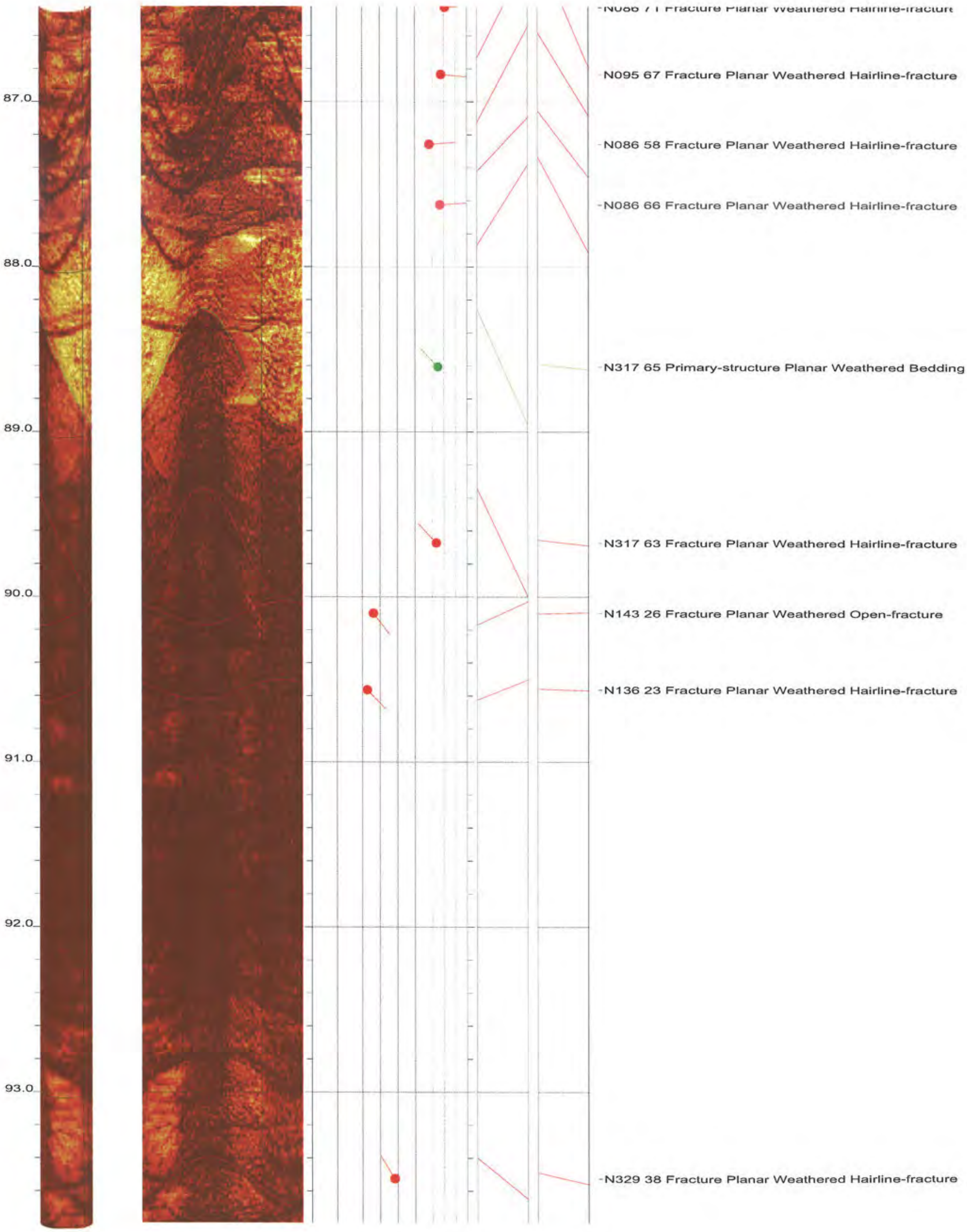
North Anna COL Boring B-907 Acoustic Televiewer Dips Sheet 10 of 22



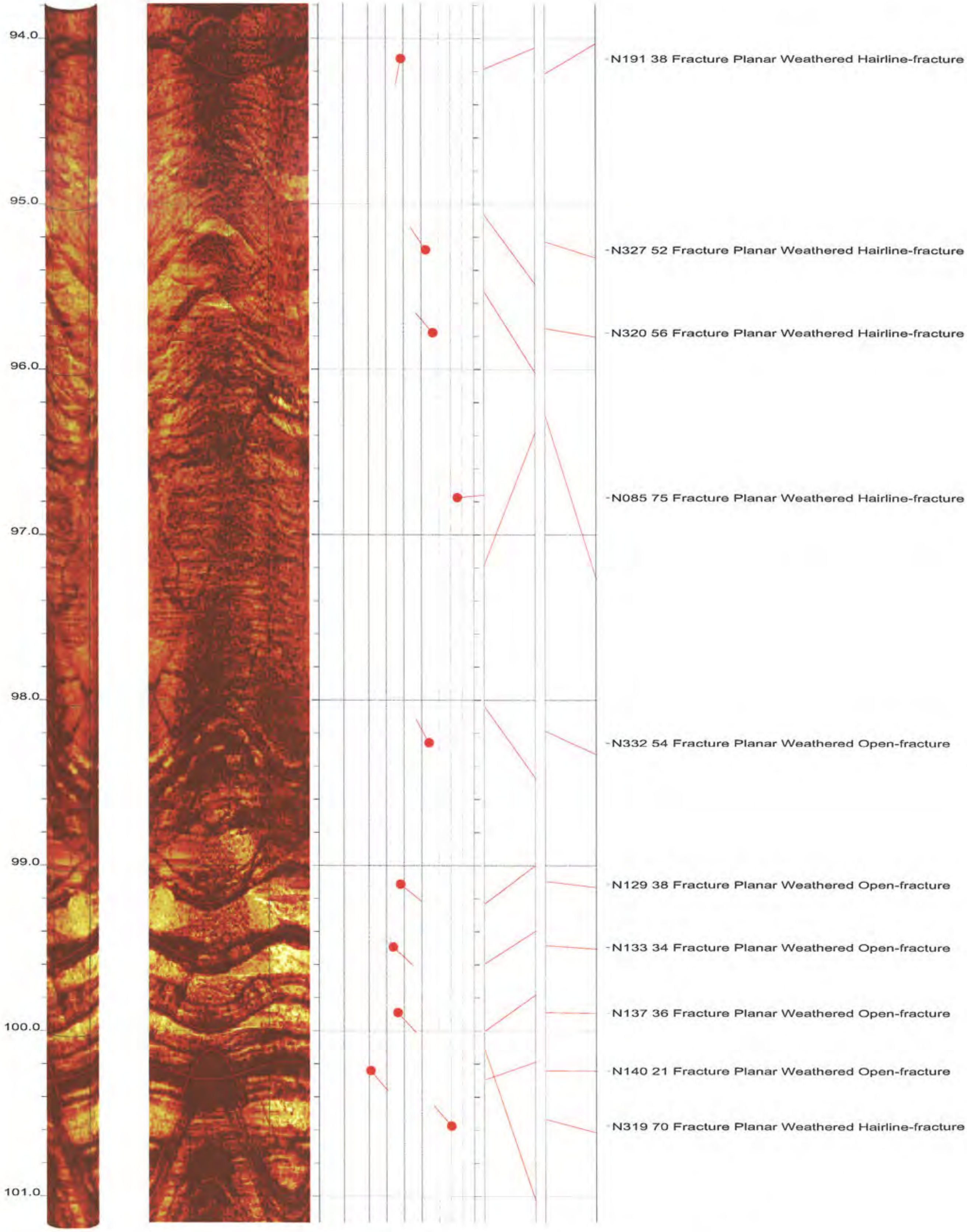
North Anna COL Boring B-907 Acoustic Televiewer Dips Sheet 11 of 22



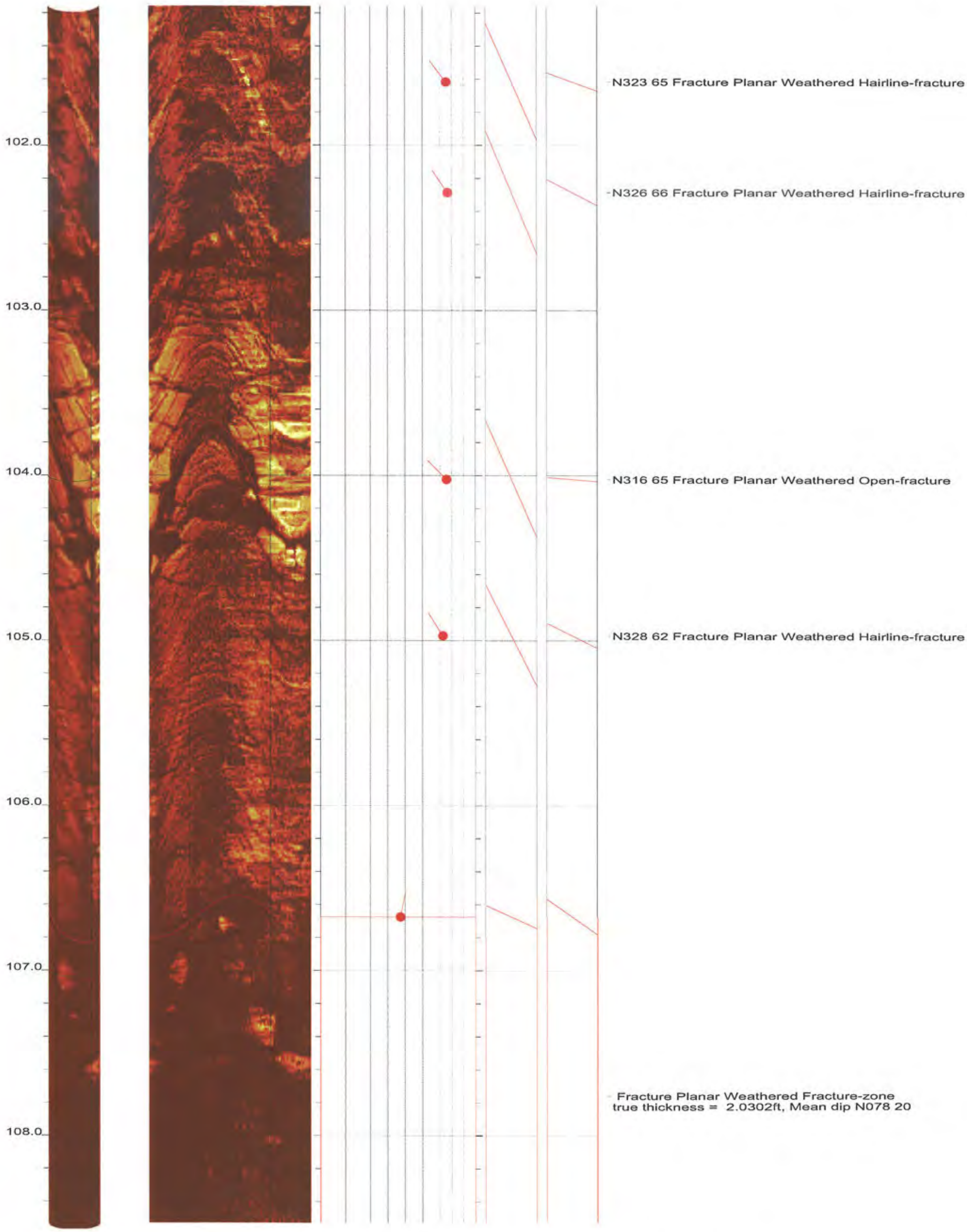
North Anna COL Boring B-907 Acoustic Televiewer Dips Sheet 12 of 22



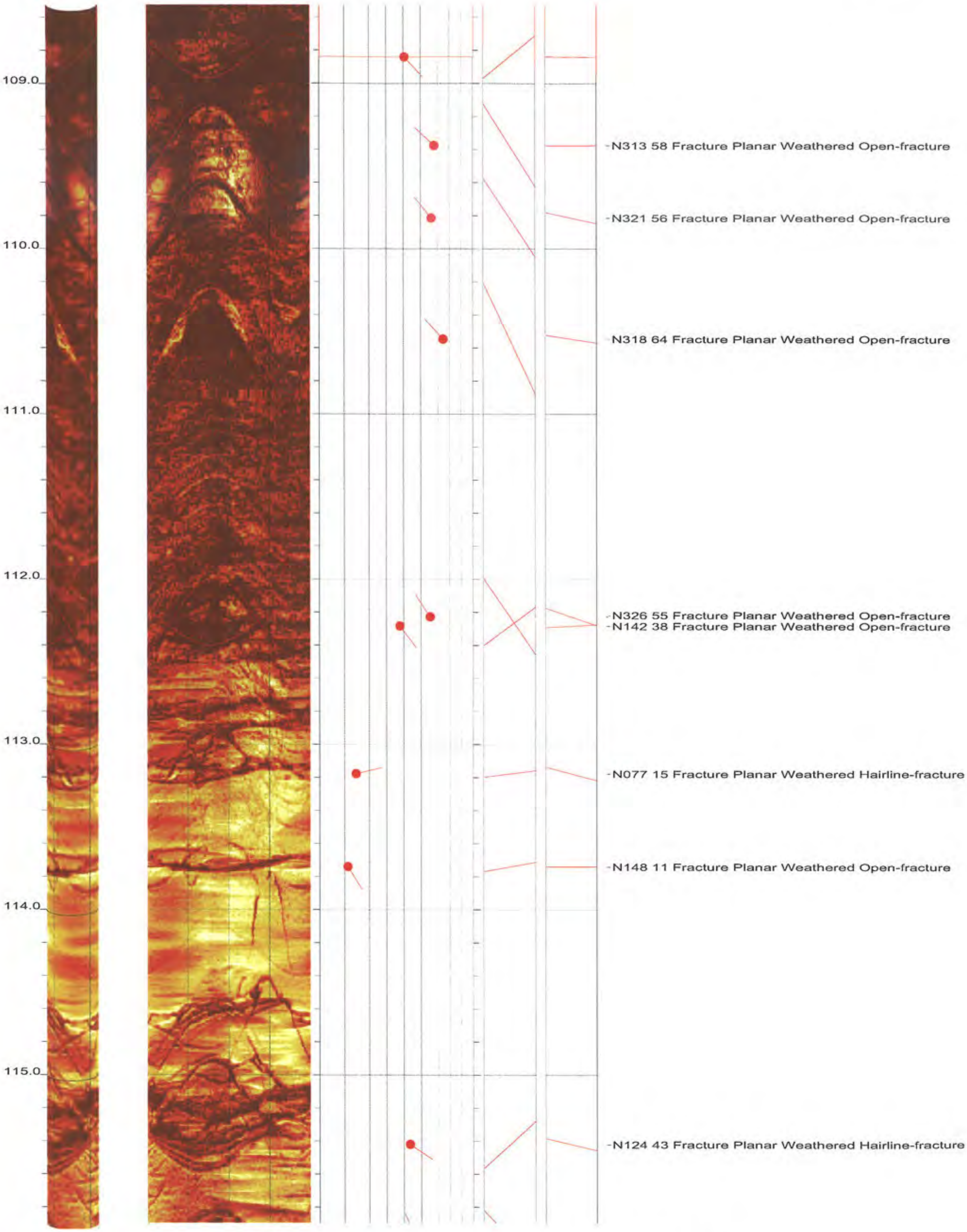
North Anna COL Boring B-907 Acoustic Televiewer Dips Sheet 13 of 22



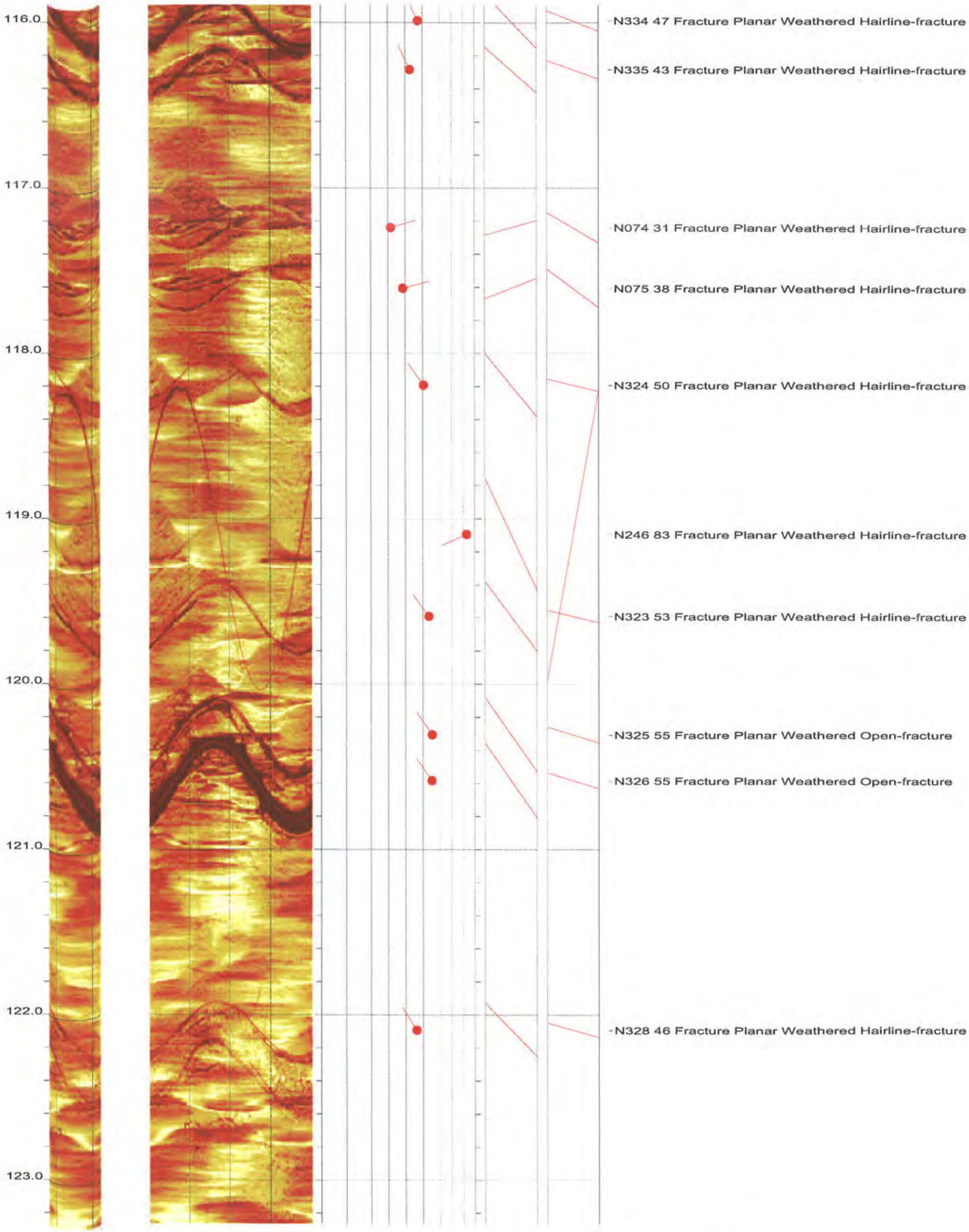
North Anna COL Boring B-907 Acoustic Televiewer Dips Sheet 14 of 22



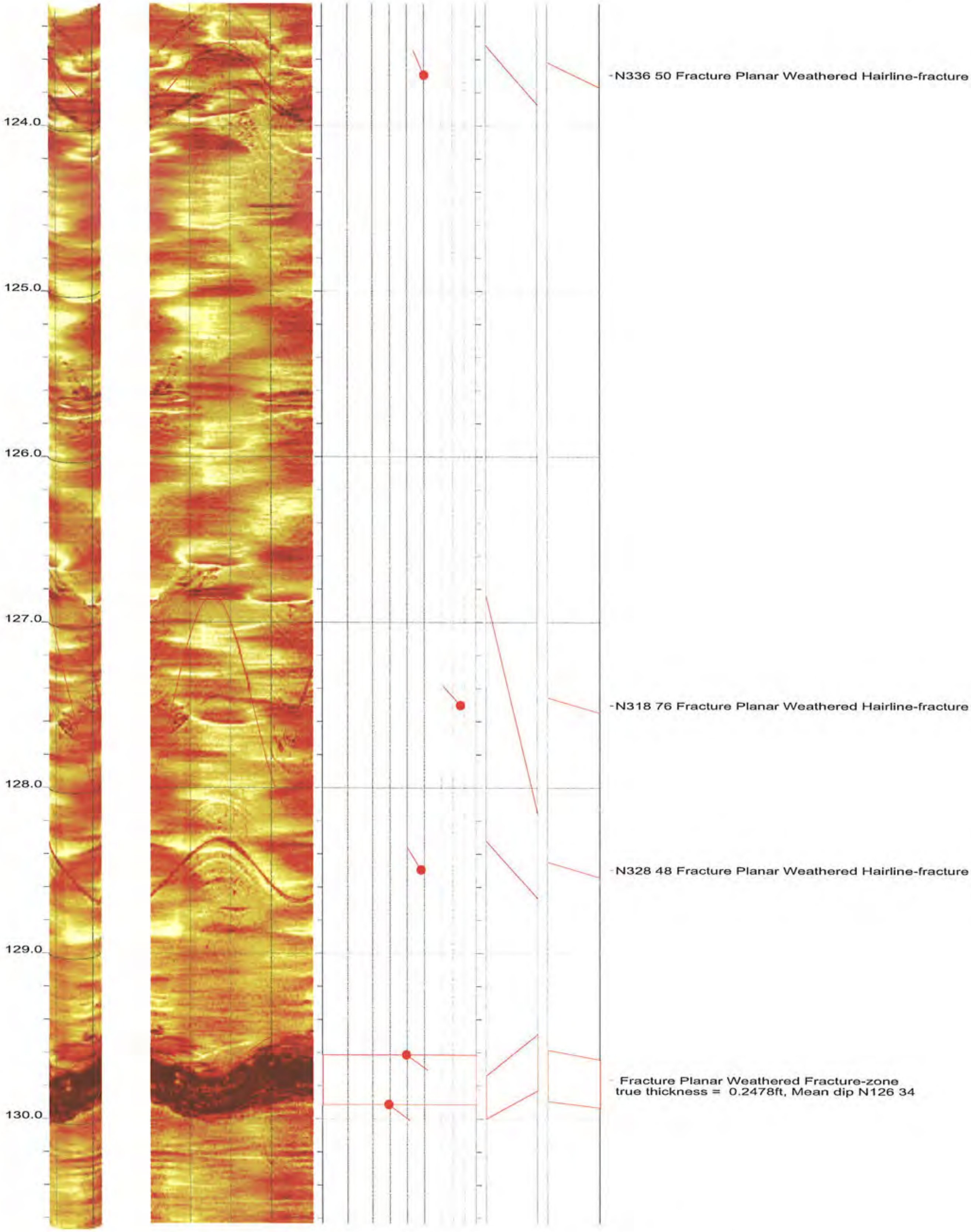
North Anna COL Boring B-907 Acoustic Televiewer Dips Sheet 15 of 22



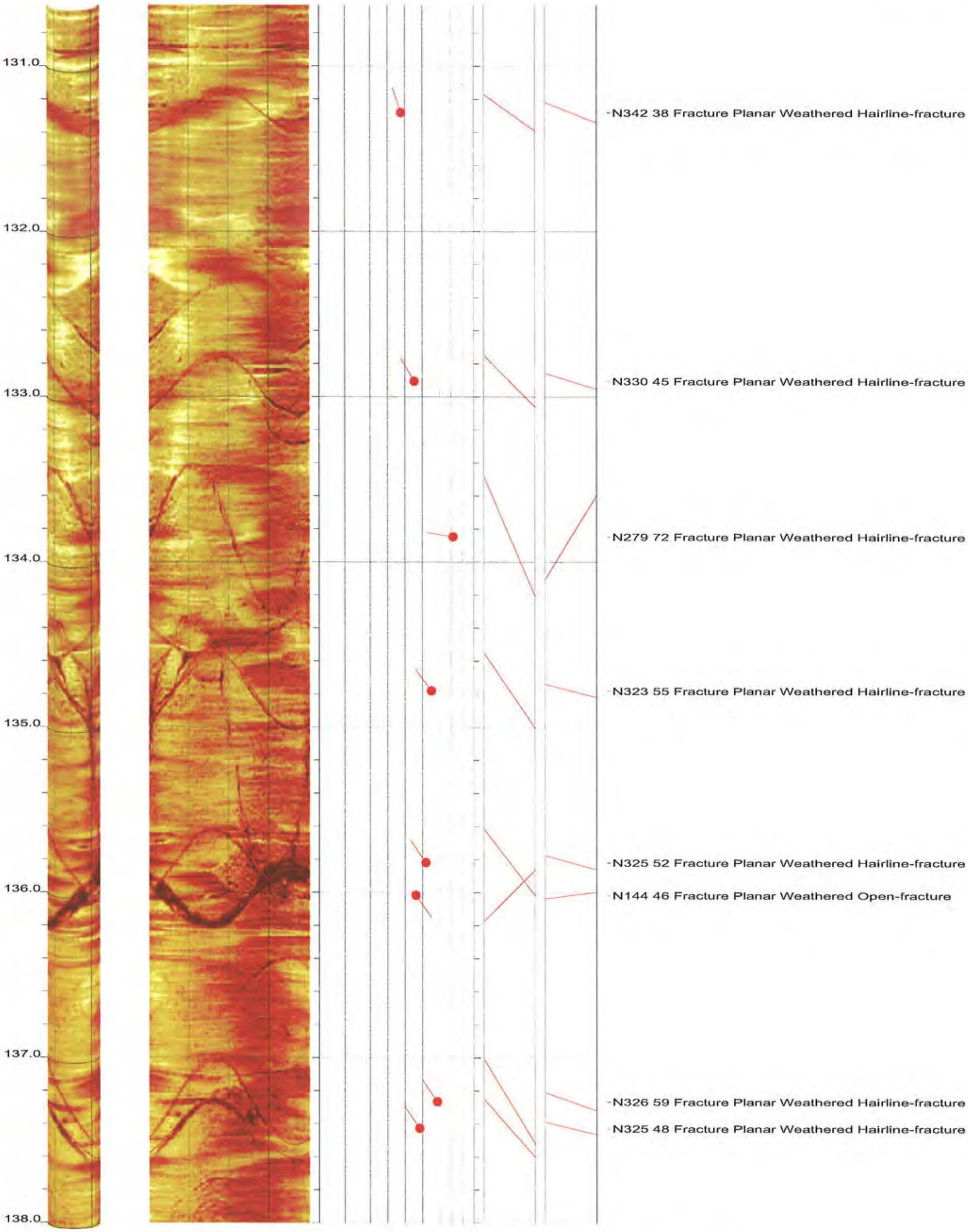
North Anna COL Boring B-907 Acoustic Televiewer Dips Sheet 16 of 22



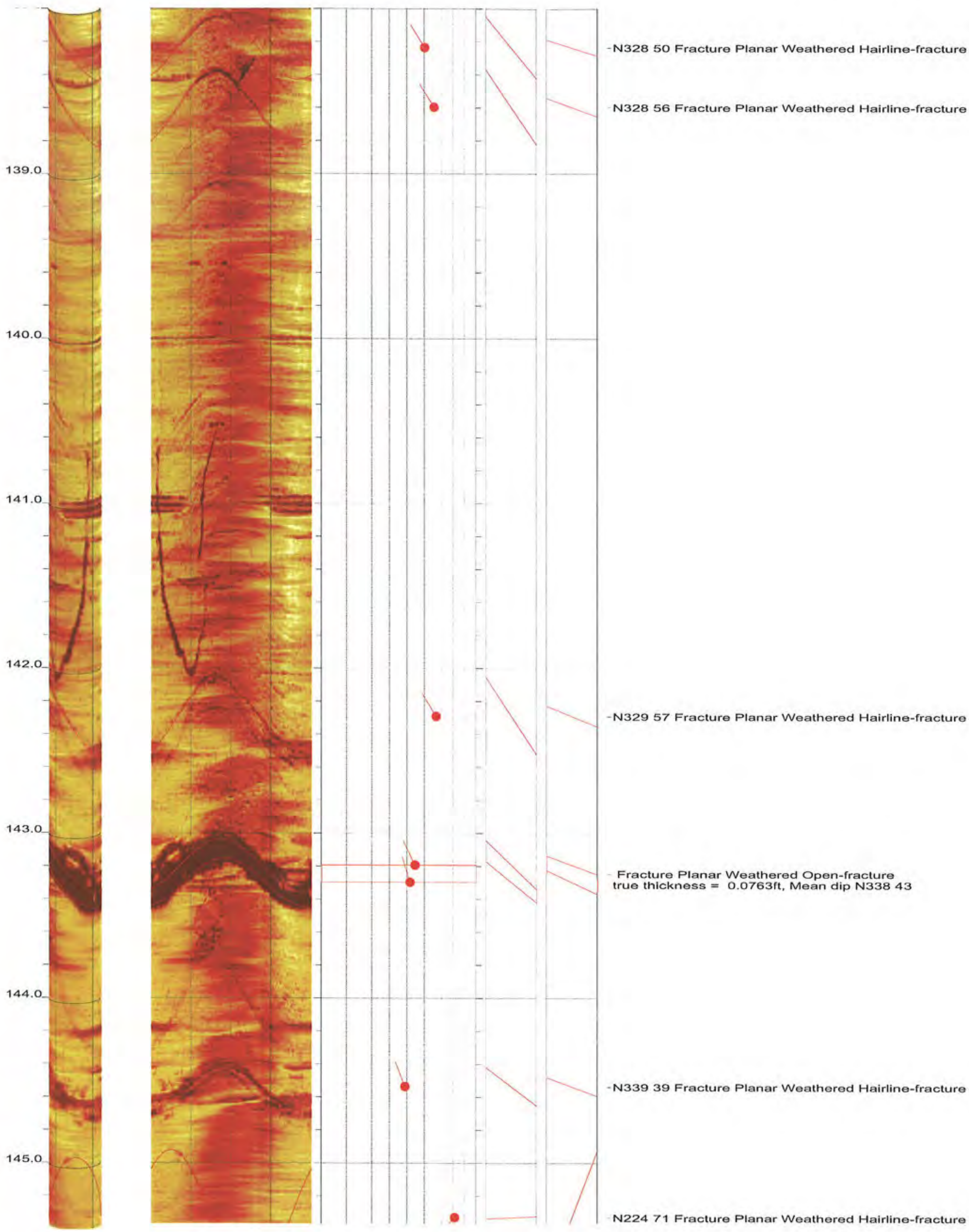
North Anna COL Boring B-907 Acoustic Televiewer Dips Sheet 17 of 22



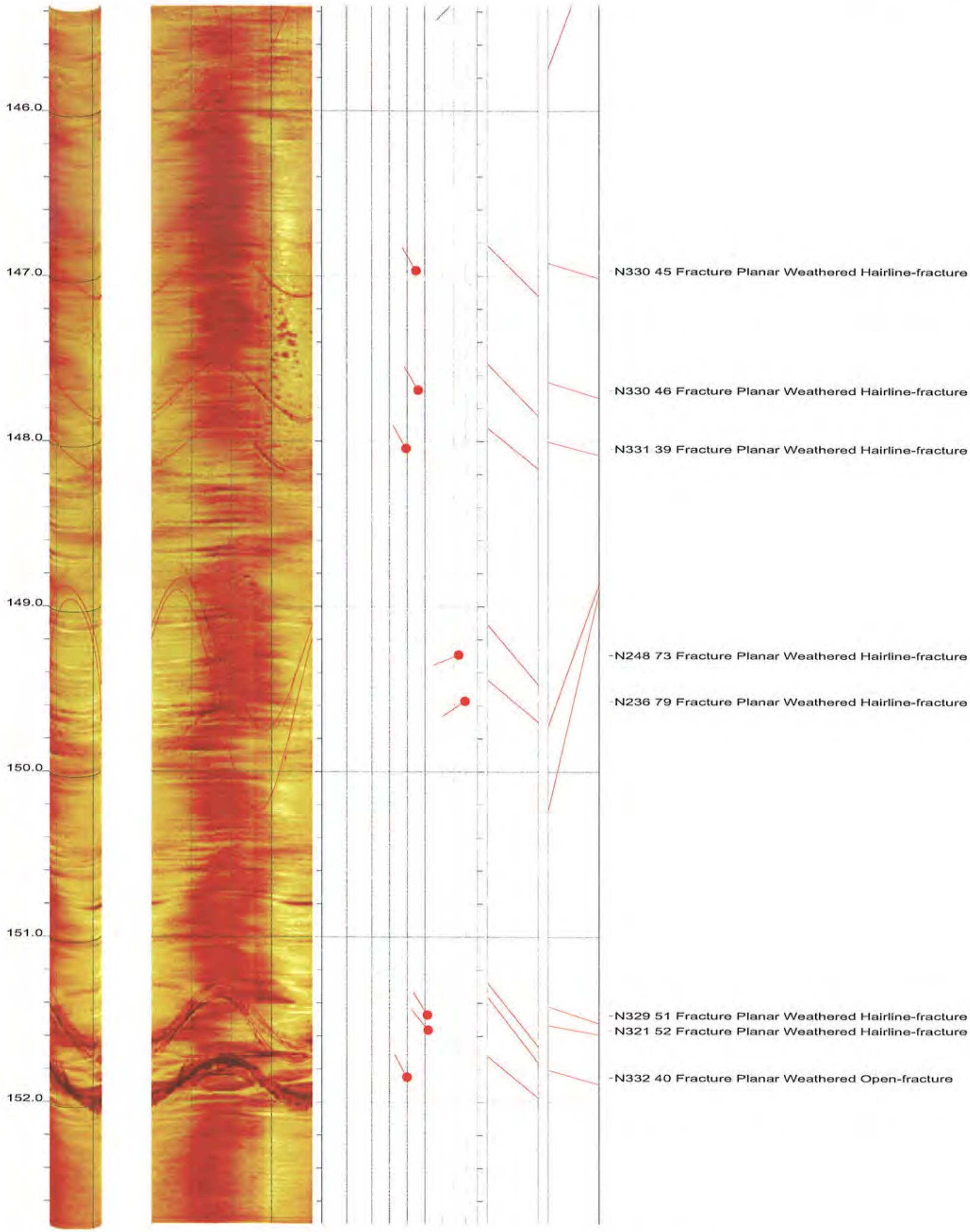
North Anna COL Boring B-907 Acoustic Televiewer Dips Sheet 18 of 22



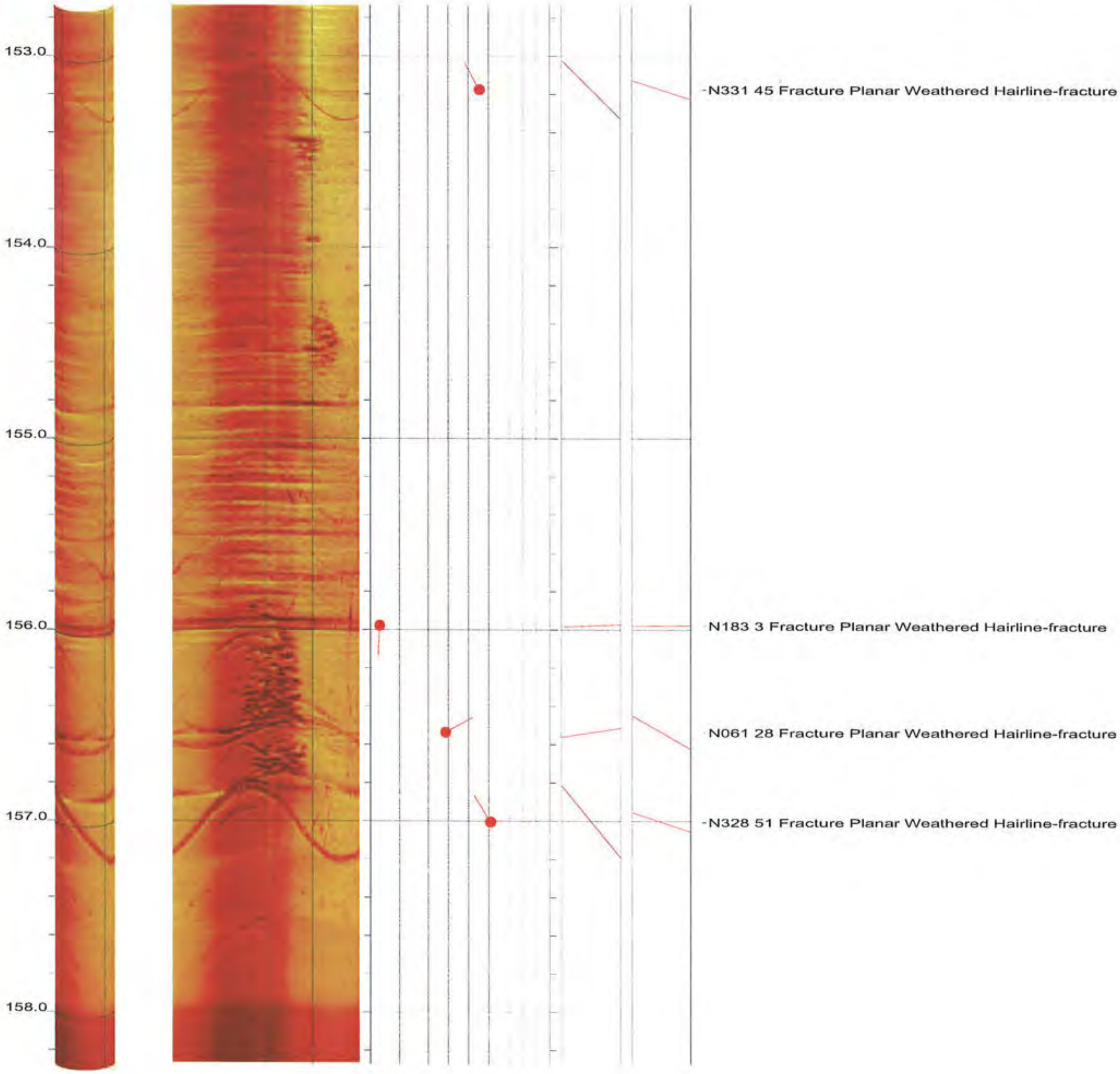
North Anna COL Boring B-907 Acoustic Televiewer Dips Sheet 19 of 22



North Anna COL Boring B-907 Acoustic Televiewer Dips Sheet 20 of 22



North Anna COL Boring B-907 Acoustic Televiewer Dips Sheet 21 of 22



North Anna COL Boring B-907 Acoustic Televiewer Dips Sheet 22 of 22

BHTV DATA PROCESSING
RGLDIP vsn 6.2
INTERPRETED BHTV DIPS LOG

22 Dec 2006

GEOVISION

Borehole: B-909

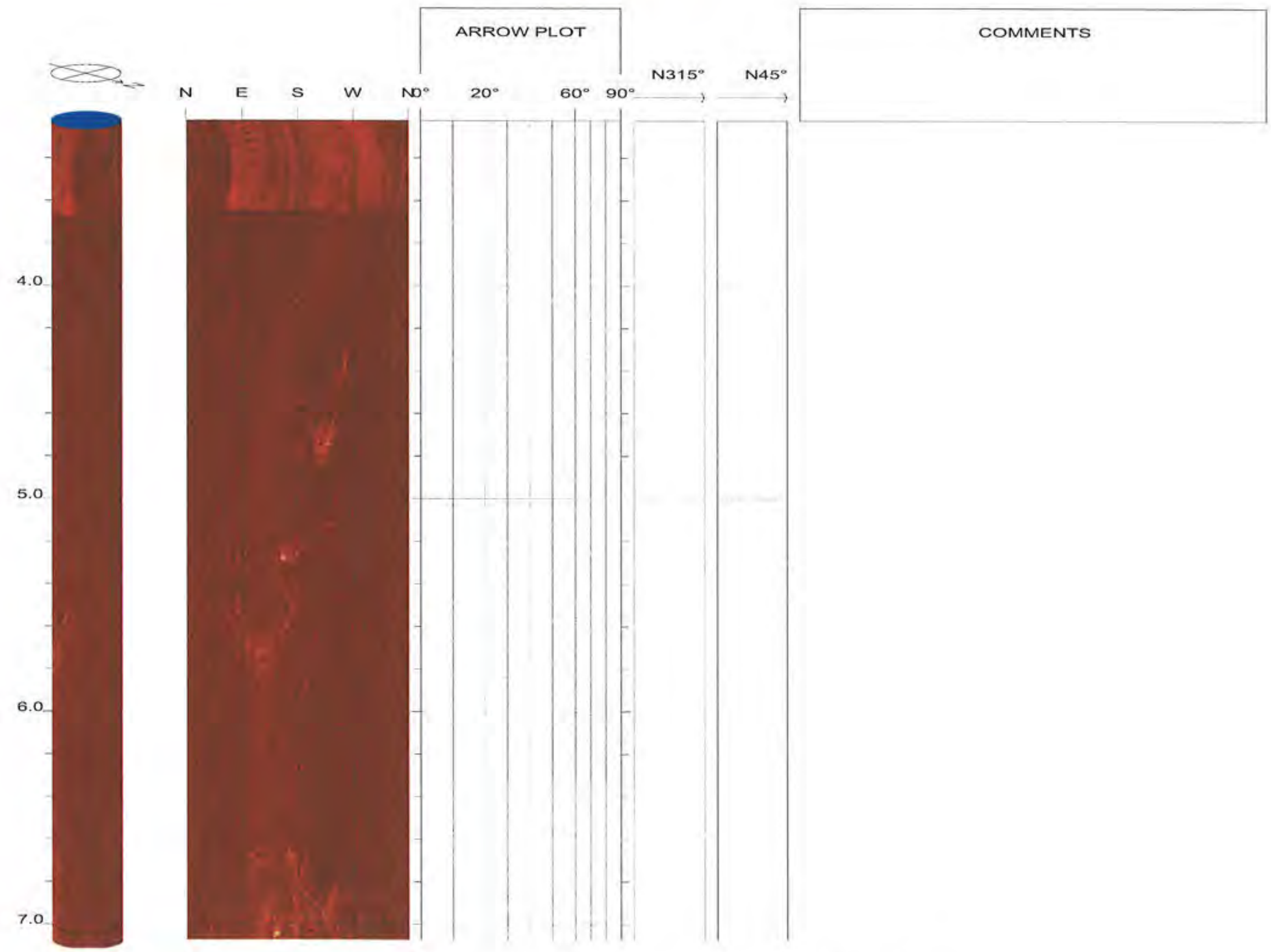
top of borehole.....
East: _
North: _
Elev: _

North ref. is true
Depth units are feet
Vertical scale: 1/10
Horiz scale = 1.00x Vert scale

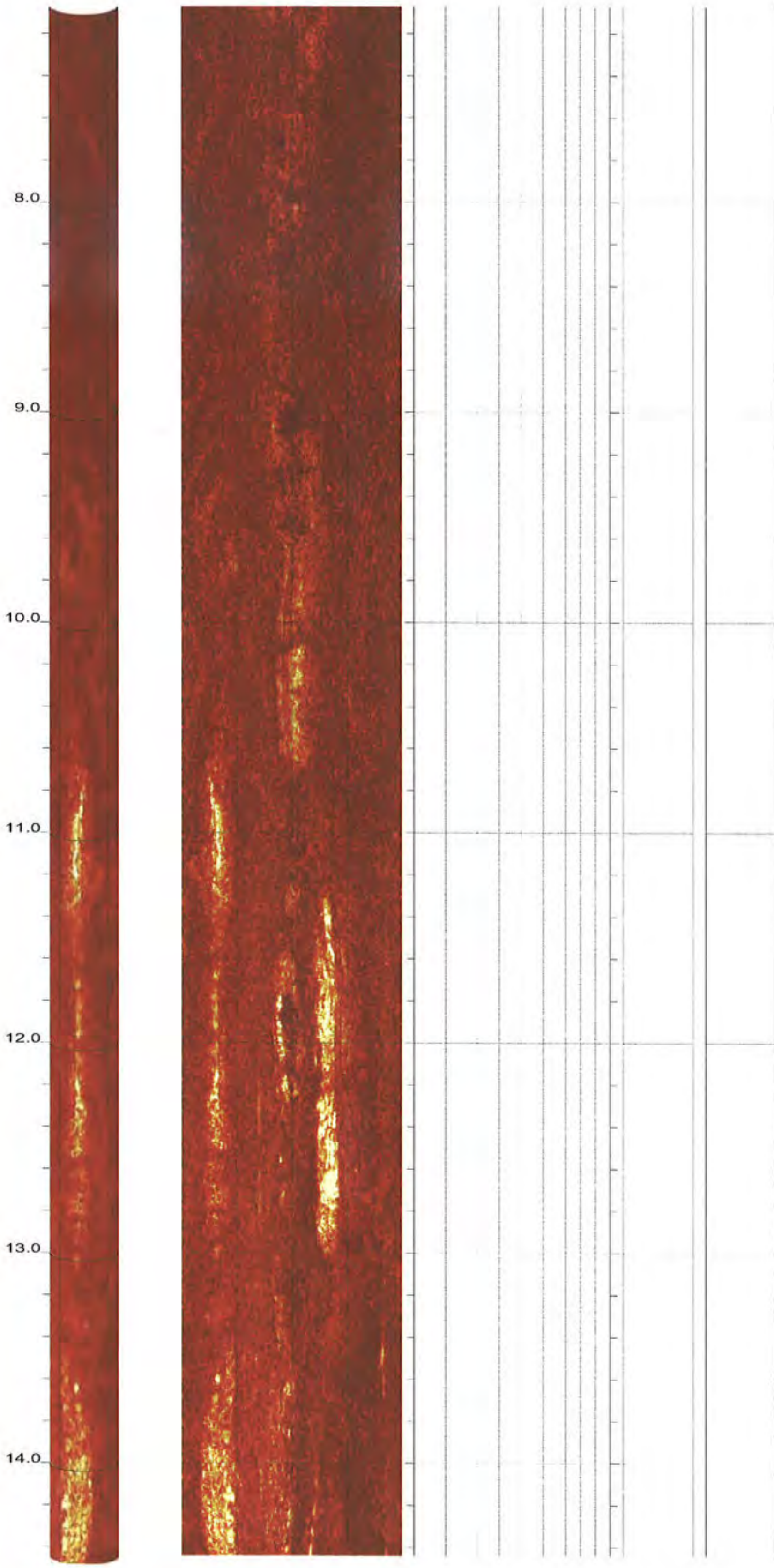
Zone from 199.888 to 3.224ft
Format: BHTV-NESWN

Borehole diam: 4.000inch
Vertical = borehole-axis
Image: Amplitude

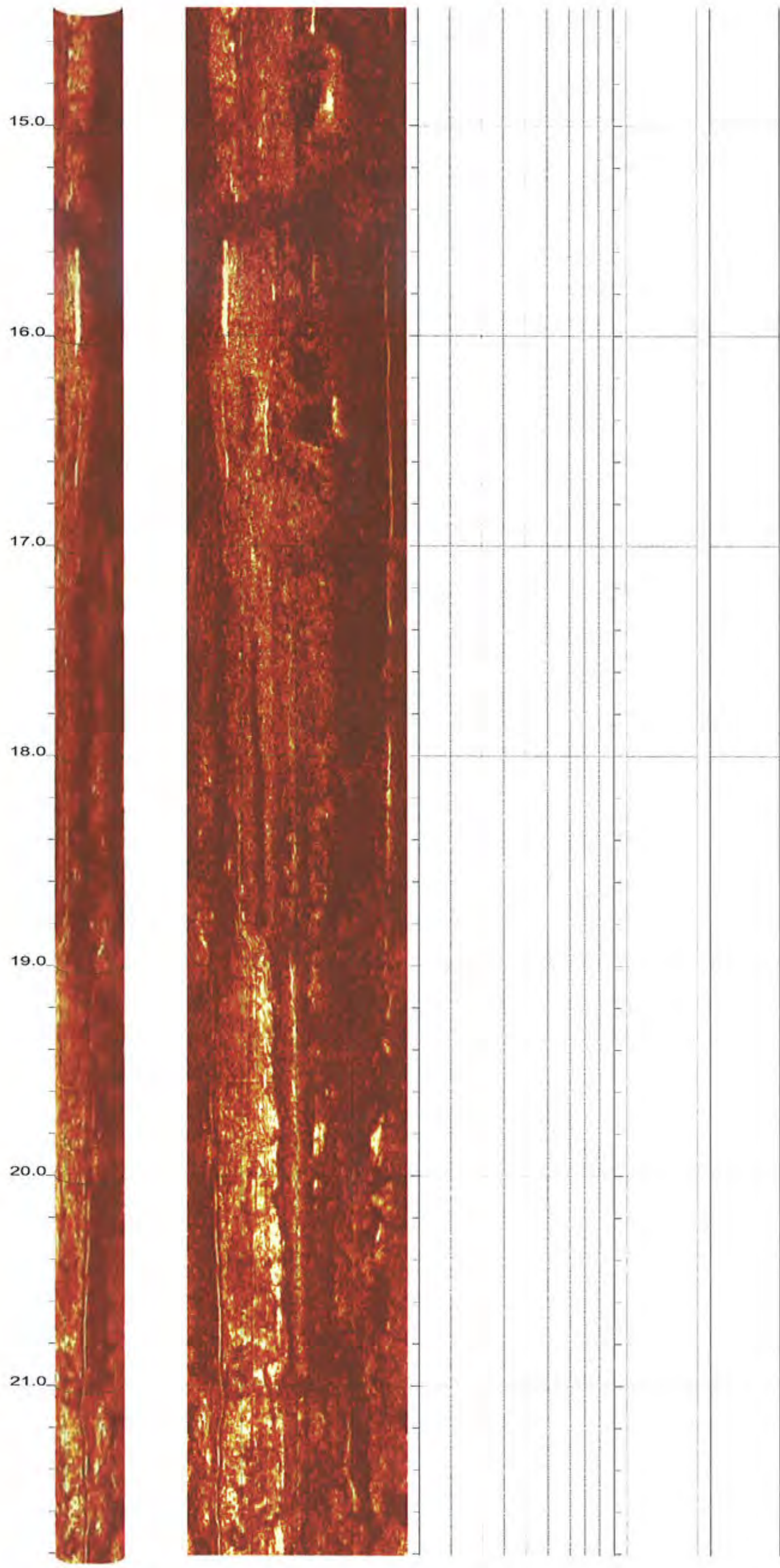
Stratigraphic dips
Non-stratigraphic dips
Identified units



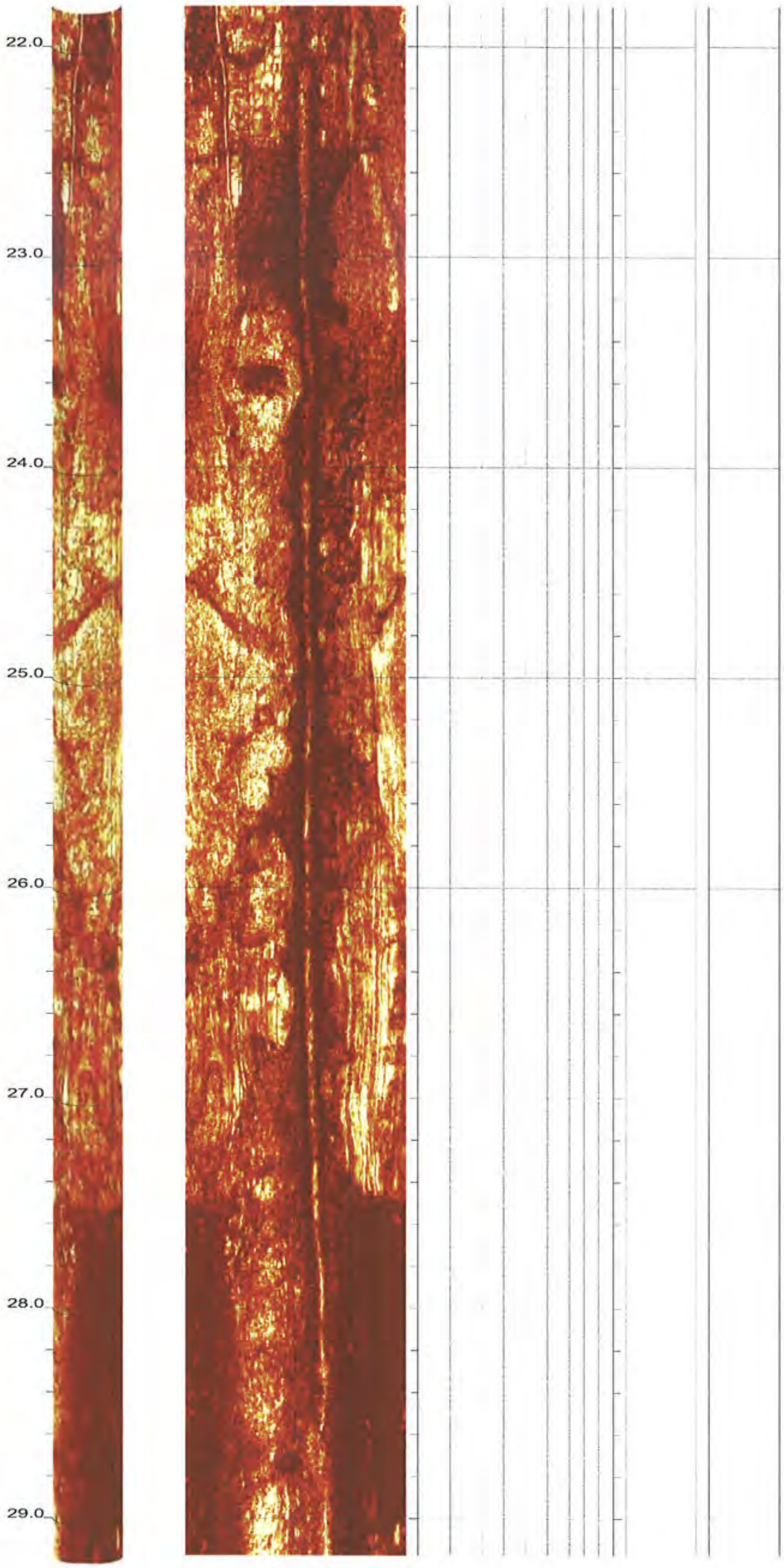
North Anna COL Boring B-909 Acoustic Televiewer Dips Sheet 1 of 28



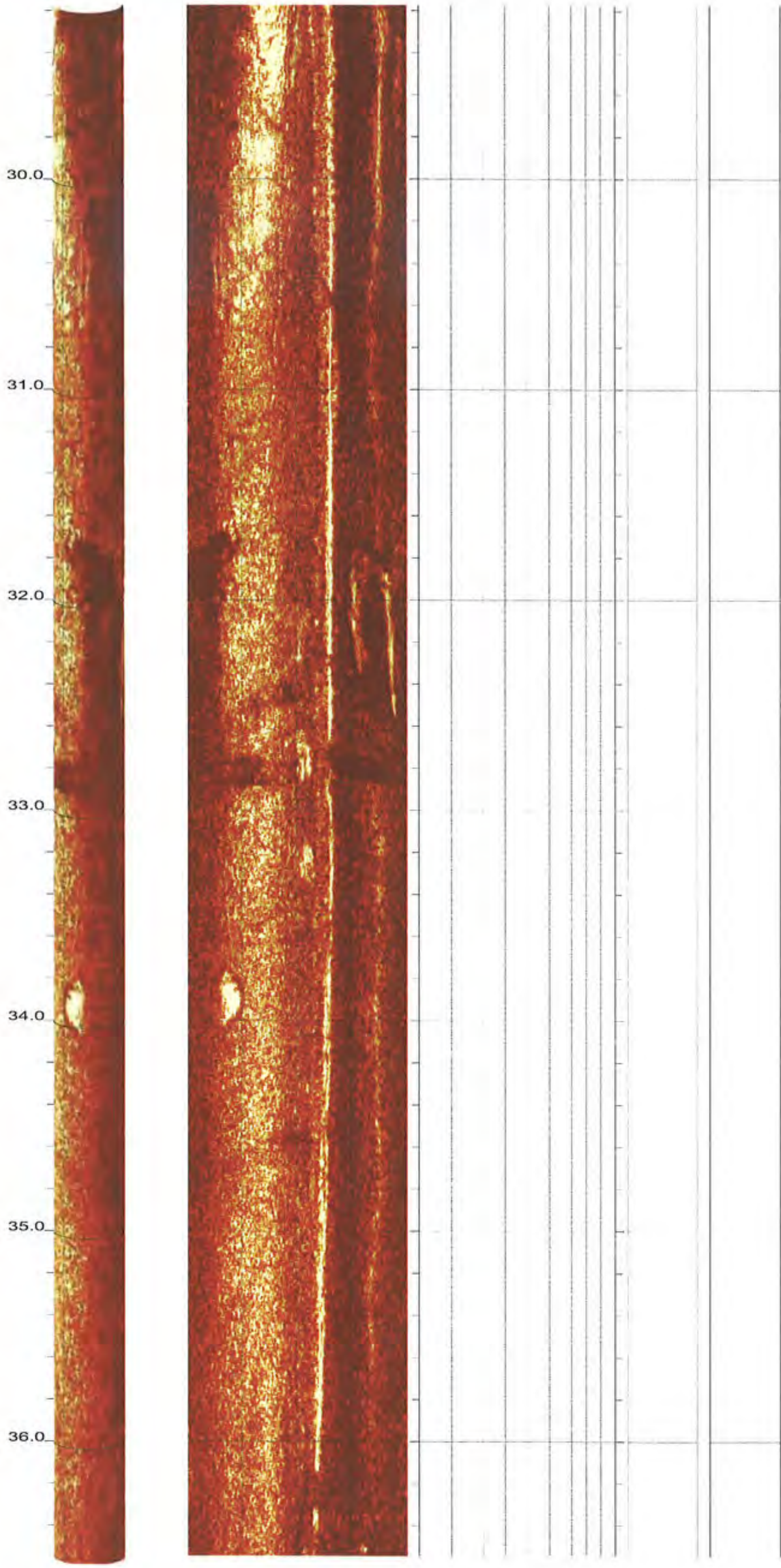
North Anna COL Boring B-909 Acoustic Televiewer Dips Sheet 2 of 28



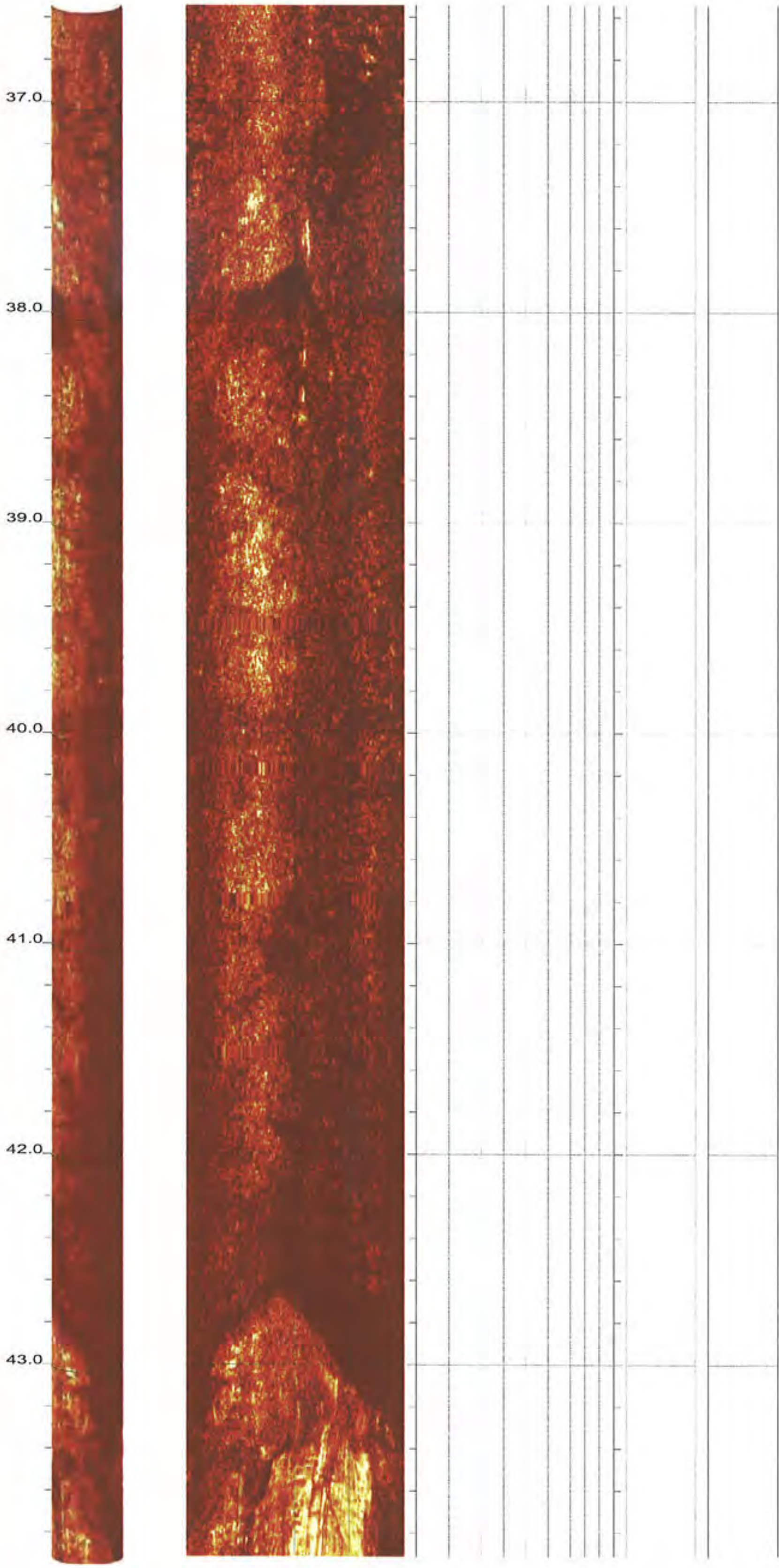
North Anna COL Boring B-909 Acoustic Televiewer Dips Sheet 3 of 28



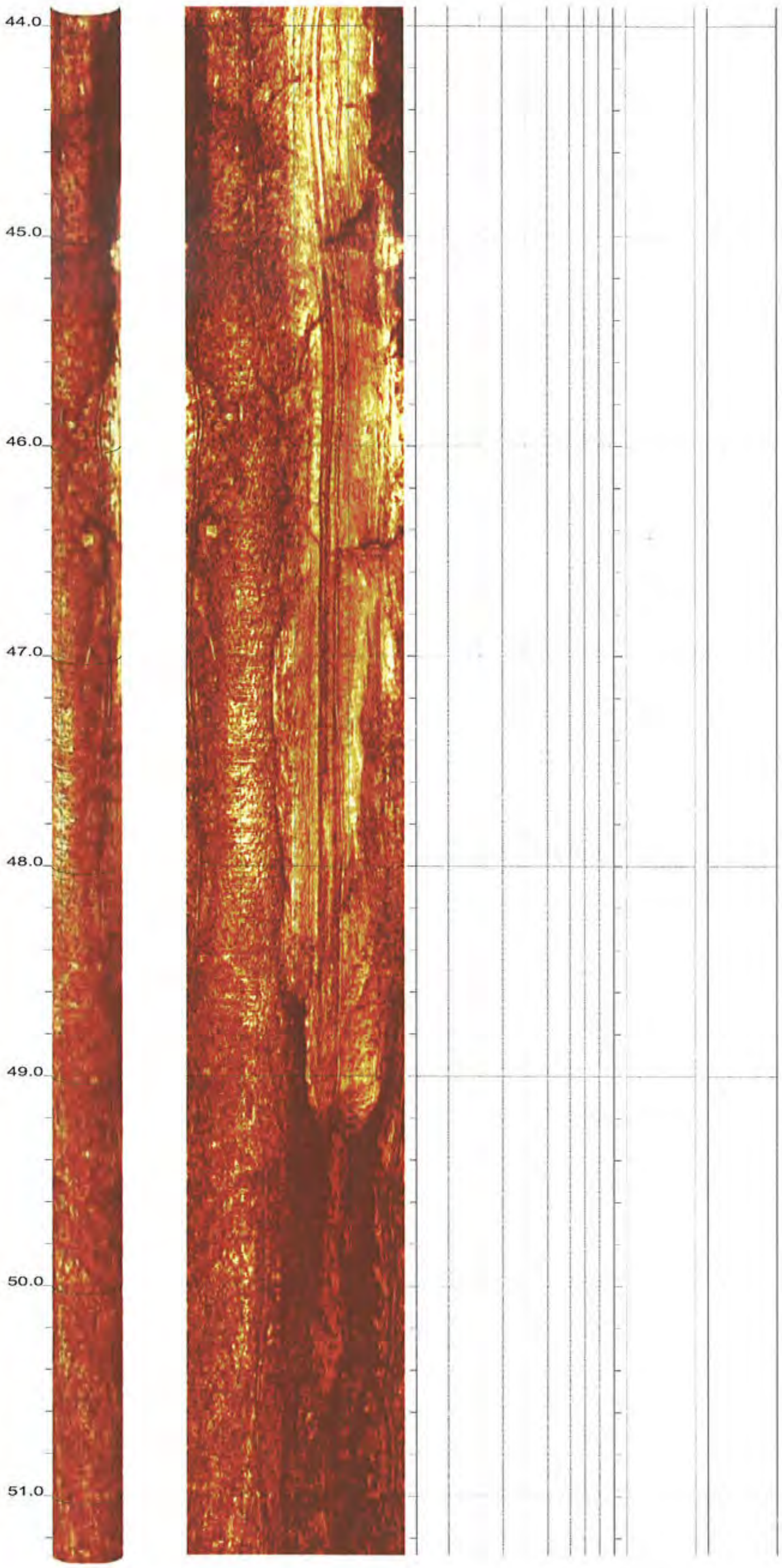
North Anna COL Boring B-909 Acoustic Televiewer Dips Sheet 4 of 28



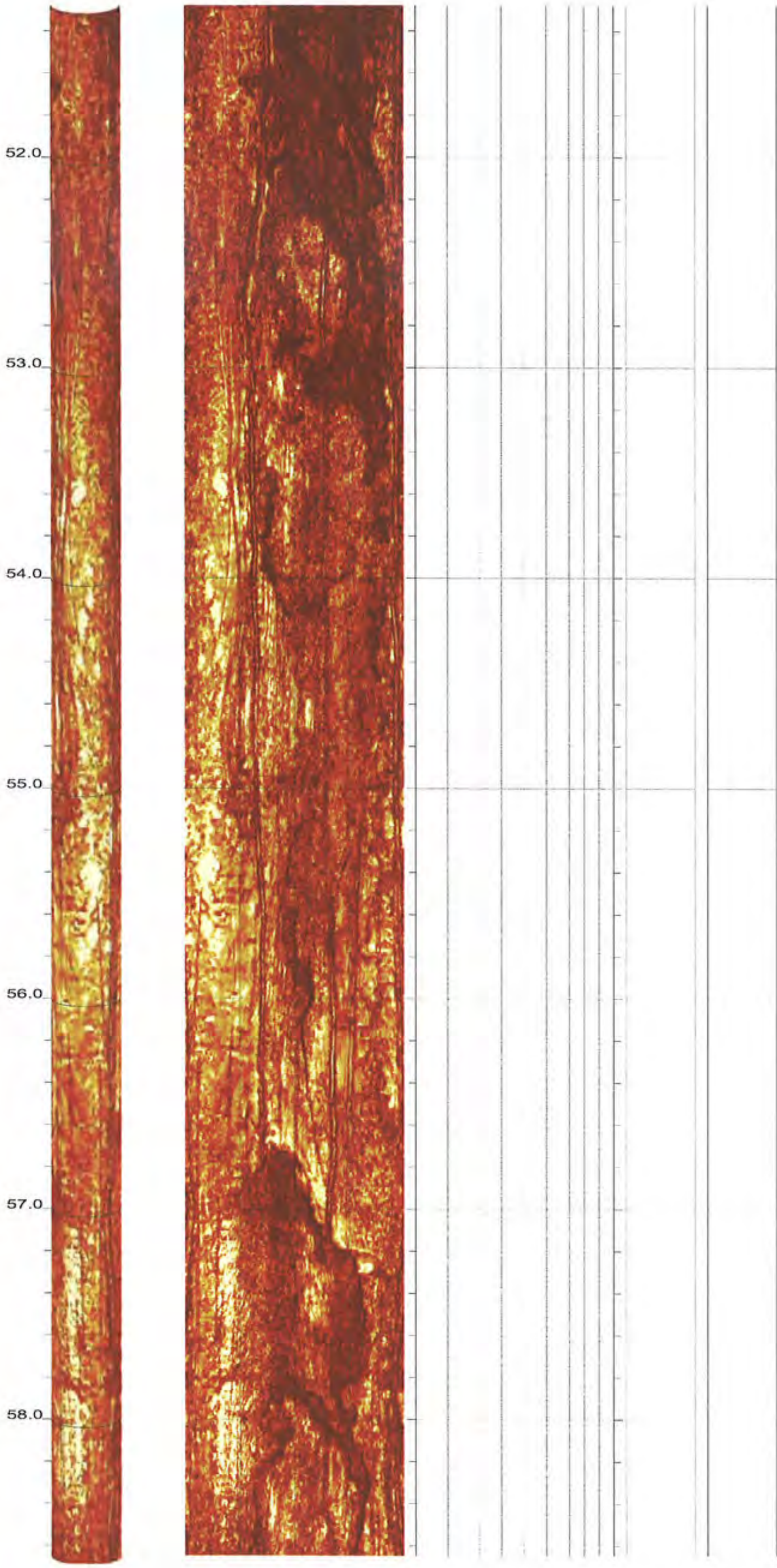
North Anna COL Boring B-909 Acoustic Televiewer Dips Sheet 5 of 28



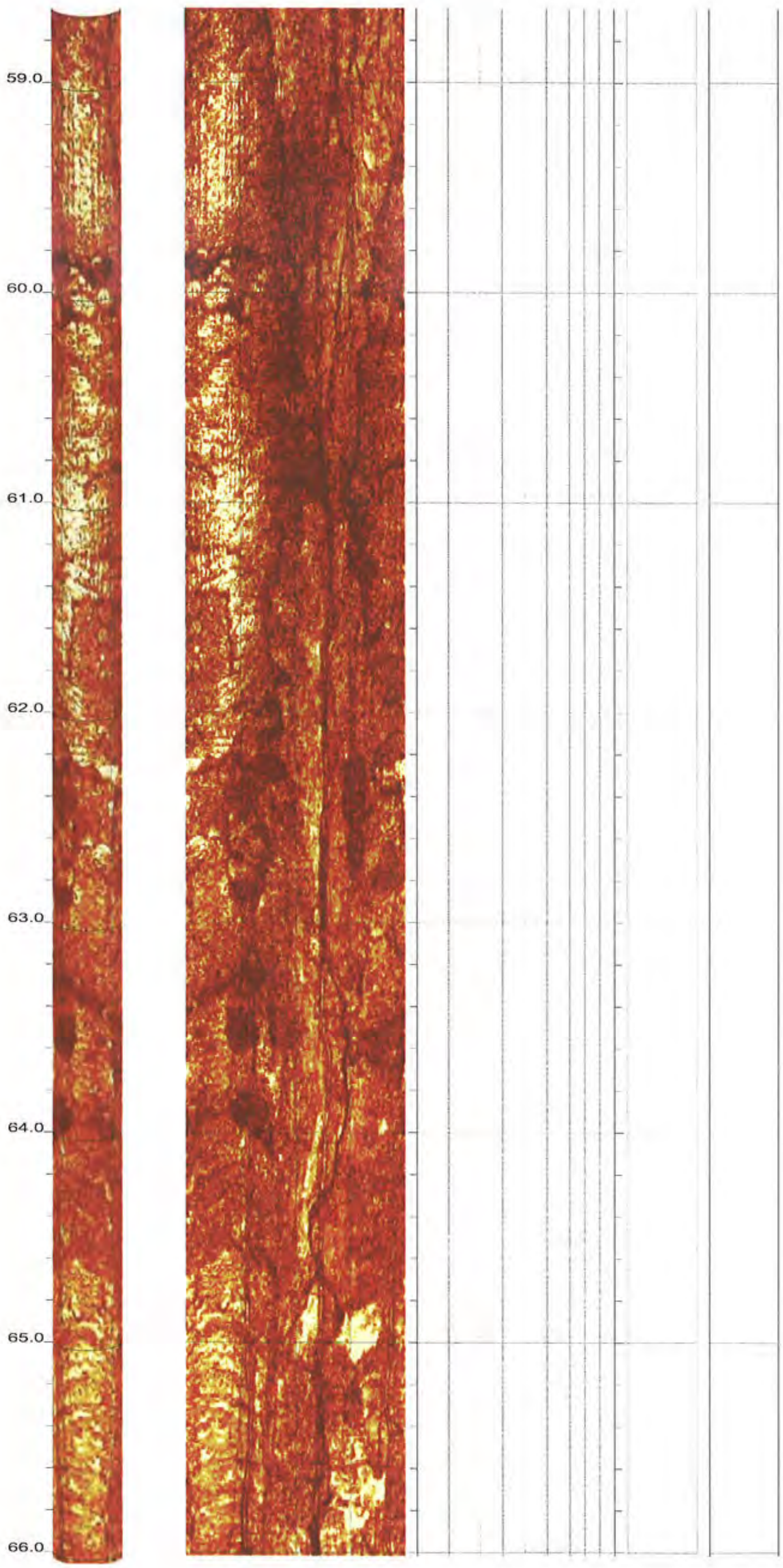
North Anna COL Boring B-909 Acoustic Televiewer Dips Sheet 6 of 28



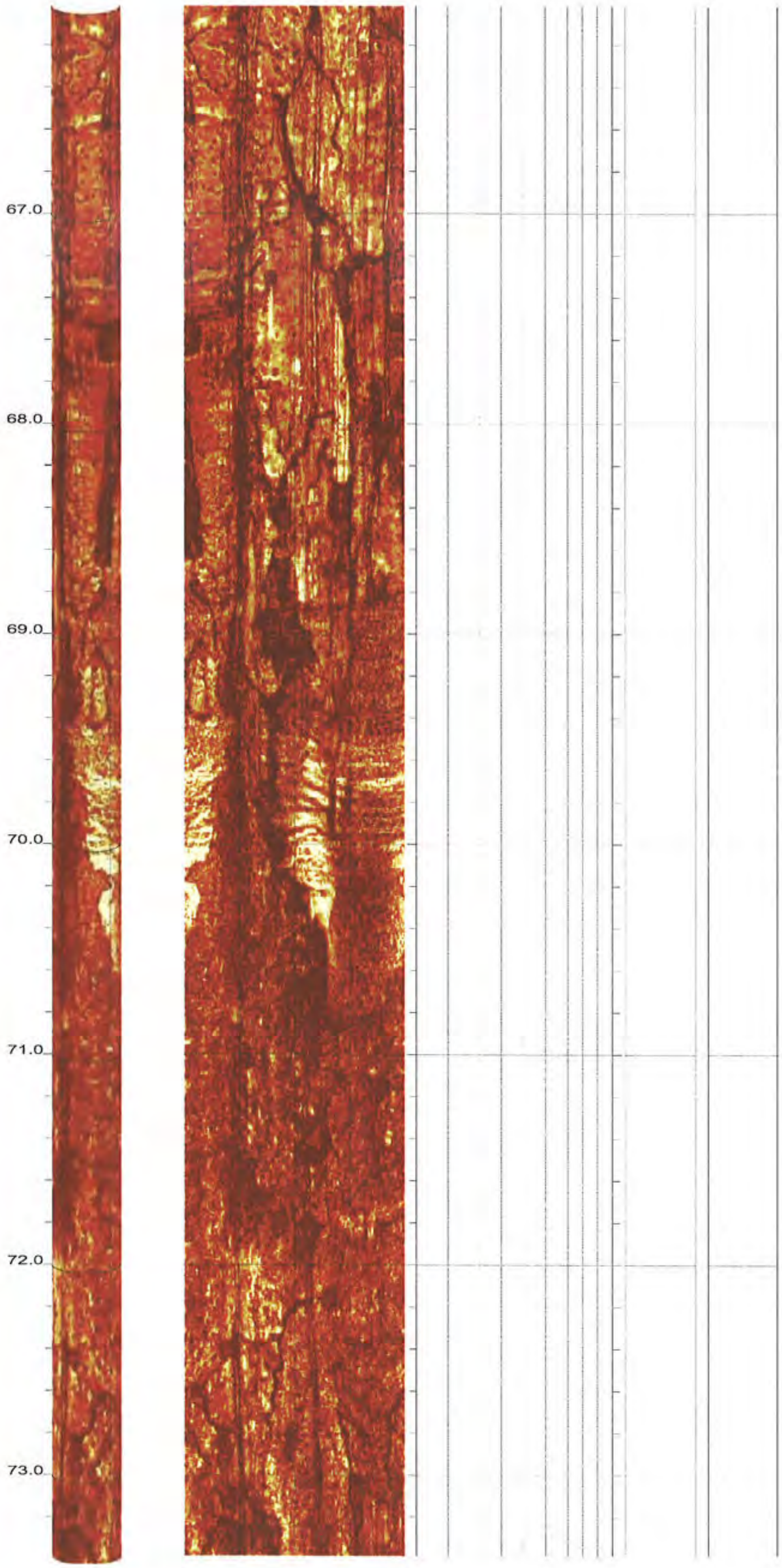
North Anna COL Boring B-909 Acoustic Televiewer Dips Sheet 7 of 28



North Anna COL Boring B-909 Acoustic Televiewer Dips Sheet 8 of 28

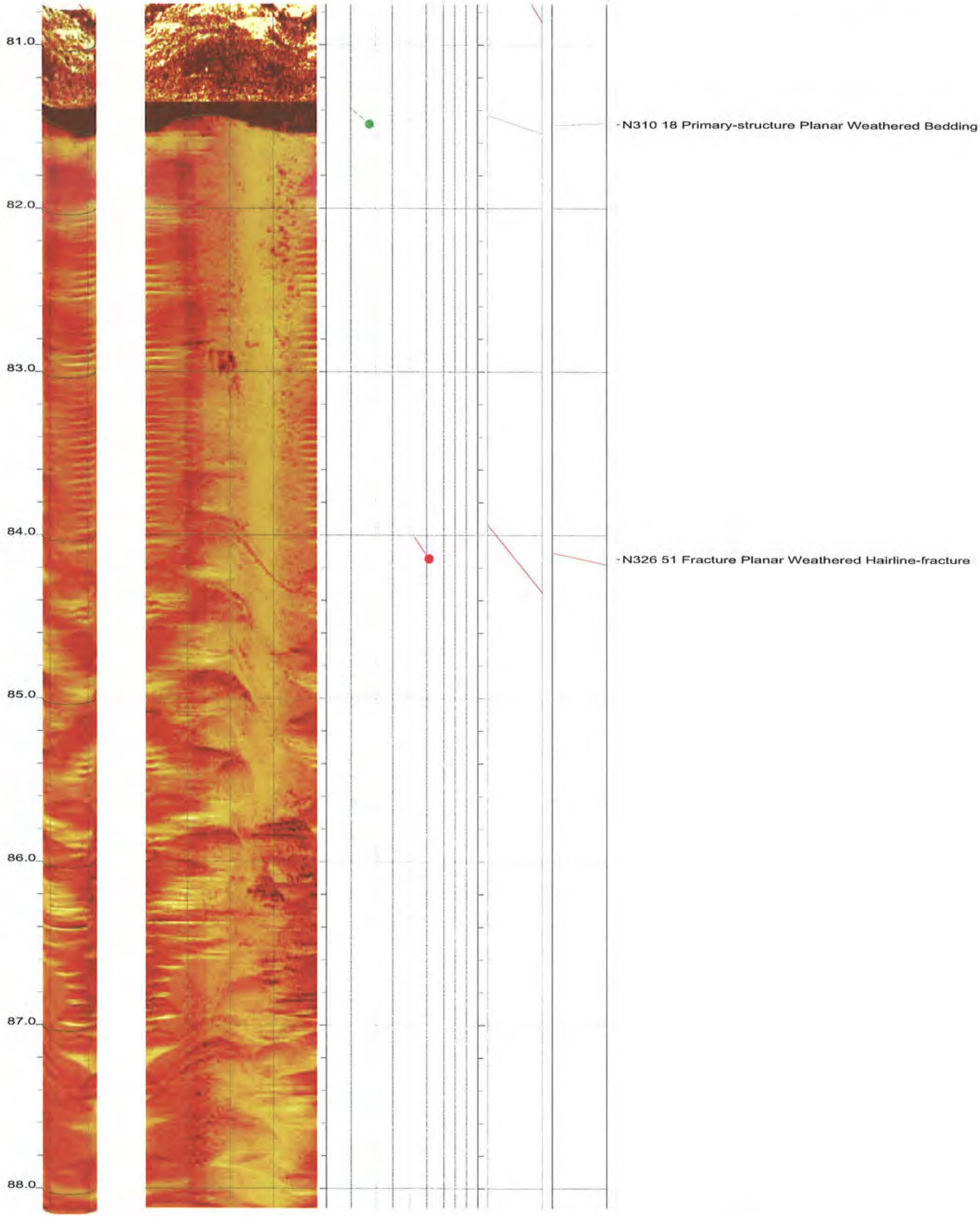


North Anna COL Boring B-909 Acoustic Televiewer Dips Sheet 9 of 28

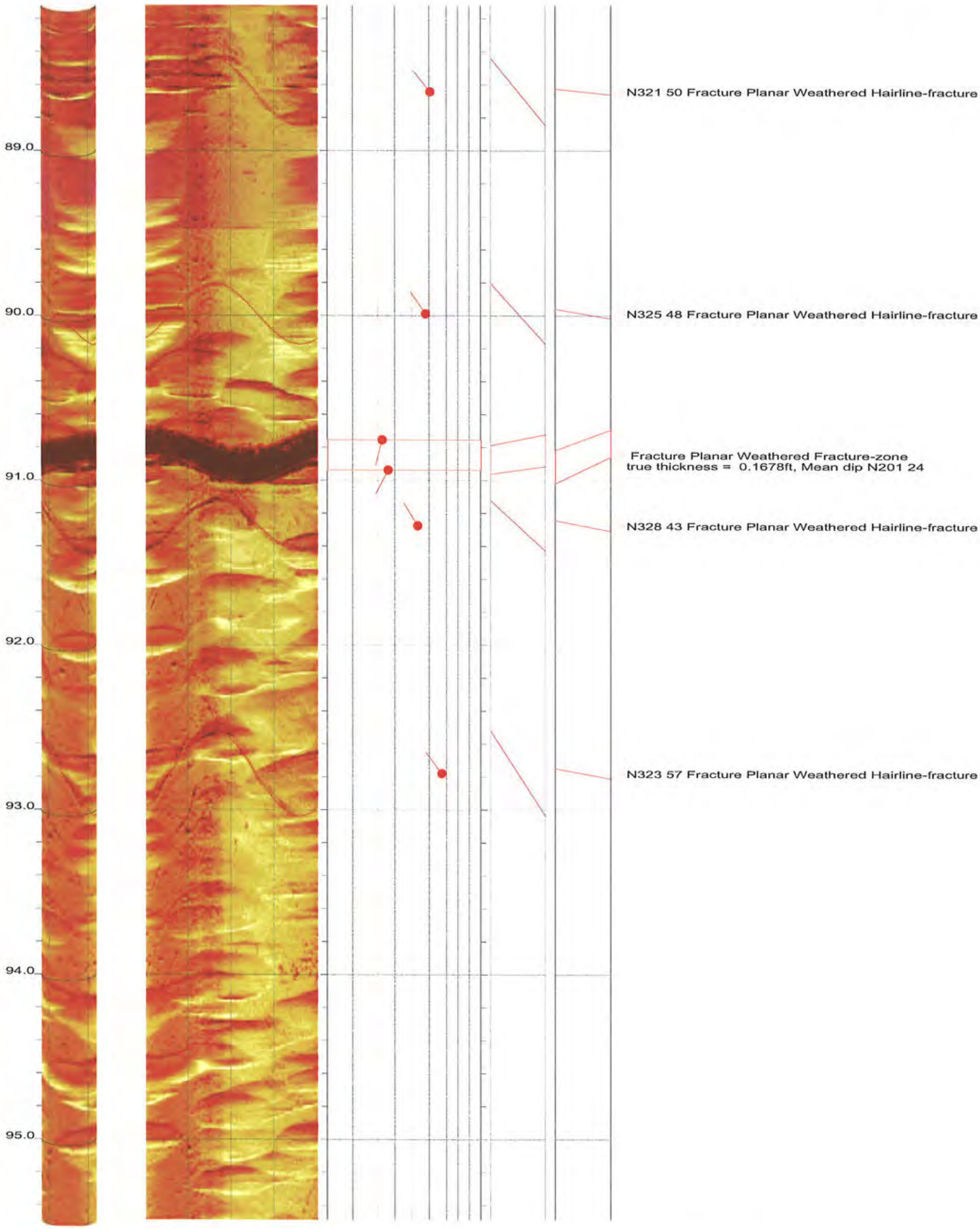


North Anna COL Boring B-909 Acoustic Televiewer Dips Sheet 10 of 28

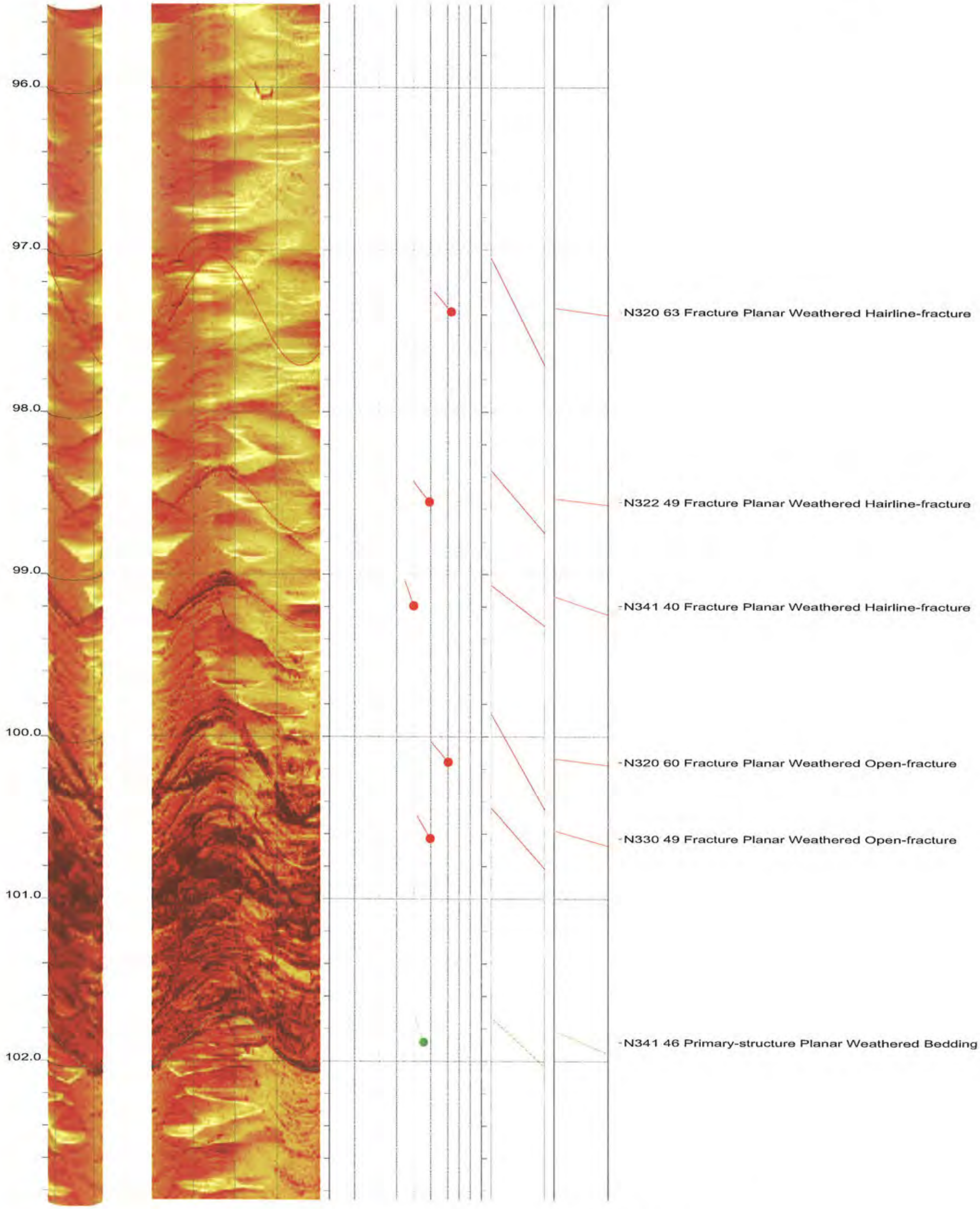
North Anna COL Boring B-909 Acoustic Televiewer Dips Sheet 11 of 28



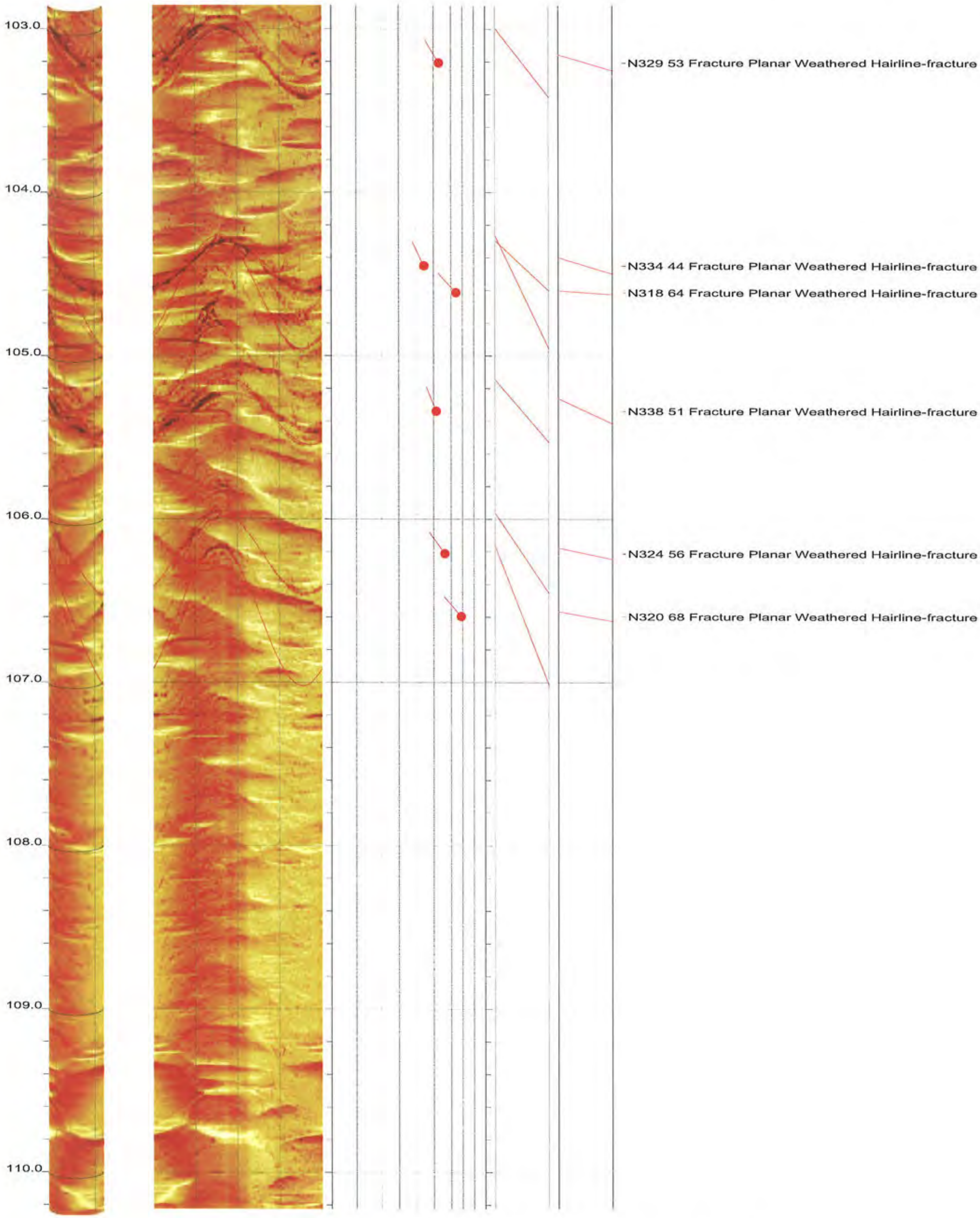
North Anna COL Boring B-909 Acoustic Televiewer Dips Sheet 12 of 28



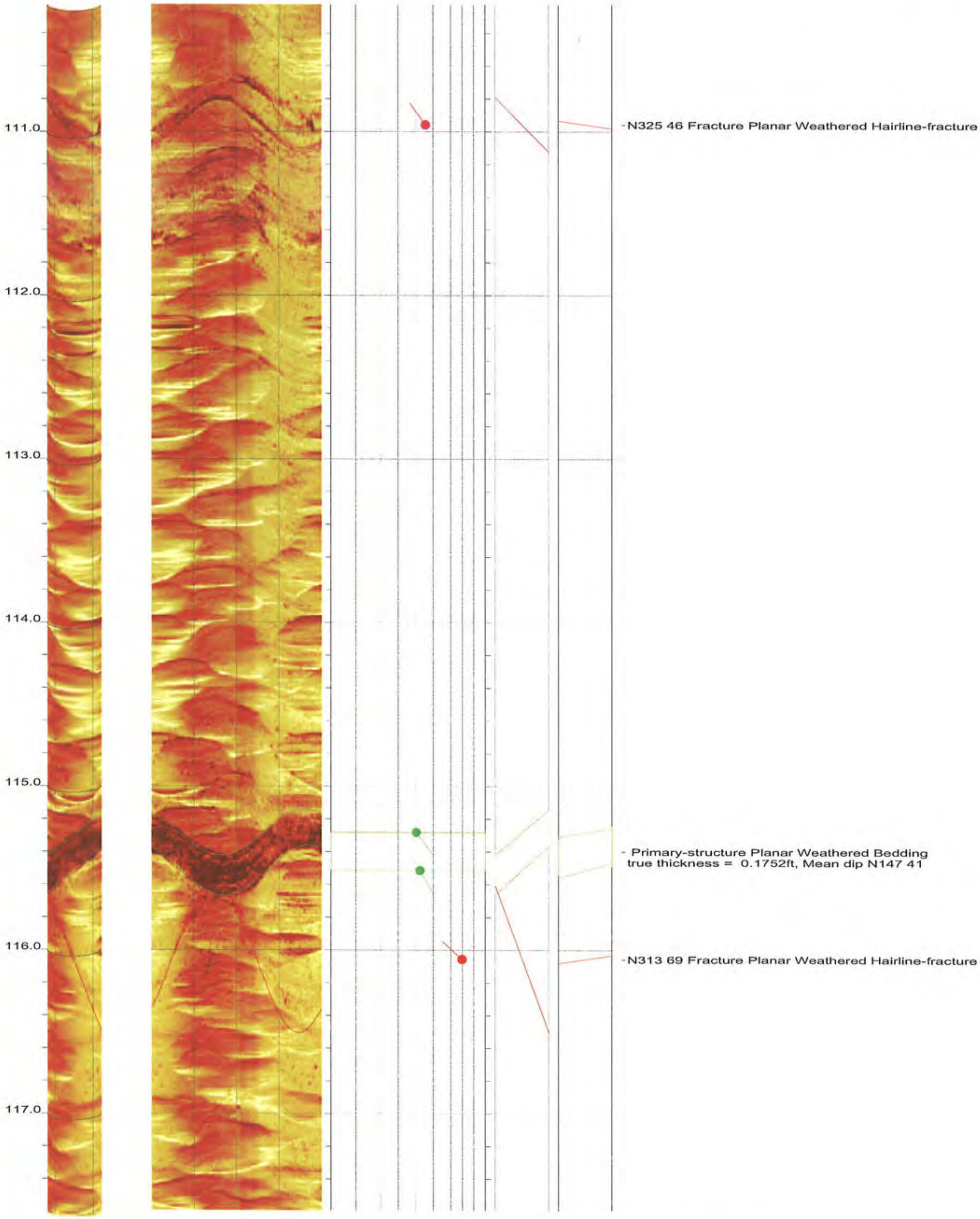
North Anna COL Boring B-909 Acoustic Televiewer Dips Sheet 13 of 28



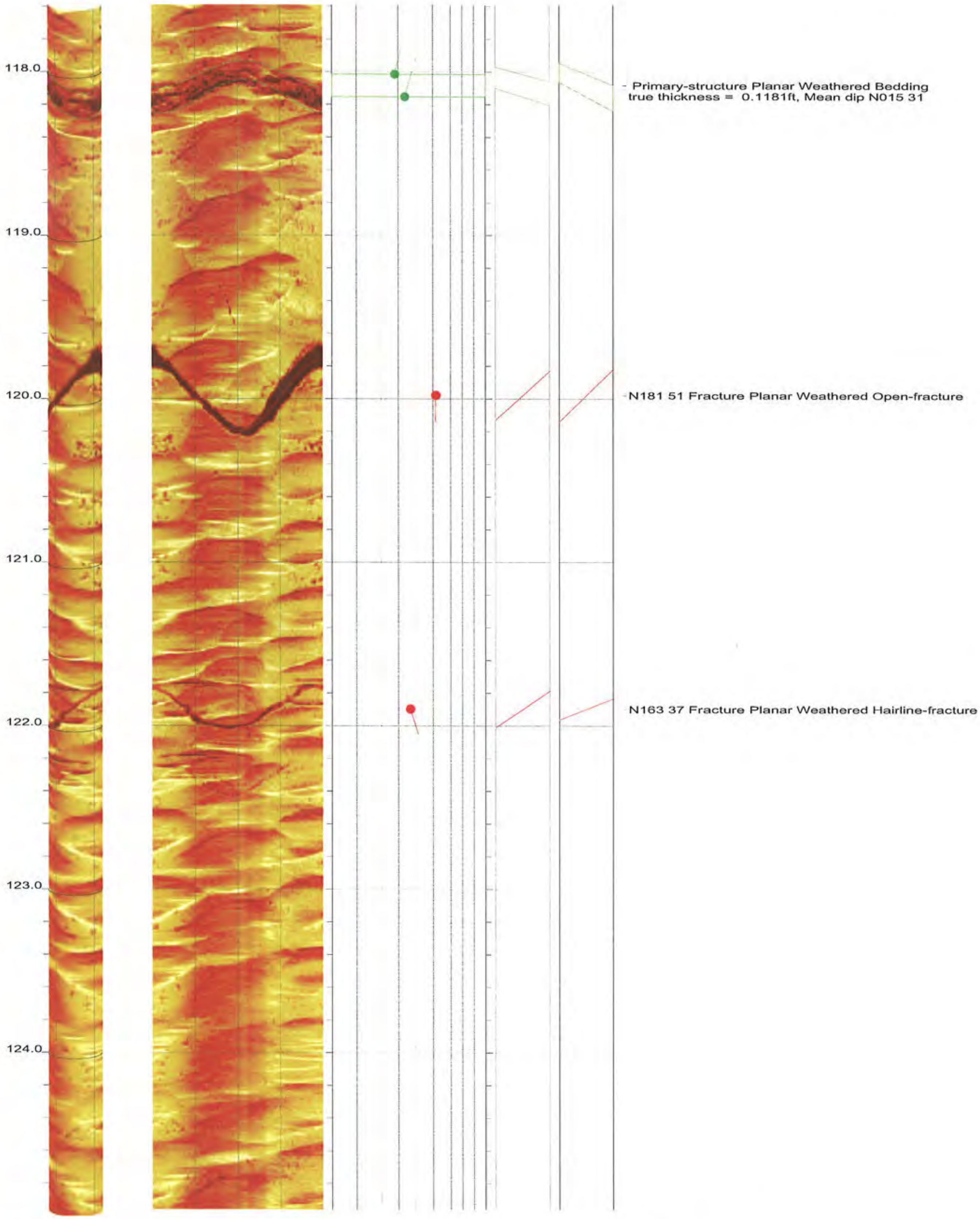
North Anna COL Boring B-909 Acoustic Televiewer Dips Sheet 14 of 28



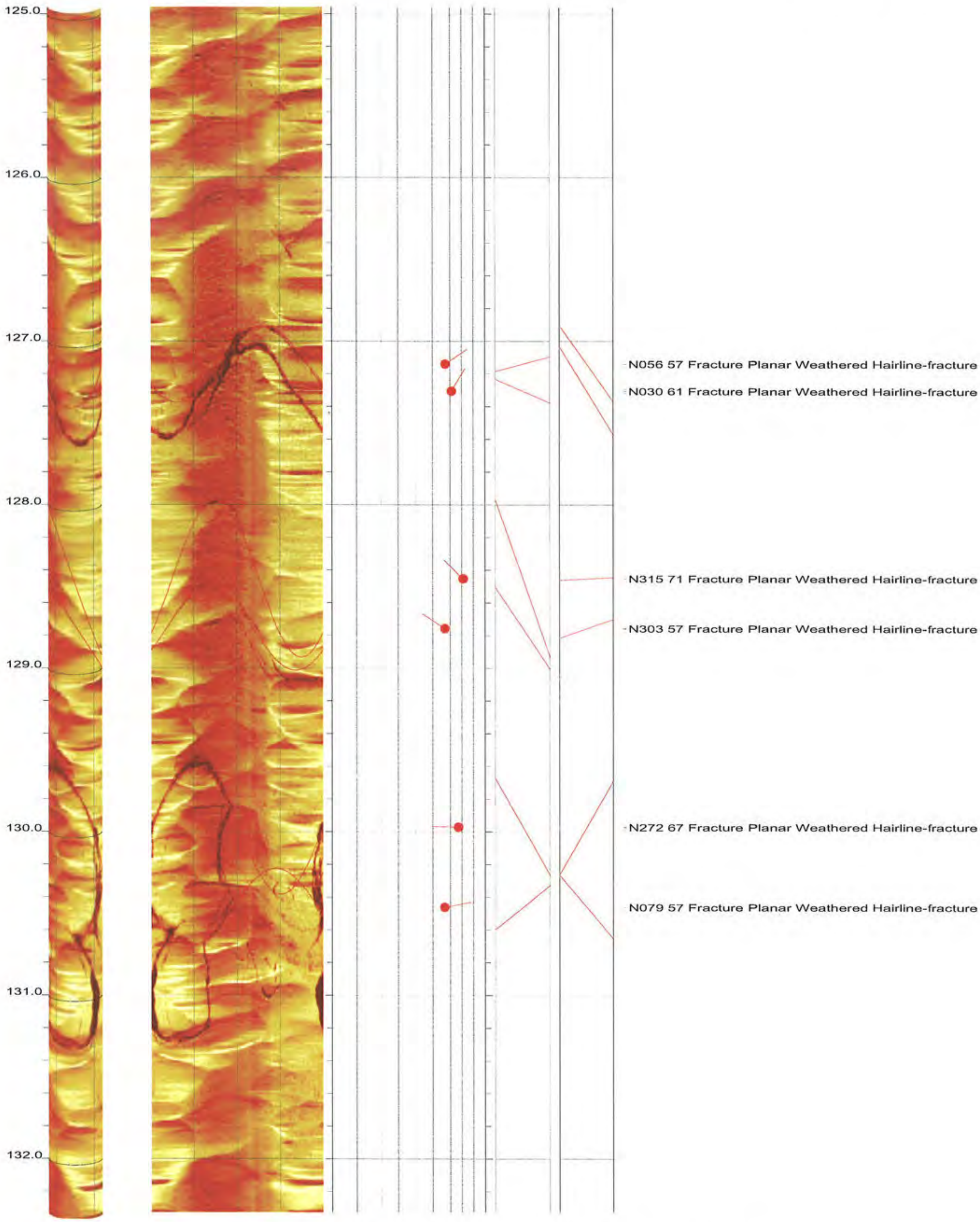
North Anna COL Boring B-909 Acoustic Televiewer Dips Sheet 15 of 28



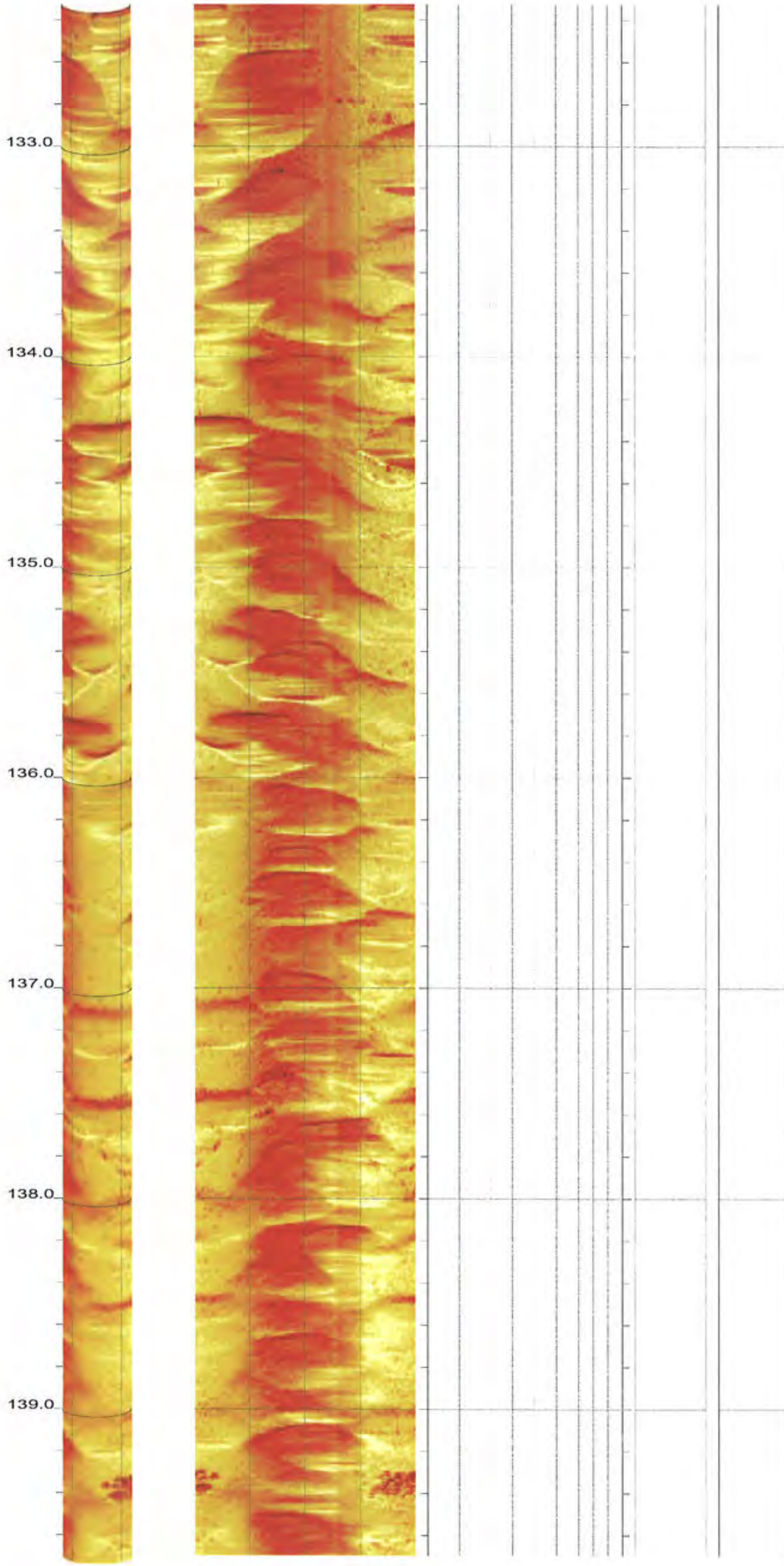
North Anna COL Boring B-909 Acoustic Televiewer Dips Sheet 16 of 28



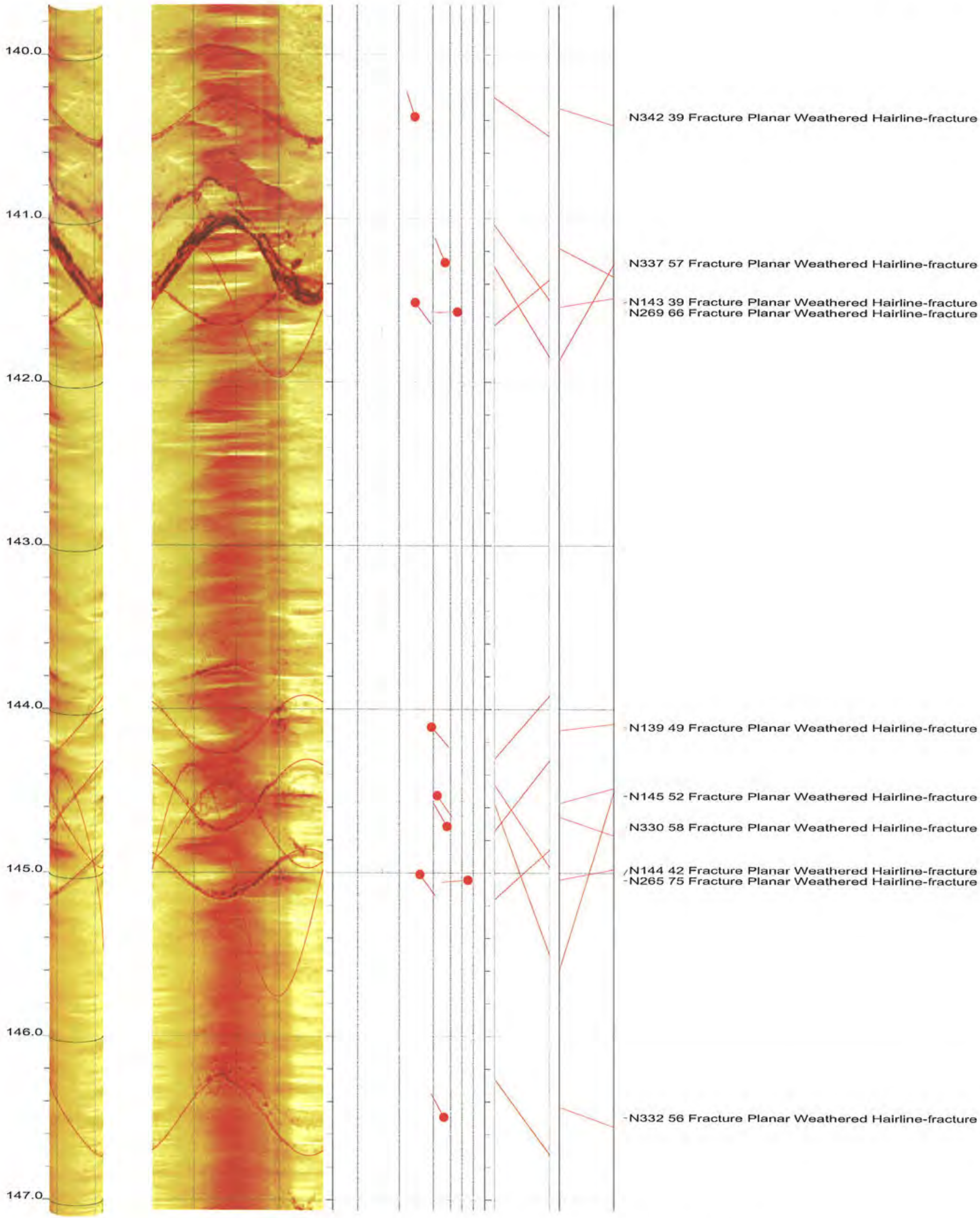
North Anna COL Boring B-909 Acoustic Televiewer Dips Sheet 17 of 28



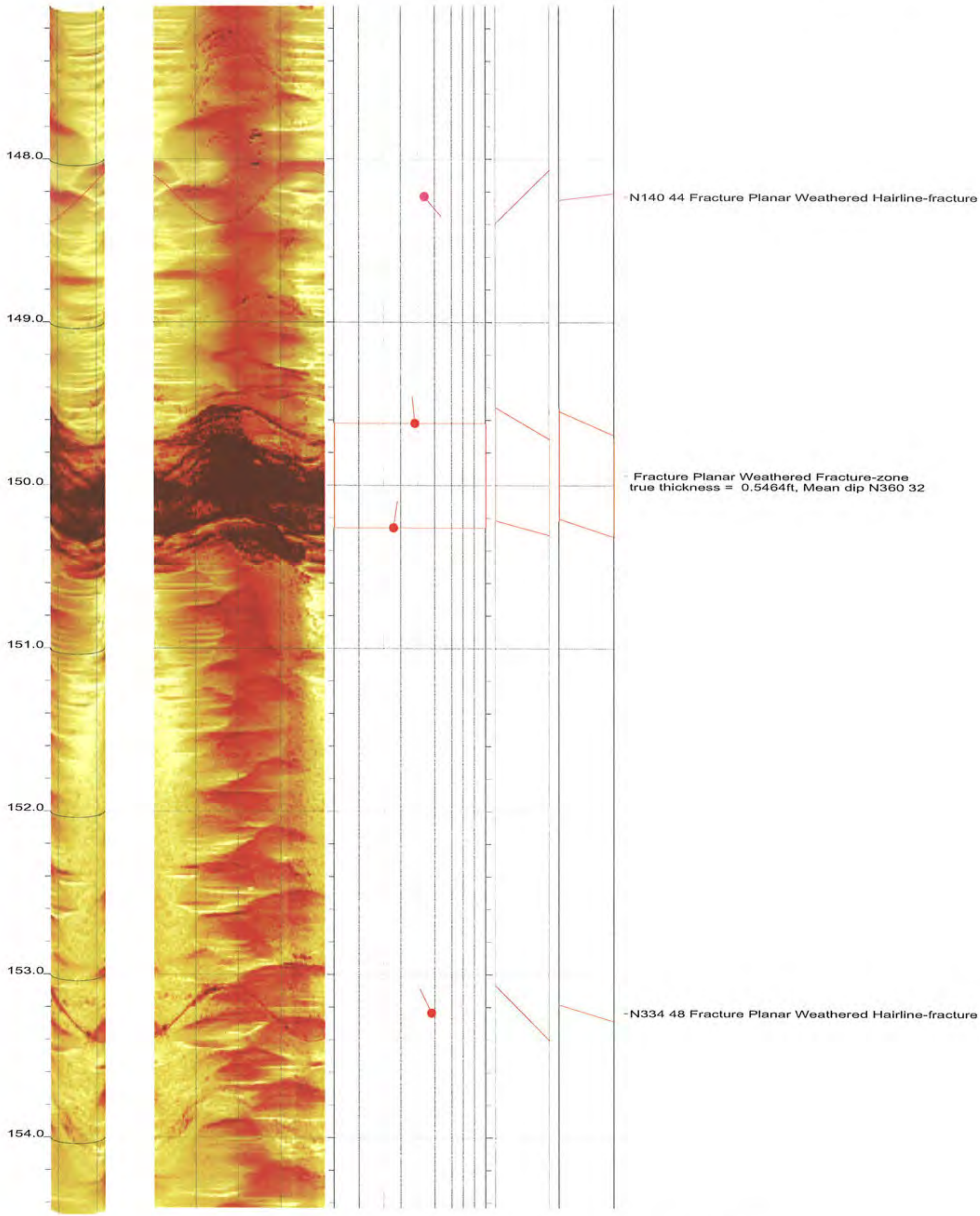
North Anna COL Boring B-909 Acoustic Televiewer Dips Sheet 18 of 28



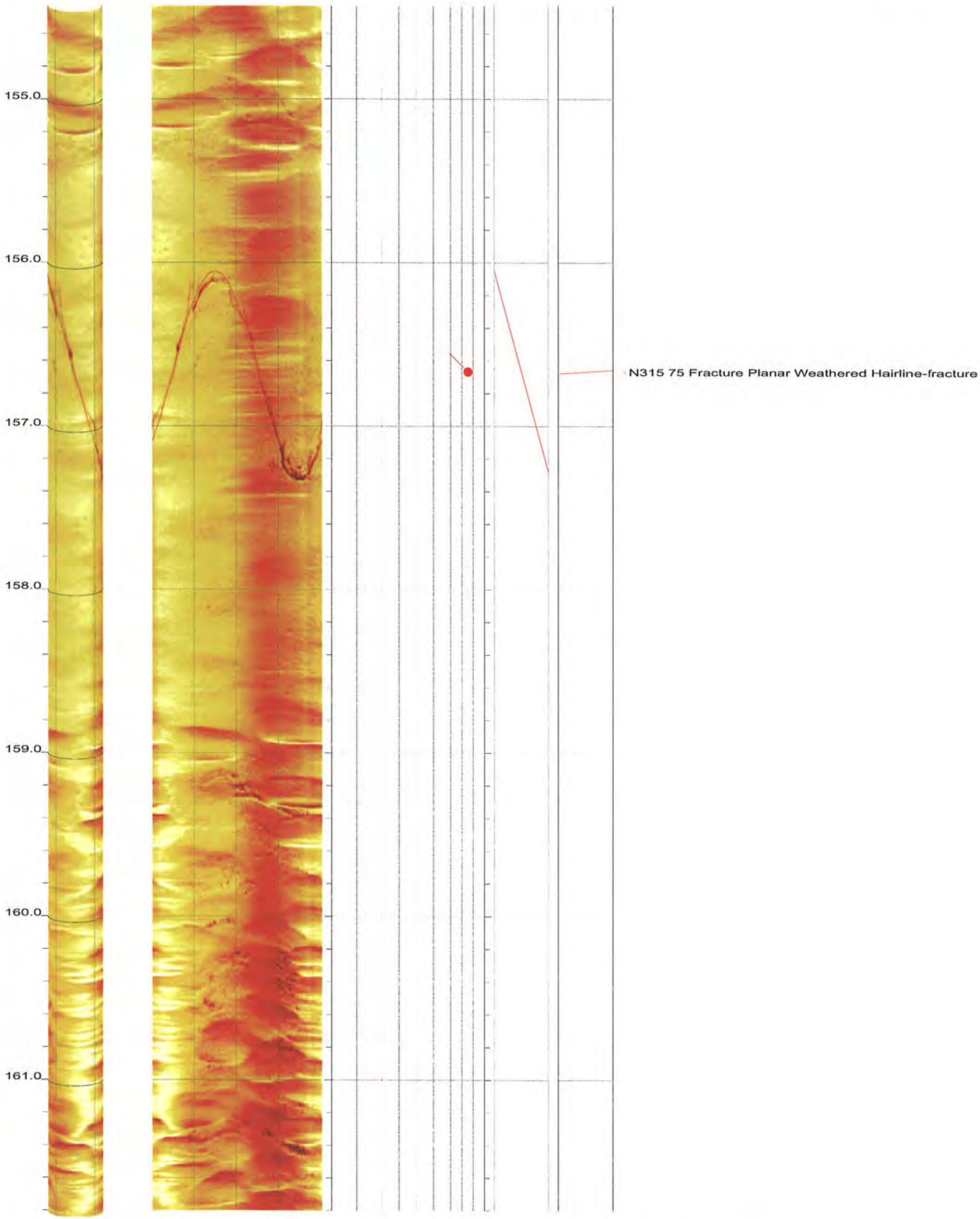
North Anna COL Boring B-909 Acoustic Televiewer Dips Sheet 19 of 28



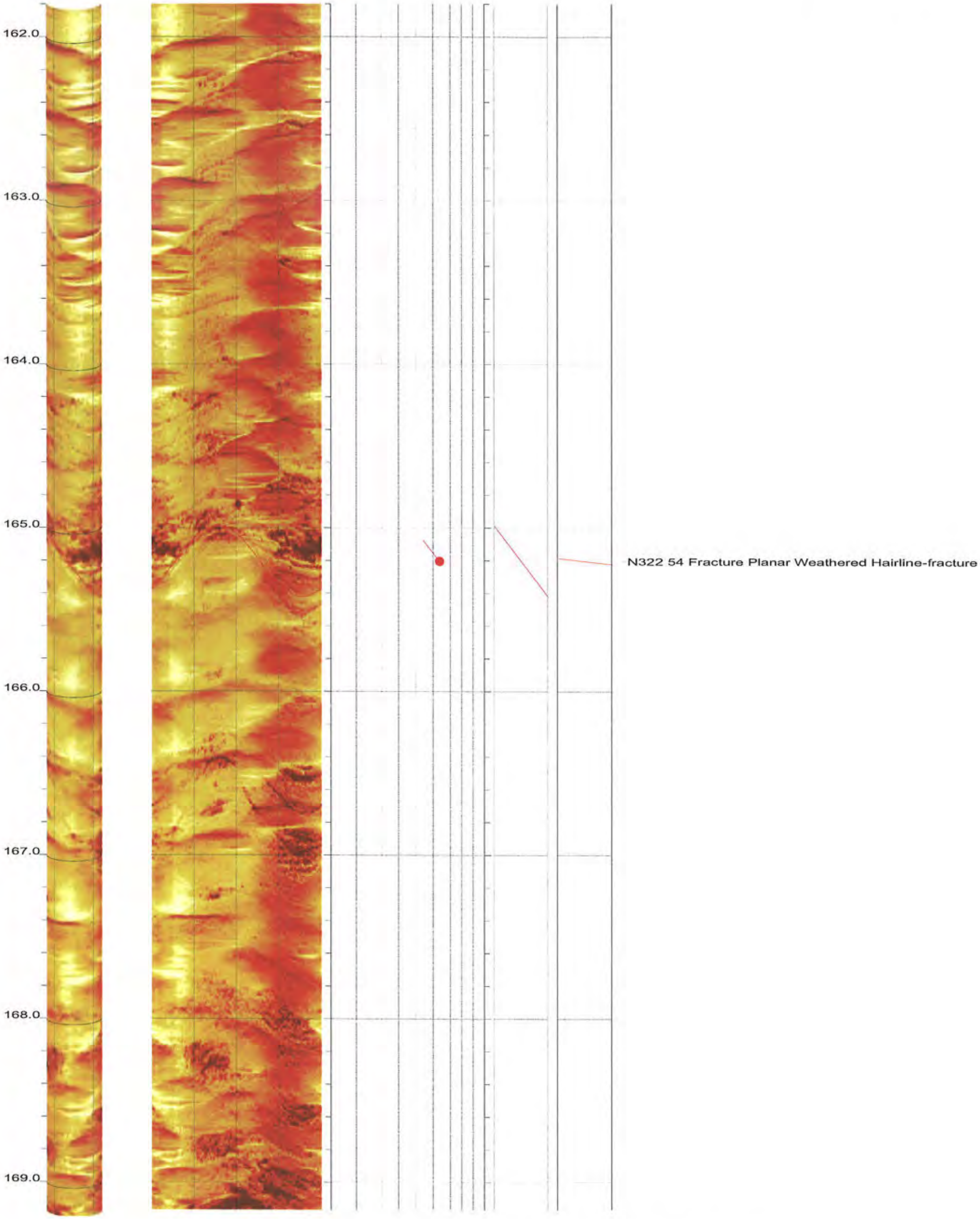
North Anna COL Boring B-909 Acoustic Televiewer Dips Sheet 20 of 28



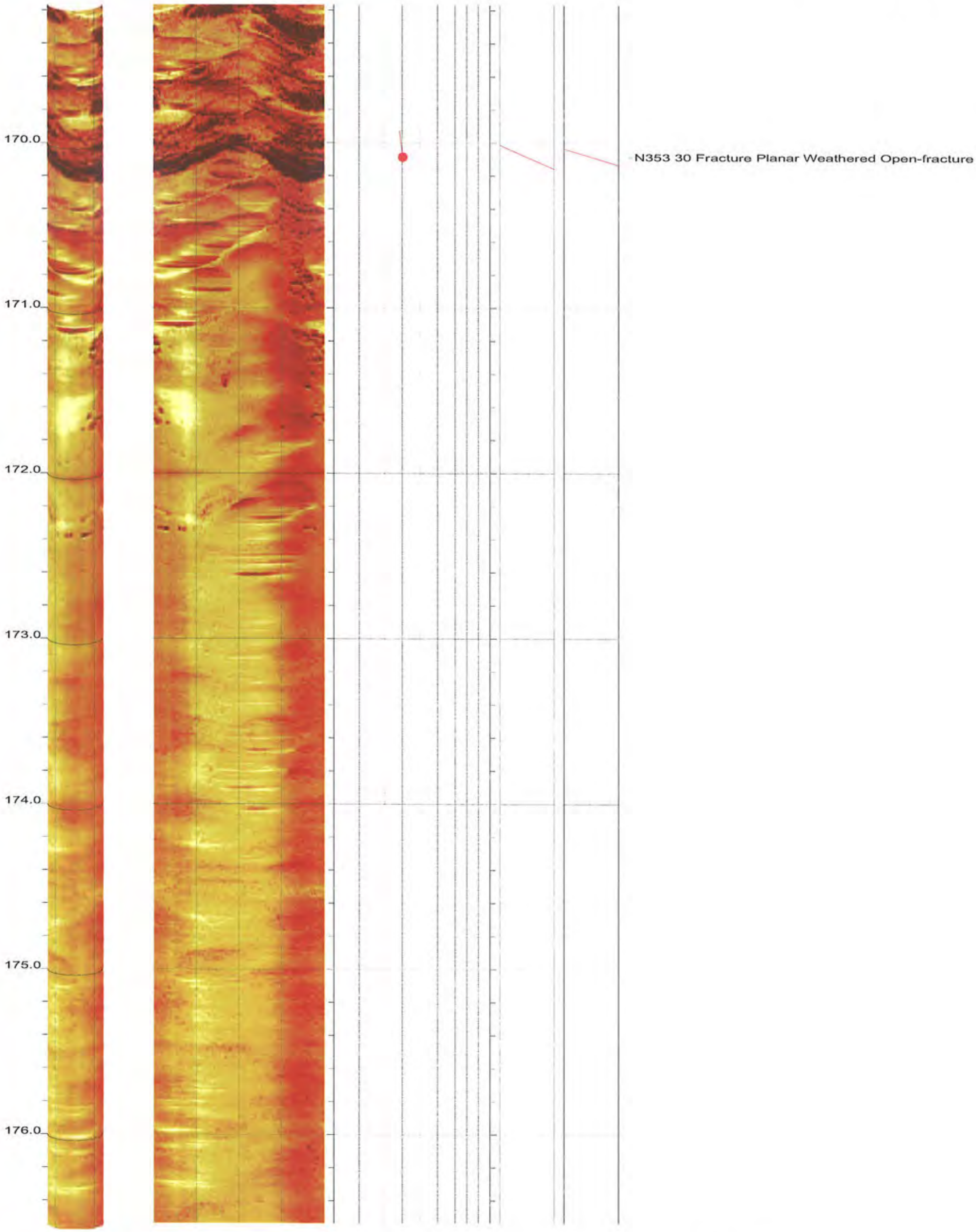
North Anna COL Boring B-909 Acoustic Televiewer Dips Sheet 21 of 28



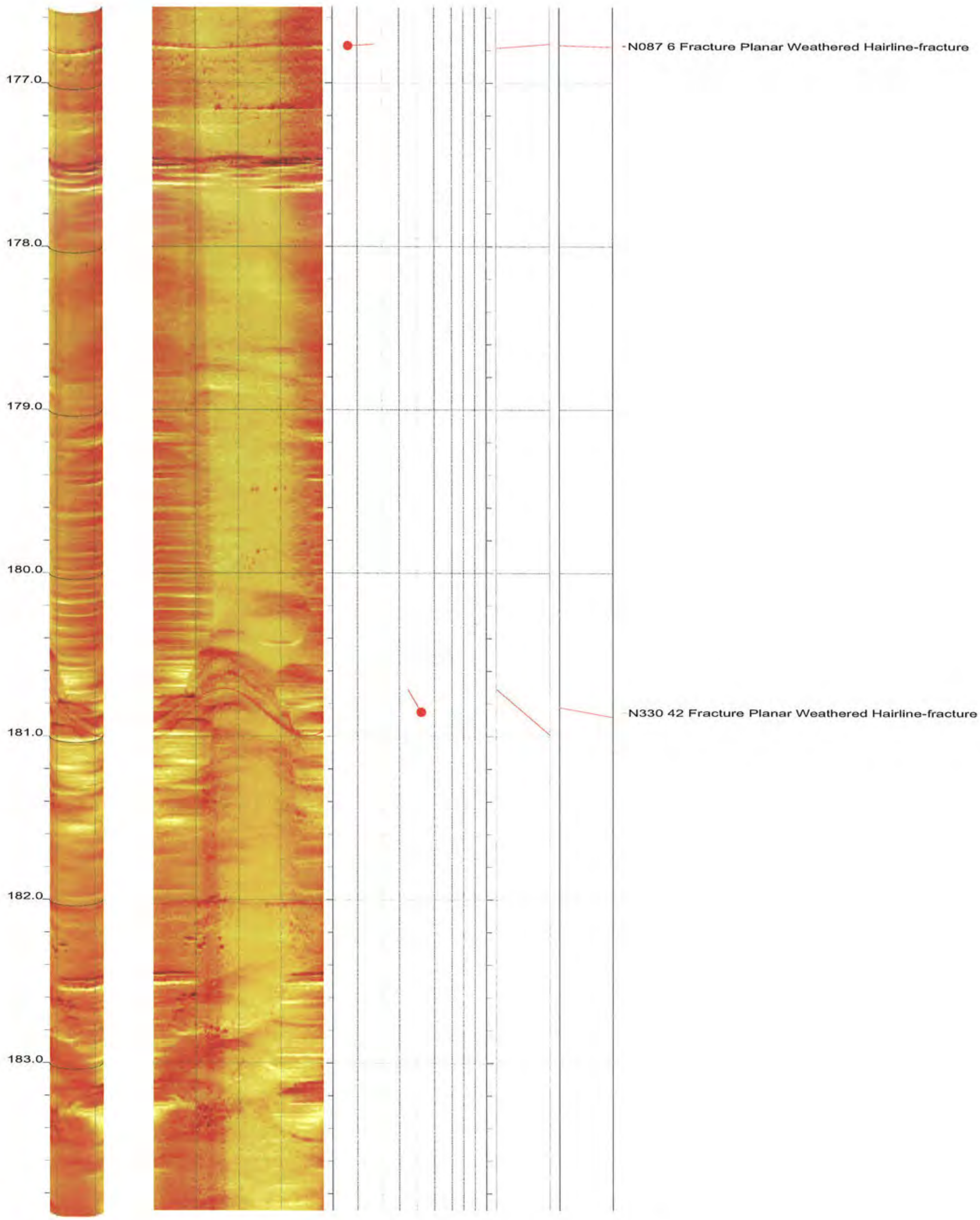
North Anna COL Boring B-909 Acoustic Televiewer Dips Sheet 22 of 28



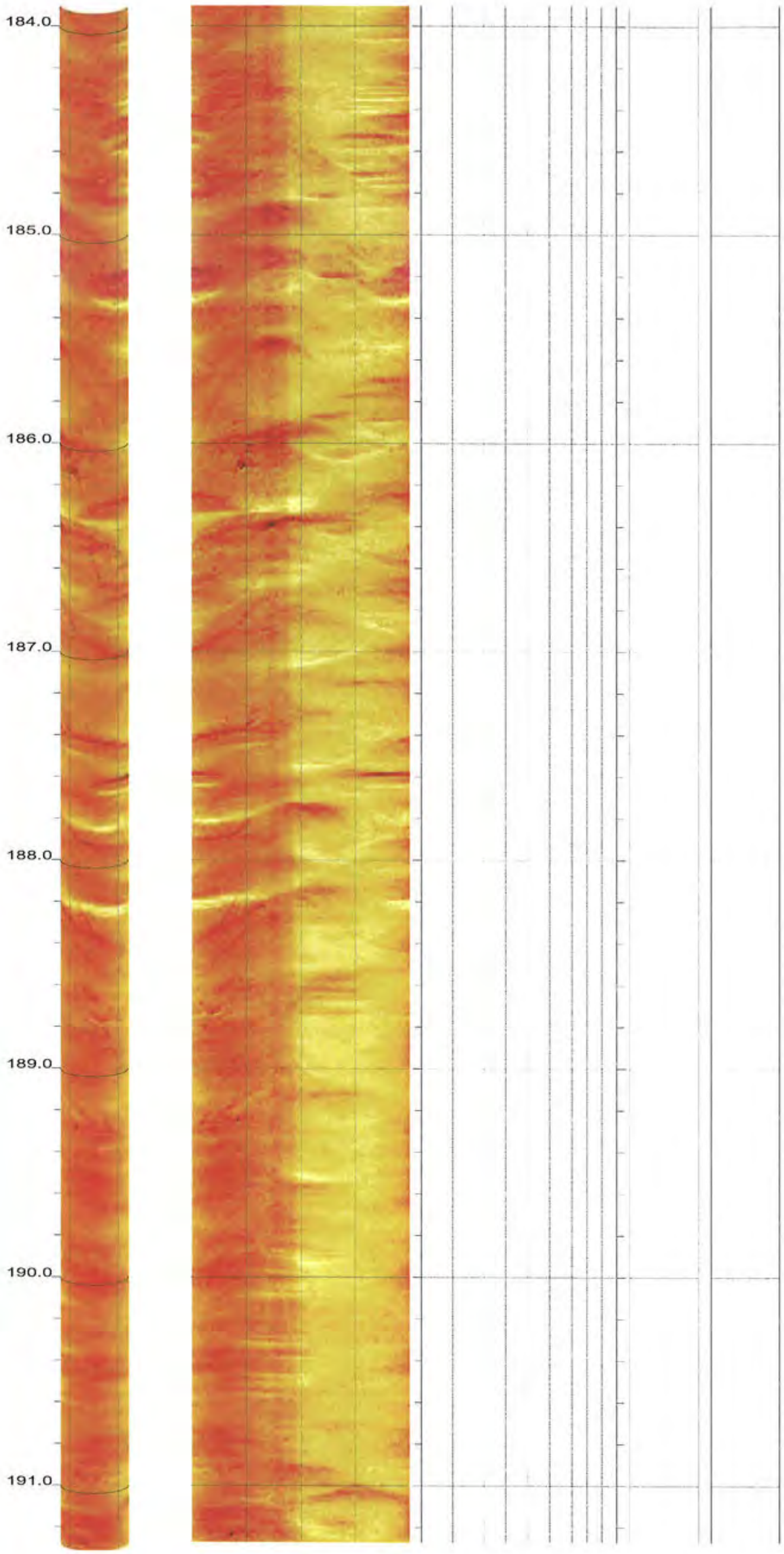
North Anna COL Boring B-909 Acoustic Televiewer Dips Sheet 23 of 28



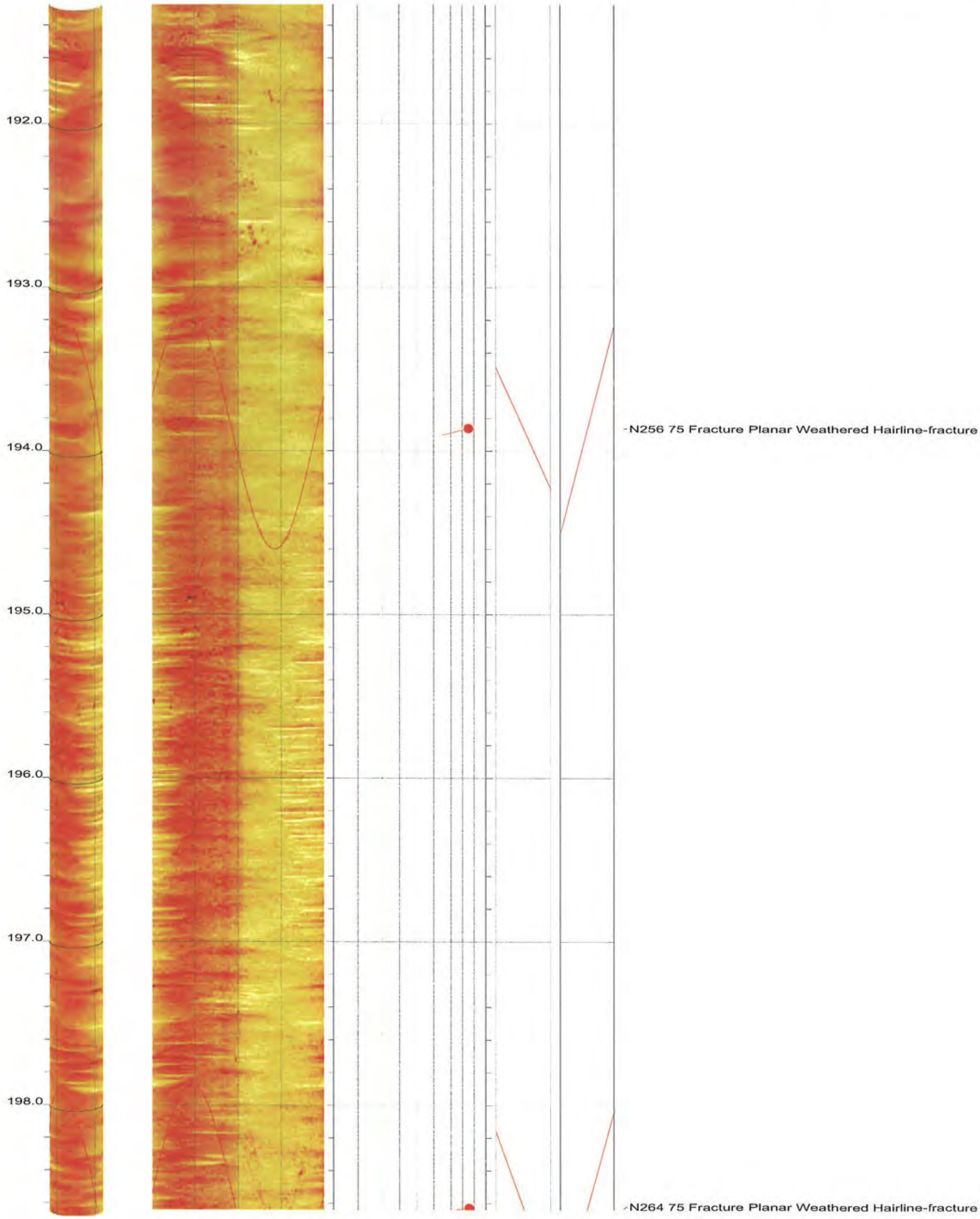
North Anna COL Boring B-909 Acoustic Televiewer Dips Sheet 24 of 28



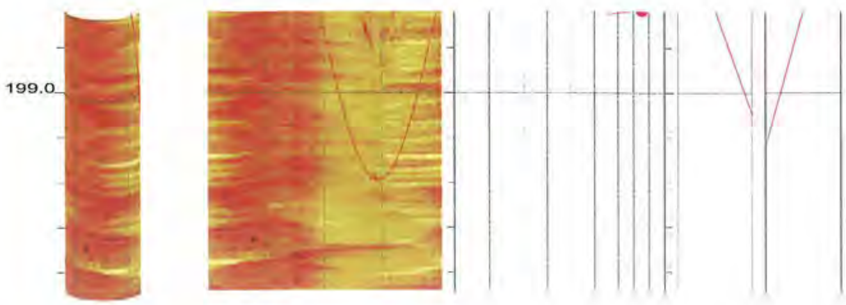
North Anna COL Boring B-909 Acoustic Televiewer Dips Sheet 25 of 28



North Anna COL Boring B-909 Acoustic Televiewer Dips Sheet 26 of 28



North Anna COL Boring B-909 Acoustic Televiewer Dips Sheet 27 of 28



North Anna COL Boring B-909 Acoustic Televiewer Dips Sheet 28 of 28

APPENDIX D

BORING GEOPHYSICAL LOGGING SYSTEMS - NIST TRACEABLE CALIBRATION PROCEDURES AND CALIBRATION RECORDS

CALIBRATION PROCEDURE FOR

GEOVision SEISMIC RECORDER/LOGGER

Reviewed 4/6/06

Objective

The timing/sampling accuracy of seismic recorders or data loggers is required for several GEOVision field procedures including Seismic Refraction, Downhole Seismic Velocity Logging, and P-S Suspension Logging. This procedure describes the method for measuring the timing accuracy of a seismic data logger, such as the OYO Model 170, OYO/Robertson Model 3403, Geometrics Strataview or Geometrics Geode. The objective of this procedure is to verify that the timing accuracy of the recorder is accurate to within 1%.

Frequency of Calibration

The calibration of each GEOVision seismic data logger is twelve (12) months. In the case of rented seismic data loggers, calibration must be performed prior to use.

Test Equipment Required

The following equipment is required. Item #2 must have current NIST traceable calibration.

1. Function generator, Krohn Hite 5400B or equivalent
2. Frequency counter, HP 5315A or equivalent
3. Test cables, from item 1 to item 2, and from item 1 to subject data logger.

Procedure

This procedure is designed to be performed using the accompanying Seismograph Calibration Data Sheet with the same revision number. All data must be entered and the procedure signed by the technician performing the test.

1. Record all identification data on the form provided.
2. Connect function generator to data logger (such as OYO Model 170) using test cable
3. Connect the function generator to the frequency counter using test cable.

4. Set up generator to produce a 100.0 Hz, 0.25 volt (amplitude is approximate, modify as necessary to yield less than full scale waveforms on logger display) peak square wave or sine wave. Verify frequency using the counter and initial space on the data sheet.

5. Initialize data logger and record a data record of at least 0.1 second using a 100 microsecond or less sample period.

6. Measure the recorded square wave frequency by measuring the duration of 9 cycles of data. This measurement can be made using the data logger display device, or by printing out a paper tape. If a paper tape can be printed, the resulting printout must be attached to this procedure. Record the data in the space provided.

7. Repeat steps 5 and 6 three more times using separate files.

Criteria

The duration for 9 cycles in any file must be 90.0 milliseconds plus or minus 0.9 milliseconds, corresponding to an average frequency for the nine cycles of 100.0 Hz plus or minus 1 Hz (obtained by dividing 9 cycles by the duration in milliseconds).

If the results are outside this range, the data logger must be marked with a GEOVision REJECT tag until it can be repaired and retested.

If results are acceptable affix label indicating the initials of the person performing the calibration, the date of calibration, and the due date for the next calibration (12 months).

Procedure Approval

Approved by:

John G. Diehl	President
Name	Title
[signature]	April 6, 2006
Signature	Date

Client Approval (if required):

Name	Title
Signature	Date

TEST NUMBER
501206

EDISON ESI

Calibration Report

METROLOGY

GEOVision Geophysical Services
1151 Pomona Road, Unit P
Corona, CA 92882
P.O. No.: 6162-060414-01

Manufacturer:	Oyo Corporation
Model Number:	3331-A
Description:	Logger, Suspension,
Asset Number:	19029
Serial Number:	19029

Calibration Date:	04/21/2006
Calibration Due Date:	04/21/2007
Calibration Interval:	12 Months
Condition As Found:	In Tolerance
Condition As Left:	In Tolerance

Remarks:
The UUT (unit under test) was calibrated using the customer's procedure. The UUT was operated by the customer's personnel and data collection was observed by SCE personnel. The UUT was found to be in tolerance to customer supplied specifications. The reference standards used are in compliance with ISO/IEC 17025:1999 and laboratory accreditation criteria established by NIST/NVLAP under the specific scope of accreditation for lab code 105014-0. Frequency is accredited.
Please see attached data.

Standards Utilized

I.D. No.	Mfg.	Model No.	Description	Cal. Date	Due Date
S1-01252	Hewlett Packard	5335A OPT 010,203040	Counter, Universal	12/09/2005	06/09/2006
S1-03355	Hewlett Packard	3325B OPT 001, 002	Generator, Function, Synthesizer	11/03/2005	11/03/2006
S1-03686	Fluke	910	Standard, Frequency, Controlled, Gps	01/16/2006	01/16/2007

Procedure:	Customer
Temperature:	23° C
Humidity:	40% RH
Test No.:	501206

Calibration Performed By:			Quality Reviewer:	
Branson, Craig A (Name)	Metrologist (Title)	714-895-0714 (Phone)	(Name)	04-21-06 (Date)

GEOVision
geophysical services

SEISMOGRAPH CALIBRATION DATA SHEET REV 4/6/06

INSTRUMENT DATA

SYSTEM MFR: OYO | MODEL NO.: 3331A
SERIAL NO.: 19029 | CALIBRATION DATE: 4/21/2006
BY: ROBERT STELLER | DUE DATE: 4/21/2007

COUNTER MFR: HEWLETT PACKARD | MODEL NO.: 5335A
SERIAL NO.: 2626A09881 | CALIBRATION DATE: 12/9/2005
BY: SCE #S1-01252 | DUE DATE: 6/9/2006

FCTN GEN MFR: HEWLETT PACKARD | MODEL NO.: 3325B
SERIAL NO.: 2847A14447 | CALIBRATION DATE: 11/3/2005
BY: SCE #S1-03355 | DUE DATE: 11/3/2006

SYSTEM SETTINGS:

GAIN: 10
FILTER: 20 KHZ
RANGE: 100 MILLISEC
DELAY: 0
STACK: 1 (STD) 1
PULSE: 1.6
DISPLAY: NA
SYSTEM: DATE = CORRECT DATE & TIME 4/21/2006, 10:30AM

PROCEDURE:
SET FREQUENCY TO 100.0HZ SQUAREWAVE WITH AMPLITUDE APPROXIMATELY 0.25 VOLT PEAK. RECORD BOTH ON DISK AND PAPER TAPE, IF AVAILABLE. ANALYZE AND PRINT WAVEFORMS FROM ANALYSIS UTILITY. ATTACH PAPER COPIES OF PRINTOUT AND PAPER TAPES, IF AVAILABLE, TO THIS FORM. AVERAGE FREQUENCY MUST BE BETWEEN 99.0 AND 101.0 HZ.

AS FOUND 100.0 AS LEFT 100.0

WAVEFORM	FILE NO	FREQUENCY	TIME FOR 9 CYCLES Hn	TIME FOR 9 CYCLES Hr	TIME FOR 9 CYCLES V	AVERAGE FREQ.
SQUARE	201	100.0	90.0	90.0	90.0	100.0
SQUARE	202	100.0	90.0	90.0	90.0	100.0
SINE	203	100.0	89.9	89.9	89.9	100.1
SINE	204	100.0	90.0	90.0	89.9	100.0

CALIBRATED BY: ROBERT STELLER (NAME) 4/21/2006 (DATE) Rob Steller (SIGNATURE)

Seismic recorder/Logger Calibration Data Sheet Rev 1.30 4-6-06

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OYO S/N 19029

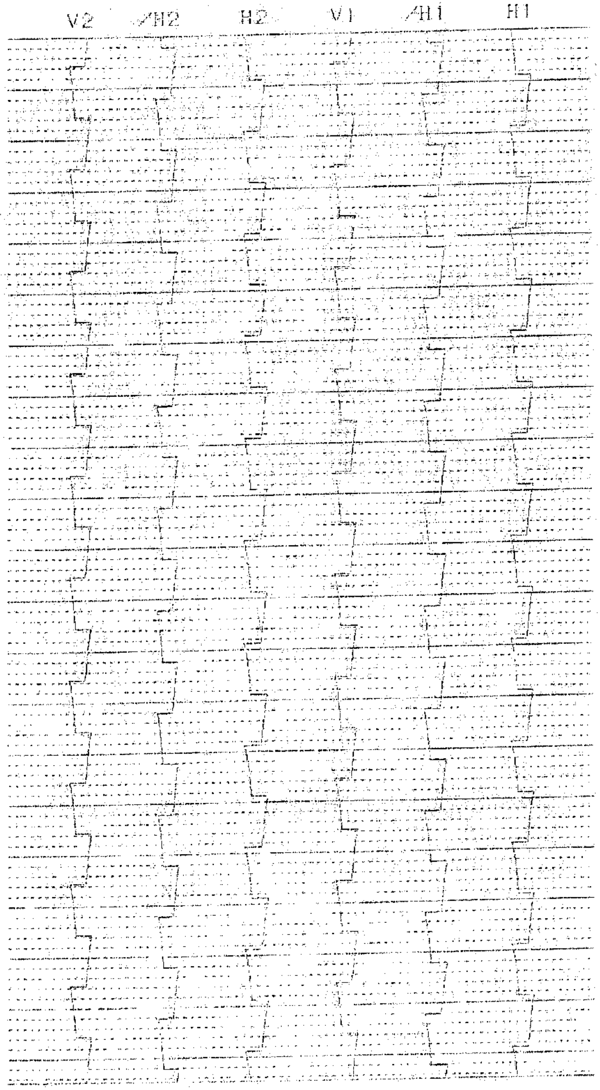
Suspension 170 4.25

ID_NO. : 201
HOLE NO. : 0
DEPTH : 0.0 [m]
DATE : 21/04/06 10:41:08 AM
H-SAMPLE RATE: 100 [μSEC]
V-SAMPLE RATE: 100 [μSEC]
PULSE WIDTH : 1.6 [mSEC]
DELAY TIME : 3 [mSEC]

	H1	/H1	V1	H2	/H2	V2
GAIN	:X 10	X 10	X 10	X 10	X 10	X 10
LCF[Hz]	: 5	5	5	5	5	5
HCF[Hz]	: 20K	20K	20K	20K	20K	20K
STACK	: 1	1	1	1	1	1

TRACE SIZE : 1
H-TIME SCALE: 1.00 [mSEC/LINE]
V-TIME SCALE: 1.00 [mSEC/LINE]

V2 /H2 H2 V1 /H1 H1



OYO S/N 19029

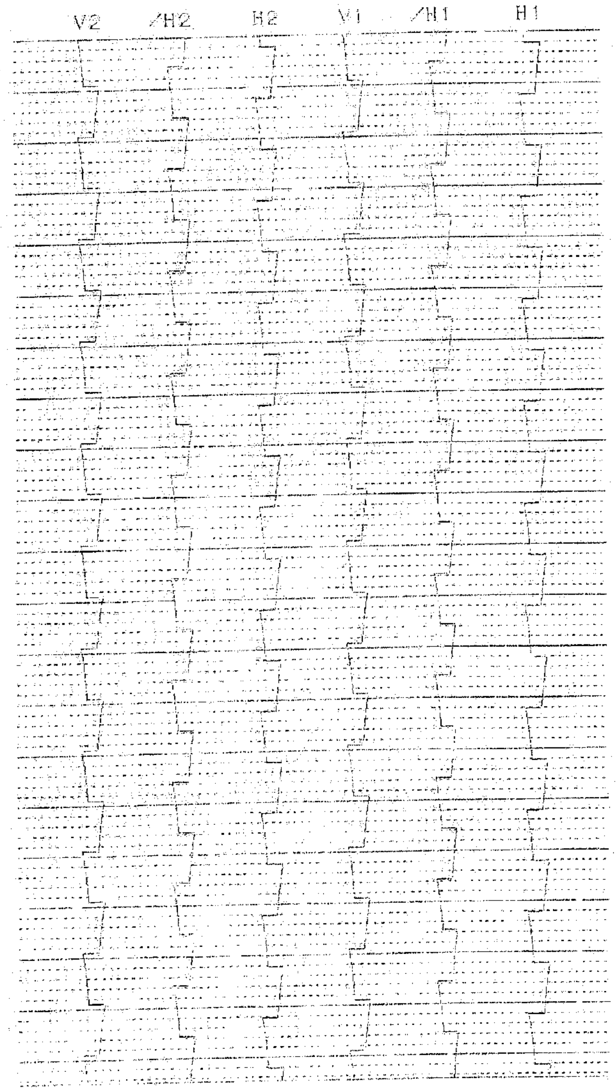
Suspension 170 4.25

ID_NO. : 202
HOLE NO. : 0
DEPTH : 0.0 [m]
DATE : 21/04/06 10:45:05 AM
H-SAMPLE RATE: 100 [μSEC]
V-SAMPLE RATE: 100 [μSEC]
PULSE WIDTH : 1.6 [mSEC]
DELAY TIME : 3 [mSEC]

	H1	/H1	V1	H2	/H2	V2
GAIN	:X 10	X 10	X 10	X 10	X 10	X 10
LCF[Hz]	: 5	5	5	5	5	5
HCF[Hz]	: 20K	20K	20K	20K	20K	20K
STACK	: 1	1	1	1	1	1

TRACE SIZE : 1
H-TIME SCALE: 1.00 [mSEC/LINE]
V-TIME SCALE: 1.00 [mSEC/LINE]

V2 /H2 H2 V1 /H1 H1



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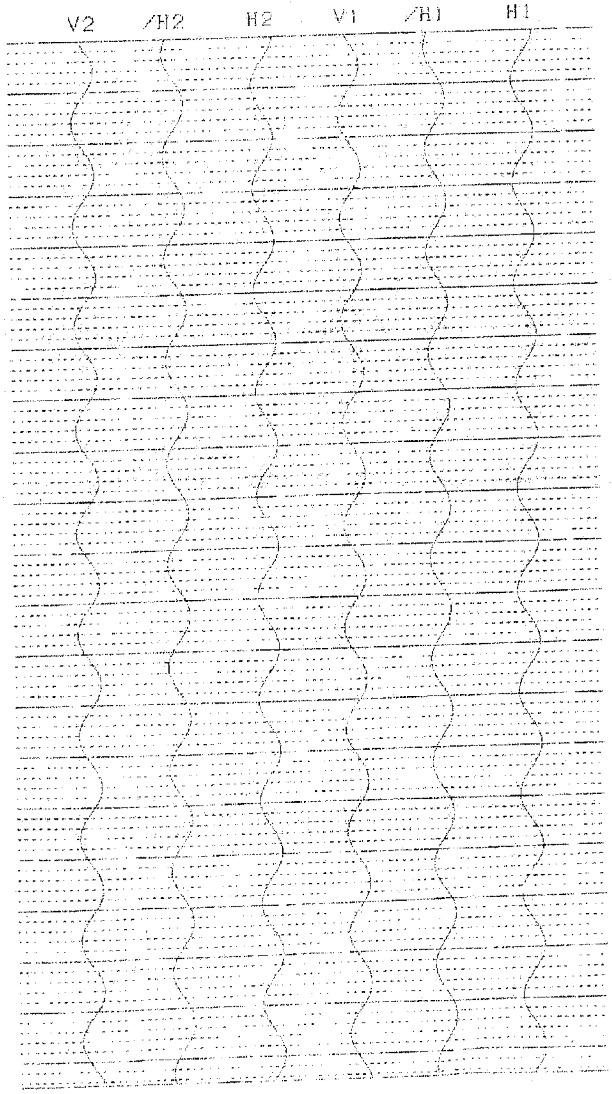
OYO S/N 19029

Suspension 170 4.25

ID_NO. : 203
HOLE NO. : 0
DEPTH : 0.0 [m]
DATE : 21/04/06 10:46:15 AM
H-SAMPLE RATE: 100 [μSEC]
V-SAMPLE RATE: 100 [μSEC]
PULSE WIDTH : 1.6 [mSEC]
DELAY TIME : 3 [mSEC]

	H1	/H1	V1	H2	/H2	V2
GAIN :	X 10	X 10	X 10	X 10	X 10	X 10
LCF[Hz] :	5	5	5	5	5	5
HCF[Hz] :	20K	20K	20K	20K	20K	20K
STACK :	1	1	1	1	1	1

TRACE SIZE : 1
H-TIME SCALE: 1.00 [mSEC/LINE]
V-TIME SCALE: 1.00 [mSEC/LINE]



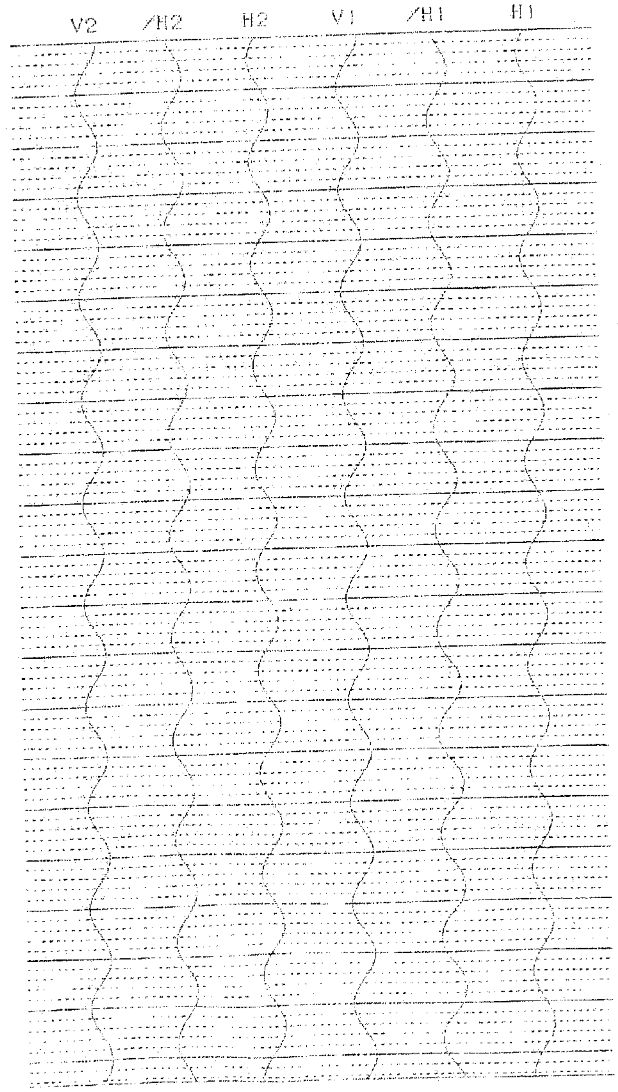
OYO S/N 19029

Suspension 170 4.25

ID_NO. : 204
HOLE NO. : 0
DEPTH : 0.0 [m]
DATE : 21/04/06 10:47:47 AM
H-SAMPLE RATE: 100 [μSEC]
V-SAMPLE RATE: 100 [μSEC]
PULSE WIDTH : 1.6 [mSEC]
DELAY TIME : 3 [mSEC]

	H1	/H1	V1	H2	/H2	V2
GAIN :	X 10	X 10	X 10	X 10	X 10	X 10
LCF[Hz] :	5	5	5	5	5	5
HCF[Hz] :	20K	20K	20K	20K	20K	20K
STACK :	1	1	1	1	1	1

TRACE SIZE : 1
H-TIME SCALE: 1.00 [mSEC/LINE]
V-TIME SCALE: 1.00 [mSEC/LINE]



TEST NUMBER
501203

EDISON ESI

METROLOGY

Calibration Report

GEOVision Geophysical Services
1151 Pomona Road, Unit P
Corona, CA 92882
P.O. No.: 6162-060414-01

Manufacturer:	Oyo
Model Number:	3403
Description:	Unit, Suspension Telemetry,
Asset Number:	160023
Serial Number:	160023

Calibration Date:	04/21/2006
Calibration Due Date:	04/21/2007
Calibration Interval:	12 Months
Condition As Found:	In Tolerance
Condition As Left:	In Tolerance

Remarks:
The UUT (unit under test) was calibrated using the customer's procedure. The UUT was operated by the customer's personnel and data collection was observed by SCE personnel. The UUT was found to be in tolerance to customer supplied specifications. The reference standards used are in compliance with ISO/IEC 17025:1999 and laboratory accreditation criteria established by NIST/NVLAP under the specific scope of accreditation for lab code 105014-0. Frequency is accredited.
Please see attached data.

Standards Utilized

I.D. No.	Mfg.	Model No.	Description	Cal. Date	Due Date
S1-01252	Hewlett Packard	5335A OPT 010,203040	Counter, Universal	12/09/2005	06/09/2006
S1-03355	Hewlett Packard	3325B OPT 001, 002	Generator, Function, Synthesizer	11/03/2005	11/03/2006
S1-03686	Fluke	910	Standard, Frequency, Controlled, Gps	01/16/2006	01/16/2007

Procedure:	Customer
Temperature:	23° C
Humidity:	40% RH
Test No.:	501203

Calibration Performed By:			Quality Reviewer:	
Branson, Craig A (Name)	Metrologist (Title)	714-895-0714 (Phone)	(Name)	04-21-06 (Date)

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4-21-06

GEOVision
geophysical services

SEISMOGRAPH CALIBRATION DATA SHEET REV 4/6/06

INSTRUMENT DATA

SYSTEM MFR:	OYO	MODEL NO.:	3403
SERIAL NO.:	160023	CALIBRATION DATE:	4/21/2006
BY:	ROBERT STELLER	DUE DATE:	4/21/2007
COUNTER MFR:	HEWLETT PACKARD	MODEL NO.:	5335A
SERIAL NO.:	2626A09881	CALIBRATION DATE:	12/9/2005
BY:	SCE #S1-01252	DUE DATE:	6/9/2006
FCTN GEN MFR:	HEWLETT PACKARD	MODEL NO.:	3325B
SERIAL NO.:	2847A14447	CALIBRATION DATE:	11/3/2005
BY:	SCE #S1-03355	DUE DATE:	11/3/2006

SYSTEM SETTINGS:

GAIN:	2
FILTER:	10 KHZ
RANGE:	100 MILLISEC, 100 MICROSECOND SAMPLE RATE
DELAY:	0
STACK: 1 (STD)	1
PULSE:	1.6
DISPLAY:	NA
SYSTEM: DATE = CORRECT DATE & TIME	4/21/2006, 11:07AM

PROCEDURE:

SET FREQUENCY TO 100.0HZ SQUAREWAVE WITH AMPLITUDE APPROXIMATELY 0.25 VOLT PEAK. RECORD BOTH ON DISK AND PAPER TAPE, IF AVAILABLE. ANALYZE AND PRINT WAVEFORMS FROM ANALYSIS UTILITY. ATTACH PAPER COPIES OF PRINTOUT AND PAPER TAPES, IF AVAILABLE, TO THIS FORM. AVERAGE FREQUENCY MUST BE BETWEEN 99.0 AND 101.0 HZ.

AS FOUND 100.0 AS LEFT 100.0

WAVEFORM	FILE NO	FREQUENCY	TIME FOR 9 CYCLES Hn	TIME FOR 9 CYCLES Hr	TIME FOR 9 CYCLES V	AVERAGE FREQ.
SQUARE	305	100.0	90.0	90.0	90.0	100.0
SQUARE	306	100.0	90.0	90.0	90.0	100.0
SINE	307	100.0	90.0	90.0	90.0	100.0
SINE	308	100.0	90.1	90.0	90.0	100.0

CALIBRATED BY:	ROBERT STELLER	4/21/2006	Robt Steller
	NAME	DATE	SIGNATURE

Seismic recorder/Logger Calibration Data Sheet Rev 1.30 4-6-06

TEST NUMBER
501204

EDISON ESI

METROLOGY

Calibration Report

GEOVision Geophysical Services
1151 Pomona Road, Unit P
Corona, CA 92882
P.O. No.: 6162-060414-01

Manufacturer:	Oyo	**Calibration Date:**	04/21/2006
Model Number:	3403	**Calibration Due Date:**	04/21/2007
Description:	Unit, Suspension Telemetry,	**Calibration Interval:**	12 Months
Asset Number:	160024	**Condition As Found:**	In Tolerance
Serial Number:	160024	**Condition As Left:**	In Tolerance

Remarks:
The UUT (unit under test) was calibrated using the customer's procedure. The UUT was operated by the customer's personnel and data collection was observed by SCE personnel. The UUT was found to be in tolerance to customer supplied specifications. The reference standards used are in compliance with ISO/IEC 17025:1999 and laboratory accreditation criteria established by NIST/NVLAP under the specific scope of accreditation for lab code 105014-0. Frequency is accredited.
Please see attached data.

Standards Utilized

I.D. No.	Mfg.	Model No.	Description	Cal. Date	Due Date
S1-01252	Hewlett Packard	5335A OPT 010,203040	Counter, Universal	12/09/2005	06/09/2006
S1-03355	Hewlett Packard	3325B OPT 001, 002	Generator, Function, Synthesizer	11/03/2005	11/03/2006
S1-03686	Fluke	910	Standard, Frequency, Controlled, Gps	01/16/2006	01/16/2007

Procedure: Customer
Temperature: 23° C
Humidity: 40% RH
Test No.: 501204

Calibration Performed By:			Quality Reviewer:	
Branson, Craig A CAB (Name)	Metrologist (Title)	714-895-0714 (Phone)	[signature] (Name)	04-21-06 (Date)

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4-21-06

GEOVision
geophysical services

SEISMOGRAPH CALIBRATION DATA SHEET REV 4/6/06

INSTRUMENT DATA

SYSTEM MFR: OYO — MODEL NO.: 3403
SERIAL NO.: 160024 — CALIBRATION DATE: 4/21/2006
BY: ROBERT STELLER — DUE DATE: 4/21/2007

COUNTER MFR: HEWLETT PACKARD — MODEL NO.: 5335A
SERIAL NO.: 2626A09881 — CALIBRATION DATE: 12/9/2005
BY: SCE #S1-01252 — DUE DATE: 6/9/2006

FCTN GEN MFR: HEWLETT PACKARD — MODEL NO.: 3325B
SERIAL NO.: 2847A14447 — CALIBRATION DATE: 11/3/2005
BY: SCE #S1-03355 — DUE DATE: 11/3/2006

SYSTEM SETTINGS:

GAIN: 2
FILTER: 10 KHZ
RANGE: 100 MILLISEC, 100 MICROSECOND SAMPLE RATE
DELAY: 0
STACK: 1 (STD) 1
PULSE: 1.6
DISPLAY: NA
SYSTEM: DATE = CORRECT DATE & TIME 4/21/2006, 11:30AM

PROCEDURE:
SET FREQUENCY TO 100.0HZ SQUAREWAVE WITH AMPLITUDE APPROXIMATELY 0.25 VOLT PEAK. RECORD BOTH ON DISK AND PAPER TAPE, IF AVAILABLE. ANALYZE AND PRINT WAVEFORMS FROM ANALYSIS UTILITY. ATTACH PAPER COPIES OF PRINTOUT AND PAPER TAPES, IF AVAILABLE, TO THIS FORM. AVERAGE FREQUENCY MUST BE BETWEEN 99.0 AND 101.0 HZ.

AS FOUND 100.0 — AS LEFT 100.0

WAVEFORM	FILE NO	FREQUENCY	TIME FOR 9 CYCLES Hn	TIME FOR 9 CYCLES Hr	TIME FOR 9 CYCLES V	AVERAGE FREQ.
SQUARE	401	100.0	90.0	90.0	90.0	100.0
SQUARE	402	100.0	90.0	90.0	90.0	100.0
SINE	403	100.0	89.9	90.0	90.1	100.0
SINE	404	100.0	90.0	90.1	90.1	99.9

CALIBRATED BY: ROBERT STELLER (NAME) — 4/21/2006 (DATE) — Robt Steller (SIGNATURE)

Seismic recorder/Logger Calibration Data Sheet Rev 1.30 4-6-06

TEST NUMBER
501205

EDISON ESI

METROLOGY

Calibration Report

GEOVision Geophysical Services
1151 Pomona Road, Unit P
Corona, CA 92882
P.O. No.: 6162-060414-01

Manufacturer:	Geometrics	**Calibration Date:**	04/21/2006
Model Number:	STRATAVIEW	**Calibration Due Date:**	04/21/2007
Description:	Siesmograph,	**Calibration Interval:**	12 Months
Asset Number:	75299	**Condition As Found:**	In Tolerance
Serial Number:	75299	**Condition As Left:**	In Tolerance

Remarks:
The UUT (unit under test) was calibrated using the customer's procedure. The UUT was operated by the customer's personnel and data collection was observed by SCE personnel. The UUT was found to be in tolerance to customer supplied specifications. The reference standards used are in compliance with ISO/IEC 17025:1999 and laboratory accreditation criteria established by NIST/NVLAP under the specific scope of accreditation for lab code 105014-0. Frequency is accredited.
Please see attached data.

Standards Utilized

I.D. No.	Mfg.	Model No.	Description	Cal. Date	Due Date
S1-01252	Hewlett Packard	5335A OPT 010,203040	Counter, Universal	12/09/2005	06/09/2006
S1-03355	Hewlett Packard	3325B OPT 001, 002	Generator, Function, Synthesizer	11/03/2005	11/03/2006
S1-03686	Fluke	910	Standard, Frequency, Controlled, Gps	01/16/2006	01/16/2007

Procedure: Customer
Temperature: 23° C
Humidity: 40% RH
Test No.: 501205

Calibration Performed By:			Quality Reviewer:	
Branson, Craig A (Name)	Metrologist (Title)	714-895-0714 (Phone)	(Name)	04-21-06 (Date)

page 2 of 6

GEOVision geophysical services

SEISMOGRAPH CALIBRATION DATA SHEET REV 4/6/06

INSTRUMENT DATA

SYSTEM MFR:	GEOMETRICS	MODEL NO.:	STRATAVIEW
SERIAL NO.:	75299	CALIBRATION DATE:	4/21/2006
BY:	ROBERT STELLER	DUE DATE:	4/21/2007
COUNTER MFR:	HEWLETT PACKARD	MODEL NO.:	5335A
SERIAL NO.:	2626A09881	CALIBRATION DATE:	12/9/2005
BY:	SCE #S1-01252	DUE DATE:	6/9/2006
FCTN GEN MFR:	HEWLETT PACKARD	MODEL NO.:	3325B
SERIAL NO.:	2847A14447	CALIBRATION DATE:	11/3/2005
BY:	SCE #S1-03355	DUE DATE:	11/3/2006

SYSTEM SETTINGS:

GAIN:	15 DB
FILTER:	NONE
RANGE:	256 MILLISEC, 31 MICROSECOND SAMPLE RATE
DELAY:	0
STACK: 1 (STD)	1
PULSE:	NA
DISPLAY:	NA
SYSTEM: DATE = CORRECT DATE & TIME	4/21/2006, 12:09PM

PROCEDURE:
SET FREQUENCY TO 100.0HZ SQUAREWAVE WITH AMPLITUDE APPROXIMATELY 0.25 VOLT PEAK. RECORD BOTH ON DISK AND PAPER TAPE, IF AVAILABLE. ANALYZE AND PRINT WAVEFORMS FROM ANALYSIS UTILITY. ATTACH PAPER COPIES OF PRINTOUT AND PAPER TAPES, IF AVAILABLE, TO THIS FORM. AVERAGE FREQUENCY MUST BE BETWEEN 99.0 AND 101.0 HZ.

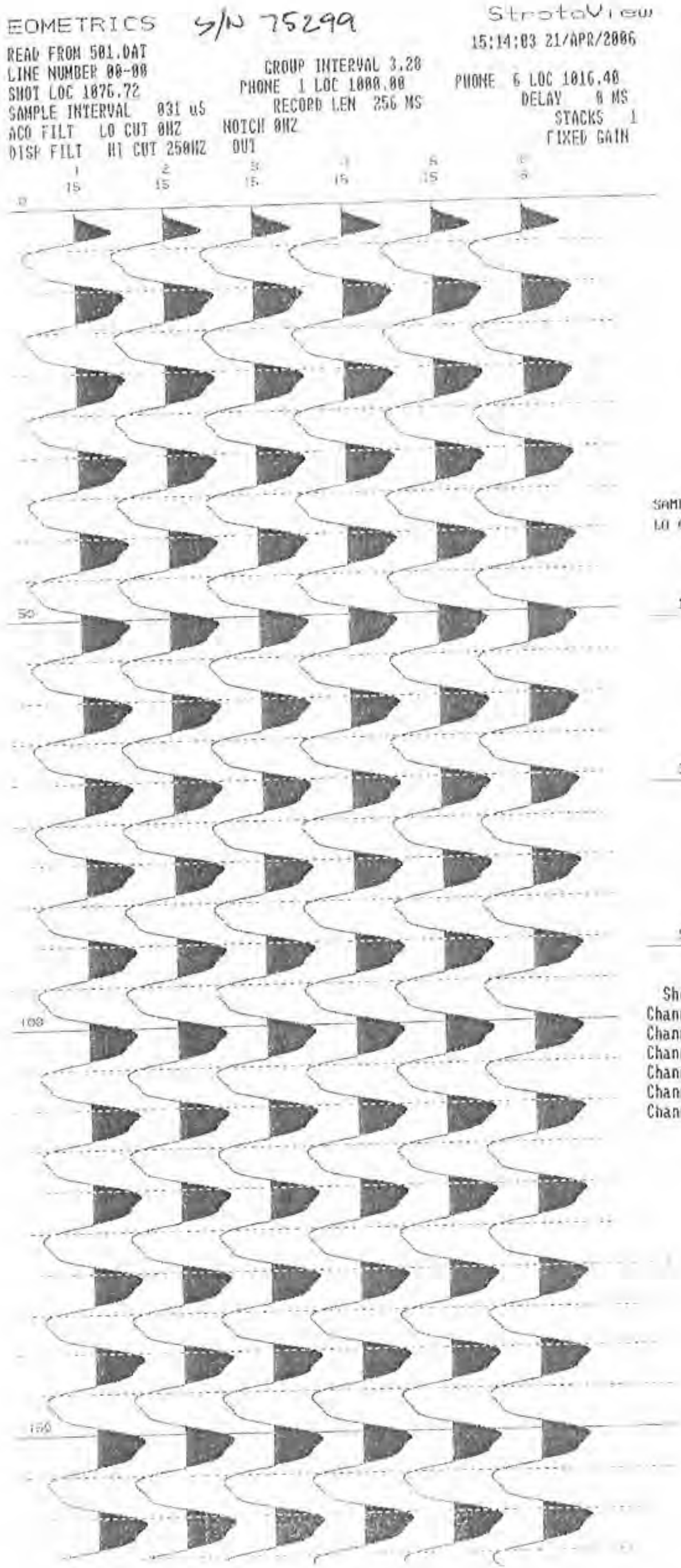
AS FOUND 100.0 AS LEFT 100.0

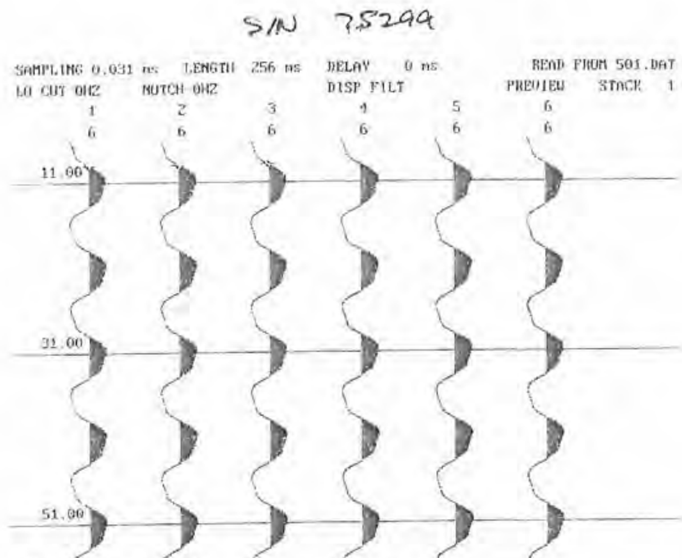
WAVEFORM	FILE NO	FREQUENCY	TIME FOR 9 CYCLES Hn	TIME FOR 9 CYCLES Hr	TIME FOR 9 CYCLES V	AVERAGE FREQ.
SQUARE	501	100.0	90.0	90.0	90.0	100.0
SQUARE	502	100.0	90.0	90.0	90.0	100.0
SINE	503	100.0	90.0	90.0	90.0	100.0
SINE	504	100.0	90.0	90.0	90.0	100.0

CALIBRATED BY:	ROBERT STELLER	4/21/2006	Robt Steller
	NAME	DATE	SIGNATURE

Seismic recorder/Logger Calibration Data Sheet Rev 1.30 4-6-06

page 3 of 6

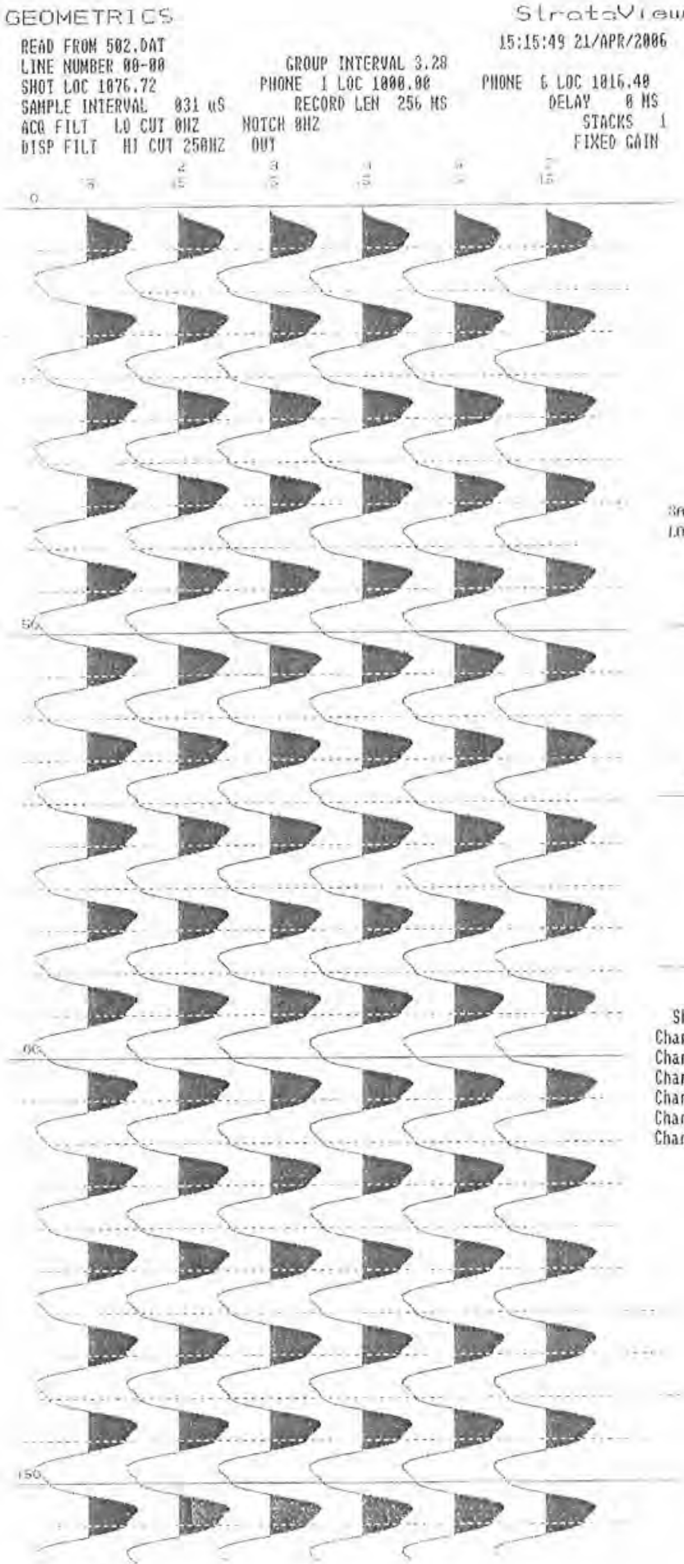




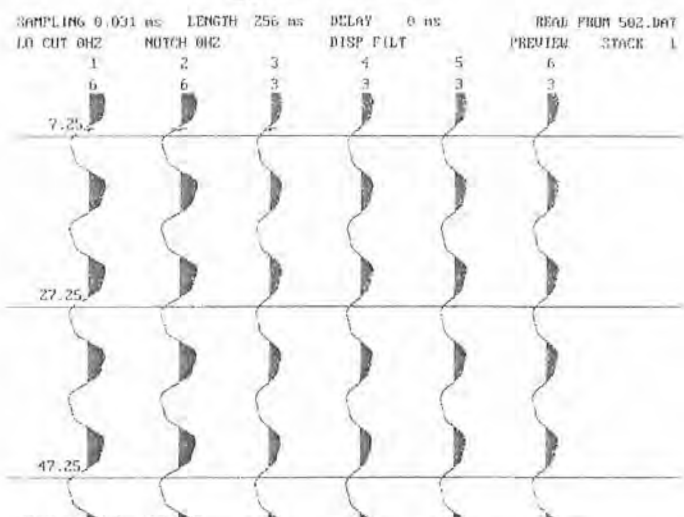
Shot point is 1076.72

Channel	1	Phone location	1000.00	Arrival time	9.0	msec
Channel	2	Phone location	1003.28	Arrival time	9.0	msec
Channel	3	Phone location	1006.56	Arrival time	8.9	msec
Channel	4	Phone location	1009.84	Arrival time	109.0	msec
Channel	5	Phone location	1013.12	Arrival time	108.9	msec
Channel	6	Phone location	1016.40	Arrival time	108.9	msec

Page 4 of 6



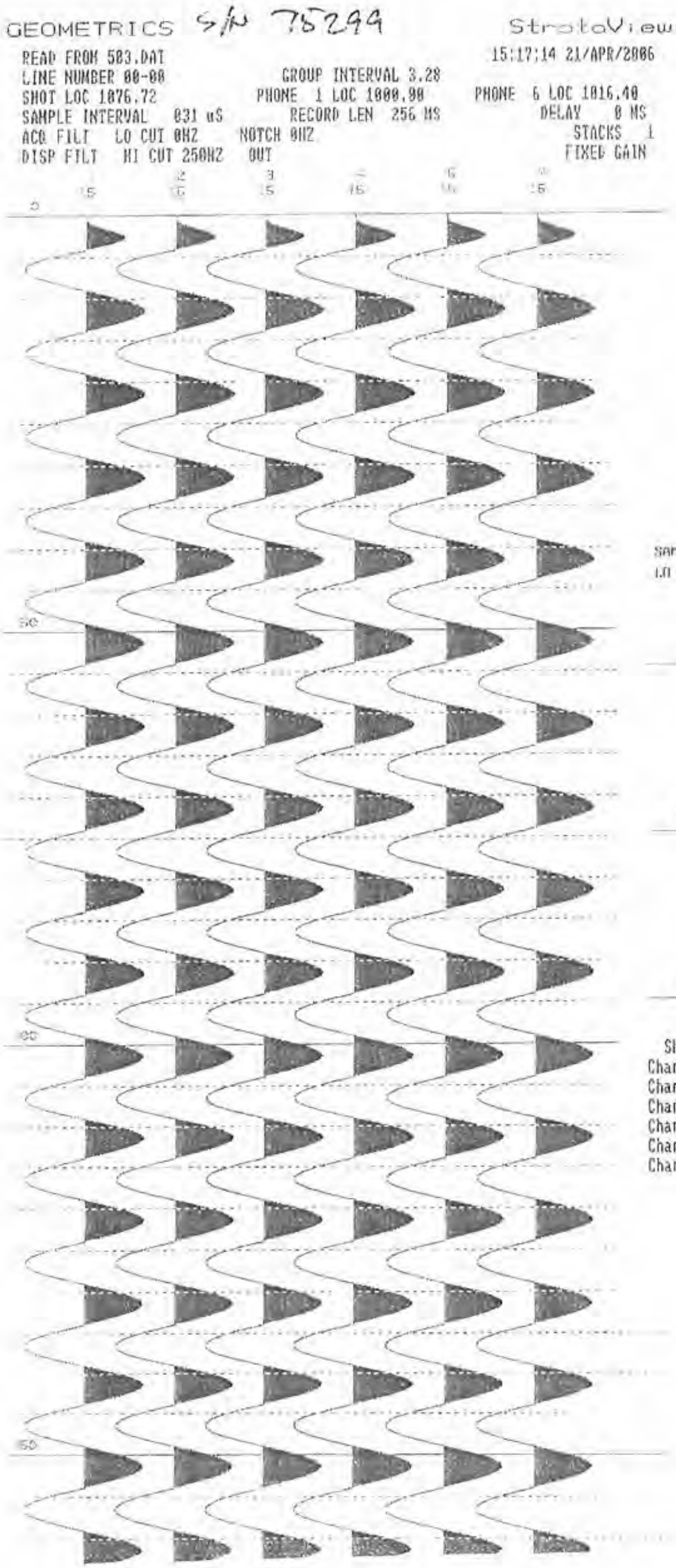
S/N 75249

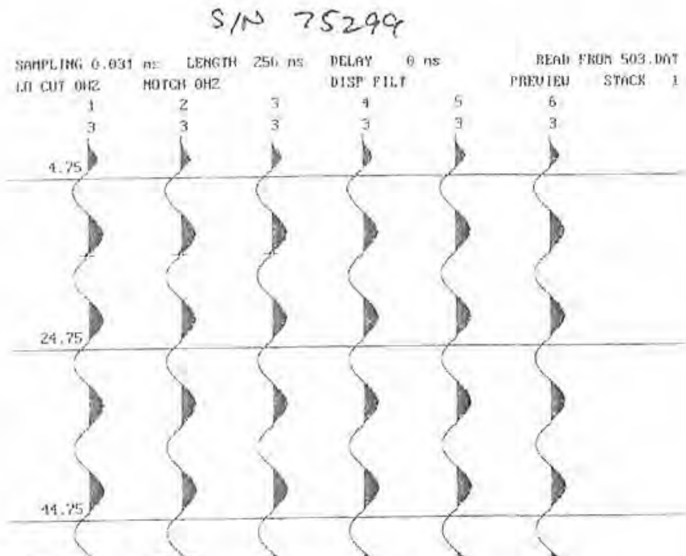


Shot point is 1076.72

Channel	1	Phone location 1000.00	Arrival time	6.4 msec	
Channel	2	Phone location 1003.28	Arrival time	6.4 msec	
Channel	3	Phone location 1006.56	Arrival time	6.4 msec	
Channel	4	Phone location 1009.84	Arrival time	96.4 msec	
Channel	5	Phone location 1013.12	Arrival time	96.4 msec	
Channel	6	Phone location 1016.40	Arrival time	96.4 msec	

page 5 of 6

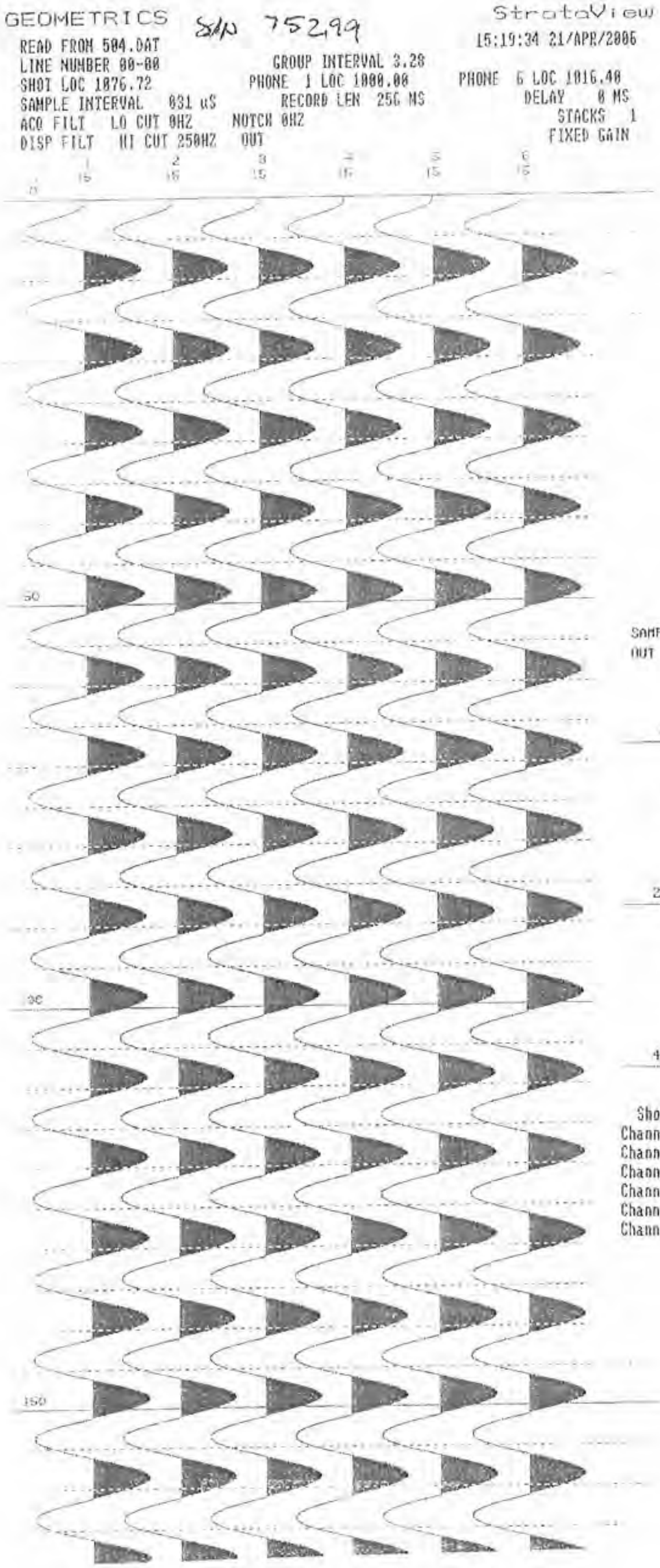


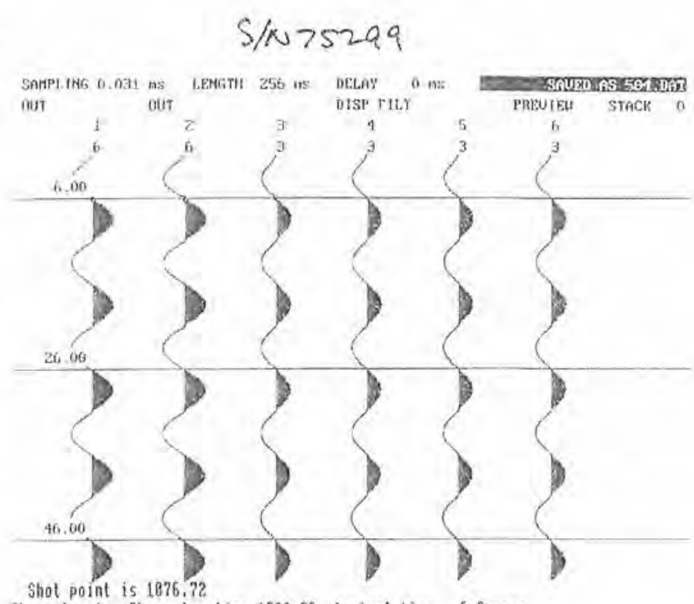


Shot point is 1076.72

Channel 1	Phone location 1000.00	Arrival time	13.8 msec
Channel 2	Phone location 1003.28	Arrival time	13.8 msec
Channel 3	Phone location 1006.56	Arrival time	13.8 msec
Channel 4	Phone location 1009.84	Arrival time	103.8 msec
Channel 5	Phone location 1013.12	Arrival time	103.8 msec
Channel 6	Phone location 1016.40	Arrival time	103.8 msec

page 6 of 6





Shot point is 1076.72

Channel 1	Phone location 1000.00	Arrival time	6.0 msec
Channel 2	Phone location 1003.28	Arrival time	6.0 msec
Channel 3	Phone location 1006.56	Arrival time	6.0 msec
Channel 4	Phone location 1009.84	Arrival time	96.0 msec
Channel 5	Phone location 1013.12	Arrival time	96.0 msec
Channel 6	Phone location 1016.40	Arrival time	96.0 msec

United States Department of Commerce
National Institute of Standards and Technology

NVLAP®

Certificate of Accreditation to ISO/IEC 17025:1999

NVLAP LAB CODE: 105014-0

Southern California Edison Company

Westminster, CA

is recognized by the National Voluntary Laboratory Accreditation Program for conformance with criteria set forth in NIST Handbook 150:2001 and all requirements of ISO/IEC 17025:1999.
Accreditation is granted for specific services, listed on the Scope of Accreditation, for:

CALIBRATION LABORATORIES

2006-04-01 through 2007-03-31
Effective dates

For the National Institute of Standards and Technology

NVLAP-01C (REV. 2005-05-19)

National Voluntary Laboratory Accreditation Program

SCOPE OF ACCREDITATION TO ISO/IEC 17025:1999

Southern California Edison Company
7300 Fenwick Lane
Westminster, CA 92683
Ms. Jennifer E. Smith
Phone: 714-895-0133 Fax: 714-895-0781
E-mail: Jennifer.Smith@sce.com
URL: http://www.edisonmetrology.com

CALIBRATION LABORATORIES **NVLAP LAB CODE 105014-0**

NVLAP Code: 20/A01 ANSI/NCSL Z540-1-1994; Part I Compliant

DIMENSIONAL

NVLAP Code: 20/D03
Gage Blocks

Nominal Length in in	*Best Uncertainty (±) in μin* [note 1]
0.01 to < 0.05	1.9
0.05 to < 0.1	1.7
0.1 to < 1.0	1.2
1.0	1.4
2.0	1.8
3.0	2.2
4.0	2.9
5.0	5.4
6.0	5.6
7.0	5.8
8.0	6.0
10.0	6.8
12.0	7.2
16.0	8.1
20.0	9.4

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Nominal Length in mm	*Best Uncertainty (±) in nm* note 1
0.5 to < 1.0	52
1.0 to < 2.5	44
2.5 to < 25.0	39
25.0	44
50.0	47
75.0	60
100.0	80

NVLAP Code: 20/D11
Spherical Diameter; Ring Gages

Range in inches	*Best Uncertainty (±) in μin* note 1	*Remarks*
0.040 to 0.825	6	Comparison to gage blocks
> 0.825 to 1.510	7	Comparison to gage blocks
> 1.510 to 2.510	8	Comparison to gage blocks
> 2.510 to 4.510	12	Comparison to gage blocks
> 4.510 to 6.510	14	Comparison to gage blocks
> 6.510 to 9.010	16	Comparison to gage blocks
> 9.010 to 12.010	19	Comparison to gage blocks
> 12.010 to 13.25	31	Comparison to gage blocks

ELECTROMAGNETICS - DC/LOW FREQUENCY

NVLAP Code: 20/E02
AC Current

Range	*Best Uncertainty (±) in ppm* note 1 *Frequency in Hz*			
	10	*20*	*40*	*400 to 10 k*
10 mA	270	199	127	116
20 mA	270	199	127	116
30 mA	270	199	127	116
50 mA	286	208	141	130
100 mA	270	199	127	116

2006-04-01 through 2007-03-31
Effective dates

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200 mA		270		199	127		116
300 mA		270		199	127		116
500 mA		270		208	141		130
	10	***20***	***40***	***400 to 5 k***	***10 k***		
1A	270	199	127	116	130		
	10	***20***	***40***	***400 to 10 k***			
2A	271	200	129	118			
3A	271	200	129	118			
	10	***20***	***40***	***400 to 5 k***	***10 k***		
5A	286	209	142	132	148		
	10	***20***	***40***	***400***	***1 k***	***5 k***	***10 k***
10A	273	233	132	121	121	143	143
							400 to 10 k
20A							144

NVLAP Code: 20/E05
DC Current

Range	***Best Uncertainty (±) in ppm*** [note 1]
10 nA	2.9
100 nA	2.3
1 μA	2.0
10 μA	2.0
100 μA	2.0
1 mA	1.9
10 mA	1.9
100 mA	1.9
1 A	10.4
10 A	10.4
30 A	20.6

2006-04-01 through 2007-03-31
Effective dates

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CALIBRATION LABORATORIES **NVLAP LAB CODE 105014-0**

DC Resistance

Nominal Value in Ω	*Best Uncertainty (±) in ppm* note 1	*Remarks*
100 μ	8.20	Automated DC Resistance Calibration System
1 m	5.50	Automated DC Resistance Calibration System
10 m	3.70	Automated DC Resistance Calibration System
100 m	2.10	Automated DC Resistance Calibration System
1	0.40	Automated DC Resistance Calibration System
10	0.40	Automated DC Resistance Calibration System
25	0.50	Automated DC Resistance Calibration System
100	0.50	Automated DC Resistance Calibration System
1 k	0.50	Automated DC Resistance Calibration System
10 k	0.50	Automated DC Resistance Calibration System
100 k	1.50	Automated DC Resistance Calibration System
1 M	2.30	Automated DC Resistance Calibration System
10 M	3.30	Automated DC Resistance Calibration System
100 M	4.00	Automated DC Resistance Calibration System

NVLAP Code: 20/E06
DC Voltage

Range	*Best Uncertainty (±) in ppm* notes 1,2	*Remarks*
1.018 V	0.80	Automated DC Calibration System
10.00 V	0,20	Automated DC Calibration System
1.000 V	0.80	Automated DC Calibration System
1 mV to 100 mV	1.3 note 6	Ratiometric Measurement Techniques performed by voltage transfer utilizing a high precision voltage
100 mV	0.7	Ratiometric Measurement Techniques performed by voltage transfer utilizing a high precision voltage
1.0 V	0.3	Ratiometric Measurement Techniques performed by voltage transfer utilizing a high precision voltage

2006-04-01 through 2007-03-31
Effective dates

For the National Institute of Standards and Technology

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CALIBRATION LABORATORIES **NVLAP LAB CODE 105014-0**

10.0 V	0.3	Ratiometric Measurement Techniques performed by voltage transfer utilizing a high precision voltage
20.0 V	0.5	Ratiometric Measurement Techniques performed by voltage transfer utilizing a high precision voltage
100.0 V	0.3	Ratiometric Measurement Techniques performed by voltage transfer utilizing a high precision voltage
1000.0 V	0.7	Ratiometric Measurement Techniques performed by voltage transfer utilizing a high precision voltage

NVLAP Code: 20/E09
LF AC Voltage

Best Uncertainty (±) in ppm notes 1,3,4
Frequency in Hz

Range	*10*	*20*	*40*	*100*	*1k*	*10k*	*20k*	*50k*	*100k*	*300k*	*500k*	*800k*	*1M*
2 mV	448	912	889	969	379	865	1073	405	1131	1265	2116	2595	2938
10 mV	119	230	102	177	245	169	180	220	343	243	676	425	488
20 mV	83	70	67	67	66	76	76	165	261	361	521	372	442
30 mV	134	111	80	78	62	63	71	133	219	345	535	688	791
100 mV	36	72	23	42	34	35	34	43	77	169	220	287	225
190 mV	36	31	22	20	21	26	21	42	80	136	124	264	215
300 mV	46	61	30	32	34	19	28	36	59	116	143	189	205
1 V	120	36	18	10	13	12	11	25	14	87	102	104	98
1.9 V	36	22	22	9	9	9	8	18	11	94	101	85	89
3 V	26	34	25	17	14	14	13	27	14	100	108	95	97
10 V	20	42	19	10	10	9	10	11	16	80	100	111	100
19 V	26	23	20	11	9	9	10	11	16	98	109	82	82
30 V	30	37	26	19	15	16	19	37	44	118			
100 V	140	46	20	16	15	19	11	40	22				
190 V	47	27	20	20	13	13	13	41	26				
300 V			37	29	18	27	22	29	46				
500 V			33	25	17	20	19	38	52				

2006-04-01 through 2007-03-31
Effective dates

For the National Institute of Standards and Technology

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CALIBRATION LABORATORIES **NVLAP LAB CODE 105014-0**

700 V	29	23	18	17	19	44	54
1000 V	22	23	21	19	22		

TIME AND FREQUENCY

NVLAP Code: 20/F01
Frequency Dissemination

Range	*Best Uncertainty* (±) [note 1]	*Remarks*
10 MHz	1.2×10^{-12}	GPS Receiver

MECHANICAL

NVLAP Code: 20/M05
Flow Rate

Nominal Flow Rate	*Best Uncertainty* (±) *in percent* [notes 1, 5]
(0.8 to 30) L/s	0.3
(0.1 to 800) mL/s	0.4
(0.006 to 0.1) mL/s	0.7

NVLAP Code: 20/M06
Force

Nominal Force in lb	*Best Uncertainty* (±) [note 1]	*Remarks*
2 to 200	0.025 %	Dead Weight
> 200 to 300	0.086 lb	Proving Ring
> 300 to 500	0.14 lb	Proving Ring
> 500 to 1000	0.28 lb	Proving Ring
> 1000 to 2000	0.55 lb	Proving Ring
> 2000 to 5000	0.84 lb	Proving Ring
> 5000 to 10 000	1.7 lb	Proving Ring
> 10 000 to 20 000	5.5 lb	Proving Ring
> 20 000 to 35 000	5.8 lb	Proving Ring
> 35 000 to 50 000	13 lb	Proving Ring

2006-04-01 through 2007-03-31
Effective dates

For the National Institute of Standards and Technology

National Voluntary Laboratory Accreditation Program

CALIBRATION LABORATORIES **NVLAP LAB CODE 105014-0**

> 50 000 to 60 000	16 lb	Proving Ring
> 60 000 to 100 000	26 lb	Proving Ring
> 100 000 to 300 000	113 lb	Proving Ring

NVLAP Code: 20/M08
Mass

Range	*Best Uncertainty (±) in mg* notes 1,2	*Remarks*
10 kg	2.3	Echelon I
5 kg	0.93	Echelon I
3 kg	0.65	Echelon I
2 kg	0.43	Echelon I
1 kg	0.052	Echelon I
500 g	0.043	Echelon I
300 g	0.041	Echelon I
200 g	0.034	Echelon I
100 g	0.020	Echelon I
50 g	0.013	Echelon I
30 g	0.013	Echelon I
20 g	0.0095	Echelon I
10 g	0.0073	Echelon I
5 g	0.0048	Echelon I
3 g	0.0038	Echelon I
2 g	0.0029	Echelon I
1 g	0.0030	Echelon I
500 mg	0.0017	Echelon I
300 mg	0.0013	Echelon I
200 mg	0.0010	Echelon I
100 mg	0.0009	Echelon I
50 mg	0.0007	Echelon I
30 mg	0.0007	Echelon I
20 mg	0.0005	Echelon I
10 mg	0.0005	Echelon I
5 mg	0.0006	Echelon I
3 mg	0.0006	Echelon I

2006-04-01 through 2007-03-31
Effective dates

For the National Institute of Standards and Technology

National Voluntary Laboratory Accreditation Program

CALIBRATION LABORATORIES **NVLAP LAB CODE 105014-0**

2 mg	0.0005	Echelon I
1 mg	0.0005	Echelon I
30 kg	56	Echelon II
20 kg	22	Echelon II

THERMODYNAMIC

NVLAP Code: 20/T05
Pressure

Range	*Best Uncertainty (±) in ppm* note 1	*Remarks*
> 1.5 to 50	20	Gas
> 50 to 1450	45	Gas
> 1450 to 16 000	90	Gas
> 1000 to 10 000	60	Oil
> 10 000 to 30 000	110	Oil
> 30 000 to 50 000	210	Oil

1. Represents an expanded uncertainty using a coverage factor, k = 2, at an approximate level of confidence of 95 %.
2. Approximate value. Actual value determined by the test statistics.
3. All ACV measurements performed via AC/DC transfer system.
4. Uncertainties listed are representative of the laboratory's accredited capabilities within the stated ranges. Accreditation is not limited to only those fixed values shown.
5. Dependent upon principle of operation of device being calibrated and its performance relative to standards at the time of the test.
6. The equation: uncert. = $(A + B/mVDC^2)^{0.5}$ (where A = 0.16 and B = 0.013333) is provided in order for potential customers to calculate approximate uncertainties for values down to 1 mV. Example: uncertainty at 1 mVDC would calculate to approximately ±115.47 ppm.
7. The laboratory maintains Echelon II capability for ranges 20 kg to 1 mg and separate Echelon III for all ranges.
8. Avoirdupois mass calibration services are available by comparison to equivalent metric standards. Uncertainties may be appropriately larger.

2006-04-01 through 2007-03-31
Effective dates

For the National Institute of Standards and Technology

RO PRECISION
LIBRATION INC.
12686 Hoover Street, Garden Grove, CA 92841
Ph. (714) 901-5659 Fax (714) 901-5649

Calibration Report

Customer: **GEOVISION**
Corona CA 92882
Account#: **15214**
Cust.PO#:
Page 1 of 2

MPC Ctrl#: **AM6766**
Report#: **199974**
Print Date: **041006**
MPC Job#: **L25384**

Instrument: **Caliper Calibration Plate**

Mfg: **Robertson Geo Logging**
Model: **N/A**
Size:
Res.:

Serial#: **201**
Cust Ctrl#:
Location:
Department:

Work Performed: **Inspected, cleaned, and calibrated.**
Parts Replaced: **None**

Calibration Condition as Received: **In tolerance**
Calibration Condition as Returned: **In tolerance**

Functions/Parameters Tested

Actual Values (inch)	As Measured
1.969	1.965
3.937	3.939
8.000	7.995
12.00	11.9965

Unless noted otherwise, Pass/Fail criteria is based on published manufacturer specifications and, unless noted otherwise, this instrument meets these specifications.
Services provided comply with ISO 17025:1999, ISO 9001:2000, MPC QM rev.3, MPC CSD rev.2 and customer purchase order requirements as required.

Calibration standards used for performance testing:

MPC#	Instrument	Due Date	Traceability
K3263	Pratt & Whitney C Super Micrometer	060706	192068
I2111	Mitutoyo 516-126 Gage Block Set	082406	397060

Environmental: 69 Deg / 40% Rh
Accuracy Ratio: 4:1
Cal Procedure: 33K6-4-552-1
Technician: CHRIS SPANGLER

Cal Int.: **12**
Cal Date: **040606**
Due Date: **040607**
Quality Approval: QC 32

Form Cert 04-25-05

GEOVision Borehole Geophysics depth wheel verification

Performed by Robert Steller on September 23, 2006

	Depth reading in #1	Depth reading out	Depth reading in #2
Depth wheel S/N 101 500 pulse/revolution Circumference = 983mm (3225.07 millifeet)	100.1 feet (30.51 m)	99.95 feet (30.46 m)	100.05 feet (30.50 m)
Depth wheel S/N 102 500 pulse/revolution Circumference = 994mm (3261.15 millifeet)	100.00 feet (30.48) m	100.05 feet (30.50 m)	100.00 feet (30.48) m
Aries winch 200 pulse/revolution Circumference = 305.9mm (1003.51 millifeet)	100.05 feet (30.50) m	100.05 feet (30.50 m)	100.00 feet (30.48) m
Depth wheel S/N 103 500 pulse/revolution Circumference = 1000mm (3.281 feet)			
Comprobe winch 500 pulse/revolution Circumference = 1000mm (3.281 feet)			

All measurements taken with a Stanley 100ft flexible stainless steel tape model number 34-130, and a Keeson 300 foot fiberglass tape, both marked in feet, inches and 1/8ths of inches. Enough cable was spooled off of the winch to allow the cable and tape measures to be laid flat on the parking lot surface side-by-side. A permanent marker was used to mark a 100.0 foot interval on the cable, and the marks were also tagged with electrical tape for visibility. The cable was then spooled back onto the winch. When the first mark was at the top of the measuring wheel, a matching permanent mark was placed, and the recording system (Robertson Micrologger) was set to 0.0 feet depth. The cable was spooled in to the second mark, and the distance was recorded. The recording system was set to 0.0 feet again, and the cable spooled out to the first mark again, and the distance was recorded. The process was repeated one more time to spool the cable back onto the winch, and the distance was recorded.

Estimated accuracy is of these measurements is +/- 0.1 foot or +/- 0.03m.

GEOVision Suspension PS probe Receiver 1–Receiver 2 (R1-R2) spacing verification

Performed by Robert Steller on September 23, 2006

	R2 center to R1 center hanging dry	R2 center to R1 center hanging submerged	R1 bottom to source center hanging submerged with 1m isolation tube S/N 280068
Receiver S/N 30086	40.2in 1.02m	40.0in 1.02m	76.0in 1.93m
Receiver S/N 20042	39.8in 1.01m	39.6in 1.01m	75.7in 1.92m
Receiver S/N 12008	40.2in 1.02m	40.0in 1.02m	76.0in 1.93m

All measurements taken with a Lufkin 3.7m flexible steel tape model number HV1034DM, marked in mm and 100th of feet. Probe suspended in 3-inch diameter clear PVC pipe, using chain clamp placed between bottom and center of Receiver 2 hard section (See Figure). Probe "bounced" to establish unrestricted hanging length before measurement. Probe allowed to relax for 5 minutes prior to each measurement. Water level set to submerge bottom of Receiver 2 hard section.. Estimated accuracy due to hysterisis in rubber section approximately +/- 0.01' or +/- 0.003m.

APPENDIX E

BORING GEOPHYSICAL LOGGING FIELD DATA LOGS

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B-901 BORING GEOPHYSICS FIELD LOG SUMMARY

SITE: NORTH ANNA COL DATE: 8/28/06
CLIENT: MACTEC JOB:
AUTHOR: R. STELLER PAGE 1 OF ~~2~~ 1 RA 8/28/06

CONTACT: STEVE CRISCENZO PHONE: 919-949-1707

BOREHOLE CONSTRUCTION: CASED • UNCASED ✓
DIAMETERS AND DEPTH RANGES: 5" 0 TO ≈40 ; 3.7", 40 TO 300'
BOREHOLE TOTAL DEPTH AS DRILLED: 300'
CONDUCTOR CASING?: YES ✓ DEPTH TO BOTTOM OF CASING ≈40' ; NO
DEPTH TO BEDROCK: ≈40'
BOREHOLE FLUID: WATER ✓ ; FRESH WATER MUD ; SALT WATER MUD ;

LOGGING CREW: R. STELLER

LOG TYPE	FILE NAME	DEPTH RANGE	DATE	TIMES
SUSPENSION PS	B901_001-B901-150	12.5m - 87.5m	8/28/06	15:52 - 17:35

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P-S SUSPENSION VELOCITY FIELD LOG

SITE: NORTH ANNA COL B-901 DATE: 8/28/06
CLIENT: MACTEC JOB:
AUTHOR: R. STELLER PAGE 1 OF 7

CONTACT: STEVE CRISCENZO OFFICE PHONE: 919-831-8047
CELL PHONE: 919-949-1707
CONTACT: OFFICE PHONE:
PHONE:
CONTACT: PHONE:
PHONE:
CONTACT: PHONE:
PHONE:
DRILLER: PHONE:
COMPANY: PHONE:

DIRECTIONS TO SITE:

GENERAL SITE CONDITIONS/LOCATION:

EA#:
BOREHOLE DESIGNATION: B-901 LOCATION:

COUNTY: RANGE: TOWNSHIP: SECTION:
BOREHOLE CONSTRUCTION: CASED UNCASED ✓
DIAMETERS AND DEPTH RANGES: 5" 0 TO ≈ 40' ; 3.7" ≈ 40' TO 300'
BOREHOLE TOTAL DEPTH AS DRILLED: 300'
CONDUCTOR CASING?: YES ✓ DEPTH TO BOTTOM OF CASING ≈ 40' ; NO
DEPTH TO BEDROCK: ≈ 40' DEPTH TO WATER TABLE: ≈ 30'
BOREHOLE FLUID: WATER ✓ ; FRESH WATER MUD ; SALT WATER MUD ;
OTHER:
DEPTH TO BOREHOLE FLUID: ≈ 30' TIME SINCE LAST CIRCULATION: NA

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RAS 8/28/06

SITE: NORTH ANNA COL 901 ~~B-304~~ DATE: 8/23/06
CLIENT: MACTEC JOB:
AUTHOR: R. STELLER PAGE 2 OF 7

LOGGING CREW: R. STELLER
VEHICLE(S) USED AND MILEAGE:
MOBILIZED FROM: FREDERICKSBURG, VA DEPARTURE TIME: 7:15
ARRIVED ON SITE: 8:00
STANDBY TIME: CAUSE:
LOGGING STARTED: 15:52 LOGGING COMPLETED: 17:35
STANDBY TIME: CAUSE:
LOGGING STARTED: LOGGING COMPLETED:
DEMOBILIZED TO: ARRIVAL TIME:
ADDITIONAL DEMOB TIME: REASON:

BATTERIES CHANGED BEFORE LOGGING: YES ✓ ; NO ___ ; STORED WITH NEW ___

WINCH	COMPROBE ☐	GREY ☐	OYO ☐	RG ☐	RAS OTH ☑	
INSTRUMENT	OYO 12004 ☐	15014 ☐	19029 ~~☑~~ RAS	RG 160023 ☑	160024 ☐	
RECEIVER S/N	12008 ☐	20042 ☐	26066 ☐	11001 ☐	23053 ☐	30086 ☑

MAINTENANCE PERFORMED ON SITE:

EQUIPMENT PROBLEMS OR FAILURES: OYO #19029 APPEARS NOT TO DISPLAY NEGATIVE GOING SIGNALS - LOSS OF NEGATIVE SUPPLY?

SUGGESTIONS, ADDITIONS, CHANGES:

COMMENTS: CASE STICK UP = 2.0' => .61 m
SO, TOP OF PROBE @ TOP OF CASE = ~~2.0~~ 2.5 - .61 m = ~~1.39~~ 1.89 m. DEPTH.
BVM @ 1.97m

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[illegible]

SITE: NORTH ANNA COL B-901 DATE 8/28/06
CLIENT: MACTEC JOB
AUTHOR: R. STELLER PAGE 3 OF 7

DEPTH METERS	DEPTH FEET	UNFILTERED FILE NO.	FILTERED FILE NO.	COMMENTS CASING, WATER, ROCK, ETC
0.5	1.64			
1.0	3.28			
1.5	4.92			
2.0	6.56			
2.5	8.20			
3.0	9.84			
3.5	11.48			
4.0	13.12			
4.5	14.76			
5.0	16.40			
5.5	18.04			
6.0	19.69			
6.5	21.33			
7.0	22.97			
7.5	24.61			
8.0	26.25			
8.5	27.89			
9.0	29.53			
9.5	31.17			
10.0	32.81			
10.5	34.45			
11.0	36.09			
11.5	37.73			
12.0	39.37			
12.5	41.01	001		STEEL 4" CASING TO > 40'
13.0	42.65	2		
13.5	44.29	3		
14.0	45.93	4		
14.5	47.57	5		
15.0	49.21	6		
15.5	50.85	7		
16.0	52.49	8		
16.5	54.13	9		
17.0	55.77	10		
17.5	57.41	11		
18.0	59.06	12		
18.5	60.70	13		
19.0	62.34	14		
19.5	63.98	15		
20.0	65.62	16		

[illegible]

SITE NORTH ANNA COL B-701 DATE 3/2/06
CLIENT MACTEC JOB
AUTHOR R STELLER PAGE 4 OF 7

DEPTH METERS	DEPTH FEET	UNFILTERED FILE NO.	FILTERED FILE NO.	COMMENTS CASING, WATER, ROCK, ETC
20.5	67.26	17		
21.0	68.90	18		
21.5	70.54	19		
22.0	72.18	20		
22.5	73.82	21		
23.0	75.46	22		
23.5	77.10	23		
24.0	78.74	24		
24.5	80.38	25		
25.0	82.02	26		
25.5	83.66	27		
26.0	85.30	28		
26.5	86.94	29		
27.0	88.58	30		
27.5	90.22	31		
28.0	91.86	32		
28.5	93.50	33		
29.0	95.14	34		
29.5	96.78	35		
30.0	98.43	36		
30.5	100.07	37		
31.0	101.71	38		
31.5	103.35	39		
32.0	104.99	40		
32.5	106.63	41		
33.0	108.27	42		
33.5	109.91	43		
34.0	111.55	44		
34.5	113.19	45		
35.0	114.83	46		
35.5	116.47	47		
36.0	118.11	48		
36.5	119.75	49		
37.0	121.39	50		
37.5	123.03	51		
38.0	124.67	52		
38.5	126.31	53		
39.0	127.95	54		
39.5	129.59	55		HARD ↓
40.0	131.23	56		

GEOVISION SUSPENSION LOGGING FIELD NOTES

SITE: NORTH ANNA COL B-901 DATE: 8/28/06
CLIENT: MACTEC JOB
AUTHOR: R. STELLER PAGE 5 OF 7

DEPTH METERS	DEPTH FEET	UNFILTERED FILE NO.	FILTERED FILE NO.	COMMENTS CASING, WATER, ROCK, ETC
40.5	132.87	57		
41.0	134.51	58		
41.5	136.15	59		
42.0	137.80	60		
42.5	139.44	61		
43.0	141.08	62		
43.5	142.72	63		
44.0	144.36	64		
44.5	146.00	65		
45.0	147.64	66		
45.5	149.28	67		
46.0	150.92	68		
46.5	152.56	69		
47.0	154.20	70		
47.5	155.84	71		
48.0	157.48	72		
48.5	159.12	73		
49.0	160.76	74		
49.5	162.40	75		
50.0	164.04	76		
50.5	165.68	77		
51.0	167.32	78		
51.5	168.96	79		
52.0	170.60	80		
52.5	172.24	81		
53.0	173.88	82		
53.5	175.52	83		
54.0	177.17	84		
54.5	178.81	~~85~~		54.5 m Skipped
55.0	180.45	~~86~~ 85		
55.5	182.09	~~[illegible]~~ 86		
56.0	183.73	~~88~~ 87 RAS	8/28/06	
56.5	185.37	~~[illegible]~~ 88		
57.0	187.01	~~90~~ 89		
57.5	188.65	90		
58.0	190.29	91		
58.5	191.93	92		
59.0	193.57	93		
59.5	195.21	94		
60.0	196.85	95		

SITE: NORTH ANNA COL B-901 DATE: 8/28/06
CLIENT: MACTEC JOB:
AUTHOR: R. STELLER PAGE 6 OF 7

DEPTH METERS	DEPTH FEET	UNFILTERED FILE NO.	FILTERED FILE NO.	COMMENTS CASING, WATER, ROCK, ETC
60.5	198.49	96		
61.0	200.13	97		
61.5	201.77	98		
62.0	203.41	99		
62.5	205.05	100		
63.0	206.69	101		
63.5	208.33	102		
64.0	209.97	103		
64.5	211.61	104		
65.0	213.25	105		
65.5	214.90	106		
66.0	216.54	107		
66.5	218.18	108		
67.0	219.82	109		
67.5	221.46	110		
68.0	223.10	111		
68.5	224.74	112		
69.0	226.38	113		
69.5	228.02	114		
70.0	229.66	115		
70.5	231.30	116		
71.0	232.94	117		
71.5	234.58	118		
72.0	236.22	119		
72.5	237.86	120		
73.0	239.50	121		
73.5	241.14	122		
74.0	242.78	123		
74.5	244.42	124		
75.0	246.06	125		
75.5	247.70	126		
76.0	249.34	127		
76.5	250.98	128		
77.0	252.62	129		
77.5	254.27	130		
78.0	255.91	131		
78.5	257.55	132		
79.0	259.19	133		
79.5	260.83	134		
80.0	262.47	135		

SITE: NORTH ANNA COL B-901 DATE: 2/28/06
CLIENT: MACTEC JOB:
AUTHOR: R. STELLER PAGE 7 OF 7

DEPTH METERS	DEPTH FEET	UNFILTERED FILE NO.	FILTERED FILE NO.	COMMENTS CASING, WATER, ROCK, ETC
80.5	264.11	136		
81.0	265.75	137		
81.5	267.39	138		
82.0	269.03	139		
82.5	270.67	140		
83.0	272.31	141		
83.5	273.95	142		
84.0	275.59	143		
84.5	277.23	144		
85.0	278.87	145		
85.5	280.51	146		
86.0	282.15	147		
86.5	283.79	148		
87.0	285.43	149		
87.5	287.07	150		Bottom measurement ?
88.0	288.71			Hit bottom 87.8 m
88.5	290.35			
89.0	291.99			
89.5	293.64			
90.0	295.28			
90.5	296.92			
91.0	298.56			
91.5	300.20			T.D @ 300'
92.0	301.84			
92.5	303.48			
93.0	305.12			
93.5	306.76			
94.0	308.40			
94.5	310.04			
95.0	311.68			
95.5	313.32			
96.0	314.96			
96.5	316.60			
97.0	318.24			
97.5	319.88			
98.0	321.52			
98.5	323.16			
99.0	324.80			
99.5	326.44			
100.0	328.08			

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B-901 BORING GEOPHYSICS FIELD LOG SUMMARY

SITE: NORTH ANNA COL DATE: 8/29/06
CLIENT: MACTEC JOB: 6410
AUTHOR: R. STELLER PAGE 1 OF ~~2~~ 1 RAS 8/29/06

CONTACT: STEVE CRISCENZO PHONE: 919-949-1707

BOREHOLE CONSTRUCTION: CASED____ UNCASED ✓
DIAMETERS AND DEPTH RANGES: 5" 0 TO 38' ; 3.7", 38' TO 300'
BOREHOLE TOTAL DEPTH AS DRILLED: 300'
CONDUCTOR CASING?: YES ✓ DEPTH TO BOTTOM OF CASING 38' ; NO____ 4" STEEL
DEPTH TO BEDROCK: 38'
BOREHOLE FLUID: WATER ✓ ; FRESH WATER MUD____; SALT WATER MUD____;

LOGGING CREW: R. STELLER

LOG TYPE	FILE NAME	DEPTH RANGE	DATE	TIMES
CALIPER TEST	B901 CALTEST01	∅	8/29/06	12:35 - 12:40
CALIPER/GAMMA	B901 CALUP01	298.0 - ∅	"	12:54 - 13:28
CALIPER TEST	B901 CALTEST02	∅	"	13:35 - 13:39
CALIPER TEST	B901 CALTEST03	∅	"	13:41 - 13:48
ACOUSTIC TV	B901 AMUP01	298.0' - 2.7'	"	14:35 - 16:05
ELOG TEST	B901 ELOGTEST01	∅	"	16:35 - 16:40
ELOG/GAMMA	B901 ELOGUP01	298.0 - 36.0'	"	16:57 - 17:27

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B-901 CALIPER FIELD LOG

SITE: NORTH ANNA COL DATE: 8/29/06
CLIENT: MACTEC JOB: 6410
AUTHOR: R. STELLER PAGE 1 OF 2

CONTACT: _OFFICE_ PHONE:
CELL PHONE:
CONTACT: _OFFICE_ PHONE:
PHONE:
CONTACT: PHONE:
PHONE:
CONTACT: PHONE:
PHONE:
DRILLER: PHONE:
COMPANY: PHONE:

GENERAL SITE CONDITIONS/LOCATION:

BOREHOLE DESIGNATION: B-901 LOCATION:

COUNTY: RANGE: TOWNSHIP: SECTION:
BOREHOLE CONSTRUCTION: CASED UNCASED ✓
DIAMETERS AND DEPTH RANGES: 5" 0 TO ≈40' ; 3.7" ≈40 TO 300'
BOREHOLE TOTAL DEPTH AS DRILLED: 300'
CONDUCTOR CASING?: YES ✓ DEPTH TO BOTTOM OF CASING ≈40' ; NO
DEPTH TO BEDROCK: NA DEPTH TO WATER TABLE: ≈30'
BOREHOLE FLUID: WATER ✓ ; FRESH WATER MUD ; SALT WATER MUD ;
OTHER:
DEPTH TO BOREHOLE FLUID: ≈30' TIME SINCE LAST CIRCULATION:

LOGGING CREW: R. STELLER
VEHICLE(S) USED AND MILEAGE: RENTAL
MOBILIZED FROM: FREDERICKSBURG, VA DEPARTURE TIME: 10:30
ARRIVED ON SITE: 11:45
STANDBY TIME: CAUSE:
LOGGING STARTED: 12:35 LOGGING COMPLETED: 13:48

SITE: NORTH ANNA COL B-901 DATE: 8/29/06
CLIENT: MACTEC JOB: 6410
AUTHOR: R. STELLER PAGE 2 OF 2

WINCH: COMPROBE ___ SILVER ✓ OYO ___ OTHER ___
MICROLOGGER 5301 ✓ OTHER ___
CALIPER PROBE 5368 ✓ OTHER ___

PROBE OFFSET CASING STICK-UP DEPTH REF. OFFSET	12 IN MAX 2.08M(6.82 FT) ARMS - 2.0' 4.82 FT	24 IN MAX ARMS -

ZERO ON EXIT = 4.75

LOG NAME	START DEPTH	START TIME	END DEPTH	END TIME
B901 CALTEST 01	Ø	12:35	Ø	12:40
B901 CALUP 01	298	12:54	Ø	13:28
B901 CALTEST 02	Ø	13:35	Ø	13:39
B901 CALTEST 03	Ø	~~14~~ 13:41 RAS 8/29/06	Ø	13:48

CALIBRATION PLATE S/N 201

	FILE NAME	AS BUILT 1.968 IN (50 MM)	3.937 IN (100 MM)	8.000 IN 203.2 MM	PVC FITTING 4.507 IN
AS MEAS.	B901 CALTEST 01	1.96	3.93	7.98	4.51
AS MEAS.	B901 CALTEST 02	2.12	3.95	7.99	4.53
AS MEAS.		RAS 8/29/06			
AS MEAS.	B901 CALTEST 03	2.10	3.98	8.02	4.54
AS MEAS.					
AS MEAS.					

MAINTENANCE PERFORMED ON SITE: ___

EQUIPMENT PROBLEMS OR FAILURES: ___

SUGGESTIONS, ADDITIONS, CHANGES: ___

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B-901 TELEVIEWER FIELD LOG

SITE: NORTH ANNA COL DATE: 8/29/06
CLIENT: MACTEC JOB: 6410
AUTHOR: R. STELLER PAGE 1 OF 2

CONTACT: _OFFICE_ PHONE:
CELL PHONE:
CONTACT: _OFFICE_ PHONE:
PHONE:
CONTACT: PHONE:
PHONE:
CONTACT: PHONE:
PHONE:
DRILLER: PHONE:
COMPANY: PHONE:

DIRECTIONS TO SITE:

GENERAL SITE CONDITIONS/LOCATION:

BOREHOLE DESIGNATION: B-901 LOCATION:

COUNTY: RANGE: TOWNSHIP: SECTION:
BOREHOLE CONSTRUCTION: CASED UNCASED ✓
DIAMETERS AND DEPTH RANGES: 5" 0 TO 38' ; 3.7", 38' TO 300'
BOREHOLE TOTAL DEPTH AS DRILLED: 300'
CONDUCTOR CASING?: YES ✓ DEPTH TO BOTTOM OF CASING 38' ; NO 4" STEEL
DEPTH TO BEDROCK: NA DEPTH TO WATER TABLE: ≈30'
BOREHOLE FLUID: WATER ✓ ; FRESH WATER MUD ; SALT WATER MUD ;
OTHER:
DEPTH TO BOREHOLE FLUID: ≈30' TIME SINCE LAST CIRCULATION: NA

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SITE: NORTH ANNA COL B-901 DATE: 8/29/06
CLIENT: MACTEC JOB: 6410
AUTHOR: R. STELLER PAGE 2 OF 2

LOGGING CREW: R. STELLER
VEHICLE(S) USED AND MILEAGE: RENTAL
MOBILIZED FROM: DEPARTURE TIME: 10:30
ARRIVED ON SITE: 11:45
STANDBY TIME: CAUSE:
LOGGING STARTED: 14:35 LOGGING COMPLETED: 16:05

WINCH: COMPROBE___ SILVER ✓ OYO___ OTHER___
MICROLOGGER 5301 ✓ OTHER___
TELEVIEWER OPTICAL #5117___ ACOUSTIC #5174 ✓ OTHER___

PROBE TILT TEST 90.81° BRUNTON TILT 91°
PROBE AZIMUTH TEST 232.9° BRUNTON AZIMUTH 227°

PROBE OFFSET	OPTICAL 1.88M(6.17FT)	ACOUSTIC 1.44M(4.72FT)
CASING STICK-UP	-	- 2.0
DEPTH REF. OFFSET		2.72 FT.

END ZERO = 2.66 FT.

LOG NAME	START DEPTH	START TIME	END DEPTH	END TIME
B901 AU UP 01	298	14:35	2.66	16:05

MAINTENANCE PERFORMED ON SITE:

EQUIPMENT PROBLEMS OR FAILURES:

SUGGESTIONS, ADDITIONS, CHANGES:

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B-901 ELOG FIELD LOG

SITE: NORTH ANNA COL DATE: 8/29/06
CLIENT: MACTEC JOB: 6410
AUTHOR: R. STELLER PAGE 1 OF 2

CONTACT: _OFFICE_ PHONE:
CELL PHONE:
CONTACT: _OFFICE_ PHONE:
PHONE:
CONTACT: PHONE:
PHONE:
CONTACT: PHONE:
PHONE:
DRILLER: PHONE:
COMPANY: PHONE:

GENERAL SITE CONDITIONS/LOCATION:

BOREHOLE DESIGNATION: B-901 LOCATION:

COUNTY: RANGE: TOWNSHIP: SECTION:
BOREHOLE CONSTRUCTION: CASED___ UNCASED ✓
DIAMETERS AND DEPTH RANGES: 5" 0 TO 38' ; 3.7", 38' TO 300'
BOREHOLE TOTAL DEPTH AS DRILLED: 300'
CONDUCTOR CASING?: YES ✓ DEPTH TO BOTTOM OF CASING 38' ; NO___ 4" STEEL
DEPTH TO BEDROCK: ≤38' DEPTH TO WATER TABLE: 22'
BOREHOLE FLUID: WATER ✓ ; FRESH WATER MUD___ ; SALT WATER MUD___ ;
OTHER:
DEPTH TO BOREHOLE FLUID: 22' TIME SINCE LAST CIRCULATION: NA

LOGGING CREW: R. STELLER
VEHICLE(S) USED AND MILEAGE: RENTAL
MOBILIZED FROM: FREDERICKSBURG, VA DEPARTURE TIME: 10:30
ARRIVED ON SITE: 11:45
STANDBY TIME: CAUSE:
LOGGING STARTED: 16:35 LOGGING COMPLETED:

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SITE: NORTH ANNA COL B-901 DATE: 8/29/06
CLIENT: MACTEC JOB: 6410
AUTHOR: R. STELLER PAGE 2 OF 2

WINCH: COMPROBE ___ SILVER ✓ OYO ___ OTHER ___
MICROLOGGER 5301 ✓ OTHER ___
ELOG PROBE 5490 ✓ OTHER ___

PROBE OFFSET	2.50M(8.20 FT)	
CASING STICK-UP	-2.0 +32.8	
DEPTH REF. OFFSET	39.0'	EXT DEPTH INDICATION = 38.95'

LOG NAME	START DEPTH	START TIME	END DEPTH	END TIME
B901 ELOG TEST 01	Ø	16:35	Ø	16:40
B901 ELOG UP 01	290.0	16:57	36.0'	17:27

MAINTENANCE PERFORMED ON SITE: ___

EQUIPMENT PROBLEMS OR FAILURES: ___

SUGGESTIONS, ADDITIONS, CHANGES: ___

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B-901 BORING GEOPHYSICS FIELD LOG SUMMARY

SITE: NORTH ANNA COL DATE: 9/11/06
CLIENT: MACTEC JOB: 6410
AUTHOR: R. STELLER PAGE 1 OF 1

CONTACT: STEVE CRISCENZO PHONE: 919-949-1707

BOREHOLE CONSTRUCTION: CASED____ UNCASED ✓
DIAMETERS AND DEPTH RANGES: 5" 0 TO 38' ; 3.7", 38' TO 300'
BOREHOLE TOTAL DEPTH AS DRILLED: 300'
CONDUCTOR CASING?: YES ✓ DEPTH TO BOTTOM OF CASING 38' ; NO__ 4" STEEL
DEPTH TO BEDROCK: 38'
BOREHOLE FLUID: WATER ✓ ; FRESH WATER MUD____ ; SALT WATER MUD____ ;

LOGGING CREW: R. STELLER

.S
9/11/06

LOG TYPE	FILE NAME	DEPTH RANGE	DATE	TIMES
~~B901ACOUP02~~				
ACOUSTIC TV.	B901 ACUP07	125.0 – 100.0	9/11/06	15:14 – 15:25
"	B901 ACUP08	125.0 – 100.0	"	15:32 – 15:43

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B-901 TELEVIEWER FIELD LOG

SITE: NORTH ANNA COL DATE: 9/11/06
CLIENT: MACTEC JOB: 6410
AUTHOR: R. STELLER PAGE 1 OF 2

CONTACT: _____ _OFFICE_ PHONE: _____
CELL PHONE: _____
CONTACT: _____ _OFFICE_ PHONE: _____
_____ PHONE: _____
CONTACT: _____ _____ PHONE: _____
_____ PHONE: _____
CONTACT: _____ _____ PHONE: _____
_____ PHONE: _____
DRILLER: _____ _____ PHONE: _____
COMPANY: _____ _____ PHONE: _____

DIRECTIONS TO SITE: _____

GENERAL SITE CONDITIONS/LOCATION: _____

BOREHOLE DESIGNATION: B-901 LOCATION: _____

COUNTY: _____ RANGE: _____ TOWNSHIP: _____ SECTION: _____
BOREHOLE CONSTRUCTION: CASED _____ UNCASED ✓
DIAMETERS AND DEPTH RANGES: 5" 0 TO 38'; 3.7", 38 TO 300'
BOREHOLE TOTAL DEPTH AS DRILLED: ~~3.9"~~ 300' CAS 9/11/06
CONDUCTOR CASING?: YES ✓ DEPTH TO BOTTOM OF CASING 38'; NO ___ 5" STEEL
DEPTH TO BEDROCK: NA DEPTH TO WATER TABLE: _____
BOREHOLE FLUID: WATER ✓; FRESH WATER MUD _____; SALT WATER MUD _____;
OTHER: _____
DEPTH TO BOREHOLE FLUID: ~~~~ 22.9' TIME SINCE LAST CIRCULATION: NA

CAS 9/11/06

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SITE: NORTH ANNA COL B-901 DATE: 9/11/06
CLIENT: MACTEC JOB: 6410
AUTHOR: R. STELLER PAGE 2 OF 2

LOGGING CREW: R. STELLER
VEHICLE(S) USED AND MILEAGE: RENTAL
MOBILIZED FROM: FREDERICKSBURG, VA DEPARTURE TIME: 6:30
ARRIVED ON SITE: 8:00
STANDBY TIME: CAUSE:
LOGGING STARTED: 15:14 RAS 9/11/06 LOGGING COMPLETED: 15:43

WINCH: COMPROBE ✓ SILVER ✓ OYO OTHER
MICROLOGGER 5301 ✓ OTHER
TELEVIEWER OPTICAL #5117 ACOUSTIC #5174 ✓ OTHER

PROBE TILT TEST 89.8° BRUNTON TILT 89.5°
PROBE AZIMUTH TEST 257.2° BRUNTON AZIMUTH 245.0°

PROBE OFFSET	OPTICAL 1.88M(6.17FT)	ACOUSTIC 1.44M(4.72FT)
CASING STICK-UP	-	- 2.0
DEPTH REF. OFFSET		2.72 FT.

LOG NAME	START DEPTH	START TIME	END DEPTH	END TIME
B901AuuP02	125	15:14	100'	15:25
B901AuuP03	125	15:32	100'	15:43.

MAINTENANCE PERFORMED ON SITE:

EQUIPMENT PROBLEMS OR FAILURES:

SUGGESTIONS, ADDITIONS, CHANGES: INTERVAL 102-117' PACKER TEST.

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B-901 BORING GEOPHYSICS FIELD LOG SUMMARY

SITE: NORTH ANNA COL DATE: 9/12/06
CLIENT: MACTEC JOB: 6410
AUTHOR: R. STELLER PAGE 1 OF 1

CONTACT: STEVE CRISCENZO PHONE: 919-949-1707

BOREHOLE CONSTRUCTION: CASED____ UNCASED ✓
DIAMETERS AND DEPTH RANGES: 5" 0 TO 38.6' ; 3.7", 38.6' TO 300.0'
BOREHOLE TOTAL DEPTH AS DRILLED: 300.0'
CONDUCTOR CASING?: YES____ DEPTH TO BOTTOM OF CASING______; NO ✓
DEPTH TO BEDROCK: 38.6'
BOREHOLE FLUID: WATER____; FRESH WATER MUD ✓; SALT WATER MUD____;

LOGGING CREW: R. STELLER

LOG TYPE	FILE NAME	DEPTH RANGE	DATE	TIMES
CALIPER TEST	B901CALTEST04	Ø	9/12/06	14:49 – 14:54
CALIPER/GAMMA	B901CALUP02	60.0' – Ø'	"	15:31 – 15:39
CALIPER TEST	B901CALTEST05	Ø	"	15:42 – 15:47
SUSPENSION PS	B901_301 → 341.00	1.6' – 67.3'	"	15:56 – 16:31
ELOG TEST	B901ELOGTEST02	Ø	"	15:05 – 15:07
ELOG/GAMMA	B901ELOGUP02	80.0' – 24.9'	"	16:55 – 17:02

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B-901 CALIPER FIELD LOG

SITE: NORTH ANNA COL DATE: 9/12/06
CLIENT: MACTEC JOB: 6410
AUTHOR: R. STELLER PAGE 1 OF 2

CONTACT: _____ OFFICE PHONE: _____
CELL PHONE: _____
CONTACT: _____ OFFICE PHONE: _____
PHONE: _____
CONTACT: _____ PHONE: _____
PHONE: _____
CONTACT: _____ PHONE: _____
PHONE: _____
DRILLER: _____ PHONE: _____
COMPANY: _____ PHONE: _____

GENERAL SITE CONDITIONS/LOCATION: _____

BOREHOLE DESIGNATION: B-901 LOCATION: _____

COUNTY: _____ RANGE: _____ TOWNSHIP: _____ SECTION: _____
BOREHOLE CONSTRUCTION: CASED _____ UNCASED ✓
DIAMETERS AND DEPTH RANGES: 5" 0 TO 38.6' ; 3.78" , 38.6' TO 300.0'
BOREHOLE TOTAL DEPTH AS DRILLED: 300'.
CONDUCTOR CASING?: YES _____ DEPTH TO BOTTOM OF CASING _____; NO ✓
DEPTH TO BEDROCK: 38.6' DEPTH TO WATER TABLE: _____
BOREHOLE FLUID: WATER _____; FRESH WATER MUD ✓; SALT WATER MUD _____;
OTHER: _____
DEPTH TO BOREHOLE FLUID: φ TIME SINCE LAST CIRCULATION: ½ HR

LOGGING CREW: R. STELLER
VEHICLE(S) USED AND MILEAGE: RENTAL
MOBILIZED FROM: FREDERICKSBURG, VA DEPARTURE TIME: 6:50
ARRIVED ON SITE: 7:45
STANDBY TIME: _____ CAUSE: _____
LOGGING STARTED: 14:49 LOGGING COMPLETED: 15:47

SITE: NORTH ANNA COL B-901 DATE: 9/12/06
CLIENT: MACTEC JOB: 6410
AUTHOR: R. STELLER PAGE 2 OF 2

WINCH: COMPROBE ___ SILVER ✓ OYO ___ OTHER ___
MICROLOGGER 5301 ✓ OTHER ___
CALIPER PROBE 5368 ✓ OTHER ___

PROBE OFFSET CASING STICK-UP DEPTH REF. OFFSET	12 IN MAX 2.08M(6.82 FT) ARMS - 0.0' 6.82'	24 IN MAX ARMS - ___

LOG NAME	START DEPTH	START TIME	END DEPTH	END TIME
B901 CALTEST04	Ø	14:41	Ø	14:54
B901 CALUP02	60.0'	15:31	Ø	15:39
B901 CALTEST05	Ø	15:42	Ø	15:47

CALIBRATION PLATE S/N 201

		AS BUILT		
		1.968 IN	3.937 IN	8.000 IN
	FILE NAME	(50 MM)	(100 MM)	203.2 MM
AS MEAS.	B901 CALTEST04	1.97	3.91	7.99
AS MEAS.	B901 CALTEST05	1.92	3.89	7.98
AS MEAS.				
AS MEAS.				
AS MEAS.				
AS MEAS.				

PVC COUPLING
4.51 INCHES.
4.51
4.47

MAINTENANCE PERFORMED ON SITE: ___

EQUIPMENT PROBLEMS OR FAILURES: ___

SUGGESTIONS, ADDITIONS, CHANGES: ___

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P-S SUSPENSION VELOCITY FIELD LOG

SITE: NORTH ANNA COL B-901 DATE: 9/12/06
CLIENT: MACTEC JOB: 6410
AUTHOR: R. STELLER PAGE 1 OF 4

CONTACT: STEVE CRISCENZO OFFICE PHONE: 919-831-8047
CELL PHONE: 919-949-1707
CONTACT: OFFICE PHONE:
PHONE:
CONTACT: PHONE:
PHONE:
CONTACT: PHONE:
PHONE:
DRILLER: PHONE:
COMPANY: PHONE:

DIRECTIONS TO SITE:

GENERAL SITE CONDITIONS/LOCATION:

EA#:
BOREHOLE DESIGNATION: B-901 LOCATION:

COUNTY: RANGE: TOWNSHIP: SECTION:
BOREHOLE CONSTRUCTION: CASED UNCASED ✓
DIAMETERS AND DEPTH RANGES: 5" 0 TO 38.6' ; 3.7", 38.6' TO 300.0'
BOREHOLE TOTAL DEPTH AS DRILLED: 300'
CONDUCTOR CASING?: YES DEPTH TO BOTTOM OF CASING ; NO ✓
DEPTH TO BEDROCK: ≠38' DEPTH TO WATER TABLE:
BOREHOLE FLUID: WATER ; FRESH WATER MUD ✓ ; SALT WATER MUD ;
OTHER:
DEPTH TO BOREHOLE FLUID: ∅ TIME SINCE LAST CIRCULATION: 14 h

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SITE: NORTH ANNA COL B-901 DATE: 9/12/06
CLIENT: MACTEC JOB: 6410
AUTHOR: R. STELLER PAGE 2 OF 4

LOGGING CREW: R. STELLER
VEHICLE(S) USED AND MILEAGE: RENTAL
MOBILIZED FROM: FREDRICKSBURG, VA DEPARTURE TIME: 6:30
ARRIVED ON SITE: 7:45
STANDBY TIME: CAUSE:
LOGGING STARTED: 15:56 LOGGING COMPLETED: 16:31
STANDBY TIME: CAUSE:
LOGGING STARTED: LOGGING COMPLETED:
DEMOBILIZED TO: ARRIVAL TIME:
ADDITIONAL DEMOB TIME: REASON:

BATTERIES CHANGED BEFORE LOGGING: YES ___; NO ✓; STORED WITH NEW ___

WINCH	COMPROBE ☐		GREY ☐	OYO ☐	RG ☐	OTH ☑
INSTRUMENT	OYO 12004 ☐	15014 ☐	19029 ☐		RG 160023 ☑	160024 ☐
RECEIVER S/N	12008 ☐	20042 ☐	26066 ☐	11001 ☐	23053 ☐	30086 ☑

MAINTENANCE PERFORMED ON SITE:

EQUIPMENT PROBLEMS OR FAILURES:

SUGGESTIONS, ADDITIONS, CHANGES:

COMMENTS: ZERO @ 2.5m (GROUND LEVEL)
ZERO ON EXIT = 2.5m.

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SITE: NORTH ANNA COL B-901 DATE: 9/12/06
CLIENT: MACTEC JOB: 6410
AUTHOR: R. STELLER PAGE 3 OF 3 4

Ras 9/1

DEPTH METERS	DEPTH FEET	UNFILTERED FILE NO.	FILTERED FILE NO.	COMMENTS CASING, WATER, ROCK, ETC
0.5	1.64	301		
1.0	3.28	302		
1.5	4.92	303		
2.0	6.56	304		
2.5	8.20	305		
3.0	9.84	306		
3.5	11.48	307		
4.0	13.12	308		
4.5	14.76	309		
5.0	16.40	310		
5.5	18.04	311		
6.0	19.69	312		
6.5	21.33	313		
7.0	22.97	314		
7.5	24.61	315		
8.0	26.25	316		
8.5	27.89	317		
9.0	29.53	318		
9.5	31.17	319		
10.0	32.81	320		
10.5	34.45	321		
11.0	36.09	322		
11.5	37.73	323		
12.0	39.37	324		
12.5	41.01	325		
13.0	42.65	326		
13.5	44.29	327		
14.0	45.93	328		
14.5	47.57	329		
15.0	49.21	330		
15.5	50.85	331		
16.0	52.49	332		
16.5	54.13	333		
17.0	55.77	334		
17.5	57.41	335		
18.0	59.06	336		
18.5	60.70	337		
19.0	62.34	338		
19.5	63.98	339		
20.0	65.62	340		

SITE: NORTH ANNA COL B-901 DATE: 9/12/06
CLIENT: MACTEC JOB: 6410
AUTHOR: R. STELLER PAGE 4 OF 4

DEPTH METERS	DEPTH FEET	UNFILTERED FILE NO.	FILTERED FILE NO.	COMMENTS CASING, WATER, ROCK, ETC
20.5	67.26	341		
21.0	68.90			
21.5	70.54			
22.0	72.18			
22.5	73.82			
23.0	75.46			
23.5	77.10			
24.0	78.74			
24.5	80.38			
25.0	82.02			
25.5	83.66			
26.0	85.30			
26.5	86.94			
27.0	88.58			
27.5	90.22			
28.0	91.86			
28.5	93.50			
29.0	95.14			
29.5	96.78			
30.0	98.43			
30.5	100.07			
31.0	101.71			
31.5	103.35			
32.0	104.99			
32.5	106.63			
33.0	108.27			
33.5	109.91			
34.0	111.55			
34.5	113.19			
35.0	114.83			
35.5	116.47			
36.0	118.11			
36.5	119.75			
37.0	121.39			
37.5	123.03			
38.0	124.67			
38.5	126.31			
39.0	127.95			
39.5	129.59			
40.0	131.23			

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B-901 ELOG FIELD LOG

SITE: NORTH ANNA COL DATE: 9/12/06
CLIENT: MACTEC JOB: 6410
AUTHOR: R. STELLER PAGE 1 OF 2

CONTACT: _____ OFFICE PHONE: _____
CELL PHONE: _____
CONTACT: _____ OFFICE PHONE: _____
PHONE: _____
CONTACT: _____ PHONE: _____
PHONE: _____
CONTACT: _____ PHONE: _____
PHONE: _____
DRILLER: _____ PHONE: _____
COMPANY: _____ PHONE: _____

GENERAL SITE CONDITIONS/LOCATION: _____

BOREHOLE DESIGNATION: B-901 LOCATION: _____

COUNTY: _____ RANGE: _____ TOWNSHIP: _____ SECTION: _____
BOREHOLE CONSTRUCTION: CASED _____ UNCASED ✓
DIAMETERS AND DEPTH RANGES: 5" 0 TO 38.6' ; 3.7", 38.6 TO 300.0'
BOREHOLE TOTAL DEPTH AS DRILLED: 300.0'
CONDUCTOR CASING?: YES _____ DEPTH TO BOTTOM OF CASING _____; NO ✓
DEPTH TO BEDROCK: 38.6 DEPTH TO WATER TABLE: _____
BOREHOLE FLUID: WATER _____; FRESH WATER MUD ✓; SALT WATER MUD _____;
OTHER: _____
DEPTH TO BOREHOLE FLUID: ϕ TIME SINCE LAST CIRCULATION: 1 HR

LOGGING CREW: R. STELLER
VEHICLE(S) USED AND MILEAGE: RENTAL
MOBILIZED FROM: FREDERICKSBURG, VA DEPARTURE TIME: 6:30
ARRIVED ON SITE: 7:45
STANDBY TIME: _____ CAUSE: _____
LOGGING STARTED: 15:05 LOGGING COMPLETED: 17:02

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SITE: NORTH ANNA COL B-901 DATE: 9/12/06.
CLIENT: MACTEC JOB: 6410
AUTHOR: R. STELLER PAGE 2 OF 2

WINCH: COMPROBE___ SILVER ✓ OYO___ OTHER___
MICROLOGGER 5301 ✓ OTHER___
ELOG PROBE 5490 ✓ OTHER___

PROBE OFFSET	2.50M(8.20 FT)	
CASING STICK-UP	-0.0 + 32.0	
DEPTH REF. OFFSET	41.0'.	

LOG NAME	START DEPTH	START TIME	END DEPTH	END TIME
B901 ELOGTEST02	0	15:05	0	15:07
B901 ELOG UP 02	80.0	16:55	24.9	17:02

MAINTENANCE PERFORMED ON SITE:___

EQUIPMENT PROBLEMS OR FAILURES:___

SUGGESTIONS, ADDITIONS, CHANGES:___

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B-907 BORING GEOPHYSICS FIELD LOG SUMMARY

SITE:_NORTH ANNA COL DATE: 8/30/06
CLIENT:_MACTEC JOB: 6410
AUTHOR:_R. STELLER PAGE 1 OF ~~2~~ 1 RAS

CONTACT:_STEVE CRISCENZO PHONE:_919-949-1707

BOREHOLE CONSTRUCTION: CASED____ UNCASED ✓
DIAMETERS AND DEPTH RANGES: 3.7 0 TO 200' ; ____, ____ TO ____
BOREHOLE TOTAL DEPTH AS DRILLED: 200'
CONDUCTOR CASING?: YES ✓ DEPTH TO BOTTOM OF CASING ≈38' ; NO____
DEPTH TO BEDROCK: NA
BOREHOLE FLUID: WATER ✓ ; FRESH WATER MUD____; SALT WATER MUD ____;

LOGGING CREW:_R. STELLER

LOG TYPE	FILE NAME	DEPTH RANGE	DATE	TIMES
SUSPENSION PS.	B907_001 → _091.ORG	37.7 - 183.7	8/30/06	13:40 - 15:02
CALIPER TEST	B907CALTEST01	Ø	"	15:35 - 15:40
CALIPER/GAMMA	B907 CALUP01	188.0 - 1.0'	"	15:47 - 16:11
CALIPER TEST	B907CALTEST02	Ø	"	16:30 - 16:35
CALIPER/GAMMA	B907 CALUP02	182.0' - 1.0'	"	16:45 - 17:00
CALIPER TEST	B907 CALTEST03	Ø	"	17:08 - 17:12

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P-S SUSPENSION VELOCITY FIELD LOG

SITE: NORTH ANNA COL B-907 DATE: 8/30/06
CLIENT: MACTEC JOB: 6410
AUTHOR: R. STELLER PAGE 1 OF 5

CONTACT: STEVE CRISCENZO OFFICE PHONE: 919-831-8047
CELL PHONE: 919-949-1707
CONTACT: OFFICE PHONE:
PHONE:
CONTACT: PHONE:
PHONE:
CONTACT: PHONE:
PHONE:
DRILLER: PHONE:
COMPANY: PHONE:

DIRECTIONS TO SITE:

GENERAL SITE CONDITIONS/LOCATION:

EA#:
BOREHOLE DESIGNATION: B-907 LOCATION:

COUNTY: RANGE: TOWNSHIP: SECTION:
BOREHOLE CONSTRUCTION: CASED UNCASED ✓
DIAMETERS AND DEPTH RANGES: 3.7 0 TO 200' ; , TO
BOREHOLE TOTAL DEPTH AS DRILLED: 200'
CONDUCTOR CASING?: YES ✓ DEPTH TO BOTTOM OF CASING? 38' ; NO
DEPTH TO BEDROCK: NA DEPTH TO WATER TABLE:
BOREHOLE FLUID: WATER ✓ ; FRESH WATER MUD ; SALT WATER MUD ;
OTHER:
DEPTH TO BOREHOLE FLUID: NA TIME SINCE LAST CIRCULATION: NA

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SITE: NORTH ANNA COL B-907 DATE: 8/30/06
CLIENT: MACTEC JOB: 6410
AUTHOR: R. STELLER PAGE 2 OF 5

LOGGING CREW: R. STELLER
VEHICLE(S) USED AND MILEAGE: RENTAL
MOBILIZED FROM: FREDERICKSBURG, VA DEPARTURE TIME: 6:15
ARRIVED ON SITE: 7:45
STANDBY TIME: CAUSE:
LOGGING STARTED: 13:40 LOGGING COMPLETED: 15:02
STANDBY TIME: CAUSE:
LOGGING STARTED: LOGGING COMPLETED:
DEMOBILIZED TO: ARRIVAL TIME:
ADDITIONAL DEMOB TIME: REASON:

BATTERIES CHANGED BEFORE LOGGING: YES ___; NO ✓; STORED WITH NEW ___

WINCH	COMPROBE ☐	GREY ☐	OYO ☐	RG ☐		OTH ☑
INSTRUMENT	OYO 12004 ☐	15014 ☐	19029 ☐		RG 160023 ☑	160024 ☐
RECEIVER S/N	12008 ☐	20042 ☐	26066 ☐	11001 ☐	23053 ☐	30086 ☑

MAINTENANCE PERFORMED ON SITE:

EQUIPMENT PROBLEMS OR FAILURES:

SUGGESTIONS, ADDITIONS, CHANGES:

COMMENTS: DEPTH REFERENCE = 2.5m - 0.63m = 1.87m
ZERO ON EXIT = 1.86m

SITE: NORTH ANNA COL B-907 DATE: 8/30/06
CLIENT: MACTEC JOB: 6410
AUTHOR: R. STELLER PAGE 3 OF 5

DEPTH METERS	DEPTH FEET	UNFILTERED FILE NO.	FILTERED FILE NO.	COMMENTS CASING, WATER, ROCK, ETC
0.5	1.64			
1.0	3.28			
1.5	4.92			
2.0	6.56			
2.5	8.20			
3.0	9.84			
3.5	11.48			
4.0	13.12			
4.5	14.76			
5.0	16.40			
5.5	18.04			
6.0	19.69			
6.5	21.33			
7.0	22.97			
7.5	24.61			
8.0	26.25			
8.5	27.89			
9.0	29.53			
9.5	31.17			
10.0	32.81			
10.5	34.45			
11.0	36.09			
11.5	37.73	001		5" PVC CASE TO ≈ 38'
12.0	39.37	2		
12.5	41.01	3		
13.0	42.65	4		
13.5	44.29	5		
14.0	45.93	6		
14.5	47.57	7		
15.0	49.21	8		
15.5	50.85	9		
16.0	52.49	10		
16.5	54.13	11		
17.0	55.77	12		
17.5	57.41	13		
18.0	59.06	14		
18.5	60.70	15		
19.0	62.34	16		
19.5	63.98	17		
20.0	65.62	18		

GEOVISION SUSPENSION LOGGING FIELD NOTES

SITE: NORTH ANNA COL B-907 DATE: 8/30/06
CLIENT: MACTEC JOB: 6410
AUTHOR: R. STELLER PAGE 4 OF 5

DEPTH METERS	DEPTH FEET	UNFILTERED FILE NO.	FILTERED FILE NO.	COMMENTS CASING, WATER, ROCK, ETC
20.5	67.26	19, 20		use #20
21.0	68.90	21		
21.5	70.54	22		
22.0	72.18	23		
22.5	73.82	24		
23.0	75.46	25		
23.5	77.10	26		
24.0	78.74	27		
24.5	80.38	28		
25.0	82.02	29		
25.5	83.66	30		
26.0	85.30	31		
26.5	86.94	32		
27.0	88.58	33		
27.5	90.22	34		
28.0	91.86	35		
28.5	93.50	36		
29.0	95.14	37		
29.5	96.78	38		
30.0	98.43	39		
30.5	100.07	40		
31.0	101.71	41		
31.5	103.35	42		
32.0	104.99	~~48~~ 43 RAS	8/30/06	
32.5	106.63	44		
33.0	108.27	45		
33.5	109.91	46		
34.0	111.55	47		
34.5	113.19	48		
35.0	114.83	49		
35.5	116.47	50		
36.0	118.11	51		
36.5	119.75	52		
37.0	121.39	53		
37.5	123.03	54		
38.0	124.67	55		
38.5	126.31	56		
39.0	127.95	57		
39.5	129.59	58		
40.0	131.23	59		

GEOVISION SUSPENSION LOGGING FIELD NOTES

SITE: NORTH ANNA COL B-907 DATE: 8/30/06
CLIENT: MACTEC JOB: 6410
AUTHOR: R. STELLER PAGE 5 OF 5

DEPTH METERS	DEPTH FEET	UNFILTERED FILE NO.	FILTERED FILE NO.	COMMENTS CASING, WATER, ROCK, ETC
40.5	132.87	60		
41.0	134.51	61		
41.5	136.15	~~62~~		41.5 ST. PPED
42.0	137.80	~~63~~ 62		
42.5	139.44	~~64~~ 63		
43.0	141.08	~~65~~ 64		
43.5	142.72	~~66~~ 65		
44.0	144.36	~~67~~ 66		
44.5	146.00	~~68~~ 67		
45.0	147.64	~~69~~ 68		
45.5	149.28	~~70~~ 69		
46.0	150.92	~~71~~ 70		
46.5	152.56	~~72~~ 71	RAS 8/30/06	
47.0	154.20	~~73~~ 72		
47.5	155.84	~~74~~ 73		
48.0	157.48	~~75~~ 74		
48.5	159.12	~~76~~ 75		
49.0	160.76	~~77~~ 76		
49.5	162.40	~~78~~ 77		
50.0	164.04	~~79~~ 78		
50.5	165.68	80, 79		USE # 80
51.0	167.32	81		
51.5	168.96	82		
52.0	170.60	83		
52.5	172.24	84		
53.0	173.88	85		
53.5	175.52	86		
54.0	177.17	87		
54.5	178.81	88		
55.0	180.45	89		
55.5	182.09	90		
56.0	183.73	91		
56.5	185.37			
57.0	187.01			
57.5	188.65			BOTTOM MEASUREMENT?
58.0	190.29			HIT BOTTOM @ 56.0 m. =>
58.5	191.93			TIP @ 195.8'
59.0	193.57			
59.5	195.21			
60.0	196.85			

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B-907 CALIPER FIELD LOG

SITE: NORTH ANNA COL DATE: 8/30/06
CLIENT: MACTEC JOB: 6410
AUTHOR: R. STELLER PAGE 1 OF 2

CONTACT: _OFFICE_ PHONE:
CELL PHONE:
CONTACT: _OFFICE_ PHONE:
PHONE:
CONTACT: PHONE:
PHONE:
CONTACT: PHONE:
PHONE:
DRILLER: PHONE:
COMPANY: PHONE:

GENERAL SITE CONDITIONS/LOCATION:

BOREHOLE DESIGNATION: B-907 LOCATION:

COUNTY: RANGE: TOWNSHIP: SECTION:
BOREHOLE CONSTRUCTION: CASED ___ UNCASED ✓
DIAMETERS AND DEPTH RANGES: 3.7 0 TO 205' ; ___, ___ TO ___
BOREHOLE TOTAL DEPTH AS DRILLED: 200'
CONDUCTOR CASING?: YES ✓ DEPTH TO BOTTOM OF CASING ___; NO ___
DEPTH TO BEDROCK: NA DEPTH TO WATER TABLE:
BOREHOLE FLUID: WATER ✓; FRESH WATER MUD ___; SALT WATER MUD ___;
OTHER:
DEPTH TO BOREHOLE FLUID: NA TIME SINCE LAST CIRCULATION: NA

LOGGING CREW: R. STELLER
VEHICLE(S) USED AND MILEAGE: RENTAL
MOBILIZED FROM: FREDERICKSBURG, VA DEPARTURE TIME: 6:15
ARRIVED ON SITE: 7:45
STANDBY TIME: CAUSE:
LOGGING STARTED: 15:35 LOGGING COMPLETED: 17:12

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SITE: NORTH ANNA COL B-907 DATE: 8/30/06
CLIENT: MACTEC JOB: 6410
AUTHOR: R. STELLER PAGE 2 OF 2

WINCH: COMPROBE ___ SILVER ✓ OYO ___ OTHER ___
MICROLOGGER 5301 ✓ OTHER ___
CALIPER PROBE 5368 ✓ OTHER ___

PROBE OFFSET CASING STICK-UP DEPTH REF. OFFSET	12 IN MAX ARMS -	2.08M(6.82 FT) 2.08 4.74	24 IN MAX ARMS -

ZERO AT EXIT 4.80'

LOG NAME	START DEPTH	START TIME	END DEPTH	END TIME
B907 CALTEST 01	Ø	15:35	Ø	15:40
B907 CALUP 01	188.0	15:47	6.0'	16:11
B907 CALTEST 02	Ø	16:30	Ø	16:35
B907 CALUP 02	182.0	16:45	1.0'	17:06
B907 CALTEST 03	Ø	17:08	Ø	17:12

CALIBRATION PLATE S/N 201

		AS BUILT			
		1.968 IN	3.937 IN	8.000 IN	PVC COUPLING
	FILE NAME	(50 MM)	(100 MM)	203.2 MM	4.507 IN
AS MEAS.	B907CALTEST01	1.99	3.94	8.01	4.52
AS MEAS.	B907 CALTEST 02	2.03	3.93	8.00	4.56
AS MEAS.	B907 CALTEST 03	2.03	3.95	8.01	4.55
AS MEAS.					
AS MEAS.					
AS MEAS.					

MAINTENANCE PERFORMED ON SITE: CALIPER ARMS CLOGGED WITH SAND ON B907CALUP01. CLEANED, TESTED BEFORE 907CALUP02

EQUIPMENT PROBLEMS OR FAILURES: ___

SUGGESTIONS, ADDITIONS, CHANGES: HIT BOTTOM @ 188.6'! ON B907 CALUP 01
HIT BOTTOM @ 192.6'! ON B907 CALUP 02

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B-907 BORING GEOPHYSICS FIELD LOG SUMMARY

SITE:_NORTH ANNA COL DATE: 8/31/06
CLIENT:_MACTEC JOB:_6410
AUTHOR:_R. STELLER PAGE 1 OF 1

CONTACT:_STEVE CRISCENZO PHONE:_919-949-1707

BOREHOLE CONSTRUCTION: CASED____ UNCASED ✓
DIAMETERS AND DEPTH RANGES: 3.7" 0 TO 200' ; ____, ____ TO ____
BOREHOLE TOTAL DEPTH AS DRILLED: 200'
CONDUCTOR CASING?: YES ✓ DEPTH TO BOTTOM OF CASING 43.5' ; NO____
DEPTH TO BEDROCK: ≈43'
BOREHOLE FLUID: WATER ✓ ; FRESH WATER MUD____; SALT WATER MUD ____;

LOGGING CREW:_R. STELLER

LOG TYPE	FILE NAME	DEPTH RANGE	DATE	TIMES
ELOG TEST	B907ELOGTEST01	ϕ	8/31/06	9:22 – 9:26
ELOG/GAMMA	B907ELOGUP01	170.7' – 38.9'	"	9:44 – 10:00
ACOUSTIC TV	B907AUUP01	158.3' – 1.5'	"	10:33 – 11:21
"	B907AUDOWN01	140.0' – 167.2'	"	11:25 – 11:36
"	B907AUUP02	167.2' – 150.0'	"	11:39 – 11:45

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B-907 ELOG FIELD LOG

SITE: NORTH ANNA COL DATE: 8/31/06
CLIENT: MACTEC JOB: 6410
AUTHOR: R. STELLER PAGE 1 OF 2

CONTACT: _____ _OFFICE_ PHONE: _____
CELL PHONE: _____
CONTACT: _____ _OFFICE_ PHONE: _____
PHONE: _____
CONTACT: _____ PHONE: _____
PHONE: _____
CONTACT: _____ PHONE: _____
PHONE: _____
DRILLER: _____ PHONE: _____
COMPANY: _____ PHONE: _____

GENERAL SITE CONDITIONS/LOCATION: _____

BOREHOLE DESIGNATION: B-907 LOCATION: _____

COUNTY: _____ RANGE: _____ TOWNSHIP: _____ SECTION: _____
BOREHOLE CONSTRUCTION: CASED _____ UNCASED ✓
DIAMETERS AND DEPTH RANGES: _____ 0 TO _____ ; _____ , _____ TO _____
BOREHOLE TOTAL DEPTH AS DRILLED: 200'
CONDUCTOR CASING?: YES ✓ DEPTH TO BOTTOM OF CASING 38' ; NO ___
DEPTH TO BEDROCK: NA DEPTH TO WATER TABLE: NA
BOREHOLE FLUID: WATER ✓ ; FRESH WATER MUD ___ ; SALT WATER MUD ___ ;
OTHER: _____
DEPTH TO BOREHOLE FLUID: NA TIME SINCE LAST CIRCULATION: NA

LOGGING CREW: R. STELLER
VEHICLE(S) USED AND MILEAGE: RENTAL
MOBILIZED FROM: FREDERICKSBURG, VA DEPARTURE TIME: 7:30
ARRIVED ON SITE: 8:30
STANDBY TIME: _____ CAUSE: _____
LOGGING STARTED: 9:22 LOGGING COMPLETED: 10:00

SITE:_NORTH ANNA COL B-907
CLIENT:_MACTEC
AUTHOR:_R. STELLER

DATE: 8/~~30~~ 31/06
JOB:_6410
PAGE 2 OF 2

WINCH: COMPROBE____ SILVER ✓ OYO____ OTHER____
MICROLOGGER 5301 ✓ OTHER____
ELOG PROBE 5490 ✓ OTHER____

PROBE OFFSET	2.50M(8.20 FT)
CASING STICK-UP	= 2.08 + 32.8'
DEPTH REF. OFFSET	38.92'

ZERO AT EXIT = 38.9'

LOG NAME	START DEPTH	START TIME	END DEPTH	END TIME
B907ELOGTEST01	∅	9:22	∅	9:26
B907ELOGUP01	170.7'	9:44	38.9	10:00

MAINTENANCE PERFORMED ON SITE:

EQUIPMENT PROBLEMS OR FAILURES:

SUGGESTIONS, ADDITIONS, CHANGES: HIT BOTTOM @170.7' ON RUN DOWN. HOLE LOSS ANOTHER ≈ 10' SINCE 8/29/06. !

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B-907 TELEVIEWER FIELD LOG

SITE: NORTH ANNA COL DATE: 8/31/06
CLIENT: MACTEC JOB: 6410
AUTHOR: R. STELLER PAGE 1 OF 2

CONTACT: ____ _OFFICE_ PHONE: ____
CELL PHONE: ____
CONTACT: ____ _OFFICE_ PHONE: ____
____ PHONE: ____
CONTACT: ____ ____ PHONE: ____
____ PHONE: ____
CONTACT: ____ ____ PHONE: ____
____ PHONE: ____
DRILLER: ____ ____ PHONE: ____
COMPANY: ____ ____ PHONE: ____

DIRECTIONS TO SITE: ____

GENERAL SITE CONDITIONS/LOCATION: ____

BOREHOLE DESIGNATION: B-907 LOCATION: ____

COUNTY: ____ RANGE: ____ TOWNSHIP: ____ SECTION: ____
BOREHOLE CONSTRUCTION: CASED ____ UNCASED ✓
DIAMETERS AND DEPTH RANGES: 3.7 0 TO 200' ; ____, ____ TO ____
BOREHOLE TOTAL DEPTH AS DRILLED: 200' 43.5', RAS 8/30/06
CONDUCTOR CASING?: YES✓ DEPTH TO BOTTOM OF CASING 30 ; NO ____
DEPTH TO BEDROCK: NA DEPTH TO WATER TABLE: NA
BOREHOLE FLUID: WATER ✓ ; FRESH WATER MUD ____; SALT WATER MUD ____;
OTHER: ____
DEPTH TO BOREHOLE FLUID: ~~NA~~ 27.5' TIME SINCE LAST CIRCULATION: NA
RAS 8/30/06

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SITE: NORTH ANNA COL B-907 DATE: 8/31/06
CLIENT: MACTEC JOB: 6410
AUTHOR: R. STELLER PAGE 2 OF 2

LOGGING CREW: R. STELLER
VEHICLE(S) USED AND MILEAGE: RENTAL
MOBILIZED FROM: FREDERICKSBURG, VA DEPARTURE TIME: 7:30
ARRIVED ON SITE: 8:30
STANDBY TIME: CAUSE:
LOGGING STARTED: LOGGING COMPLETED:

WINCH: COMPROBE___ SILVER ✓ OYO___ OTHER___
MICROLOGGER 5301 ✓ OTHER___
TELEVIEWER OPTICAL #5117___ ACOUSTIC #5174 ✓ OTHER___

PROBE TILT TEST 85.80 BRUNTON TILT 86.0
PROBE AZIMUTH TEST 331.4 BRUNTON AZIMUTH 327'

PROBE OFFSET	OPTICAL 1.88M(6.17FT)	ACOUSTIC 1.44M(4.72FT)
CASING STICK-UP	-	- 2.08'
DEPTH REF. OFFSET		2.64'

DEPTH REFERENCE W EXT = 2.64'

LOG NAME	START DEPTH	START TIME	END DEPTH	END TIME
B907 AH UP 01	158.3'	10:53	1.50'	11:21
B907 AH DOWN 01	140.0	11:25	167.2	11:36
B907 AH UP 02	167.2	11:39	150.0	11:45

MAINTENANCE PERFORMED ON SITE:

EQUIPMENT PROBLEMS OR FAILURES:

SUGGESTIONS, ADDITIONS, CHANGES: AT TOP OF RUN GAIN=12 DB, BLANKING = ~~140~~ 150 μSEC WINDOW= 80 μSEC POS.

FOR 3" CASING GAIN = 11 DB ; BLANKING = 145 μSEC, WINDOW = 80 μSEC

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B-907 BORING GEOPHYSICS FIELD LOG SUMMARY

SITE:_NORTH ANNA COL DATE: 9/11/06
CLIENT:_MACTEC JOB:_6410
AUTHOR:_R. STELLER PAGE 1 OF 1

CONTACT:_STEVE CRISCENZO PHONE:_919-949-1707

BOREHOLE CONSTRUCTION: CASED____ UNCASED ✓
DIAMETERS AND DEPTH RANGES: 5" 0 TO 39.5'; 3.7", 39.5' TO 200'
BOREHOLE TOTAL DEPTH AS DRILLED: 200'
CONDUCTOR CASING?: YES____ DEPTH TO BOTTOM OF CASING____; NO ✓
DEPTH TO BEDROCK: ≈39.5'
BOREHOLE FLUID: WATER____; FRESH WATER MUD ✓; SALT WATER MUD ____;

LOGGING CREW:_R. STELLER

LOG TYPE	FILE NAME	DEPTH RANGE	DATE	TIMES
CALIPER-TEST	B907CALTEST04	Ø	9/11/06	10:50 - 10:55
CALIPER/GAMMA	B907CALUP03	80.0 - Ø	"	12:25 - 12:33
CALIPER TEST	B907CALTEST05	Ø	"	12:35 - 12:40
SUSPENSION PS	B907_301 → 340.0BS	1.6' - 65.6'	"	12:35 - 13:28
ELOG TEST	B907ELOGTEST02	Ø	"	11:08 - 11:12
ELOG/GAMMA	B907ELOGUP02	83.0' - 25.0'	"	13:48 - 13:55

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B-907 CALIPER FIELD LOG

SITE: NORTH ANNA COL DATE: 9/11/06
CLIENT: MACTEC JOB: 6410
AUTHOR: R. STELLER PAGE 1 OF 2

CONTACT: ______ _OFFICE_ PHONE: ______
CELL PHONE: ______
CONTACT: ______ _OFFICE_ PHONE: ______
PHONE: ______
CONTACT: ______ PHONE: ______
PHONE: ______
CONTACT: ______ PHONE: ______
PHONE: ______
DRILLER: ______ PHONE: ______
COMPANY: ______ PHONE: ______

GENERAL SITE CONDITIONS/LOCATION: ______

BOREHOLE DESIGNATION: B-907 LOCATION: ______

COUNTY: ______ RANGE: ______ TOWNSHIP: ______ SECTION: ______
BOREHOLE CONSTRUCTION: CASED ____ UNCASED ✓
DIAMETERS AND DEPTH RANGES: 5" 0 TO 39.5 ; 3.7", 39.5 TO 200'
BOREHOLE TOTAL DEPTH AS DRILLED: 200'
CONDUCTOR CASING?: YES ____ DEPTH TO BOTTOM OF CASING ____; NO ✓
DEPTH TO BEDROCK: ≈ 39.5' DEPTH TO WATER TABLE: ______
BOREHOLE FLUID: WATER ____; FRESH WATER MUD ✓; SALT WATER MUD ____;
OTHER: ______
DEPTH TO BOREHOLE FLUID: ∅ TIME SINCE LAST CIRCULATION: 1/2 HR

LOGGING CREW: R. STELLER
VEHICLE(S) USED AND MILEAGE: RENTAL
MOBILIZED FROM: FREDERICKSBURG, VA DEPARTURE TIME: 6:30
ARRIVED ON SITE: 8:00
STANDBY TIME: ______ CAUSE: ______
LOGGING STARTED: 10:50 LOGGING COMPLETED: 12:40

SITE: NORTH ANNA COL B-907 DATE: 9/11/06
CLIENT: MACTEC JOB: 6410
AUTHOR: R. STELLER PAGE 2 OF 2

WINCH: COMPROBE ___ SILVER ✓ OYO ___ OTHER ___
MICROLOGGER 5301 ✓ OTHER ___
CALIPER PROBE 5368 ✓ OTHER ___

PROBE OFFSET	12 IN MAX 2.08M(6.82 FT)	24 IN MAX
CASING STICK-UP	ARMS - 1.75	ARMS -
DEPTH REF. OFFSET	5.07	

LOG NAME	START DEPTH	START TIME	END DEPTH	END TIME
B907CALTEST 02	Ø	10:50	Ø	10:55
B907CALIP03	80.0	12:25	Ø	12:33
B907CALTEST05	Ø	12:35	Ø	12:40

CALIBRATION PLATE S/N 201

		AS BUILT		
		1.968 IN	3.937 IN	8.000 IN
	FILE NAME	(50 MM)	(100 MM)	203.2 MM
AS MEAS.	B907CALTEST02	1.99	3.96	7.99
AS MEAS.	B907CALTEST05	2.02	3.97	7.99
AS MEAS.		RS 9/11/06		
AS MEAS.				
AS MEAS.				
AS MEAS.				

PVC COUPLING 4.507 IN.
4.53
4.54

MAINTENANCE PERFORMED ON SITE: ___

EQUIPMENT PROBLEMS OR FAILURES: ___

SUGGESTIONS, ADDITIONS, CHANGES: ___

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P-S SUSPENSION VELOCITY FIELD LOG

SITE:_NORTH ANNA COL B-907 DATE: 9/11/06
CLIENT:_MACTEC JOB:_6410
AUTHOR:_R. STELLER PAGE 1 OF 3

CONTACT:_STEVE CRISCENZO OFFICE PHONE:_919-831-8047
CELL PHONE:_919-949-1707
CONTACT: OFFICE PHONE:
PHONE:
CONTACT: PHONE:
PHONE:
CONTACT: PHONE:
PHONE:
DRILLER: PHONE:
COMPANY: PHONE:

DIRECTIONS TO SITE:

GENERAL SITE CONDITIONS/LOCATION:

EA#:
BOREHOLE DESIGNATION: B-907 LOCATION:

COUNTY: RANGE: TOWNSHIP: SECTION:
BOREHOLE CONSTRUCTION: CASED____ UNCASED ✓
DIAMETERS AND DEPTH RANGES: 5" 0 TO 38.5" ; 3.7", 38.5 TO 200'
BOREHOLE TOTAL DEPTH AS DRILLED: 200'
CONDUCTOR CASING?: YES____ DEPTH TO BOTTOM OF CASING____; NO ✓
DEPTH TO BEDROCK: 38.5' DEPTH TO WATER TABLE: NA
BOREHOLE FLUID: WATER____; FRESH WATER MUD ✓; SALT WATER MUD____;
OTHER:
DEPTH TO BOREHOLE FLUID: ∅ TIME SINCE LAST CIRCULATION: ½ HR

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SITE: NORTH ANNA COL B-907 DATE: 9/11/06
CLIENT: MACTEC JOB: 6410
AUTHOR: R. STELLER PAGE 2 OF 3

LOGGING CREW: R. STELLER
VEHICLE(S) USED AND MILEAGE: RENTAL
MOBILIZED FROM: FREDERICKSBURG, VA DEPARTURE TIME: 6:30
ARRIVED ON SITE: 8:00
STANDBY TIME: CAUSE:
LOGGING STARTED: ~~13:03~~ 12:55 LOGGING COMPLETED: 13:28
STANDBY TIME: RDS 9/11/06 CAUSE:
LOGGING STARTED: LOGGING COMPLETED:
DEMOBILIZED TO: ARRIVAL TIME:
ADDITIONAL DEMOB TIME: REASON:

BATTERIES CHANGED BEFORE LOGGING: YES ___; NO ✓ ; STORED WITH NEW ___

WINCH	COMPROBE ☐	GREY ☐	OYO ☐	RG ☐		OTH ☑
INSTRUMENT	OYO 12004 ☐	15014 ☐	19029 ☐		RG 160023 ☑	160024 ☐
RECEIVER S/N	12008 ☐	20042 ☐	26066 ☐	11001 ☐	23053 ☐	30086 ☑

MAINTENANCE PERFORMED ON SITE:

EQUIPMENT PROBLEMS OR FAILURES:

SUGGESTIONS, ADDITIONS, CHANGES:

COMMENTS: DEPTH ZERO = 2.5 - .53 = 2.0m

SITE: NORTH ANNA COL B-907 DATE: 9/11/06
CLIENT: MACTEC JOB: 6410
AUTHOR: R. STELLER PAGE 3 OF 3

DEPTH METERS	DEPTH FEET	UNFILTERED FILE NO.	FILTERED FILE NO.	COMMENTS CASING, WATER, ROCK, ETC
0.5	1.64	301		
1.0	3.28	302		
1.5	4.92	303		
2.0	6.56	304		
2.5	8.20	305		
3.0	9.84	306		
3.5	11.48	307		
4.0	13.12	308		
4.5	14.76	309		
5.0	16.40	310		
5.5	18.04	311		
6.0	19.69	312		
6.5	21.33	313		
7.0	22.97	314		
7.5	24.61	315		
8.0	26.25	316		
8.5	27.89	317		
9.0	29.53	318		
9.5	31.17	319		
10.0	32.81	320		
10.5	34.45	321		
11.0	36.09	322		
11.5	37.73	323		
12.0	39.37	324		
12.5	41.01	325		
13.0	42.65	326		
13.5	44.29	327		
14.0	45.93	328		
14.5	47.57	329		
15.0	49.21	330		
15.5	50.85	331		
16.0	52.49	332		
16.5	54.13	333		
17.0	55.77	334		
17.5	57.41	335		
18.0	59.06	336		
18.5	60.70	337		
19.0	62.34	338		
19.5	63.98	339		
20.0	65.62	340		

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B-907 ELOG FIELD LOG

SITE: NORTH ANNA COL DATE: 9/11/06
CLIENT: MACTEC JOB: 6410
AUTHOR: R. STELLER PAGE 1 OF 2

CONTACT: ______ OFFICE PHONE: ______
CELL PHONE: ______
CONTACT: ______ OFFICE PHONE: ______
PHONE: ______
CONTACT: ______ PHONE: ______
PHONE: ______
CONTACT: ______ PHONE: ______
PHONE: ______
DRILLER: ______ PHONE: ______
COMPANY: ______ PHONE: ______

GENERAL SITE CONDITIONS/LOCATION: ______

BOREHOLE DESIGNATION: B-907 LOCATION: ______

COUNTY: ______ RANGE: ______ TOWNSHIP: ______ SECTION: ______
BOREHOLE CONSTRUCTION: CASED ______ UNCASED ✓
DIAMETERS AND DEPTH RANGES: 5" 0 TO 38.5 ; 3.7", 38.5 TO 200'
BOREHOLE TOTAL DEPTH AS DRILLED: 200'
CONDUCTOR CASING?: YES ______ DEPTH TO BOTTOM OF CASING ______; NO ✓
DEPTH TO BEDROCK: 38.5' DEPTH TO WATER TABLE: NA
BOREHOLE FLUID: WATER ______; FRESH WATER MUD ✓; SALT WATER MUD ______;
OTHER: ______
DEPTH TO BOREHOLE FLUID: Ø TIME SINCE LAST CIRCULATION: 1/2 HR

LOGGING CREW: R. STELLER
VEHICLE(S) USED AND MILEAGE: RENTAL
MOBILIZED FROM: Fredericksburg, VA DEPARTURE TIME: 6:30
ARRIVED ON SITE: 8:00
STANDBY TIME: ______ CAUSE: ______
LOGGING STARTED: 11:08 LOGGING COMPLETED: 13:55

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SITE: NORTH ANNA COL B-907 DATE: 9/11/06
CLIENT: MACTEC JOB: 6410
AUTHOR: R. STELLER PAGE 2 OF 2

WINCH: COMPROBE____ SILVER ✓ OYO____ OTHER____
MICROLOGGER 5301 ✓ OTHER____
ELOG PROBE 5490 ✓ OTHER____

PROBE OFFSET	2.50M(8.20 FT)
CASING STICK-UP	-1.75 + 32.8
DEPTH REF. OFFSET	31.25

LOG NAME	START DEPTH	START TIME	END DEPTH	END TIME
B907ELOGTEST02	Ø	11:08	Ø	11:12
B907ELOGUP02	83.0	13:48	25.0	13:55

MAINTENANCE PERFORMED ON SITE:

EQUIPMENT PROBLEMS OR FAILURES: 10 OHM METER SCALE ON LONG NORMAL NOT INDICATING CORRECTLY. APPEARS TO BE IN TEST BOX. WHEN LONG & SHORT N ARE SWAPPED SHORT DOES NOT INDICATE CORRECTLY.

SUGGESTIONS, ADDITIONS, CHANGES:

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B-909 BORING GEOPHYSICS FIELD LOG SUMMARY

SITE: NORTH ANNA COL DATE: 8/30/06
CLIENT: MACTEC JOB: 6410
AUTHOR: R. STELLER PAGE 1 OF ~~2~~ RAS 8/30/06

CONTACT: STEVE CRISCENZO PHONE: 919-949-1707

BOREHOLE CONSTRUCTION: CASED____ UNCASED ✓
DIAMETERS AND DEPTH RANGES: 3.7 0 TO ~~200'~~ 201.5; ____, ____ TO ____
BOREHOLE TOTAL DEPTH AS DRILLED: 201.5 RAS 8/30/06
CONDUCTOR CASING?: YES ✓ DEPTH TO BOTTOM OF CASING 80'; NO____
DEPTH TO BEDROCK: ~80'
BOREHOLE FLUID: WATER ✓; FRESH WATER MUD____; SALT WATER MUD____;

LOGGING CREW: R. STELLER

LOG TYPE	FILE NAME	DEPTH RANGE	DATE	TIMES
ELOG TEST	B909ELOGTEST01	∅	8/30/06	9:00 - 9:04
ELOG/GAMMA	B909ELOGUP01	200.0' - 35.25'	8/30/06	9:15 - 9:33
CALIPER TEST	B909CALTEST01	∅	"	9:51 - 9:55
CALIPER/GAMMA	B909CALUP01	200.0' - 1.0'	"	10:05 - 10:28
CALIPER TEST	B909CALTEST02	∅	"	10:31 - 10:36
ACOUSTIC TV	B909AUUP01	200.0' - 2.0'	"	11:00 - 12:05
SUSPENSION PS.	B909_001 → _066.SR6	82.0' - 188.7'	"	12:30 - 13:05

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B-909 ELOG FIELD LOG

SITE: NORTH ANNA COL DATE: 8/30/06
CLIENT: MACTEC JOB: 6410
AUTHOR: R. STELLER PAGE 1 OF 2

CONTACT: ______ _OFFICE_ PHONE: ______
CELL PHONE: ______
CONTACT: ______ _OFFICE_ PHONE: ______
PHONE: ______
CONTACT: ______ PHONE: ______
PHONE: ______
CONTACT: ______ PHONE: ______
PHONE: ______
DRILLER: ______ PHONE: ______
COMPANY: ______ PHONE: ______

GENERAL SITE CONDITIONS/LOCATION: ______

BOREHOLE DESIGNATION: B-909 LOCATION: ______

COUNTY: ______ RANGE: ______ TOWNSHIP: ______ SECTION: ______
BOREHOLE CONSTRUCTION: CASED ______ UNCASED ✓
DIAMETERS AND DEPTH RANGES: 3.7 0 TO 200'; ______, ______ TO ______
BOREHOLE TOTAL DEPTH AS DRILLED: 200'
CONDUCTOR CASING?: YES ✓ DEPTH TO BOTTOM OF CASING ≈ 78'; NO ______
DEPTH TO BEDROCK: NA DEPTH TO WATER TABLE: NA
BOREHOLE FLUID: WATER ✓; FRESH WATER MUD ______; SALT WATER MUD ______;
OTHER: ______
DEPTH TO BOREHOLE FLUID: NA TIME SINCE LAST CIRCULATION: NA

LOGGING CREW: R. STELLER
VEHICLE(S) USED AND MILEAGE: RENTAL
MOBILIZED FROM: FREDERICKSBURG, VA DEPARTURE TIME: 6:15
ARRIVED ON SITE: 7:45
STANDBY TIME: ______ CAUSE: ______
LOGGING STARTED: 9:15 LOGGING COMPLETED: 9:33

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SITE: NORTH ANNA COL B-909 DATE: 8/30/06
CLIENT: MACTEC JOB: 6410
AUTHOR: R. STELLER PAGE 2 OF 2

WINCH: COMPROBE____ SILVER ✓ OYO____ OTHER____
MICROLOGGER 5301 ✓ OTHER____
ELOG PROBE 5490 ✓ OTHER____

PROBE OFFSET	2.50M(8.20 FT)
CASING STICK-UP	- .75 +32.8 ft
DEPTH REF. OFFSET	40.25'

LOG NAME	START DEPTH	START TIME	END DEPTH	END TIME
B909 ELOG TEST 01	Ø	9:00	Ø	9:04
B909 ELOG UP 01	200.0'	9:15	35.25'	9:33

MAINTENANCE PERFORMED ON SITE:____

EQUIPMENT PROBLEMS OR FAILURES:____

SUGGESTIONS, ADDITIONS, CHANGES:____

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B-909 CALIPER FIELD LOG

SITE: NORTH ANNA COL DATE: 8/30/06
CLIENT: MACTEC JOB: 6410
AUTHOR: R. STELLER PAGE 1 OF 2

CONTACT: _____ _OFFICE_ PHONE: _____
CELL PHONE: _____
CONTACT: _____ _OFFICE_ PHONE: _____
PHONE: _____
CONTACT: _____ PHONE: _____
PHONE: _____
CONTACT: _____ PHONE: _____
PHONE: _____
DRILLER: _____ PHONE: _____
COMPANY: _____ PHONE: _____

GENERAL SITE CONDITIONS/LOCATION: _____

BOREHOLE DESIGNATION: B-909 LOCATION: _____

COUNTY: _____ RANGE: _____ TOWNSHIP: _____ SECTION: _____
BOREHOLE CONSTRUCTION: CASED _____ UNCASED ✓
DIAMETERS AND DEPTH RANGES: 3.7" 0 TO 200' ; _____, _____ TO _____
BOREHOLE TOTAL DEPTH AS DRILLED: 200'
CONDUCTOR CASING?: YES ✓ DEPTH TO BOTTOM OF CASING 78' ; NO _____
DEPTH TO BEDROCK: NA DEPTH TO WATER TABLE: NA
BOREHOLE FLUID: WATER ✓ ; FRESH WATER MUD _____ ; SALT WATER MUD _____ ;
OTHER: _____
DEPTH TO BOREHOLE FLUID: NA TIME SINCE LAST CIRCULATION: NA

LOGGING CREW: R. STELLER
VEHICLE(S) USED AND MILEAGE: RENTAL
MOBILIZED FROM: FREDERICKSBURG, VA DEPARTURE TIME: 6:15
ARRIVED ON SITE: 7:45
STANDBY TIME: _____ CAUSE: _____
LOGGING STARTED: 9:51 LOGGING COMPLETED: 10:30

SITE: NORTH ANNA COL B-909 DATE: 8/30/06
CLIENT: MACTEC JOB: 6410
AUTHOR: R. STELLER PAGE 2 OF 2

WINCH: COMPROBE ✓ SILVER ____ OYO ____ OTHER ____
MICROLOGGER 5301 ✓ OTHER ____
CALIPER PROBE 5368 ✓ OTHER ____

PROBE OFFSET	12 IN MAX	2.08M(6.82 FT)	24 IN MAX	
CASING STICK-UP	ARMS	- .75	ARMS	-
DEPTH REF. OFFSET		6.07		

DEPTH ZERO ON EXIT = 6.10'

LOG NAME	START DEPTH	START TIME	END DEPTH	END TIME
B909CALTEST01	Ø	9:51	Ø	9:55
B909 CALUP01	200.0	10:05	1.0'	10:28
B909 CALTEST02	Ø	10:31	Ø	10:36

CALIBRATION PLATE S/N 201

		AS BUILT			
		1.968 IN	3.937 IN	8.000 IN	PVC coupling
	FILE NAME	(50 MM)	(100 MM)	203.2 MM	4.507 IN
AS MEAS.	B909 CALTEST 01	1.98	3.93	7.99	4.52
AS MEAS.	B909 CALTEST 02	2.02	3.97	8.04	4.55
AS MEAS.					
AS MEAS.					
AS MEAS.					
AS MEAS.					

MAINTENANCE PERFORMED ON SITE: ____

EQUIPMENT PROBLEMS OR FAILURES: ____

SUGGESTIONS, ADDITIONS, CHANGES: ____

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B-909 TELEVIEWER FIELD LOG

SITE: NORTH ANNA COL DATE: 8/30/06
CLIENT: MACTEC JOB: 6410
AUTHOR: R. STELLER PAGE 1 OF 2

CONTACT: ______ OFFICE PHONE: ______
CELL PHONE: ______
CONTACT: ______ OFFICE PHONE: ______
PHONE: ______
CONTACT: ______ PHONE: ______
PHONE: ______
CONTACT: ______ PHONE: ______
PHONE: ______
DRILLER: ______ PHONE: ______
COMPANY: ______ PHONE: ______

DIRECTIONS TO SITE: ______

GENERAL SITE CONDITIONS/LOCATION: ______

BOREHOLE DESIGNATION: B-909 LOCATION: ______

COUNTY: ______ RANGE: ______ TOWNSHIP: ______ SECTION: ______
BOREHOLE CONSTRUCTION: CASED ______ UNCASED ✓
DIAMETERS AND DEPTH RANGES: 3.7" 0 TO 200' ; ______, ______ TO ______
BOREHOLE TOTAL DEPTH AS DRILLED: 200'
CONDUCTOR CASING?: YES ✓ DEPTH TO BOTTOM OF CASING 78' ; NO ______
DEPTH TO BEDROCK: NA DEPTH TO WATER TABLE: 16.0'
BOREHOLE FLUID: WATER ✓ ; FRESH WATER MUD ______; SALT WATER MUD ______;
OTHER: ______
DEPTH TO BOREHOLE FLUID: ~~NA~~ 16.0' TIME SINCE LAST CIRCULATION: NA

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SITE: NORTH ANNA COL B-909 DATE: 8/30/06
CLIENT: MACTEC JOB: 6410
AUTHOR: R. STELLER PAGE 2 OF 2

LOGGING CREW: R. STELLER
VEHICLE(S) USED AND MILEAGE: RENTAL
MOBILIZED FROM: FREDERICKSBURG, VA DEPARTURE TIME: 6:15
ARRIVED ON SITE: 7:45
STANDBY TIME: CAUSE:
LOGGING STARTED: 11:00 LOGGING COMPLETED: 12:05

WINCH: COMPROBE___ SILVER ✓ OYO___ OTHER___
MICROLOGGER 5301 ✓ OTHER___
TELEVIEWER OPTICAL #5117___ ACOUSTIC #5174 ✓ OTHER___

PROBE TILT TEST 88.9° BRUNTON TILT 89°
PROBE AZIMUTH TEST 337.3° BRUNTON AZIMUTH 336°

PROBE OFFSET	OPTICAL 1.88M(6.17FT)	ACOUSTIC 1.44M(4.72FT)
CASING STICK-UP	-	- .75
DEPTH REF. OFFSET		3.97'

DEPTH ZERO ON EXIT = 4.05'

LOG NAME	START DEPTH	START TIME	END DEPTH	END TIME
B909 Au UP 01	200.0'	11:00	2.0'	12:05

MAINTENANCE PERFORMED ON SITE:

EQUIPMENT PROBLEMS OR FAILURES:

SUGGESTIONS, ADDITIONS, CHANGES:

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P-S SUSPENSION VELOCITY FIELD LOG

SITE: NORTH ANNA COL B-909 DATE: 8/30/06
CLIENT: MACTEC JOB: 6410
AUTHOR: R. STELLER PAGE 1 OF 4

CONTACT: STEVE CRISCENZO OFFICE PHONE: 919-831-8047
CELL PHONE: 919-949-1707
CONTACT: OFFICE PHONE:
PHONE:
CONTACT: PHONE:
PHONE:
CONTACT: PHONE:
PHONE:
DRILLER: PHONE:
COMPANY: PHONE:

DIRECTIONS TO SITE:

GENERAL SITE CONDITIONS/LOCATION:

EA#:
BOREHOLE DESIGNATION: B-909 LOCATION:

COUNTY: RANGE: TOWNSHIP: SECTION:
BOREHOLE CONSTRUCTION: CASED UNCASED ✓
DIAMETERS AND DEPTH RANGES: 3.7" 0 TO 200' ; , TO
BOREHOLE TOTAL DEPTH AS DRILLED: 200'
CONDUCTOR CASING?: YES ✓ DEPTH TO BOTTOM OF CASING 80' ; NO
DEPTH TO BEDROCK: NA DEPTH TO WATER TABLE: 16'
BOREHOLE FLUID: WATER ✓ ; FRESH WATER MUD ; SALT WATER MUD ;
OTHER:
DEPTH TO BOREHOLE FLUID: 16' TIME SINCE LAST CIRCULATION: NA

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SITE: NORTH ANNA COL B-909 DATE: 8/30/06
CLIENT: MACTEC JOB: 6410
AUTHOR: R. STELLER PAGE 2 OF 4

LOGGING CREW: R. STELLER
VEHICLE(S) USED AND MILEAGE: RENTAL
MOBILIZED FROM: FREDERICKSBURG, VA DEPARTURE TIME: 6:15
ARRIVED ON SITE: 7:45
STANDBY TIME: CAUSE:
LOGGING STARTED: 12:30 LOGGING COMPLETED: 13:05
STANDBY TIME: CAUSE:
LOGGING STARTED: ~~12:30~~ RAS LOGGING COMPLETED:
DEMOBILIZED TO: ARRIVAL TIME:
ADDITIONAL DEMOB TIME: REASON:

BATTERIES CHANGED BEFORE LOGGING: YES ___; NO ✓; STORED WITH NEW ___

WINCH	COMPROBE ☐	GREY ☐	OYO ☐	RG ☐	OTH ☑	
INSTRUMENT	OYO 12004 ☐	15014 ☐	19029 ☐		RG 160023 ☑	160024 ☐
RECEIVER S/N	12008 ☐	20042 ☐	26066 ☐	11001 ☐	23053 ☐	30086 ☑

MAINTENANCE PERFORMED ON SITE:

EQUIPMENT PROBLEMS OR FAILURES:

SUGGESTIONS, ADDITIONS, CHANGES:

RAS 8/30/06

COMMENTS: DEPTH ZERO = ~~2.0m~~ 2.5 m .23 m = ~~1.77m~~ 2.27 m.

GEOVISION SUSPENSION LOGGING FIELD NOTES

SITE: NORTH ANNA COL B - 909 DATE: 8/30/06
CLIENT: MACTEC JOB: 6410
AUTHOR: R. STELLER PAGE 3 OF 4

DEPTH METERS	DEPTH FEET	UNFILTERED FILE NO.	FILTERED FILE NO.	COMMENTS CASING, WATER, ROCK, ETC
20.5	67.26			
21.0	68.90			
21.5	70.54			
22.0	72.18			
22.5	73.82			
23.0	75.46			
23.5	77.10			
24.0	78.74			
24.5	80.38			5" PVC CASE TO 80'
25.0	82.02	1		WITH STEEL CASING SHOE
25.5	83.66	2		
26.0	85.30	3		
26.5	86.94	4		
27.0	88.58	5		
27.5	90.22	6		
28.0	91.86	7		
28.5	93.50	8		
29.0	95.14	9		
29.5	96.78	10		
30.0	98.43	11		
30.5	100.07	12		
31.0	101.71	13		
31.5	103.35	14		
32.0	104.99	15		
32.5	106.63	16		
33.0	108.27	17		
33.5	109.91	18		
34.0	111.55	19		
34.5	113.19	20		
35.0	114.83	21		
35.5	116.47	22		
36.0	118.11	23		
36.5	119.75	24		
37.0	121.39	25		
37.5	123.03	26		
38.0	124.67	27		
38.5	126.31	28		
39.0	127.95	29		
39.5	129.59	30		
40.0	131.23	31		

GEOVISION SUSPENSION LOGGING FIELD NOTES

SITE: NORTH ANNA COL B-909 DATE: 8/30/06
CLIENT: MACTEC JOB: 6410
AUTHOR: R. STELLER PAGE 4 OF 4

DEPTH METERS	DEPTH FEET	UNFILTERED FILE NO.	FILTERED FILE NO.	COMMENTS CASING, WATER, ROCK, ETC
40.5	132.87	32		
41.0	134.51	33		
41.5	136.15	34		
42.0	137.80	35		
42.5	139.44	36		
43.0	141.08	37		
43.5	142.72	38		
44.0	144.36	39		
44.5	146.00	40		
45.0	147.64	41		
45.5	149.28	42		
46.0	150.92	43		
46.5	152.56	44		
47.0	154.20	45		
47.5	155.84	46		
48.0	157.48	47		
48.5	159.12	48		
49.0	160.76	49		
49.5	162.40	50		
50.0	164.04	51		
50.5	165.68	52		
51.0	167.32	53		
51.5	168.96	54		
52.0	170.60	55		
52.5	172.24	56		
53.0	173.88	57		
53.5	175.52	58		
54.0	177.17	59		
54.5	178.81	60		
55.0	180.45	61		
55.5	182.09	62		
56.0	183.73	63		
56.5	185.37	64		
57.0	187.01	65		
57.5	188.65	66		BOTTOM MEASUREMENT?
58.0	190.29			HIT BOTTOM @ 57.75M. =>
58.5	191.93			PROBE TIP @ 201.6'
59.0	193.57			
59.5	195.21			
60.0	196.85			

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B-909 BORING GEOPHYSICS FIELD LOG SUMMARY

SITE: NORTH ANNA COL DATE: 9/12/06
CLIENT: MACTEC JOB:
AUTHOR: R. STELLER PAGE 1 OF 2

CONTACT: STEVE CRISCENZO PHONE: 919-949-1707

BOREHOLE CONSTRUCTION: CASED____ UNCASED ✓
DIAMETERS AND DEPTH RANGES: 5" 0 TO ≈40' ; 3.7" , ≈40' TO 200'
BOREHOLE TOTAL DEPTH AS DRILLED: 200'
CONDUCTOR CASING?: YES____ DEPTH TO BOTTOM OF CASING______; NO ✓
DEPTH TO BEDROCK: ≈ 40'
BOREHOLE FLUID: WATER____; FRESH WATER MUD ✓; SALT WATER MUD ____;

LOGGING CREW: R. STELLER

LOG TYPE	FILE NAME	DEPTH RANGE	DATE	TIMES
CALIPERTEST	B909CALTEST03	Ø	9/12/06	9:38 – 9:40
CALIPER/GAMMA	B909CALUP02	110.0' – Ø	"	9:54 – 10:08
CALIPERTEST	B909CALTEST04	Ø	"	10:15 – 10:20
SUSPENSION PS	B909_001 → 060.OR4	1.6' – 98.4'	"	10:35 – 11:31
ACOUSTIC TV	B909ALUP	100.0' – 3.14'	"	12:00 – 12:28
ELOG TEST	B909ELOGTEST02	Ø	"	9:07 – 9:10
ELOG/GAMMA	B909ELOGUP02	120.0' – 25.2'	"	12:41 – 12:54

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B-909 CALIPER FIELD LOG

SITE: NORTH ANNA COL DATE: 9/12/06
CLIENT: MACTEC JOB: 6410
AUTHOR: R. STELLER PAGE 1 OF 2

CONTACT: ______ OFFICE PHONE: ______
CELL PHONE: ______
CONTACT: ______ OFFICE PHONE: ______
PHONE: ______
CONTACT: ______ PHONE: ______
PHONE: ______
CONTACT: ______ PHONE: ______
PHONE: ______
DRILLER: ______ PHONE: ______
COMPANY: ______ PHONE: ______

GENERAL SITE CONDITIONS/LOCATION: ______

BOREHOLE DESIGNATION: B-909 LOCATION: ______

COUNTY: ______ RANGE: ______ TOWNSHIP: ______ SECTION: ______
BOREHOLE CONSTRUCTION: CASED ___ UNCASED ✓
DIAMETERS AND DEPTH RANGES: 5" 0 TO ≈40' ; 3.7", ≈40 TO 200'
BOREHOLE TOTAL DEPTH AS DRILLED: 200'
CONDUCTOR CASING?: YES ___ DEPTH TO BOTTOM OF CASING ___ ; NO ✓
DEPTH TO BEDROCK: ≈40' DEPTH TO WATER TABLE: NA
BOREHOLE FLUID: WATER ___ ; FRESH WATER MUD ✓ ; SALT WATER MUD ___ ;
OTHER: ______
DEPTH TO BOREHOLE FLUID: Ø TIME SINCE LAST CIRCULATION: ½ HR

LOGGING CREW: R. STELLER
VEHICLE(S) USED AND MILEAGE: RENTAL
MOBILIZED FROM: FREDERICKSBURG, VA DEPARTURE TIME: 6:30
ARRIVED ON SITE: 7:45
STANDBY TIME: – CAUSE: ______
LOGGING STARTED: 9:35 LOGGING COMPLETED: 10:20

SITE: NORTH ANNA COL B-909 DATE: 9/12/06
CLIENT: MACTEC JOB: 6410
AUTHOR: R. STELLER PAGE 2 OF 2

WINCH: COMPROBE ___ SILVER ✓ OYO ___ OTHER ___
MICROLOGGER 5301 ✓ OTHER ___
CALIPER PROBE 5368 ✓ OTHER ___

PROBE OFFSET CASING STICK-UP DEPTH REF. OFFSET	12 IN MAX 2.08M(6.82 FT) ARMS - 1.58' 5.24'	24 IN MAX ARMS - ___

ZERO ON [illegible] = 5.20'

LOG NAME	START DEPTH	START TIME	END DEPTH	END TIME
B909CALTEST03	ø	9:35	ø	9:40
B909 CALIP02	1100.0	9:54	ø	10:08
B909 CALTEST04	ø	10:15	ø	10:20

CALIBRATION PLATE S/N 201

	FILE NAME	AS BUILT 1.968 IN (50 MM)	3.937 IN (100 MM)	8.000 IN 203.2 MM	PVC COUPLING 4.57' IN.
AS MEAS.	B909CALTEST03	2.01	3.97	7.99	4.55
AS MEAS.	B909 CALTEST 04	2.05	3.94	8.00	4.55
AS MEAS.					
AS MEAS.					
AS MEAS.					
AS MEAS.					

MAINTENANCE PERFORMED ON SITE: ___

EQUIPMENT PROBLEMS OR FAILURES: ___

SUGGESTIONS, ADDITIONS, CHANGES: ___

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P-S SUSPENSION VELOCITY FIELD LOG

SITE:_NORTH ANNA COL B-909 DATE: 9/12/06
CLIENT:_MACTEC JOB:_6410
AUTHOR:_R. STELLER PAGE 1 OF 4

CONTACT:_STEVE CRISCENZO OFFICE PHONE:_919-831-8047
CELL PHONE:_919-949-1707
CONTACT: OFFICE PHONE:
PHONE:
CONTACT: PHONE:
PHONE:
CONTACT: PHONE:
PHONE:
DRILLER: PHONE:
COMPANY: PHONE:

DIRECTIONS TO SITE:

GENERAL SITE CONDITIONS/LOCATION:

EA#:
BOREHOLE DESIGNATION: B-909 LOCATION:

COUNTY: RANGE: TOWNSHIP: SECTION:
BOREHOLE CONSTRUCTION: CASED ___ UNCASED ✓
DIAMETERS AND DEPTH RANGES: 5" 0 TO ≈ 40' ; 3.7", ≈ 40' TO 200'
BOREHOLE TOTAL DEPTH AS DRILLED: 200'
CONDUCTOR CASING?: YES ___ DEPTH TO BOTTOM OF CASING ___; NO ✓
DEPTH TO BEDROCK: ≈ 40' DEPTH TO WATER TABLE:
BOREHOLE FLUID: WATER ___; FRESH WATER MUD ✓; SALT WATER MUD ___;
OTHER:
DEPTH TO BOREHOLE FLUID: Ø TIME SINCE LAST CIRCULATION: 1 HR

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SITE: NORTH ANNA COL B-909 DATE: 9/12/06
CLIENT: MACTEC JOB: 6410
AUTHOR: R. STELLER PAGE 2 OF 4

LOGGING CREW: R. STELLER
VEHICLE(S) USED AND MILEAGE:
MOBILIZED FROM: FREDERICKSBURG, VA DEPARTURE TIME: 6:30
ARRIVED ON SITE: 7:45
STANDBY TIME: CAUSE:
LOGGING STARTED: 10:35 LOGGING COMPLETED: 11:31
STANDBY TIME: CAUSE:
LOGGING STARTED: LOGGING COMPLETED:
DEMOBILIZED TO: ARRIVAL TIME:
ADDITIONAL DEMOB TIME: REASON:

BATTERIES CHANGED BEFORE LOGGING: YES ✓ ; NO ; STORED WITH NEW

WINCH	COMPROBE ☐	GREY ☐	OYO ☐	RG ☐	OTH ☑	
INSTRUMENT	OYO 12004 ☐	15014 ☐	19029 ☐		RG 160023 ☑	160024 ☐
RECEIVER S/N	12008 ☐	20042 ☐	26066 ☐	11001 ☐	23053 ☐	30086 ☑

MAINTENANCE PERFORMED ON SITE:

EQUIPMENT PROBLEMS OR FAILURES:

SUGGESTIONS, ADDITIONS, CHANGES:

COMMENTS: DEPTH ZERO = 2.5m - .48m = 2.02m
EXIT DEPTH ZERO = 2.03m

SITE: NORTH ANNA COL B-909 DATE: 9/12/06
CLIENT: MACTEC JOB: 6410
AUTHOR: R. STELLER PAGE 3 OF 4

DEPTH METERS	DEPTH FEET	UNFILTERED FILE NO.	FILTERED FILE NO.	COMMENTS CASING, WATER, ROCK, ETC
0.5	1.64	301		
1.0	3.28	302		
1.5	4.92	303		
2.0	6.56	304		
2.5	8.20	305		
3.0	9.84	306		
3.5	11.48	307		
4.0	13.12	308		
4.5	14.76	309		
5.0	16.40	310		
5.5	18.04	311		
6.0	19.69	312		
6.5	21.33	313		
7.0	22.97	314		
7.5	24.61	315		
8.0	26.25	316		
8.5	27.89	317		
9.0	29.53	318		
9.5	31.17	319		
10.0	32.81	320		
10.5	34.45	321		
11.0	36.09	322		
11.5	37.73	323		
12.0	39.37	324		
12.5	41.01	325		
13.0	42.65	326		
13.5	44.29	327		
14.0	45.93	328		
14.5	47.57	329		$V_s \approx 2200$ m/s
15.0	49.21	330		
15.5	50.85	331		
16.0	52.49	332		
16.5	54.13	333		
17.0	55.77	334		
17.5	57.41	335		
18.0	59.06	336		
18.5	60.70	337		
19.0	62.34	338		
19.5	63.98	339		
20.0	65.62	340		

SITE: NORTH ANNA COL B-909 DATE: 9/12/06
CLIENT: MACTEC JOB: 6410
AUTHOR: R. STELLER PAGE 4 OF 4

DEPTH METERS	DEPTH FEET	UNFILTERED FILE NO.	FILTERED FILE NO.	COMMENTS CASING, WATER, ROCK, ETC
20.5	67.26	341		
21.0	68.90	342		
21.5	70.54	343		
22.0	72.18	344		
22.5	73.82	345		
23.0	75.46	346		
23.5	77.10	347		
24.0	78.74	348		
24.5	80.38	349		
25.0	82.02	350		
25.5	83.66	351		
26.0	85.30	352		
26.5	86.94	353		
27.0	88.58	354		
27.5	90.22	355		
28.0	91.86	356		
28.5	93.50	357		
29.0	95.14	358		
29.5	96.78	359		
30.0	98.43	360		
30.5	100.07			
31.0	101.71			
31.5	103.35			
32.0	104.99			
32.5	106.63			
33.0	108.27			
33.5	109.91			
34.0	111.55			
34.5	113.19			
35.0	114.83			
35.5	116.47			
36.0	118.11			
36.5	119.75			
37.0	121.39			
37.5	123.03			
38.0	124.67			
38.5	126.31			
39.0	127.95			
39.5	129.59			
40.0	131.23			

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B-909 TELEVIEWER FIELD LOG

SITE: NORTH ANNA COL DATE: 9/12/06
CLIENT: MACTEC JOB: 6410
AUTHOR: R. STELLER PAGE 1 OF 2

CONTACT: _____ _OFFICE_ PHONE: _____
CELL PHONE: _____
CONTACT: _____ _OFFICE_ PHONE: _____
PHONE: _____
CONTACT: _____ PHONE: _____
PHONE: _____
CONTACT: _____ PHONE: _____
PHONE: _____
DRILLER: _____ PHONE: _____
COMPANY: _____ PHONE: _____

DIRECTIONS TO SITE: _____

GENERAL SITE CONDITIONS/LOCATION: _____

BOREHOLE DESIGNATION: B-909 LOCATION: _____

COUNTY: _____ RANGE: _____ TOWNSHIP: _____ SECTION: _____
BOREHOLE CONSTRUCTION: CASED _____ UNCASED ✓
DIAMETERS AND DEPTH RANGES: 5" 0 TO ≈40' ; 3.7' , ≈40 TO 200'
BOREHOLE TOTAL DEPTH AS DRILLED: 200'
CONDUCTOR CASING?: YES ___ DEPTH TO BOTTOM OF CASING _____; NO ✓
DEPTH TO BEDROCK: ≈40 DEPTH TO WATER TABLE: _____
BOREHOLE FLUID: WATER ____; FRESH WATER MUD ✓ ; SALT WATER MUD ____;
OTHER: _____
DEPTH TO BOREHOLE FLUID: Ø TIME SINCE LAST CIRCULATION: 1.5 HR.

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SITE: NORTH ANNA COL B-909 DATE: 9/12/06
CLIENT: MACTEC JOB: 6410
AUTHOR: R. STELLER PAGE 2 OF 2

LOGGING CREW: R. STELLER
VEHICLE(S) USED AND MILEAGE: RENTAL
MOBILIZED FROM: FREDERICKSBURG, VA DEPARTURE TIME: 6:30
ARRIVED ON SITE: 7:45
STANDBY TIME: CAUSE:
LOGGING STARTED: 12:00 LOGGING COMPLETED: 12:28

WINCH: COMPROBE___ SILVER ✓ OYO___ OTHER___
MICROLOGGER 5301 ✓ OTHER___
TELEVIEWER OPTICAL #5117___ ACOUSTIC #5174 ✓ OTHER___

PROBE TILT TEST 88.1° BRUNTON TILT 88.5° FREE HANGING @ 0.5°.
PROBE AZIMUTH TEST 56.0° BRUNTON AZIMUTH 59.0°

PROBE OFFSET	OPTICAL 1.88M(6.17FT)	ACOUSTIC 1.44M(4.72FT)
CASING STICK-UP	-	- 1.58'
DEPTH REF. OFFSET		5.14'

EXIT DEPTH REFERENCE = 3.14'

LOG NAME	START DEPTH	START TIME	END DEPTH	END TIME
B909 AcUP 02	100.0	12:00	3.14'	12:28

MAINTENANCE PERFORMED ON SITE: HARD ROCK @ 81.3'

EQUIPMENT PROBLEMS OR FAILURES:

SUGGESTIONS, ADDITIONS, CHANGES: ROCK GAIN @ 7 DB., SOIL GAIN @ 22 DB.

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B-909 ELOG FIELD LOG

SITE: NORTH ANNA COL — DATE: 9/12/06
CLIENT: MACTEC — JOB: 6410
AUTHOR: R. STELLER — PAGE 1 OF 2

CONTACT: ______ _OFFICE_ PHONE: ______
CELL PHONE: ______
CONTACT: ______ _OFFICE_ PHONE: ______
PHONE: ______
CONTACT: ______ PHONE: ______
PHONE: ______
CONTACT: ______ PHONE: ______
PHONE: ______
DRILLER: ______ PHONE: ______
COMPANY: ______ PHONE: ______

GENERAL SITE CONDITIONS/LOCATION: ______

BOREHOLE DESIGNATION: B-909 LOCATION: ______

COUNTY: ______ RANGE: ______ TOWNSHIP: ______ SECTION: ______
BOREHOLE CONSTRUCTION: CASED ______ UNCASED ✓
DIAMETERS AND DEPTH RANGES: 5" 0 TO ≈40' ; 3.7", ≈40 TO 200'
BOREHOLE TOTAL DEPTH AS DRILLED: 200'
CONDUCTOR CASING?: YES ______ DEPTH TO BOTTOM OF CASING ______ ; NO ✓
DEPTH TO BEDROCK: ≈40' DEPTH TO WATER TABLE: ______
BOREHOLE FLUID: WATER ______ ; FRESH WATER MUD ✓ ; SALT WATER MUD ______ ;
OTHER: ______
DEPTH TO BOREHOLE FLUID: ∅ TIME SINCE LAST CIRCULATION: 1HR

LOGGING CREW: R. STELLER
VEHICLE(S) USED AND MILEAGE: RENTAL
MOBILIZED FROM: FREDERICKSBURG, VA DEPARTURE TIME: 6:30
ARRIVED ON SITE: 7:45
STANDBY TIME: ______ CAUSE: ______
LOGGING STARTED: 9:07 LOGGING COMPLETED: 12:54

SITE: NORTH ANNA COL B-909 DATE: 9/12/06
CLIENT: MACTEC JOB: 6410
AUTHOR: R. STELLER PAGE 2 OF 2

WINCH: COMPROBE ___ SILVER ✓ OYO ___ OTHER ___
MICROLOGGER 5301 ✓ OTHER ___
ELOG PROBE 5490 ✓ OTHER ___

PROBE OFFSET	2.50M(8.20 FT)
CASING STICK-UP	-1.58' +32.80
DEPTH REF. OFFSET	39.42'
EXT ZERO =	39.40'

LOG NAME	START DEPTH	START TIME	END DEPTH	END TIME
B909ELOGTEST02	Ø	9:07	Ø	9:10
B909ELOGUP02	120.0'	12:41	25.2'	12:54

MAINTENANCE PERFORMED ON SITE:

EQUIPMENT PROBLEMS OR FAILURES: LONG RESISTIVITY TEST @ 10 OHM-METER SCALE NOT READING CORRECTLY, FAILURE OF TEST BOX.

SUGGESTIONS, ADDITIONS, CHANGES:

APPENDIX F

BORING GEOPHYSICAL LOGGING FIELD MEASUREMENT PROCEDURES

PROCEDURE FOR

OYO P-S SUSPENSION SEISMIC VELOCITY LOGGING

Background

This procedure describes a method for measuring shear and compressional wave velocities in soil and rock. The OYO P-S Suspension Method is applied by generating shear and compressional waves in a borehole using the OYO P-S Suspension Logger borehole tool and measuring the travel time between two receiver geophones or hydrophones located in the same tool.

Objective

The outcome of this procedure is a plot and table of P and S_H wave velocity versus depth for each borehole. Standard analysis is performed on receiver to receiver data. Data is presented in report format, with ASCII data files and digital records transmitted on diskette.

Instrumentation

1. OYO Model 170 Digital Logging Recorder or equivalent
2. OYO P-S Suspension Logger probe or equivalent, including two sets horizontal and vertical geophones, seismic source, and power supply for the source and receivers
3. Winch and winch controller, with logging cable
4. Batteries to operate P-S Logger and winch

The Suspension P-S Logger system, manufactured by OYO Corporation, or the Robertson Digital P-S Suspension Probe with the Robertson Micrologger2 are currently the only commercially available suspension logging systems. As shown in Figure 1, these systems consists of a borehole probe suspended by a cable and a recording/control electronics package on the surface.

The suspension system probe consists of a combined reversible polarity solenoid horizontal shear-wave generator (S_H) and compressional-wave generator (P), joined to two biaxial geophones by a flexible isolation cylinder. The separation of the two geophones is one meter, allowing average wave velocity in the region between the geophones to be determined by inversion of the wave travel time between the two geophones. The total length of the probe is approximately 7 meters; the center point of the geophones is approximately 5 meters above the bottom end of the probe.

The probe receives control signals from, and sends the amplified geophone signals to, the instrumentation package on the surface via an armored 4 or 7 conductor cable. The cable is wound onto the drum of a winch and is used to support the probe. Cable travel is measured by a rotary encoder to provide probe depth data.

The entire probe is suspended by the cable and may be centered in the borehole by nylon "whiskers." Therefore, source motion is not coupled directly to the borehole walls; rather, the source motion creates a horizontally propagating pressure wave in the fluid filling the borehole and surrounding the source. This pressure wave produces a horizontal displacement of the soil forming the wall of the borehole. This displacement propagates up and down the borehole wall, in turn causing a pressure wave to be generated in the fluid surrounding the geophones as the soil displacement wave passes their location.

Environmental Conditions

The OYO P-S Suspension Logging Method can be used in either cased or uncased boreholes. For best results, the uncased borehole must be between 10 and 20 cm in diameter, or 4 to 8 inches. A cased borehole may be as small as 3 inches, if properly grouted (see below) and the grout annulus does not exceed 1 inch.

Uncased boreholes are preferred because the effects of the casing and grouting are removed. It is recommended that the borehole be drilled using the rotary mud method. This method does little damage to the borehole wall, and the drilling fluid coats and seals the borehole wall reducing fluid loss and wall collapse. The borehole fluid is required for the logging, and must be well circulated prior to logging.

If the borehole must be cased, the casing must be PVC and properly installed and grouted. Any voids in the grout will cause problems with the data. Likewise, large grout bulbs used to fill cavities will also cause problems. The grout must be set before testing. This means the grouting must take place at least 48 hours before testing.

For borehole casing, applicable preparation procedures are presented in ASTM Standard D4428/D4428M-91 Section 4.1 (see ASTM website for copy).

Calibration

Calibration of the digital recorder is required. Calibration is limited to the timing accuracy of the recorder. GEOVision's Seismograph Calibration Procedure or equivalent should be used. Calibration must be performed on an annual basis.

Measurement Procedure

The entire probe is lowered into the borehole to a specific measurement depth by the winch. A measurement sequence is then initiated by the operator from the instrumentation package control panel. No further operator intervention is then needed to complete the measurement sequence described below.

The system electronics activates the SH-wave source in one direction and records the output of the two horizontally oriented geophone axes which are situated parallel to the axis of motion of the source. The source is then activated in the opposite direction, and the horizontal output signals are again recorded, producing a SH-wave record of polarity opposite to the previous record. The source is finally actuated in the first direction again, and the responses of the vertical geophone axes to the resultant P-wave are recorded during this sampling.

The data from each geophone during each source activation is recorded as a different channel on the recording system. The seismograph has at least six channels (two simultaneous recording channels), each with at least a 12 bit 1024 sample record. Newer seismographs may have longer record lengths. The recorded data is displayed on a CRT or LCD display and possibly on paper tape output as six channels with a common time scale. Data is stored on digital media for further processing. Up to 8 sampling sequences can be stacked (averaged) to improve the signal to noise ratio of the signals.

Review of the data on the display or paper tape allows the operator to set the gains, filters, delay time, pulse length (energy), sample rate, and stacking number in order to optimize the quality of the data before recording. In the case of the Model 170, printed data is verified by the operator prior to moving the probe. In the case of the Robertson Micrologger2, storage on the hard disk should be verified from time-to-time, certainly before exiting the borehole.

Typical depth spacing for measurements is 1.0 meters, or 3.3 feet. Alternative spacing is 0.5 meter, or 1.6 feet.

Required Field Records

1) Field log for each borehole showing

   a) Borehole identification

   b) Date of test

   c) Tester or data recorder

d) Description of measurement

e) Any deviations from test plan and action taken as a result

f) QA Review

2) Paper output records are no longer required, since the Micrologger2 cannot generate them. However, data must be stored in at least 2 places prior to leaving the site

3) List of record ID numbers (for data on digital media) and corresponding depth

4) Diskettes, CDRom, or USB flash drives with backup copies of data on hard disk, labeled with borehole designation, record ID numbers, date, and tester name.

An example Field Log is attached to this procedure.

Analysis

Following completion of field work, the recorded digital records are processed by computer using the OYO Corporation software program PSLOG and interactively analyzed by an experienced geophysicist to produce plots and tables of P and S_H wave velocity versus depth.

The digital time series records from each depth are transferred to a personal computer for analysis. Figure 2 shows a sample of the data from a single depth. These digital records are analyzed to locate the first minima on the vertical axis records, indicating the arrival of P-wave energy. The difference in travel time between these arrivals is used to calculate the P-wave velocity for that 1-meter interval. When observable, P-wave arrivals on the horizontal axis records are used to verify the velocities determined from the vertical axis data. In addition, the soil velocity calculated from the travel time from source to first receiver is compared to the velocity derived from the travel time between receivers.

The digital records are studied to establish the presence of clear SH-wave pulses, as indicated by the presence of opposite polarity pulses on each pair of horizontal records. Ideally, the SH-wave signals from the 'normal' and 'reverse' source pulses are very nearly inverted images of each other. Digital FFT – IFFT lowpass filtering are used to remove the higher frequency P-wave signal from the SH-wave signal.

The first maxima are picked for the 'normal' signals and the first minima are picked for the 'reverse' signals. The absolute arrival time of the 'normal' and 'reverse' signals may vary by +/- 0.2 milliseconds, due to differences in actuation time of the solenoid source caused by constant mechanical bias in the source or by borehole inclination. This variation does not affect the velocity determinations, as the differential time is measured between arrivals of waves created by the same source actuation. The final velocity value is the average of the values obtained from the 'normal' and 'reverse' source actuations.

In Figure 2, the time difference over the 1-meter interval of 1.70 millisecond is equivalent to a SH-wave velocity of 588 m/sec. Whenever possible, time differences are determined from several phase points on the S_H -wave pulse trains to verify the data obtained from the first arrival of the S_H -wave pulse. In addition, the soil velocity calculated from the travel time from source to first receiver is compared to the velocity derived from the travel time between receivers.

Figure 3 is a sample composite plot of the far normal horizontal geophone records for a range of depths. This plot shows the waveforms at each depth, clearly showing the S-wave arrivals. This display format is used during analysis to observe trends in velocity with changing depth.

Once the proper picks are entered in PSLOG, the picks are transferred to an Excel spreadsheet where Vs and Vp are calculated. The spreadsheet allows output for presentation in charts and tables.

Standard analysis is performed on receiver 1 to receiver 2 data, with separate analysis performed on source to receiver data as a quality assurance procedure.

Registered Geophysicist Antony Martin Date 4/10/06

QA Review [signature] Date 4/10/06

References:

1. "In Situ P and S Wave Velocity Measurement", Ohya, S. 1986. Proceedings of In-Situ '86, *Use of In-Situ Tests In Geotechnical Engineering*, an ASCE Specialty Conference sponsored by the Geotechnical Engineering Division of ASCE and co-sponsored by the Civil Engineering Dept of Virginia Tech.

2. Guidelines for Determining Design Basis Ground Motions, Report TR-102293, Electric Power Research Institute, Palo Alto, California, November 1993, Sections 7 and 8.

3. "Standard test Methods for Crosshole Seismic Testing", ASTM Standard D4428/D4428M-91, July 1991, Philadelphia, PA

OYO SUSPENSION P-S VELOCITY LOGGING SETUP

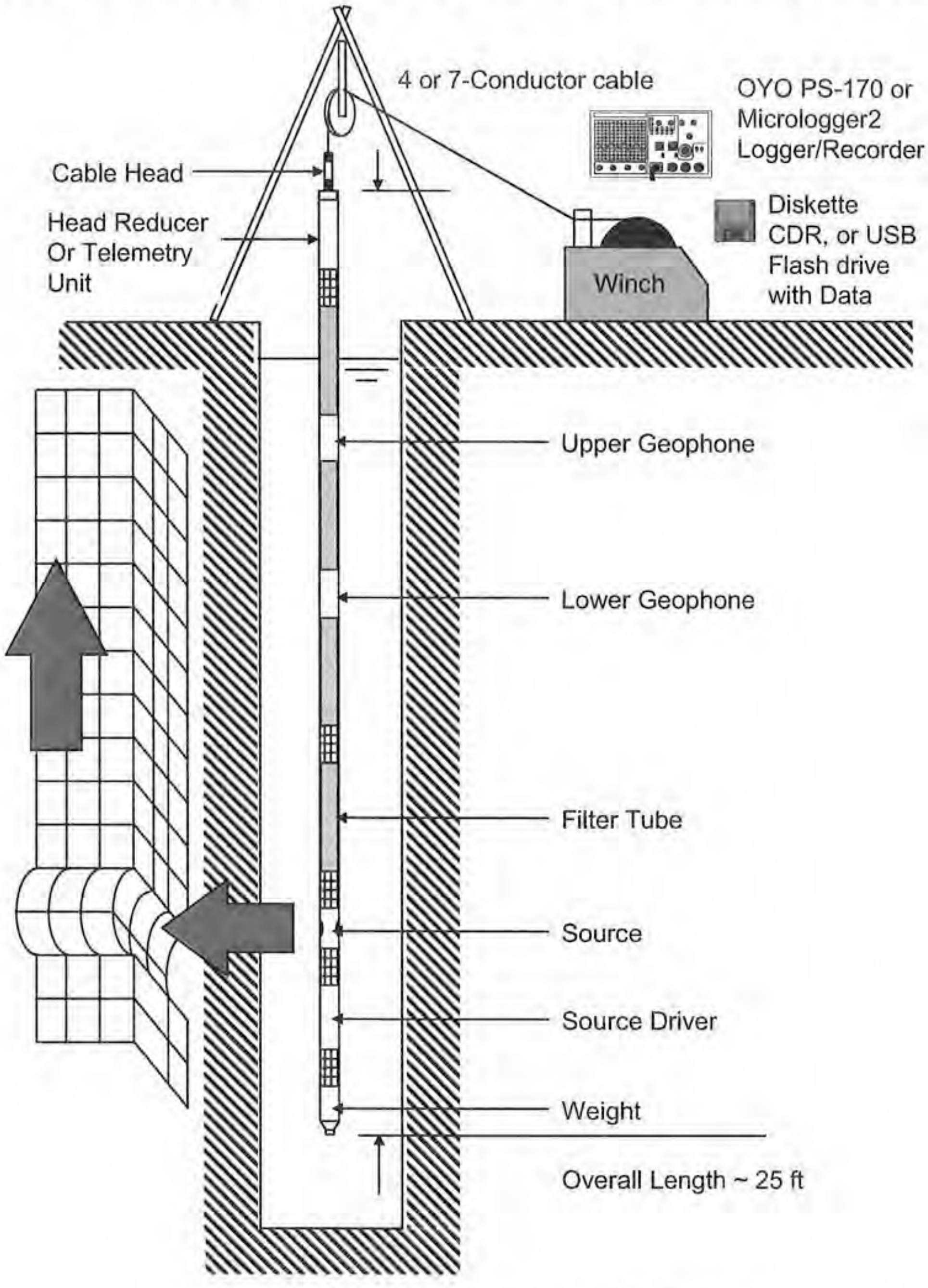

Figure 1. Suspension PS logging method setup

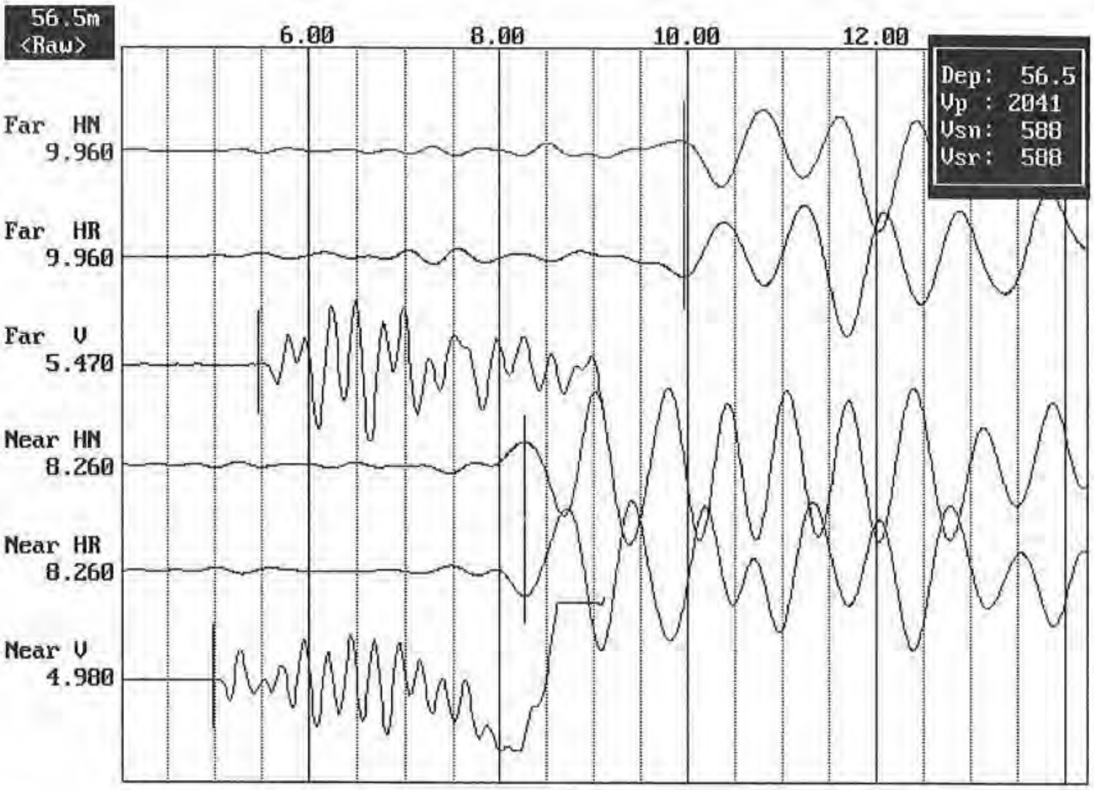

Figure 2. Sample suspension method waveform data showing horizontal normal and reversed (HR and HN), and vertical (V) waveforms received at the near (bottom 3 channels) and far (top 3 channels) geophones. The arrivals in milliseconds for each pick are shown on the left. The box in the upper right corner shows the depth in the borehole and the velocities calculated based on the picks.

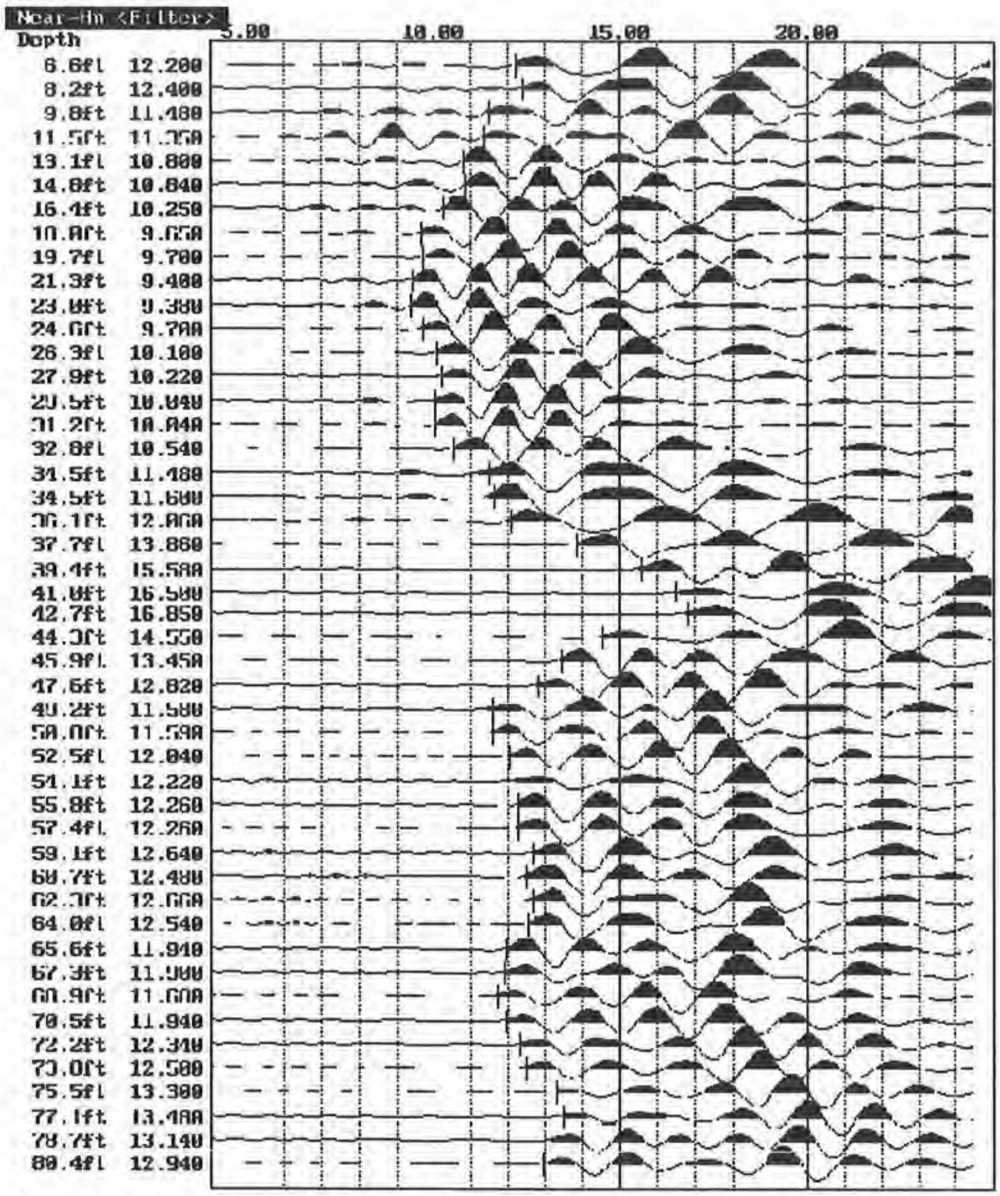

Figure 3. Sample composite waveform plot for normal shear waves received at the near geophone in a single borehole

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P-S SUSPENSION VELOCITY FIELD LOG

SITE:______________________ DATE:______________
CLIENT:______________________ JOB:______________
AUTHOR:______________________ PAGE 1 OF _____

CONTACT:______________ _OFFICE_ PHONE:______________
_________ PHONE:______________
CONTACT:______________ _OFFICE_ PHONE:______________
_________ PHONE:______________
CONTACT:______________ _________ PHONE:______________
_________ PHONE:______________
CONTACT:______________ _________ PHONE:______________
_________ PHONE:______________
DRILLER:______________ _________ PHONE:______________
COMPANY:______________ _________ PHONE:______________

DIRECTIONS TO SITE:________________________________

GENERAL SITE CONDITIONS/LOCATION:________________________

EA#:______________________
BOREHOLE DESIGNATION:______________ LOCATION:______________

COUNTY:__________ RANGE:________ TOWNSHIP:__________ SECTION:______
BOREHOLE CONSTRUCTION: CASED_____ UNCASED______
DIAMETERS AND DEPTH RANGES: _______ 0 TO _________ ; ______, _______ TO ________
BOREHOLE TOTAL DEPTH AS DRILLED:______________
CONDUCTOR CASING?: YES____ DEPTH TO BOTTOM OF CASING______; NO____
DEPTH TO BEDROCK:________ DEPTH TO WATER TABLE:_________
BOREHOLE FLUID: WATER_____; FRESH WATER MUD_____; SALT WATER MUD _____;
OTHER:______________________________
DEPTH TO BOREHOLE FLUID:__________ TIME SINCE LAST CIRCULATION:__________

GEOVision Geophysical Services 1151 Pomona Road, Suite P, Corona, CA 92882 Ph (951) 549-1234 Fx (951) 549-1236

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SITE:______________________ DATE:______________
CLIENT:____________________ JOB:______________
AUTHOR:____________________ PAGE 2 OF ____

LOGGING CREW:______________________________
VEHICLE(S) USED AND MILEAGE: ______________________
MOBILIZED FROM:______________ DEPARTURE TIME:______________
ARRIVED ON SITE:______________
STANDBY TIME:______________ CAUSE:______________
LOGGING STARTED:______________ LOGGING COMPLETED:______________
STANDBY TIME:______________ CAUSE:______________
LOGGING STARTED:______________ LOGGING COMPLETED:______________
DEMOBILIZED TO:______________ ARRIVAL TIME:______________
ADDITIONAL DEMOB TIME:______________ REASON:______________

BATTERIES CHANGED BEFORE LOGGING: YES____; NO____; STORED WITH NEW____

WINCH		COMPROBE ☐	GREY ☐	OYO ☐	RG ☐	OTH ☐
INSTRUMENT	OYO 12004 ☐	15014 ☐	19029 ☐		RG 160023 ☐	160024 ☐
RECEIVER S/N	12008 ☐	20042 ☐	26066 ☐	11001 ☐	23053 ☐	

MAINTENANCE PERFORMED ON SITE:______________________________

EQUIPMENT PROBLEMS OR FAILURES:______________________________

SUGGESTIONS, ADDITIONS, CHANGES:______________________________

COMMENTS:______________________________

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GEOVISION SUSPENSION LOGGING FIELD NOTES

SITE: ____________________ DATE: __________

CLIENT: ____________________ JOB: __________

AUTHOR: ____________________ PAGE ______ OF ______

DEPTH METERS	DEPTH FEET	UNFILTERED FILE NO.	FILTERED FILE NO.	COMMENTS CASING, WATER, ROCK, ETC
0.5	1.64			
1.0	3.28			
1.5	4.92			
2.0	6.56			
2.5	8.20			
3.0	9.84			
3.5	11.48			
4.0	13.12			
4.5	14.76			
5.0	16.40			
5.5	18.04			
6.0	19.69			
6.5	21.33			
7.0	22.97			
7.5	24.61			
8.0	26.25			
8.5	27.89			
9.0	29.53			
9.5	31.17			
10.0	32.81			
10.5	34.45			
11.0	36.09			
11.5	37.73			
12.0	39.37			
12.5	41.01			
13.0	42.65			
13.5	44.29			
14.0	45.93			
14.5	47.57			
15.0	49.21			
15.5	50.85			
16.0	52.49			
16.5	54.13			
17.0	55.77			
17.5	57.41			
18.0	59.06			

GEOVISION SUSPENSION LOGGING FIELD NOTES

SITE: ______ DATE: ______
CLIENT: ______ JOB: ______
AUTHOR: ______ PAGE ______ OF ______

DEPTH METERS	DEPTH FEET	UNFILTERED FILE NO.	FILTERED FILE NO.	COMMENTS CASING, WATER, ROCK, ETC
18.5	60.70			
19.0	62.34			
19.5	63.98			
20.0	65.62			
20.5	67.26			
21.0	68.90			
21.5	70.54			
22.0	72.18			
22.5	73.82			
23.0	75.46			
23.5	77.10			
24.0	78.74			
24.5	80.38			
25.0	82.02			
25.5	83.66			
26.0	85.30			
26.5	86.94			
27.0	88.58			
27.5	90.22			
28.0	91.86			
28.5	93.50			
29.0	95.14			
29.5	96.78			
30.0	98.43			
30.5	100.07			
31.0	101.71			
31.5	103.35			
32.0	104.99			
32.5	106.63			
33.0	108.27			
33.5	109.91			
34.0	111.55			
34.5	113.19			
35.0	114.83			
35.5	116.47			
36.0	118.11			

GEOVISION SUSPENSION LOGGING FIELD NOTES

SITE: ______ DATE: ______
CLIENT: ______ JOB: ______
AUTHOR: ______ PAGE ______ OF ______

DEPTH METERS	DEPTH FEET	UNFILTERED FILE NO.	FILTERED FILE NO.	COMMENTS CASING, WATER, ROCK, ETC
36.5	119.75			
37.0	121.39			
37.5	123.03			
38.0	124.67			
38.5	126.31			
39.0	127.95			
39.5	129.59			
40.0	131.23			
40.5	132.87			
41.0	134.51			
41.5	136.15			
42.0	137.80			
42.5	139.44			
43.0	141.08			
43.5	142.72			
44.0	144.36			
44.5	146.00			
45.0	147.64			
45.5	149.28			
46.0	150.92			
46.5	152.56			
47.0	154.20			
47.5	155.84			
48.0	157.48			
48.5	159.12			
49.0	160.76			
49.5	162.40			
50.0	164.04			
50.5	165.68			
51.0	167.32			
51.5	168.96			
52.0	170.60			
52.5	172.24			
53.0	173.88			
53.5	175.52			
54.0	177.17			

GEOVISION SUSPENSION LOGGING FIELD NOTES

SITE: ______ DATE: ______
CLIENT: ______ JOB: ______
AUTHOR: ______ PAGE ______ OF ______

DEPTH METERS	DEPTH FEET	UNFILTERED FILE NO.	FILTERED FILE NO.	COMMENTS CASING, WATER, ROCK, ETC
54.5	178.81			
55.0	180.45			
55.5	182.09			
56.0	183.73			
56.5	185.37			
57.0	187.01			
57.5	188.65			
58.0	190.29			
58.5	191.93			
59.0	193.57			
59.5	195.21			
60.0	196.85			
60.5	198.49			
61.0	200.13			
61.5	201.77			
62.0	203.41			
62.5	205.05			
63.0	206.69			
63.5	208.33			
64.0	209.97			
64.5	211.61			
65.0	213.25			
65.5	214.90			
66.0	216.54			
66.5	218.18			
67.0	219.82			
67.5	221.46			
68.0	223.10			
68.5	224.74			
69.0	226.38			
69.5	228.02			
70.0	229.66			
70.5	231.30			
71.0	232.94			
71.5	234.58			
72.0	236.22			

GEOVISION SUSPENSION LOGGING FIELD NOTES

SITE: ______________________ DATE: __________

CLIENT: ______________________ JOB: __________

AUTHOR: ______________________ PAGE ______ OF ______

DEPTH METERS	DEPTH FEET	UNFILTERED FILE NO.	FILTERED FILE NO.	COMMENTS CASING, WATER, ROCK, ETC
72.5	237.86			
73.0	239.50			
73.5	241.14			
74.0	242.78			
74.5	244.42			
75.0	246.06			
75.5	247.70			
76.0	249.34			
76.5	250.98			
77.0	252.62			
77.5	254.27			
78.0	255.91			
78.5	257.55			
79.0	259.19			
79.5	260.83			
80.0	262.47			
80.5	264.11			
81.0	265.75			
81.5	267.39			
82.0	269.03			
82.5	270.67			
83.0	272.31			
83.5	273.95			
84.0	275.59			
84.5	277.23			
85.0	278.87			
85.5	280.51			
86.0	282.15			
86.5	283.79			
87.0	285.43			
87.5	287.07			
88.0	288.71			
88.5	290.35			
89.0	291.99			
89.5	293.64			
90.0	295.28			

GEOVISION SUSPENSION LOGGING FIELD NOTES

SITE: ______ DATE: ______
CLIENT: ______ JOB: ______
AUTHOR: ______ PAGE ______ OF ______

DEPTH METERS	DEPTH FEET	UNFILTERED FILE NO.	FILTERED FILE NO.	COMMENTS CASING, WATER, ROCK, ETC
90.5	296.92			
91.0	298.56			
91.5	300.20			
92.0	301.84			
92.5	303.48			
93.0	305.12			
93.5	306.76			
94.0	308.40			
94.5	310.04			
95.0	311.68			
95.5	313.32			
96.0	314.96			
96.5	316.60			
97.0	318.24			
97.5	319.88			
98.0	321.52			
98.5	323.16			
99.0	324.80			
99.5	326.44			
100.0	328.08			
100.5	329.72			
101.0	331.36			
101.5	333.01			
102.0	334.65			
102.5	336.29			
103.0	337.93			
103.5	339.57			
104.0	341.21			
104.5	342.85			
105.0	344.49			
105.5	346.13			
106.0	347.77			
106.5	349.41			
107.0	351.05			
107.5	352.69			
108.0	354.33			

GEOVISION SUSPENSION LOGGING FIELD NOTES

SITE: ______________________ DATE: ____________

CLIENT: ______________________ JOB: ____________

AUTHOR: ______________________ PAGE ______ OF ______

DEPTH METERS	DEPTH FEET	UNFILTERED FILE NO.	FILTERED FILE NO.	COMMENTS CASING, WATER, ROCK, ETC
108.5	355.97			
109.0	357.61			
109.5	359.25			
110.0	360.89			
110.5	362.53			
111.0	364.17			
111.5	365.81			
112.0	367.45			
112.5	369.09			
113.0	370.73			
113.5	372.38			
114.0	374.02			
114.5	375.66			
115.0	377.30			
115.5	378.94			
116.0	380.58			
116.5	382.22			
117.0	383.86			
117.5	385.50			
118.0	387.14			
118.5	388.78			
119.0	390.42			
119.5	392.06			
120.0	393.70			
120.5	395.34			
121.0	396.98			
121.5	398.62			
122.0	400.26			
122.5	401.90			
123.0	403.54			
123.5	405.18			
124.0	406.82			
124.5	408.46			
125.0	410.10			
125.5	411.75			
126.0	413.39			

PROCEDURE FOR USING THE ROBERTSON GEOLOGGING HI-RESOLUTION ACOUSTIC TELEVIEWER (HiRAT)

Reviewed 2/13/06

Background

The acoustic televiewer is a device for producing a qualitative image of the wall of a borehole. Because it uses ultrasound rather than visible light it is able to work in dirty or opaque borehole fluids, although heavy drilling mud will cause excessive dispersion of the acoustic beam. The picture below shows the sonde's lower nylon section, and one of the bowspring attachments which are used to centralize the sonde in the borehole.

Pulses of ultrasound (0.5 - 1.5MHz) are generated by a piezo-electric resonator. The pulses are transmitted through the oil in which the resonator is immersed, through the wall of the acoustic housing, then propagate through the borehole fluid and are reflected from the wall of the borehole. The reflected energy is picked up by the same transducer, from which is recorded both the ***amplitude*** of the returned pulse and the ***travel-time*** which have elapsed. Blanking must be applied to prevent the transducer from registering reflections from the inside surface of the acoustic housing. The material of the housing is chosen so that its acoustic properties are similar to the oil which fills it. The housing is not designed to withstand borehole fluid pressures, but has a piston device to allow equalization between inside and outside pressure.

The ***amplitude*** of the returned pulse is a function of the acoustic reflectivity of the borehole wall. If the beam strikes a hard borehole wall normally to the surface the energy will be returned to the transducer and a strong return will be recorded. If the formation is softer, then less energy will be reflected. Also, if the surface of the borehole is rough, or effectively missing because of the presence of a fracture or other structure, then energy will be dispersed and a poor return will be recorded.

The ***travel-time*** is a simple function of the diameter of the borehole and the velocity of sound in the borehole fluid (typically 1.5Km/sec). An A/D converter monitors the output from the transducer once the blanking period has expired and a comparator is used to detect the peak amplitude during the sampling window.

The coaxially-mounted transducer has a planar radiating surface, but the vibration characteristics are such that the acoustic pulse is emitted as a 'pencil' beam. The emitted beam is deflected by a planar mirror so that it leaves the acoustic housing at right angles to the sonde axis. The mirror is rotated to scan the borehole wall. The ultrasound pulses are synchronized with rotation of the mirror so that up to 360 pulses are emitted in every revolution. Because of the time which must elapse for the two-way transit of the borehole fluid, there is an upper limit upon the number of radial samples that may be acquired from a borehole of a particular radius. In larger boreholes, therefore, it may be necessary to reduce the number of radial samples. The sonde is able to operate at 90, 180 or 360 samples per revolution.

An image of the borehole wall is produced by moving the sonde along the borehole axis while it is scanning radially. By the same logic as shown above, it can be seen that any horizontal point will be imaged by more than one sweep of the acoustic beam so long as the axial movement of the sonde during one complete sweep is no greater than the beam diameter. An upper limit is therefore imposed upon the logging speed which will be a function of the rotational speed of the transducer, the radial sampling interval and borehole diameter.

Objective

The objective of this procedure is to provide a pseudo "core" of the borehole, and map the orientation and angles of cracks and voids in rock boreholes.

Instrumentation

This procedure is written specifically for the Robertson Geologging High-Resolution Acoustic Televiewer (HiRAT). The required equipment includes:

1. The Robertson High-Resolution Acoustic Televiewer (HiRAT) sonde with centralizers
2. A 4-conductor wire-line winch with cable at least 30m (100ft) longer than the depth of the borehole (RG Smart Winch or equivalent. GEOVision has adapted all our 4-conductor winches)
3. A sheave with depth encoder with minimum 500 pulse/revolution
4. A Robertson Geologging Micrologger II
5. A laptop with Winlogger installed and the following minimum system requirements:
    - Windows 98SE or above
    - 64M System memory
    - 800x600x24 SVGA Display with DirectX 8.0
    - 500Mhz CPU
    - USB 2.0 connection
6. Battery power supply with cables

Environmental Conditions

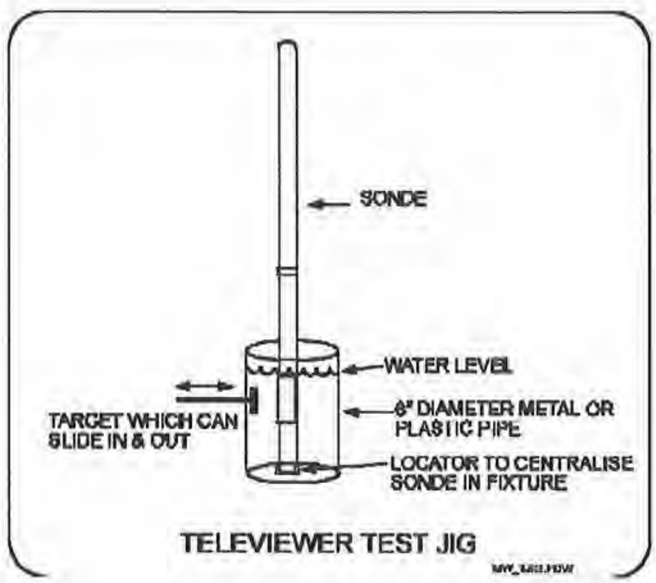
This tool is designed for fluid-filled boreholes between 67 and 150mm (3-6in) in rock. Since fine cracks are usually not visible in the walls of soil borings, the televiewers add very little information from a soil boring than a simple video. Now if the boring has soil AND rock, televiewer visuals in the soil may still be useful.

Calibration

The acoustic televiewer uses the variability in reflectance and the travel time to make an image of the borehole wall, mostly resulting from relative differences of materials and the physical characteristics of the wall. Since these are relative measurements, no field calibration of the sonde is required. However, it is important that the same location in the borehole be checked at the start and finish of the logging to make sure that the response or functionality haven't changed during the measurement.

A test fixture may be used to check function of the acoustic televiewer prior to use. This test fixture should comprise a plastic pipe, with a known internal diameter between 3 and 6 inches. This should be filled with water and the sonde stood upright in the fixture. A target made of metal or metal foil is glued on the inside of the container, or optionally on a seal and shaft so that it can be moved in and out on a line radial to the center-line of the pipe. A representation of this is shown in the figure below.

The purpose of this test fixture is to check the ability of the sonde to differentiate between materials of different acoustic reflectances, and different travel times, and to check the calibration of the caliper function of the sensor using the measured diameter of the pipe. However, if calibrated caliper measurements are required, it is recommended that a mechanical 3-arm caliper tool be used for this purpose because it can be calibrated in the field prior to use. The HiRAT will give very accurate results but this procedure does not cover calibration.



TELEVIEWER TEST JIG

Hi-RAT Field Procedure

Because the logging software is a standalone module, there are a number of settings which must be initialized independently of the WinLogger software. These include the depth measurement subsystem and sonde operating modes. Click on 'System' on the menu bar to show the following dialog boxes:

1.0 Log Mode

The sonde can operate in three distinct modes:

- Vertical mode is used for boreholes which are drilled from the surface and are deviated at less than 70 degrees from the vertical. Most exploration boreholes will fall into this class. In this mode the image is orientated according to compass directions (magnetic co-ordinates).
- Horizontal mode is used for boreholes which are sub-horizontal so their inclination will probably exceed 70 degrees from the vertical. Boreholes in this class would normally be drilled as part of ground investigations for tunneling and mining, drilling ahead of a drive to determine the nature and extent of fracturing. In this mode the image is orientated according to gravitational coordinates (up/down) since there is no unique point of the image circle which can be orientated to North with any precision.
- Test mode is used to exercise all sonde functions without creating a log. The image will scroll on the screen in the normal fashion, and orientation readouts will be refreshed continuously.

2.0 Scan Parameters

The scan parameters control the radial sampling of the borehole. The values will be retained between logging sessions, so the sonde will be initialized correctly at power-on. There are three parameters in the dialog:

- The radial sampling rate can be set to one of 90, 120, 180, 360 samples per revolution. There is a relationship between the logging speed and the radial sampling rate, since the time taken to send the dataset to the surface depends upon its length. The size of the log file is also determined by the radial sampling rate. The probe will always try to use the maximum head speed entered. If limited by a low Baud rate or a large 'window' setting then the probe will reduce its head speed automatically to compensate - see sonde operation section.

3.0 Depth Wheel Configuration

The depth measurement system is dependent upon the combination of depth measurement wheel with its calibrated groove, and the shaft encoder which translates rotation into pulses which are counted by the logging system controller. Two parameters are therefore required: depth wheel circumference and encoder pulse rate. The encoder parameters are covered in a subsequent topic.

- Select Metric or Imperial depth measurement units from the left-hand pane.

- Type the circumference of the depth measurement wheel into the 'wheel size' box. The standard sizes of GEOVision wheels are 1000mm. If you are measuring in Imperial units (or changing back to metric units), the standard wheel size can be converted automatically by clicking the left mouse button and choosing the appropriate conversion. The size is always specified in units of 1/1000 of the depth unit i.e. millimetres (mm) or millifeet (mft).

4.0 Encoder Configuration

The depth measurement system is dependent upon the combination of depth measurement wheel with its calibrated groove, and the shaft encoder which translates rotation into pulses which are counted by the logging system controller. The depth wheel circumference is covered in a previous topic. In order to accommodate a variety of encoders, their operational characteristics can be configured in the software.

- Select supply voltage from the radio buttons in the left-hand pane. The options are 5 Volt and 12 Volt. GEOVision encoders are always specified for 5 Volt operation.

- Type the number of pulses emitted per revolution into the central box. The standard values for all GEOVision winches are 500 pulses/rev.

- The logical direction of movement can be reversed if required to accommodate the directional characteristics (phase lead or lag) of the different encoder types.

5.0 Winch and Cable Configuration

Support for remote control of the RG Smart Winch is provided, and can be enabled by checking the ***Enable*** control in the left-hand Smart Winch pane. If the Smart Winch control is enabled, it is also necessary to select the measure units in force - select ***Metric*** or ***Imperial*** from the radio buttons on offer.

The Baud settings can be chosen to match the *quality* of the communication channel. The channel will be effected by cable type and length. Typically a Baudrate of 312.5K is used. The remaining controls in the dialog relate to the communications parameters. The operation is entirely compatible with the WinLogger software operation and the values would be expected to be the same as those in force for logging six-channel type sondes with that software. (Certain probe types may be fitted with a digital interface that does not require set-up and in this case the parameter edit boxes will not appear.)

- ***Cable Option*** is used to select the logging cable type which is available on the winch. The options are *Not Connected*, *Std. 4 Core*, *Differential* and *Monocable*. The only cable types used in GEOVision systems is Std. 4 Core. Select the appropriate type from the drop-down menu box. Note this value can only be changed when the probe power is turned off.
- ***Gain*** is related to cable length and uphole signal attenuation. Gain values range from 0-3 and control the amplification applied to the incoming signal. Use the *Scope* dialog to visualize the incoming signals. Gain should be set so that the signal reaches between 70% and 100% of the height of the display, generally obtained with a setting of 0 for GEOVision winches. If the peak height exceeds this level, clipping will result in artifacts which will be detected erroneously. Click *Apply* to set the parameters before proceeding to the *Scope* dialog.
- ***Threshold*** is the level at which the incoming signals are detected. Gain and Threshold are related, and can be visualized using the *Scope* dialog. Set the gain so that the signal reaches between 70% and 100% of the height of the display. Then adjust the threshold so that it is between 50% and 70% of the height of the pulses displayed and clear of any region of 'overshoot' of the positive and negative pulses. This will ensure that peaks are detected and noise is ignored. Generally a setting of 25 is used for GEOVision winches. When the scope dialog is displayed, the position of the mouse is reported as a threshold value to make it simpler to infer the correct setting. The scope option is greyed out when the probe power is turned off.
- ***Drive*** sets the strength of the downhole signal. It is not possible to visualize the downhole signal, but the effect of insufficient drive is to disable downhole communication, which will result in the commands being ignored by the sonde. Values range from 0 -127, and for GEOVision winches will be around 10. Increase the drive for longer cables.
- ***Pulse Width*** This is the width of the transmitted communication pulses in 100nS steps. The default is 25 equivalent to 2.5uS. The range is from 8 to 64. The pulse width can be reduced to prevent signal overshoot on short cables. The default value is used in most cases. Note any changes only come into effect during a log. (Note setting too large a pulse width when using the highest Baud rates will automatically be prevented within the probe and the pulse width reduced.)

IMPORTANT Please note the effects of changing 'Baud' will not appear until the first new log is made. The setting for 'threshold' may be effected by an increase in the 'Baud' rate please recheck 'threshold' if 'Baud' is altered using the 'Scope' function after making a short test log.

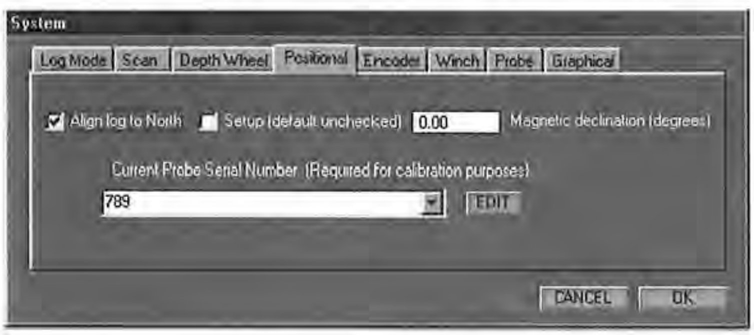
The parameters which are entered will be applied automatically if you close the dialog with ***OK***. The above parameters once set correctly will be remembered by the system and should never need to be altered.

6.0 Probe Configuration

The probe is normally energized at 90 Volts from the surface. However, it may be necessary to compensate for voltage drop on longer cables due to the higher power draw of this sonde. The voltage at the surface may be increased in order to deliver 90 Volts at the sonde. Simply type the value into the text box provided. The voltage should be set at 90V for all GEOVision winches. Values outside the indicated range will be rejected.

7.0 Positional Configuration

The probe includes a 3-axis orientation package, and is capable of producing a borehole image aligned to geographic North. This is achieved by determining and applying two image rotation parameters:



- ***Magnetic Declination*** is used to correct for the difference between Magnetic North and True North. The value varies from place to place, so the local value must be inserted here if you wish to perform this correction during data collection. This correction may also be made during processing. If the value is zero, the log will be referred to Magnetic North.
- ***Align to North*** is a check-box used to select image rotation to start at Magnetic North. If in addition a value is set for Magnetic Declination (see above) the image will be rotated to start at True North. If the box is not checked, the image will not be oriented to geographic co-ordinates, but will use the local co-ordinate frame of the sonde (X, Y, Z axis of the orientation module). This mode may be used to inspect the inside of magnetic casing, where an orientated image would be subjected to random effects caused by the metalwork.
- Set-up mode is selected by checking the ***Setup*** box, and is used to determine the required image rotation offset to correct for the angle between the axis of the orientation package and the index mark of the rotating transducer section. In set-up mode the normal sonde azimuth display is modified, and will instead show the 'relative bearing' which is measured between the high side of the borehole and the orientation sensor index. Check ***Setup***, then OK to close the dialog. The icon adjacent to the sonde azimuth readout at the top of the screen is modified with the legend CAL when the system is in set-up mode. The sonde must now be placed in a stand or jig so that it

is inclined at about 20 degrees to the vertical, and adjacent to a target fixed to the jig so that it is directly above the transducer in the vertical plane. Lower the sonde with its attachment into a large bucket of water so that the transducer and target are fully immersed. Start the radial amplitude display, when it will be possible to see the strong signal returning from the target. Rotate the sonde so that the image of the target moves to the top of the display. When the two are coincident, the 'relative bearing' reads out the image rotation offset. This value is fixed for the sonde unless it is disassembled and rebuilt, at which point the procedure MUST be repeated. Please see the additional topic on the Radial Amplitude Display for further details.

- The ***Serial Number*** list box is used to select the sonde which is in use. When the appropriate sonde is selected, the image rotation offset determined by the above procedure is selected. To edit the image offset click the '***Edit***' and enter the new offset. Several serial numbers and associated offsets can be stored and selected as required.

8.0 Graphical

The palette can be changed between a colored and grey scale setting. The changes affect the log screen palette display and are also applied when replaying a log. Selecting Full range in the 'AGC Palette' will cause the software to spread the palette over the full 16bit signal. 'Mid range' will spread the palette over the first quarter of the 16bit range and 'Low range' will spread the palette over the first eighth of the 16 bit range. In most cases the 'Low range' selection is used. Note these settings do not affect the stored log data in any way. The 'Filter Width' is applied to the Natural Gamma trace data and is a simply running average filter. The range of the filter width is from 1 to 50 (x 10 millidepth units ie. mm or mft).

9.0 Sonde Operation

When the operations specified above have been reviewed and the correct settings have been selected, the system is ready for use. The main screen area is divided into 3 horizontal elements. At the top is the depth and orientation readout, together with the scale headings for the scrolling display of unwrapped borehole image.

On the left side of the depth track is the travel time display, with text boxes for sonde inclination, azimuth and head temperature.

On the right side is the display of amplitude and indication of current operating mode. Located in the center above the depth track are the text boxes for depth and cable speed (computed at the surface). The ranges for the 'Natural Gamma' channel overlay (optional) are shown above the Amplitude.

The central area is utilized for the scrolling display of unwrapped borehole data. The display is orientated with the left edge corresponding to North point of the aligned image data (if orientation is selected) according to the outputs of the sonde's orientation package.

The lower area has controls for the winch (applicable to RG Smart Winch only), depth initialization and sonde control.

The winch control area is only displayed when RG SmartWinch operation is enabled - see section 5 - and has four controls. Set Target Speed by typing the required speed into the window and pressing Enter.

Cable movement is initiated by clicking on either the UP or DOWN arrow control.

Cable movement is halted by clicking on the square STOP control.

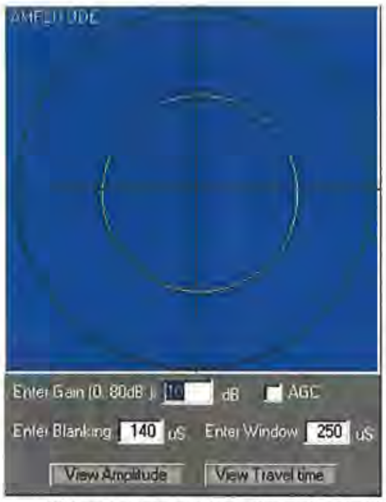
Depth is initialized by typing the required value into the entry box and pressing Enter. The entry box is not available at times when the system is in logging mode and the depth should not be changed by user entry.

Sonde power is applied by clicking on the green-colored 1 button. Power is turned off by clicking on the red-colored 0 button. There is no indicator for the state of the power supply on the desktop, so the external indicators should be observed for this purpose.

To make a log ensure that the Test Mode is disabled - see section 1, Log Mode setting. Click File|New Log and select a filename. Old logs may be overwritten if necessary -TAKE CARE. The header editor will be started automatically. A previous set of header data may be loaded by clicking LOAD and choosing a template.

To start logging, click on the red Record (circle) control. The log data will start to scroll down the screen after a brief pause for synchronization. The messages "DSP2: Detecting data stream" and "Updating probe settings" will be observed at the bottom of the screen during this process. Note that the screen scrolling direction is not affected by the actual direction of movement of the sonde. To cease logging, click on the black STOP control (square). The data should be immediately backed up to a USB drive, CD, or other data storage prior to beginning another log.

If the data display from a probe which is properly connected appears to occupy only half of the track area, with the remainder filled with random colors such as green which are not part of the regular palette, then it is most likely that the downhole data communication is not functioning properly. This symptom is due to the fact that the probe settings cannot be communicated properly, and it is operating in its default power-up mode. If this is the case, the Drive setting of the System|Winch dialog should be increased or decreased accordingly. See section 5 for full details.



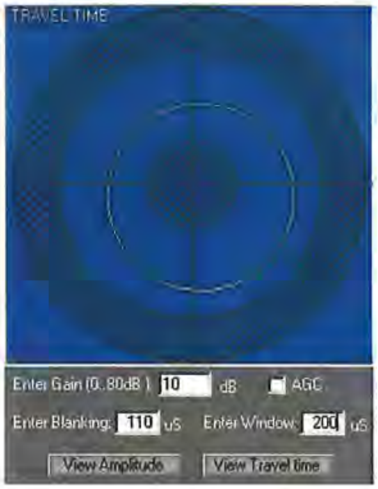

To adjust the sonde gain it is necessary to use the Radial Amplitude plot, which is enabled by clicking on the circle with cross-hairs symbol. When the dialog is active a new window will open on top of the unwrapped data display. In this display, the data is presented as a 'polar' plot. Press the 'View Amplitude' button to display the amplitude plot. This plot shows amplitude increasing towards the outside of the circle and the compass direction following the sweep of the transducer. The line indicating the data is drawn in the regular palette, so that high amplitudes are drawn in white and low amplitudes in black/brown. The picture here shows the image of the inside of a cylinder.

If the data is concentrated in a small circle at the center, the gain is too low and should be increased. If the data is obviously clipped at the outside of the circle, then the gain should be reduced. Type the new gain value into the entry box and press Enter. The ideal would be to set a gain value which allows the peak values to be displayed without clipping, with the majority of the data around the half-way level. It may also be necessary to adjust the blanking to ensure that internal reflections from the acoustic housing are not detected at the new gain value. This will be apparent in the unwrapped data display as pronounced patterning unrelated to the true target. The AGC option causes the probe to set gain automatically thus preventing signal saturation in most cases. (The gain is varied in 6dB steps

Blanking Period and window length can be set independently. Blanking is set to avoid reflections from the housing of the acoustic transducer or random reflections from a rugose borehole, and window length is set to accommodate the range of borehole radius that might be expected. An error will be indicated if the sum of the blanking period and window length would be greater than 409 microseconds, which is the maximum range of the timer. The default value for the blanking period is 145 microseconds, which is the minimum required for the two-way transit from the transceiver to the outer surface of the acoustic housing. It is not advisable to reduce this value beyond the default setting, although it may be increased for larger boreholes at the rate of 1.5mm of one-way travel per microsecond.

Window Length (sample time) defines the period during which the arrival gate remains open to detect the returned acoustic pulse. The acoustic pulse will travel in water at a speed of approximately 1.5mm per microsecond. The default window length is 150 microseconds, which is equivalent to 225 mm of (two-way) travel in the borehole fluid, or approximately 110mm of borehole diameter. If this is added to the default blanking period, which is equivalent to the outside diameter of the acoustic housing, it can be seen that the default set-up will be correct for boreholes up to 150mm. An error will be indicated if the sum of the blanking period and window length would be greater than 409 microseconds, which is the maximum range of the timer. Choose your window setting to best match the borehole diameter.

Pressing the 'View Travel time' button changes the display to that shown below:



The unhatched ring between the two cross hatched zones represents the sample window. The width of this ring will vary with window length value. The profile of a cylinder is represented here appearing as a circle in the sample window.

Pressing this button displays the following dialog box:

This box allows you to enable the Natural Gamma option by checking the 'Enable Overlay' check box. The Overlay appears as a trace upon the Amplitude plot. The trace range and color can also be set by this dialog. The level of filtering can also be altered (see section 8) (note that any displayed trace data is automatically aligned with the acoustic scan data but only when logging up. The Natural Gamma sensor occupies a higher position in the probe so sufficient data has to be prebuffered so that the acoustic data can depth aligned with gamma. The prebuffering results in a delay at the start of a log before correct gamma data appears this is normal.)

Data Analysis and Interpretation

RG-DIP, the manufacturer's image interpretation package, offers manual and automatic feature recognition options. Feature orientations (dip/strike and azimuth) are automatically calculated. Display options include stereographic projections of zone axes, orientation frequency plots and 'synthetic cores' for comparison with real core data. The last option is invaluable for orientating core samples, particularly in the case of incomplete recovery.

Reporting

The final report will include the objective and scope of the survey, location of the boreholes, discussion of instrumentation and procedures in the field and lab. For each borehole there will be a plot showing the dip/strike and azimuth of features. The next page shows an example.

Assumptions and limitations of the results will be discussed. Supporting references will be listed as necessary

Required Field Records

Field log for each borehole showing

a) Location and description of the borehole

b) Date of test

c) Field personnel

d) Instrumentation

e) Any deviations from test plan and action taken as a result

This procedure has been reviewed and approved by the undersigned:

Professional Geophysicist ____ Date Feb 13, 2006

QA Review ____ Date Feb 13, 2006

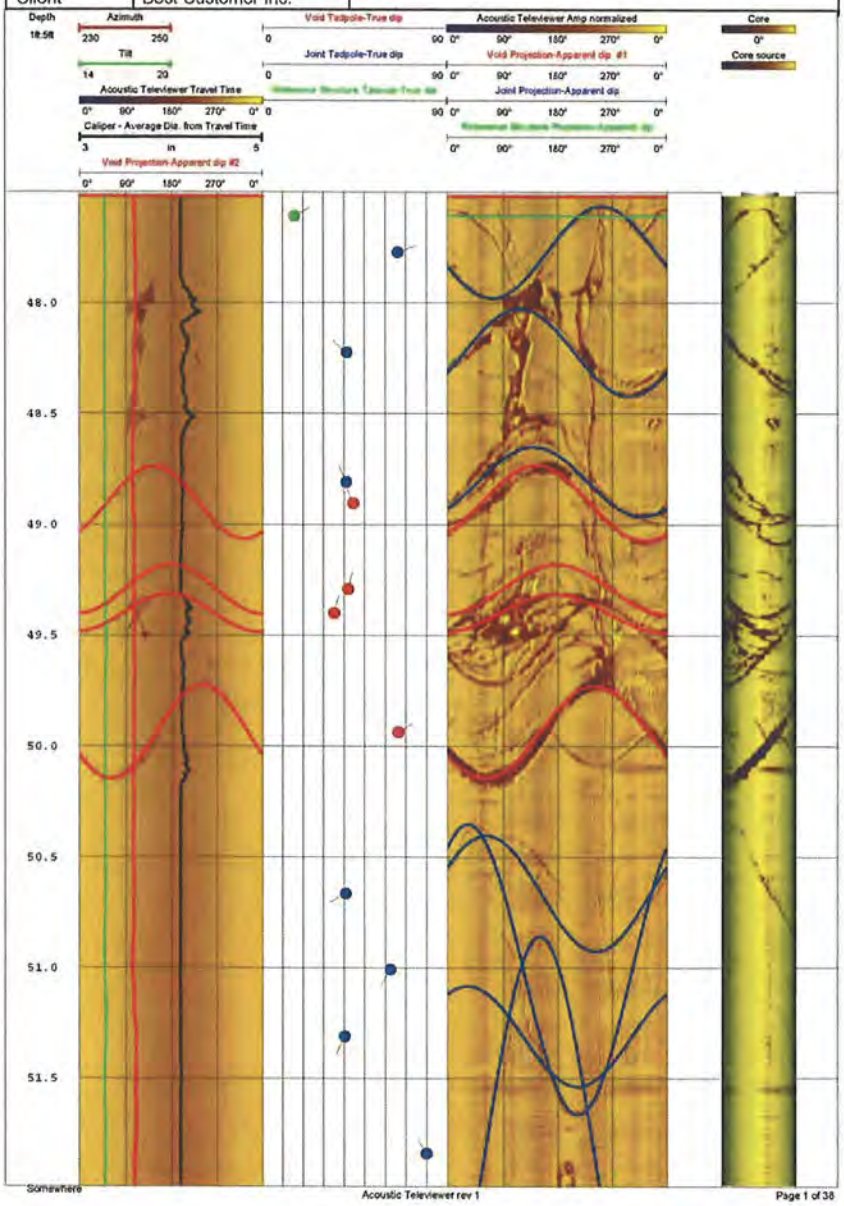
B-XXX	Company	Geovision Geophysical Services
	Location	Somewhere Dam

BH	B-XXX Acoustic Televiewer		
Date	7/8/05	BH Fluid	Air/Water
Casing	4" Steel to 15 ft		
File Name	BXXXdown1		
Depth Drilled	300 feet		
Depth Logged	299.3 feet		
Logged by	Rob Steller		
Client	Best Customer Inc.		

Notes:

1) All orientations referenced to True North

2) Tadpole tails indicate dip direction with True North as up.



Designation: D 5753 – 05

Standard Guide for Planning and Conducting Borehole Geophysical Logging[1]

This standard is issued under the fixed designation D 5753; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide covers the documentation and general procedures necessary to plan and conduct a geophysical log program as commonly applied to geologic, engineering, ground-water, and environmental (hereafter referred to as geotechnical) investigations. It is not intended to describe the specific or standard procedures for running each type of geophysical log and is limited to measurements in a single borehole. It is anticipated that standard guides will be developed for specific methods subsequent to this guide.

1.2 Surface or shallow-depth nuclear gages for measuring water content or soil density (that is, those typically thought of as construction quality assurance devices), measurements while drilling (MWD), cone penetrometer tests, and logging for petroleum or minerals are excluded.

1.3 Borehole geophysical techniques yield direct and indirect measurements with depth of the (*1*) physical and chemical properties of the rock matrix and fluid around the borehole, (*2*) fluid contained in the borehole, and (*3*) construction of the borehole.

1.4 To obtain detailed information on operating methods, publications (for example, **2, 5, 7, 18, 24, 29, 34, 35,** and **36**)[2] should be consulted. A limited amount of tutorial information is provided, but other publications listed herein, including a glossary of terms and general texts on the subject, should be consulted for more complete background information.

1.5 This guide provides an overview of the following: (*1*) the uses of single borehole geophysical methods, (*2*) general logging procedures, (*3*) documentation, (*4*) calibration, and (*5*) factors that can affect the quality of borehole geophysical logs and their subsequent interpretation. Log interpretation is very important, but specific methods are too diverse to be described in this guide.

1.6 Logging procedures must be adapted to meet the needs of a wide range of applications and stated in general terms so that flexibility or innovation are not suppressed.

1.7 *This standard does not purport to address all of the safety and liability concerns, if any, (for example, lost or lodged probes and radioactive sources[3]) associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.8 *This guide offers an organized collection of information or a series of options and does not recommend a specific course of action. This document cannot replace education or experience and should be used in conjunction with professional judgment. Not all aspects of this guide may be applicable in all circumstances. This ASTM standard is not intended to represent or replace the standard of care by which the adequacy of a given professional service must be judged, nor should this document be applied without consideration of a project's many unique aspects. The word "Standard" in the title of this document means only that the document has been approved through the ASTM consensus process.*

2. Referenced Documents

2.1 *ASTM Standards:* [4]

D 653 Terminology Relating to Soil, Rock, and Contained Fluids

D 5088 Practice for the Decontamination of Field Equipment Used at Non-Radioactive Waste Sites

D 5608 Practice for the Decontamination of Field Equipment Used at Low Level Radioactive Waste Sites

3. Terminology

3.1 Definitions—Definitions shall be in accordance with Terminology D 653.

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[1] This guide is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.01 on Surface and Subsurface Characteristics.

Current edition approved June 1, 2005. Published June 2005. Originally approved in 1995. Last previous edition approved in 1995 as D 5753–95.

[2] The boldface numbers in parentheses refer to the list of references at the end of this standard.

[3] The use of radioactive materials required for some log measurements is regulated by federal, state, and local agencies. Specific requirements and restrictions must be addressed prior to their use.

[4] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

3.2 *Definitions of Terms Specific to This Standard:* Descriptions of Terms Specific to This Standard—Terms shall be in accordance with Ref (1).

4. Summary of Guide

4.1 This guide applies to borehole geophysical techniques that are commonly used in geotechnical investigations. This guide briefly describes the significance and use, apparatus, calibration and standardization, procedures and reports for planning and conducting borehole geophysical logging. These techniques are described briefly in Table 1 and their applications in Table 2.[5]

4.2 Many other logging techniques and applications are described in the textbooks in the reference list. There are a number of logging techniques with potential geotechnical applications that are either still in the developmental stage or have limited commercial availability. Some of these techniques and a reference on each are as follows: buried electrode direct current resistivity (37), deeply penetrating electromagnetic techniques (38), gravimeter (39), magnetic susceptibility (40), magnetometer, nuclear activation (41), dielectric constant (42), radar (50), deeply penetrating seismic (39), electrical polarizability (45), sequential fluid conductivity (46), and diameter (48). Many of the guidelines described in this guide also apply to the use of these newer techniques that are still in the research phase. Accepted practices should be followed at the present time for these techniques.

5. Significance and Use

5.1 An appropriately developed, documented, and executed guide is essential for the proper collection and application of borehole geophysical logs.

5.1.1 The benefits of its use include improving the following:

5.1.1.1 Selection of logging methods and equipment,

5.1.1.2 Log quality and reliability, and

5.1.1.3 Usefulness of the log data for subsequent display and interpretation.

5.1.2 This guide applies to commonly used logging methods (see Table 1 and Table 2) for geotechnical investigations.

5.1.3 It is essential that personnel (see 7.3.3) consult up-to-date textbooks and reports on each of the logging techniques, applications, and interpretation methods. A partial list of selected publications is given at the end of this guide.

5.1.4 This guide is not meant to describe the specific or standard procedures for running each type of geophysical log and is limited to measurements in a single borehole.

6. Apparatus

6.1 *Geophysical Logging System,* including probes, cable, draw works, depth measurement system, interfaces and surface controls, and digital and analog recording equipment.

6.1.1 Logging probes, also called sondes or tools, enclose the sensors, sources, electronics for transmitting and receiving signals, and power supplies.

[5] The references indicated in these tables should be consulted for detailed information on each of these techniques and applications.

6.1.2 Logging cable routinely carries signals to and from the logging probe and supports the weight of the probe.

6.1.3 The draw works move the logging cable and probe up and down the borehole and provide the connection with the interfaces and surface controls.

6.1.4 The depth measurement system provides probe depth information for the interfaces and surface controls and recording systems.

6.1.5 The surface interfaces and controls provide some or all of the following: electrical connection, signal conditioning, power, and data transmission between the recording system and probe.

6.1.6 The recording system includes the digital recorder and an analog display or hard copy device.

7. Calibration and Standardization of Geophysical Logs

7.1 *General*:

7.1.1 National Institute of Standards and Technology (NIST) calibration and operating procedures do not exist for the borehole geophysical logging industry. However, calibration or standardization physical models are available (see Appendix X1).

7.1.2 Geophysical logs can be used in a qualitative (for example, comparative) or quantitative manner, depending on the project objectives. (For example, a gamma-gamma log can be used to indicate that one rock is more or less dense than another, or it can be expressed in density units.)

7.1.3 The calibration and standardization scope and frequency shall be sufficient for project objectives.

7.1.3.1 Calibration or standardization should be performed each time a logging probe is modified or repaired or at periodic intervals.

7.2 *Calibration*:

7.2.1 Calibration is the process of establishing values for log response. It can be accomplished with a representative physical model or laboratory analysis of representative samples. Calibration data values related to the physical properties (for example, porosity) may be recorded in units (for example, pulses/s or μm/ft) that can be converted to apparent porosity units.

7.2.1.1 At least three, and preferably more, values are needed to establish a calibration curve, and the interface or contact between different values in the model should be recorded. Because of the variability in subsurface conditions, many more values are needed if sample analyses are used for calibration.

7.2.1.2 The statistical scatter in regression of core analysis against geophysical log values may be caused by the difference between the sample size and geophysical volume of investigation and may not represent measurement error.

7.2.2 *Physical Models*—A representative model simulates the chemical and physical composition of the rock and fluids to be measured.

7.2.2.1 Physical models include calibration pits, coils, resistors, rings, temperature baths, etc.

7.2.2.2 The calibration of nuclear probes should be performed in a physical model that is nearly infinite with respect to probe response.

TABLE 1 Common Geophysical Logs

Type of Log (References)	Varieties and Related Techniques	Properties Measured	Required Hole Conditions	Other Limitations	Typical Measuring Units and Calibration or Standardization	Brief Probe Description
Spontaneous potential (**7, 8, 12**)	differential	electric potential caused by salinity differences in borehole and interstitial fluids, streaming potentials	uncased hole filled with conductive fluid	salinity difference needed between borehole fluid and interstitial fluids; needs correction for other than NaCl fluids	mV; calibrated power supply	records natural voltages between electrode in well and another at surface
Single-point resistance (**7**)	conventional, differential	resistance of rock, saturating fluid, and borehole fluid	uncased hole filled with conductive fluid	not quantitative; hole diameter effects are significant	Ω; V-Ω meter	constant current applied across lead electrode in well and another at surface of well
Multi-electrode resistivity (**7, 8, 13**)	various normal focused, guard, lateral arrays	resistivity and saturating fluids	uncased hole filled with conductive fluid	reverses or provides incorrect values and thickness in thin beds	Ω-m; resistors across electrodes	current and potential electrodes in probe and remote current and potential electrodes
Induction (**10, 11**)	various coil spacings	conductivity or resistivity of rock and saturating fluids	uncased hole or nonconductive casing; air or fluid filled	not suitable for high resistivities	mS or Ω-m; standard dry air zero check or conductive ring	transmitting coil(s) induce eddy currents in formation; receiving coil(s) measures induced voltage from secondary magnetic field
Gamma (**5, 7, 22**)	gamma spectral (**44**)	gamma radiation from natural or artificial radioisotopes	any hole conditions	may be problem with very large hole, or several strings of casing and cement	pulses per second or API units; gamma source	scintillation crystal and photomultiplier tube measure gamma radiation
Gamma-gamma (**23, 24**)	compensated (dual detector)	electron density	optimum results in uncased hole; can be calibrated for casing	severe hole-diameter effects; difficulty measuring formation density through casing or drill stem	gs/cm^3; Al, Mg, or Lucite blocks	scintillation crystal(s) shielded from radioactive source measure Compton scattered gamma
Neutron (**7, 14, 25**)	epithermal, thermal, compensated sidewall, activation, pulsed	hydrogen content	optimum results in uncased hole; can be calibrated for casing	hole diameter and chemical effects	pulses/s or API units; calibration pit or plastic sleeve	crystal(s) or gas-filled tube(s) shielded from radioactive neutron source
Acoustic velocity (**5, 26, 27**)	compensated, waveform, cement bond	compressional wave velocity or transit time, or compressional wave amplitude	fluid filled, uncased, except cement bond	does not detect secondary porosity; cement bond and wave form require expert analysis	velocity units, for example, ft/s or m/s or µs/ft; steel pipe	1 or more transmitters and 2 or more receivers
Acoustic televiewer (**28, 7**)	acoustic caliper	acoustic reflectivity of borehole wall	fluid filled, 3 to 16-in. diameter; problems in deviated holes	heavy mud or mud cake attenuate signal; very slow logging speed	orientated image-magnetometer must be checked	rotating transducer sends and receives high-frequency pulses
Borehole video	axial or side view (radial)	visual image on tape	air or clean water; clean borehole wall	may need special cable	NA[A]	video camera and light source
Caliper (**29, 7**)	oriented, 4-arm high-resolution, *x-y* or max-min bow spring	borehole or casing diameter	any conditions	deviated holes limit some types; significant resolution difference between tools	distance units, for example, in.; jig with holes or rings	1 to 4 retractable arms contact borehole wall
Temperature (**30, 31, 32**)	differential	temperature of fluid near sensor	fluid filled	large variation in accuracy and resolution of tools	°C or °F; ice bath or constant temperature bath	thermistor or solid-state sensor
Fluid conductivity (**7**)	fluid resistivity	most measure resistivity of fluid in hole	fluid filled	accuracy varies, requires temperature correction	µS/cm or Ω-m; conductivity cell	ring electrodes in a tube
Flow (**12, 33, 7**)	impellers, heat pulse	vertical velocity of fluid column	fluid filled	impellers require higher velocities. Needs to be centralized.	velocity units, for example, ft/min; lab flow column or log in casing	rotating impellers; thermistors detect heated water; other sensors measure tagged fluid.
Deviation (**4, 7, 47**)	magnetic, gyroscopic, or mechanical	horizontal and vertical displacement of borehole	any conditions (see limitations)	magnetic methods orientation not valid in steel casing	degrees and depth units; orientation and inclination must be checked	various techniques to measure inclination and bearing of borehole

[A] NA = not applicable.

TABLE 2 Log Selection Chart for Geotechnical Applications Using Common Geophysical Logs[A]

	Acoustic		Electric and Induction					Fluid Logs				Radioactive or Nuclear				Other Methods			
Information Desired	Acoustic Tele-viewer	Acoustic Velocity, Δt, CBL, VDL, FWS	Induced Polari-zation	Multi-electrode Resistivity, Normal, Lateral, Micro Guard Resistivity	Single-Point Resis-tance	Sponta-neous Poten-tial	Induc-tion (Conduc-tivity)	Flow Meter	Fluid Resistivity	Fluid Sampler	Temper-ature, Differ-ential Temper-ature	Gamma-Gamma Density	Gamma	Neutron	Spectral Gamma	Borehole Video	Caliper	Casing Collar Locator	Deviation
Lithology and Correlation																			
Bed/aquifer thickness; correlation, structure	●	●		●	●	●	★					Δ	√	Δ	√	◊	√		
Lithology—depositional environment	?	●		●	●	●	★					Δ	√	Δ	√	◊	√		
Shale or clay content			●	●		●	★					Δ	√	Δ	√				
Bulk density												Δ							
Formation resistivity				●			★												
Injection/production profiles				?			?	□	□		□	Δ		Δ					
Permeability estimates		●						□	□		□		√						
Porosity (amount and type)	●	●		●			★					Δ		Δ					
Mineral identification			●									Δ			√				
Potassium-uranium thorium content (KUT)															√				
Rock Structure																			
Strike and dip of bedding	●															◊			√
Fracture detection (number of fractures), RQD	●	●		●	●											◊	√		
Fracture orientation and character	●															◊			√
Thin bed resolution	●			?	●											◊	√		
Fluid Parameters																			
Borehole fluid characteristics								?	□	□	□								
Fluid flow						●		□	□		□					◊			
Formation water quality				●		●	★			□									
Moisture content—water saturation				?			?					Δ		Δ					
Temperature		?									□								
Water level and water table	●	●		●	●	●	?		□		□	Δ		Δ		◊			
Borehole Parameters																			
Casing evaluation integrity, leaks, damage, screen location	■	●					?	■			■					◆	√	†	
Deviation of borehole																			√
Diameter of borehole	●																√		
Examination behind casing		●					★					Δ		Δ					
Location of debris in wells	●															◆	√	√	
Well completion evaluation, for example, cement bond, seal location, grout location	?	■					★					Δ	√	Δ					

[A] Required hole conditions: ■ = cased fluid-filled hole, ◆ = clear fluid or dry cased hole, □ = screened or open fluid-filled hole, ◊ = clear fluid or dry open hole, † = steel casing only, Δ = active nuclear log to be run in stable holes, ★ = open or nonconductive cased holes, dry or fluid filled, √ = no restrictions, ● = open fluid-filled hole only, and ? = possible applications.

7.2.2.3 Some probes have internal devices such as resistors, but this does not substitute for checking the probe response in an environment that simulates borehole conditions, and the use of such devices is considered standardization.

7.2.2.4 *Calibration Facilities*—Commonly used calibration pits or models for use by anyone at the present time are listed in Appendix X1 (14-18). The user should inquire concerning the present validity of any facility.

7.2.3 *Sample Analyses*:

7.2.3.1 Representative samples from boreholes in the project area that have been collected carefully and analyzed quantitatively also may be used to calibrate log response.

7.2.3.2 To reduce depth errors, the sample recovery of rock cores in calibration holes needs to approach 100 % for the intervals used for calibration. Log response should be used to select sample depths to span the range of desired log calibration values and to be within thick units to minimize the effects of potential depth errors. Samples need to be analyzed immediately or steps taken to preserve them for later analysis.

7.2.3.3 Samples to be used for log calibration should be analyzed only from depth intervals at which the log response is relatively uniform for a depth interval considerably greater than the vertical dimension of the volume of investigation of the logging probe. Samples near lithologic contacts or fluid interfaces should not be used because of possible boundary effects or depth errors.

7.3 *Standardization*:

7.3.1 Standardization is the process of checking the log response to reveal evidence of repeatability and consistency.

7.3.2 Standardization is needed to establish comparability between logs made with different equipment or at different times and to ensure the accuracy of measurements.

7.3.2.1 Standardization checks should include at least two different measurement values approximating the range of interest (For example, aluminum and magnesium or plastic blocks are used commonly to check the response of gamma-gamma density logging systems in the field.)

7.3.3 Standardization uses some type of a standard that may be used in the field or laboratory and repeat logs.

7.3.3.1 Log response needs to be checked using field standards often enough to satisfy the project objectives. Standardization of the log response provides the basis for correcting for changes (for example, changes in output with time due to system drift or changes of equipment).

7.3.3.2 Selected log intervals should be repeated (that is, re-logged). Repeat logs provide information on the stability of logging equipment.

7.3.3.3 A representative borehole may be used to check log response periodically. This borehole environment and the rocks and fluids penetrated may change with time.

8. Procedure

8.1 *Planning the Logging Program*:

8.1.1 A work plan should be developed prior to implementing the logging program.

8.1.2 The key steps in developing a logging work plan should include the following:

8.1.2.1 *Log Selection*—See Table 1 and Table 2.

8.1.2.2 *Personnel Selection*—See 8.3.2.

8.1.2.3 *Quality Control and Documentation*—See 8.4.

8.1.2.4 *Calibration and Standardization Procedures*—See Section 7.

8.1.2.5 *Equipment Liability*—See 1.7.

8.1.2.6 *Equipment Decontamination*—In environmental investigations, equipment decontamination may be required before, after, and between individual wells. Equipment decontamination may involve a number of standardized procedures, depending on the nature of the project (see Practices D 5088 and D 5608). A decontamination program should be agreed upon by all parties before logging commences, and procedures specified by the work plan should be followed.[6]

8.1.2.7 *Log Interpretation*—See 8.5.

8.2 *Field Assessment of Borehole Conditions*:

8.2.1 Borehole conditions can have a profound influence on the quality of log data and subsequent interpretation. Important parameters to consider include the following:

8.2.1.1 Drilling method, casing, drill hole history, and well completion materials.

8.2.1.2 *Borehole Fluid Properties*—Resistivity, temperature, density, viscosity, and chemistry at the time of logging.

8.2.1.3 Borehole diameter, rugosity, and stability.

8.2.1.4 Deviation of borehole.

8.2.1.5 Wellhead pressure.

8.2.2 *Logging Operations*:

8.2.2.1 Determine the sequence and direction of logging. The sequence in which a suite of logs is run is important from both a data quality and operational viewpoint. Because logging operations mix the borehole fluid, logs of fluid properties (for example, temperature, fluid resistivity, and fluid sampling should be run prior to other logs). Consideration should also be given to when borehole video surveys are performed because some logging tools may degrade borehole clarity. Tools that have arms or bowsprings that contact the borehole wall should be run late in the logging sequence because of the greater possibility of material from the borehole wall falling into the borehole. Because of the consequences of losing a tool with a radioactive source, these tools should be run last, and after a caliper log. Unstable boreholes should not be logged with radioactive source probes. All logs except fluid properties and video should be run with the probe moving up the borehole to reduce depth errors.

8.2.2.2 Select the depth reference. The selected depth reference needs to be stable and accessible.

8.2.2.3 Select horizontal and vertical scales.

8.2.2.4 Select the digitizing interval. See 8.3.1.2.

8.3 *Other Considerations*:

8.3.1 *Data Formats*—There are two methods of recording log data, digital and analog. Digital recording of logs should be used because of the numerous benefits of data manipulation. Digital recording is not yet practical for some logs such as video or acoustic televiewer.

8.3.1.1 An analog display should be available to be viewed in the field to verify the correct tool operation. Depth scales and units of measurement for the horizontal scale must be indicated clearly on each log.

8.3.1.2 The digital data are recorded at an operator-selected depth interval that should be as small as possible, at most, half the thickness of the smallest rock unit that can be resolved. The time interval for digital samples can also be selected by the operator. ASCII is the recommended format except for such logs as spectral gamma, full waveform sonic, borehole video, and acoustic televiewer. The digital file header should include all of the necessary information to reconstruct the logging

[6] Equipment decontamination procedures may have specific safety and equipment limitations that must be addressed prior to their use.

procedures accurately and should duplicate the information included in the written header of the log.

8.3.1.3 Unprocessed data should be available. Nonproprietary processing algorithms shall be furnished if processed data is provided.

8.3.2 *Personnel*:

8.3.2.1 Personnel not having specialized training or experience should be cautious about using borehole geophysics and should solicit assistance from qualified practitioners or attend courses on borehole geophysics.

8.3.2.2 Personnel operating logging equipment should have an understanding of the theory, field procedures, and methods of log interpretation.

8.3.2.3 A geoscientist, with experience in borehole geophysics, who understands the project objectives and local geohydrology may need to be available to examine logging results during logging operations when consistent with objectives of the program. This geoscientist is responsible for determining whether the instructions selected in the pre-logging conference are being followed and whether changes should be made.

8.3.2.4 Log interpretation should be performed by a geoscientist with experience in borehole geophysics and knowledge of the site geology and hydrology.

8.4 *Field Documentation*—A documentation plan for both the analog plot and digital data file should be established and become part of the work plan. Documentation of the following procedures is needed: calibration of logging probes, field operation of geophysical logging equipment, applicable decontamination, and format for presenting geophysical well log data. Repair, standardization, and calibration information should also be documented. Probes should be numbered to simplify the identification of associated documentation. Document all field problems including equipment malfunctions. This should include the steps taken to solve the problem and how the logs might have been affected. Repeat runs and field standardization should be more frequent when equipment problems occur. The use of one borehole on the project to check the probe response may aid in the identification of equipment or other problems. Probes should be recalibrated in a physical model after major repairs have been made.

8.4.1 *Log Headings (Headers)*—The log heading should contain all of the information that is necessary to analyze the log trace. Because auxiliary documents are frequently unavailable to other users of the log, all of the critical information concerning the log should be included on the final log heading. The header information should also be included in the same computer file as the log data. The following items listed are necessary and should be included on the log headings and computer files when appropriate. If information is not available or applicable, it should be noted on the heading. The following information should be included:

8.4.1.1 *Background Well Information*:

Owner of well and address, location of well (UTM coordinates, ¼ section, etc.); date; logging contractor and address; logging operator; drilling contractor and address; client and address; observer and address; elevation of top casing and distance above ground; and drilling history, methods etc.

8.4.1.2 *Borehole Conditions*:

Casing description; description of log depth datum; elevation of log depth datum; type of drilling fluid; resistivity and temperature of borehole fluid; depth of origin of borehole fluid samples; fluid level; time since last mud circulation; bottom hole temperature; and problems and unusual conditions.

8.4.1.3 *Equipment Data and Logging Parameters*:

Description of probe reference point; model and manufacturer of logging tools; logging company tool number; date and type of last calibration; date, type, and response of field standardization; top and bottom of logged interval; logging speed and direction; vertical depth error after logging; time constant or the time interval of digital samples; identification of disk containing digitized logs; and equipment problems.

8.4.1.4 *Specific Information for Nuclear Logging Probes*:

Source description, initial source strength, and date determined; source to detector or receiver spacing; detector description; and data filtering or enhancement parameters.

8.4.1.5 *Specific Information for Acoustic and Electric Logging Probes*:

source or transmitter description and signal output; source or transmitter to detector or receiver spacing; detector or receiver description; and data filtering or enhancement parameters.

8.4.2 *Quality Control During Logging Operations*:

request changes in logging speed and time constant; repeat logs or log intervals based on field log analysis; check depth readout against log; note errors or changes on the log; and verify documentation listed above.

8.5 *Log Interpretation*—The full potential of a logging program cannot be realized until the logging measurements are interpreted. Log interpretation should start at the time of data acquisition and should continue as an iterative process throughout the project.

8.5.1 Logs should be analyzed and described as a suite and combined with information on lithology and fluid quality because of the synergistic nature of log data. The nonunique response of logs dictates the use of data from other sources to check the log interpretation, and this background data must be included in the report. A computer will be used in most cases to aid analysis of the logs, and information on the software and algorithms used should be included in the report.

8.5.2 Important interpretation steps include the following:

8.5.2.1 Establishing database (for example, format conversion, depth corrections, editing, and filtering).

8.5.2.2 Applying borehole corrections (for example, correct electric logs for borehole diameter and fluid resistivity).

8.5.2.3 Performing initial data inversion-conversion log units to values appropriate for investigation (for example, density units to porosity).

8.5.2.4 Performing large-scale data inversion (for example, cross sections, regional correlation, and model parameters).

9. Report

9.1 Depending on the project objective, report only data or data and interpretations.

9.1.1 Both types of reports should include the following:

9.1.1.1 Objectives and scope.

9.1.1.2 Field Documentation (for example, site conditions, borehole conditions, data collection procedures, calibration and standardization of logging probes, field operation of geophysical logging equipment, and format for recording geophysical log data, including any filtering or processing of the data, problems, and unusual conditions; see 8.4).

9.1.1.3 Both the digital log data and log plots.

9.1.1.4 Abstract, executive summary, or conclusions.

9.1.2 Interpretation reports should include the following:

9.1.2.1 Log composites (for example, summary plots showing logs, lithology, well construction, and water quality zones). These composites are commonly annotated to indicate the features of interest and correlated with lithologic descriptions.

9.1.2.2 Brief description of the geologic and hydrologic setting.

9.1.2.3 Specific information on log analysis, that is, depth corrections and recalibration of logs, physical models or sample analyses that were used for calibration, methods of log interpretation, software used, and copies of cross-plots or other plots of data resulting from log analysis.

9.1.2.4 Well-to-well correlation sections and comparison to surface geophysical and other testing data, when available.

10. Keywords

10.1 acoustic logging; acoustic televiewer; borehole geophysics; borehole video; caliper logging; chemical properties and physical properties; deviation; electric logging; environmental; fluid conductivity/resistivity logging; fluid logging; gamma logging; gamma-gamma logging; geology; geophysics; geotechnical; ground water; hydrology; induction logging; log calibration and standardization; log headings; neutron logging; nuclear logging; resistivity logging; singlepoint resistance logging; spontaneous potential logging; temperature logging; well logging

APPENDIX

(Nonmandatory Information)

X1. CALIBRATION FACILITIES AVAILABLE FOR PUBLIC USE (1989)

X1.1 *Name and Location*—American Petroleum Institute Calibration Facility, University of Houston, Houston, TX: four pits (**14**, **19**, **20**).

X1.2 *Who to Contact:* University of Houston, Cullen College of Engineering, (713) 749-3423.

X1.3 *Probes That Can Be Calibrated*—Pit 1: neutron and gamma-gamma; Pit 2: gamma (simulated shale); Pits 3 and 4: spectral gamma.

X1.3.1 *Name and Location*—U.S. Department of Energy, Grand Junction, CO: 20 models or pits (**18**).

X1.3.2 *Who to Contact*—U.S. Department of Energy, Grand Junction Operations Office, or the prime contractor at the U.S. Department of Energy office, (303) 248-7768 or 6702.

X1.4 *Probes That Can Be Calibrated*—Gamma, gamma spectral, neutron, gamma-gamma, and magnetic susceptibility. Also, wet and dry borehole size factors and a 300-ft borehole with radium foil at known depths for check of depth measurements.

X1.4.1 *Name and Location*—U.S. Bureau of Mines density pits Pit 1: six holes and magnetic susceptibility (Pits 2). Denver Federal Center, Lakewood, CO: Pit six holes; Pit 2: three holes (**17**).

X1.4.2 *Who to Contact*—U.S. Geological Survey, Water Resources Division, Borehole Geophysics Project, Building 25, Denver Federal Center, (303) 236-5913.

X1.5 *Probes That Can Be Calibrated*—Pit 1: gamma-gamma, acoustic, resistivity; and Pit 2: magnetic susceptibility.

X1.5.1 *Name and Location*—U.S. Department of Energy, Fractured igneous rock calibration models, Denver Federal Center, Lakewood, CO: Three models or pits (**16**).

X1.5.2 *Who to Contact*—U.S. Geological Survey, Water Resources Division, Borehole Geophysics Project, Building 25, Denver Federal Center, (303) 236-5913.

X1.6 *Probes That Can Be Calibrated*—Fracture detection probes, neutron, gamma-gamma, short-spaced resistivity, and acoustic velocity.

X1.7 *Other Facilities*—The Geological Survey of Canada is developing a system of deep test holes and calibration facilities that are presently available at several locations in Canada. Gamma, gamma spectral, and coal property models are completed, and other physical property models are under construction (**15**). Calibration facilities at universities, private logging companies, and government agencies may also be available at other locations for use by outside logging groups.

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The following is a partial list of references intended to provide basic information on the various logging methods. There are many more pertinent references, but they are too numerous for listing in this guide **(34, 36, 51)**.

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Designation: D 6167 – 97 (Reapproved 2004)

Standard Guide for Conducting Borehole Geophysical Logging: Mechanical Caliper[1]

This standard is issued under the fixed designation D 6167; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide covers the general procedures necessary to conduct caliper logging of boreholes, wells, access tubes, caissons, or shafts (hereafter referred as boreholes) as commonly applied to geologic, engineering, ground-water, and environmental (hereafter referred as geotechnical) investigations. Caliper logging for mineral or petroleum exploration and development are excluded.

1.2 This guide defines a caliper log as a record of borehole diameter with depth.

1.2.1 Caliper logs are essential in the interpretation of geophysical logs since they can be significantly affected by borehole diameter.

1.2.2 Caliper logs are commonly used to measure borehole diameter, shape, roughness, and stability; calculate borehole volume; provide information on borehole construction; and delineate lithologic contacts, fractures, and solution cavities and other openings.

1.3 This guide is restricted to mechanically based devices with spring-loaded arms, which are the most common calipers used in caliper logging with geotechnical applications.

1.4 This guide provides an overview of caliper logging, including general procedures, specific documentation, calibration and standardization, and log quality and interpretation.

1.5 To obtain additional information on caliper logs see Section 9 of this guide.

1.6 This guide is to be used in conjunction with Guide D 5753.

1.7 This guide should not be used as a sole criterion for caliper logging and does not replace professional judgement. Caliper logging procedures should be adapted to meet the needs of a range of applications and stated in general terms so that flexibility or innovation is not suppressed.

1.8 The geotechnical industry uses English or SI units. The caliper log is typically recorded in units of inches, millimetres, or centimetres.

1.9 *This guide does not purport to address all of the safety and liability problems (for example, lost or lodged probes and equipment decontamination) associated with its use.*

1.10 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

D 653 Terminology Relating to Soil, Rock and Contained Fluids

D 5088 Practice for Decontamination of Field Equipment Used at Nonradioactive Waste Sites

D 5608 Practice for Decontamination of Field Equipment Used at Low Level Radioactive Waste Sites

D 5753 Guide for Planning and Conducting Borehole Geophysical Logging

3. Terminology

3.1 *Definitions:* Definitions shall be in accordance with Terminology D 653, Section 12, Ref **(1)**,[3] or as defined below:

3.1.1 *accuracy, n*—how close a measured log values approaches true value. It is determined in a controlled environment. A controlled environment represents a homogeneous sample volume with known properties.

3.1.2 *depth of investigation, n*—the radial distance from the measurement point to a point where the predominant measured response may be considered centered, that is not to be confused with borehole depth (for example, distance) measured from the surface.

3.1.3 *measurement resolution, n*—the minimum change in measured value that can be detected.

[1] This guide is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.01 on Surface and Subsurface Characterization.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] The boldface numbers given in parentheses refer to a list of references at the end of the text.

3.1.4 *repeatability, n*—the difference in magnitude of two measurements with the same equipment and in the same environment.

3.1.5 *vertical resolution, n*—the minimum thickness that can be separated into distinct units.

3.1.6 *volume of investigation, n*—the volume that contributes 90 % of the measured response. It is determined by a combination of theoretical and empirical modeling. The volume of investigation is non-spherical and has gradational boundaries.

4. Summary of Guide

4.1 This guide applies to borehole caliper logging and is to be used in conjunction with Guide D 5753.

4.2 This guide briefly describes the significance and use, apparatus, calibration and standardization, procedures, and reports for conducting borehole caliper logging.

5. Significance and Use

5.1 An appropriately developed, documented, and executed guide is essential for the proper collection and application of caliper logs. This guide is to be used in conjunction with Guide D 5753.

5.2 The benefits of its use include the following: improving selection of caliper logging methods and equipment, caliper log quality and reliability, and usefulness of the caliper log data for subsequent display and interpretation.

5.3 This guide applies to commonly used caliper logging methods for geotechnical applications.

5.4 It is essential that personnel (see the Personnel section of Guide D 5753) consult up-to-date textbooks and reports on the caliper technique, application, and interpretation methods.

6. Interferences

6.1 Most extraneous effects on caliper logs are caused by instrument problems and borehole conditions.

6.2 Instrument problems include the following: electrical leakage of cable and grounding problems, temperature drift, wear of mechanical components including the hinge pins and in the linear potentiometer (mechanical hysteresis), damaged or bent arms, and lack of lubrication of the mechanical components.

6.3 Borehole conditions include heavy drilling mud, borehole deviation, and drilling-related borehole irregularities.

7. Apparatus

7.1 A geophysical logging system has been described in the general guide (see the Apparatus section of Guide D 5753).

7.2 Caliper logs may be obtained with probes having a single arm, three arms (averaging or summation), multiple independent arms (x-y caliper), multiple-feeler arms, bow springs, or gap wheels. Single-arm and three-arm averaging probes are most commonly used for geotechnical investigations.

7.2.1 A single-arm caliper commonly provides a record of borehole diameter while being used to decentralize another type of log, such as a side-collimated gamma-gamma probe (see Fig. 1). The caliper arm generally follows the high side of a deviated hole. The single-arm decentralizing caliper may not have the resolution needed for some applications.

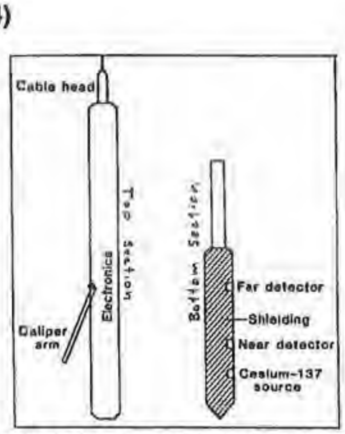

FIG. 1 Probe for Making Side-Collimated Gamma-Gamma Logs with Single-Arm Caliper (2)

7.2.2 The three-arm averaging or summation caliper has arms of equal length oriented 120° apart (see Fig. 2). All arms move together, which provides an average diameter measurement. This caliper provides higher resolution than the single-arm caliper measurement (see Fig. 3).

7.2.3 Multiple independent arm calipers generally have three or four independent arms of equal length; these arms are sometimes oriented. Horizontal resolution, that provides accurate borehole-diameter measurement regardless of borehole shape, is related to the number of independent arms. In general, calipers with four or more independent arms will have higher resolution than three-arm averaging (see Fig. 3). The four independent-arm caliper log may show borehole elongation (elliptical borehole shape) and better indicates the actual irregularity of the borehole.

7.3 Caliper probes using arms are typically spring loaded. The arms are retracted and opened with an electric motor and

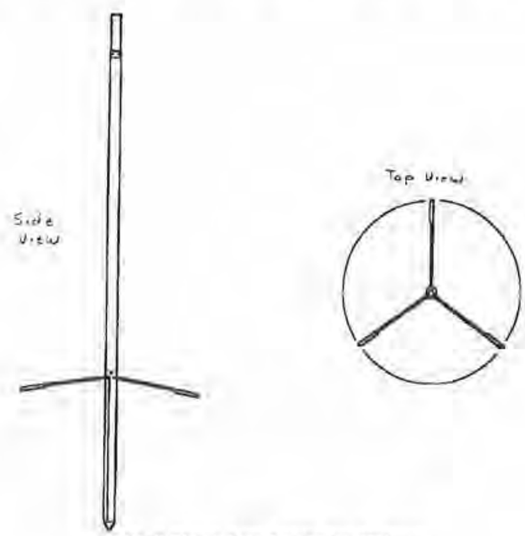

FIG. 2 Three-Arm Averaging Caliper

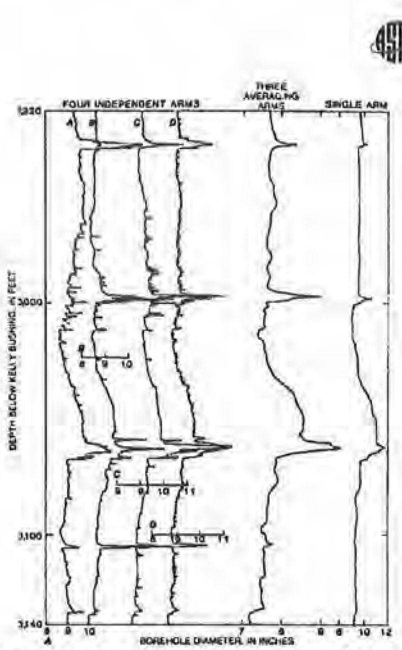

FIG. 3 Caliper Logs From Probes Having Four Independent Arms, Three Averaging Arms, and a Single Arm, Madison Limestone Test Well 1, Wyoming (2)

retention spring. The arms and gears are lubricated. Caliper probes closed by hand are held closed with an electric solenoid or weighted retention ring that is released with a sudden drop. Typically, the caliper arms are mechanically connected to a linear or rotary potentiometer such that changes in the angle of the arms causes changes in resistance. These changes in resistance are proportional to average borehole diameter. In some probes, the voltage changes are converted to a varying pulse rate or digitized downhole to eliminate or minimize cable transmission noise. Different arm length can be used to optimize sensitivity for the borehole-diameter range expected.

7.4 The concepts of volume of investigation and depth of investigation are not applicable to caliper logs since it is a surface-contact measurement.

7.5 Vertical resolution of caliper measurements is a function of the size of the contact surface (arm tip or pad), the response of the mechanical and electronic components, and digitizing interval used. The theoretical limit of vertical resolution is equal to the width of the caliper pad or tip. Selection of arm lengths and angle, and tip diameter will affect sensitivity. Shorter arms generally will provide more detail of the rugosity (borehole roughness as defined by Ref. (**2**)) of the borehole wall than longer arms. However, size of caliper probe and borehole diameter may also determine arm lengths used.

7.6 Measurement resolution of typical caliper probes is 0.05 in. (0.13 cm) of borehole diameter.

7.7 A variety of caliper logging equipment is available for geotechnical investigations. It is not practical to list all of the sources of potentially acceptable equipment.

8. Calibration and Standardization of Caliper Logs

8.1 *General:*

8.1.1 National Institute of Standards and Technology (NIST) calibration and standardization procedures do not exist for caliper logging.

8.1.2 Caliper logs can be used in a qualitative (for example, comparative) or quantitative (for example, borehole diameter corrections) manner depending upon the project objectives.

8.1.3 Caliper calibration methods and frequency shall be sufficient to meet project objectives.

8.1.3.1 Calibration and standardization should be performed each time a caliper probe is suspected to be damaged, modified, repaired, and at periodic intervals.

8.2 Calibration is the process of establishing values for caliper response and is accomplished with a physical model of a known diameter. Calibration data values related to the physical properties (for example, borehole diameter, roughness) may be recorded in units (for example, counts per second), that can be converted to units of length (for example, inches, millimetres, or centimetres.)

8.2.1 At least two, and preferably more, values, which approximate the anticipated operating range, are needed to establish a calibration curve (for example, 4- and 10-in. (10.2- and 25.4-cm) rings) if the borehole diameter to be logged is 5 in. (12.7 cm)).

8.2.2 Physical models of measured diameter that may be used to calibrate the caliper response may include rings or bars made of rigid materials that are not easily deformed and resist wear.

8.2.2.1 Calibration of caliper probes is done most accurately in rings of different diameters.

8.2.2.2 A calibration bar is a plate that is drilled and marked at regular intervals and machined to fit over the body of the probe (see Fig. 4). One arm is placed in the appropriate hole for the range to be logged.

8.2.2.3 Calibration can be checked by using casing of measured diameter logged in the borehole.

8.3 Standardization is the process of checking logging response to show evidence of repeatability and consistency.

8.3.1 Calibration serves as a check of standardization.

8.3.2 A representative borehole may be used to periodically check caliper response providing the borehole environment does not change with time. Caliper response may not repeat exactly because the probe may rotate, causing the arms to follow slightly different paths within the borehole.

9. Procedure

9.1 See the Procedure section of Guide D 5753 for planning a logging program, data formats, personnel qualifications, field documentation, and header documentation.

9.2 Caliper specific information (for example, arm length) should be documented.

9.3 Identify caliper logging objectives.

9.4 Select appropriate equipment to meet objectives.

9.4.1 Caliper equipment decontamination is addressed according to project specifications (see Practice D 5088 for non-radioactive waste sites and Practice D 5608 for low level radioactive waste sites). Some materials commonly used for caliper-arm lubrication may be environmentally sensitive.

9.5 Select the order in the logging sequence in which the caliper probe is to be run (see 8.2.2.1 of Guide D 5753).

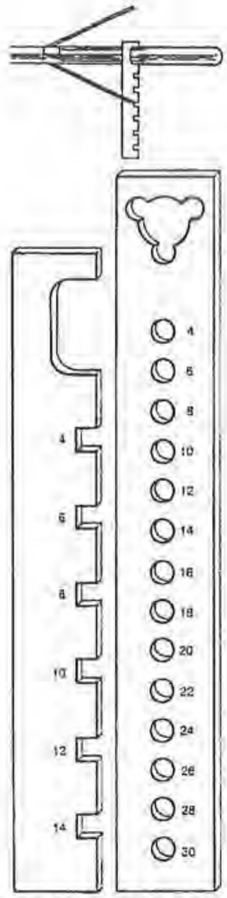

FIG. 4 Calibration Bars for Caliper Probes (3)

9.5.1 Caliper probes are run before any probe utilizing nuclear sources and more expensive centralized probes.

9.5.2 Caliper probes are run after any television camera and fluid property probes are run.

9.6 Caliper operation and calibration are checked at the start of each borehole or at an interval consistent with project objectives. (see the Procedure section of Guide D 5753). After calibration, the caliper arms are closed before lowering.

9.7 Select and document the depth reference.

9.7.1 The selected depth reference needs to be stable and accessible (for example, top of borehole casing).

9.8 Determine and document probe zero reference point (for example, top of probe or cablehead) and depth offset to caliper measurement point.

9.8.1 The measurement point of a caliper is the end of caliper arms and it changes as the arms open and close with the sine of arm angle multiplied by length of arm. Typically, the measurement point varies less than a few tenths of a foot (a few centimetres).

9.8.2 The measurement point will change if the arm length is changed.

9.9 Select horizontal and vertical scales for log display.

9.10 Select digitizing interval (or sample rate if applicable) to meet project objectives (see 8.3.1.2 of Guide D 5753).

9.10.1 Maximum vertical resolution requires the selection of a digitizing interval at least as small as the arm tip contact height.

9.10.2 Typically, this interval is no larger than 0.1 ft (0.03 m) for high-resolution applications.

9.11 The caliper probe is lowered to the bottom of the borehole.

9.11.1 Any time the caliper probe is lowered in the borehole, the arms should be closed to avoid damaging equipment or borehole.

9.11.2 Selection of probe speed while lowering is based on knowledge of borehole depth, stability, and other conditions.

9.12 Open caliper arm(s).

9.13 Select logging speed.

9.13.1 A logging speed of approximately 15 ft (5 m) per min is recommended for high-resolution applications. Faster logging speeds may induce noise due to the caliper probe bumping the borehole wall. Slower logging speeds will not enhance measurement resolution for most systems.

9.14 Collect caliper data while the probe is moving up the borehole.

9.15 When the probe reaches the top of the borehole:

9.15.1 If surface casing is present, compare and document caliper measurement.

9.15.2 Check depth reference and document after survey depth error (ASDE).

9.15.3 Determine if ASDE meets project objectives.

9.15.4 Typical tolerance for ASDE is ±0.4 ft per 100-ft (0.4 m per 100-m) interval logged.

9.16 Selected borehole intervals should be repeated (that is, relogged) under similar logging parameters as the initial log. Repeat logs provide information on the stability of the caliper equipment. The interval repeated should have enough variability, if possible, to check repeatability and resolution.

9.16.1 Repeat logs should be compared with the original log to ensure correct operation of the probe prior to ending a logging event.

9.16.2 Repeat sections may not repeat exactly due to a different orientation of the logging probe on the repeat run or changes in the borehole between logging runs (see Section 6).

9.16.3 Close caliper arms prior to lowering the probe down the borehole for a repeat section.

9.17 Evaluate the field log quality and compare log with drilling and completion information.

9.17.1 A reduction in borehole diameter over large depth sections may be indicative of borehole deviation on three-arm averaging caliper logs.

9.17.1.1 The magnitude of borehole deviation that causes this effect depends upon the length of the caliper arms being used and the strength of the tensioning spring within the caliper. Typically, a borehole deviation of greater than 15° is likely to produce this effect.

9.17.1.2 Converting the three-arm averaging caliper by removing two of the caliper arms may allow a good log to be obtained in these types of boreholes.

9.17.2 Mud can prevent caliper arms from opening fully, and thick mud cake may prevent accurate measurement of drilled diameter. Lack of caliper arm movement, especially in the bottom of a mud drilled borehole, may be indicative of arm sticking due to heavy mud.

9.17.2.1 If mud interferences are suspected, the borehole may be reconditioned, the caliper probe cleaned and lubricated, and the caliper log repeated.

9.18 Post-acquisition calibration checks may be required (surface casing or calibration standard) to meet the objectives of the logging program. Typical tolerances between pre- and post-calibration are ±0.2 in. (0.5 cm).

10. Interpretation of Results

10.1 See the Log Interpretation section of Guide D 5753 for procedures on log interpretation.

10.2 A valid caliper log is essential in the interpretation of the logs that are affected by changes in borehole diameter, including those logs that are labeled 'borehole compensated.' It is not always possible to compensate logs for substantial differences in borehole diameter.

10.2.1 Caliper logs can be analyzed individually (that is, borehole volume).

10.2.2 Caliper logs can be analyzed as part of a suite to take advantage of the synergistic nature of log data.

10.3 The caliper log should be depth correlated with the other geophysical logs as the first step to interpretation. This is especially important for logs that use the caliper data for borehole correction and depth adjustment.

10.4 Other pertinent information, including borehole construction (casing size), drilling history (hole size, drill method, penetration rate, core loss, fluid loss, etc.), and geologic information, should be integrated with the caliper-log data.

10.5 Interpretations based on changes in borehole diameter may be related to changes in drilling, mud cake, mud rings, borehole construction, lithology and structure, fractures and solution openings, and stress-induced breakouts.

10.6 The measured borehole diameter may be significantly different than the drilled diameter because of plastic formations extruded into the borehole and friable formations enlarging the borehole. A series of caliper logs may also show increases or decreases in borehole diameter with time.

10.6.1 Caliper logs are useful for determining what other logs can be made and what range of borehole diameters will be accepted by centralizers or decentralizers.

10.7 Fractures and solution openings may be obvious on a caliper log; however, their character may not be uniquely defined.

10.7.1 The single-arm caliper log may completely miss a feature or indicate only a small anomaly.

10.7.2 The three-arm averaging caliper log of a fracture dipping at an angle such that the three arms enter the opening at different depths will indicate three separate anomalies rather than one.

10.8 Borehole-diameter information is essential for calculation of volumetric rate from flowmeter logs.

10.9 Caliper logs provide useful information for borehole completion and testing.

10.9.1 Caliper logs are used to locate the optimum placement of inflatable packers for borehole testing. Inflatable packers can only form an effective seal within a specified range of borehole diameters, and can be damaged if they are set in rough or irregular parts of the borehole.

10.9.2 Caliper logs are used to estimate the volume of borehole completion material (cement, gravel, etc.) needed to fill the annular space between borehole and casing(s) or well screen.

10.10 Caliper logs may be applied to correlate lithology between boreholes based upon enlargements related to lithology.

11. Report

11.1 Consult the Report section, Guide D 5753 for requirements of the report.

11.2 Reports presenting caliper logs shall describe the components of the caliper logging system, the principles of the methods used, and their limits, methods and results of calibration and standardization, and performance verification (for example, diameter of surface casing, correlation with other logs, repeat sections, ASDE, etc.).

11.3 Information on the software and algorithms used should be included in the report.

11.4 Any deviations from this guide should be justified with documentation.

11.5 Presentation of caliper logs should be designed to meet project objectives. At a minimum, depth (y-axis) and units of measurement (x-axis) scales should be clearly marked (see Fig. 3). There may be a difference between presentations of data collected in the field versus in final report. Any scale "wraps" should be clearly marked.

11.5.1 Caliper logs are typically displayed with linear scales in inches, millimetres, or centimetres.

12. Keywords

12.1 borehole correction; borehole diameter; borehole geophysics; borehole volume; caliper log; ground water; single-arm caliper; three-arm caliper; well construction; well logging

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Designation: D 6274 – 98 (Reapproved 2004)

Standard Guide for Conducting Borehole Geophysical Logging - Gamma[1]

This standard is issued under the fixed designation D 6274; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide covers the general procedures necessary to conduct gamma, natural gamma, total count gamma, or gamma ray (hereafter referred to as gamma) logging of boreholes, wells, access tubes, caissons, or shafts (hereafter referred to as boreholes) as commonly applied to geologic, engineering, ground-water, and environmental (hereafter referred to as geotechnical) investigations. Spectral gamma and logging where gamma measurements are made in conjunction with a nuclear source are excluded (for example, neutron activation and gamma-gamma density logs). Gamma logging for minerals or petroleum applications are excluded.

1.2 This guide defines a gamma log as a record of gamma activity of the formation adjacent to a borehole with depth (See Fig. 1).

1.2.1 Gamma logs are commonly used to delineate lithology, correlate measurements made on different logging runs, and define stratigraphic correlation between boreholes (See Fig. 2).

1.3 This guide is restricted to gamma logging with nuclear counters consisting of scintillation detectors (crystals coupled with photomultiplier tubes), which are the most common gamma measurement devices used in geotechnical applications.

1.4 This guide provides an overview of gamma logging including general procedures, specific documentation, calibration and standardization, and log quality and interpretation.

1.5 To obtain additional information on gamma logs, see Section 13.

1.6 This guide is to be used in conjunction with Guide D 5753.

1.7 Gamma logs should be collected by an operator that is trained in geophysical logging procedures. Gamma logs should be interpreted by a professional experienced in log analysis.

1.8 The geotechnical industry uses English or SI units. The gamma log is typically recorded in units of counts per second (cps) or American Petroleum Institute (API) units.

1.9 *This guide does not purport to address all of the safety and liability problems (for example, lost or lodged probes and equipment decontamination) associated with its use.*

1.10 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.11 *This guide offers an organized collection of information or a series of options and does not recommend a specific course of action. This document cannot replace education or experience and should be used in conjunction with professional judgment. Not all aspects of this guide may be applicable in all circumstances. This ASTM standard is not intended to represent or replace the standard of care by which the adequacy of a given professional service must be judged, nor should this document be applied without consideration of a project's many unique aspects. The word "Standard" in the title of this document means only that the document has been approved through the ASTM consensus process.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

- D 653 Terminology Relating to Soil, Rock and Contained Fluids
- D 5088 Practice for Decontamination of Field Equipment Used at Nonradioactive Waste Sites
- D 5608 Practice for Decontamination of Field Equipment Used at Low Level Radioactive Waste Sites
- D 5753 Guide for Planning and Conducting Borehole Geophysical Logging
- D 6167 Guide for Conducting Borehole Geophysical Logging: Mechanical Caliper

3. Terminology

3.1 *Definitions:*

3.1.1 Definitions shall be in accordance with Terminology D 653, Section 13, Ref **(1)**, or as defined below.

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[1] This guide is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.01 on Surface and Subsurface Characterization.

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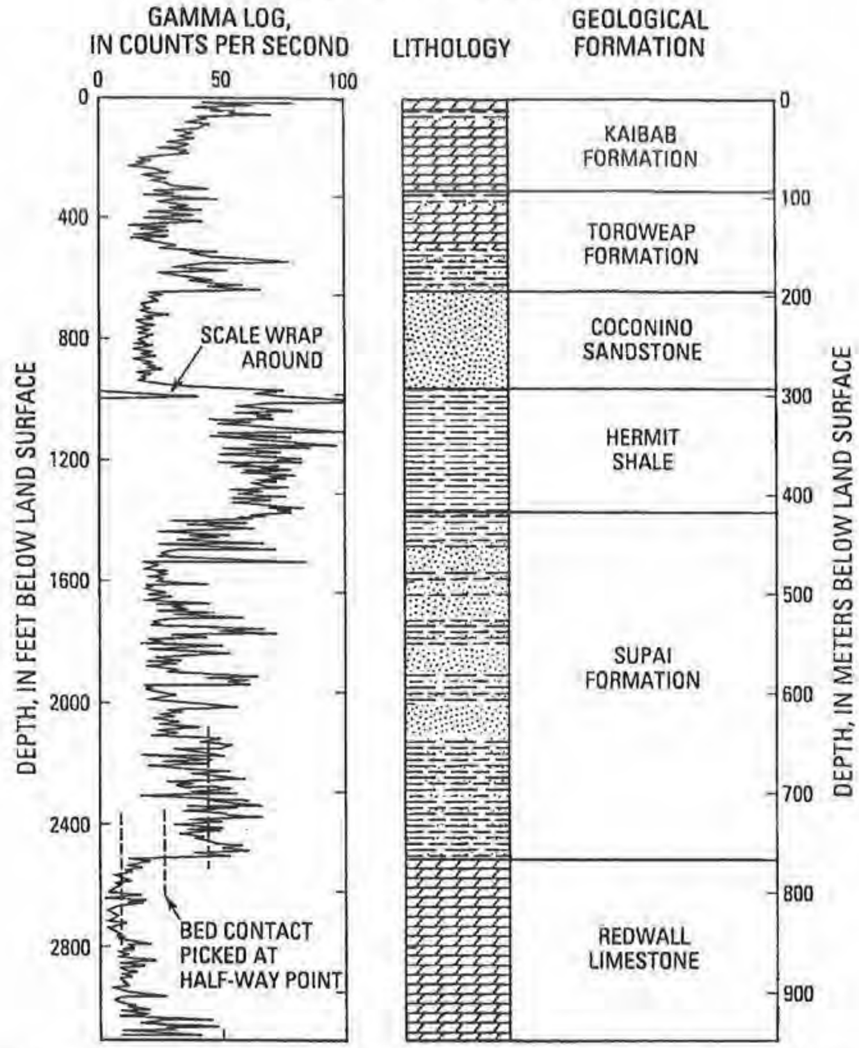
[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.



NOTE 1—This figure demonstrates how the log can be used to identify specific formations, illustrating scale wrap-around for a local gamma peak, and showing how the contact between two formations is picked to coincide with the half-way point of the transition between the gamma activities of the two formations.

FIG. 1 Example of a Gamma Log From Near the South Rim of the Grand Canyon

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *accuracy, n*—how close measured log values approach true value. It is determined in a controlled environment. A controlled environment represents a homogeneous sample volume with known properties.

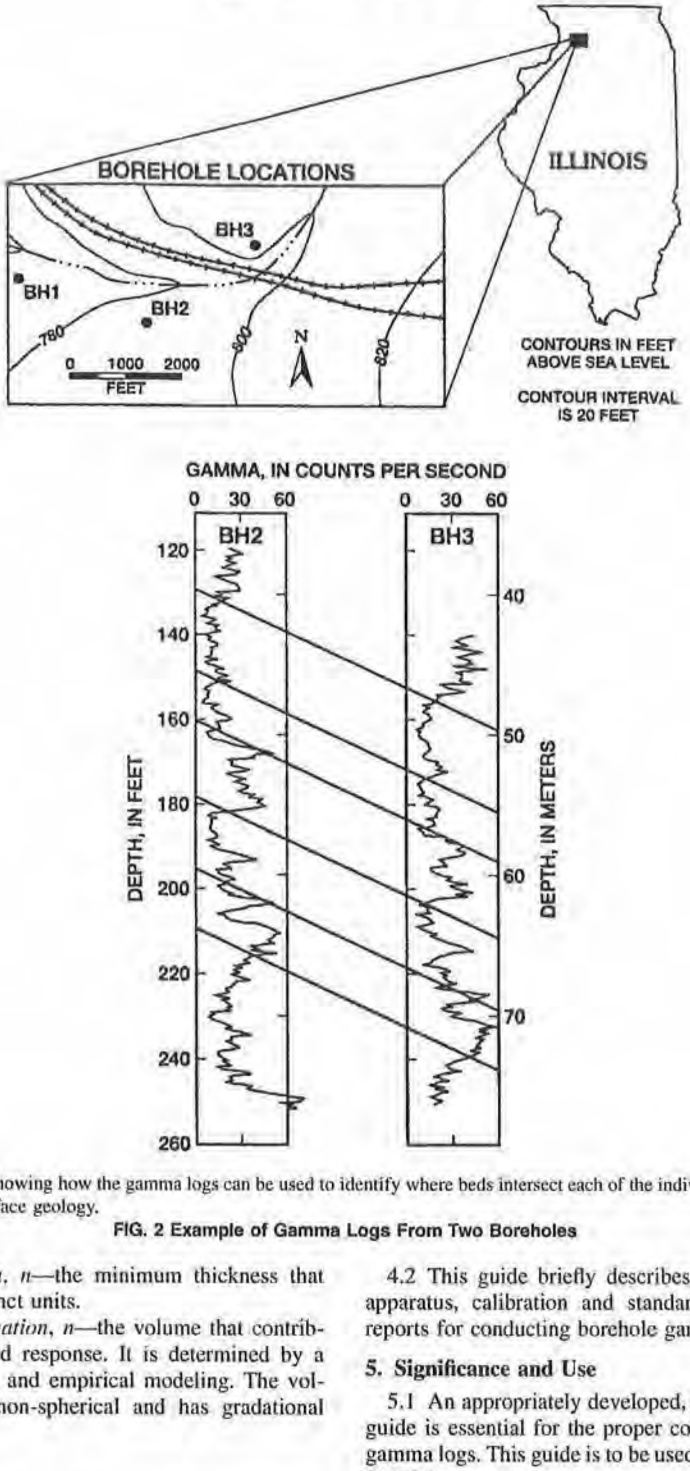
3.2.2 *dead time, n*—the time after each pulse when a second pulse cannot be detected.

3.2.3 *dead time effect, n*—the inability to distinguish closely-spaced nuclear counts leads to a significant underestimation of gamma activity in high radiation environments and is known as the "dead time effect".

3.2.4 *depth of investigation, n*—the radial distance from the measurement point to a point where the predominant measured response may be considered centered, which is not to be confused with borehole depth (for example, distance) measured from the surface.

3.2.5 *measurement resolution, n*—the minimum change in measured value that can be detected.

3.2.6 *repeatability, n*—the difference in magnitude of two measurements with the same equipment and in the same environment.



NOTE 1—From a study site showing how the gamma logs can be used to identify where beds intersect each of the individual boreholes, demonstrating lateral continuity of the subsurface geology.

FIG. 2 Example of Gamma Logs From Two Boreholes

3.2.7 *vertical resolution, n*—the minimum thickness that can be separated into distinct units.

3.2.8 *volume of investigation, n*—the volume that contributes 90 % of the measured response. It is determined by a combination of theoretical and empirical modeling. The volume of investigation is non-spherical and has gradational boundaries.

4. Summary of Guide

4.1 This guide applies to borehole gamma logging and is to be used in conjunction with Guide D 5753.

4.2 This guide briefly describes the significance and use, apparatus, calibration and standardization, procedures, and reports for conducting borehole gamma logging.

5. Significance and Use

5.1 An appropriately developed, documented, and executed guide is essential for the proper collection and application of gamma logs. This guide is to be used in conjunction with Guide D 5753.

5.2 The benefits of its use include improving selection of gamma logging methods and equipment, gamma log quality and reliability, and usefulness of the gamma log data for subsequent display and interpretation.

5.3 This guide applies to commonly used gamma logging methods for geotechnical applications.

5.4 It is essential that personnel (see the Personnel section of Guide D 5753) consult up-to-date textbooks and reports on the gamma technique, application, and interpretation methods.

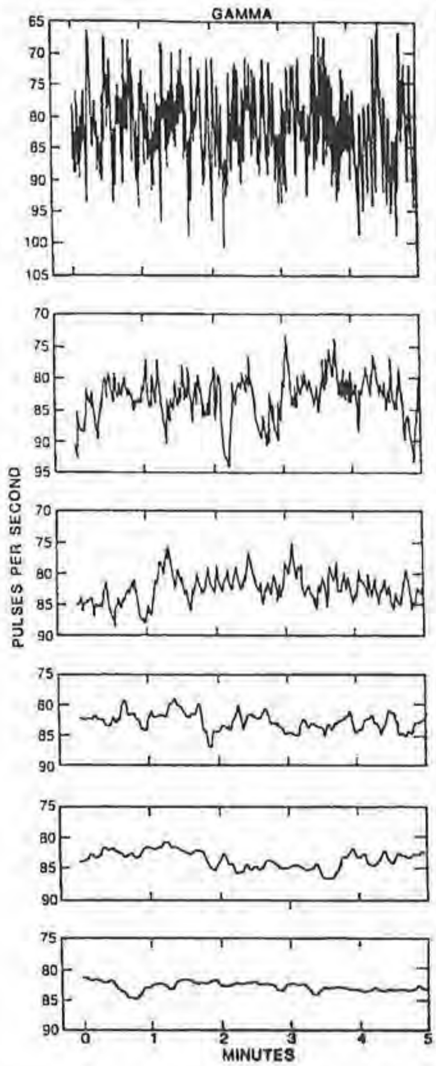
6. Interferences

6.1 Most extraneous effects on gamma logs are caused by logging too fast, instrument problems, borehole conditions, and geologic conditions.

6.2 Logging too fast can significantly degrade the quality of gamma logs. Gamma counts originating at a given depth need to be averaged over a time interval such that the natural statistical variation in the rate of gamma photon emission is negligible (see Fig. 3).

6.3 Instrument problems include electrical leakage of cable and grounding problems, degradation of detector efficiency attributed to loss of crystal transparency (fogging) or fractures or breaks in the crystal, and mechanical damage causing separation of crystal and photomultiplier tube.

6.4 Borehole conditions include changes in borehole diameter (especially in the fluid-filled portion); casing type and number; radioactive elements in drilling fluid in the borehole, or in cement or slurry behind casing; and steel casing or cement in the annulus around casing, and thickness of the annulus.



TIME CONSTANT	MEAN	STANDARD DEVIATION
1 second	Not calculated	
3 seconds	83.0	4.7
5 seconds	82.9	2.5
10 seconds	83.1	1.5
15 seconds	83.6	1.4
20 seconds	83.0	0.8

NOTE 1—The fluctuations in gamma activity in counts per second is shown to vary by progressively smaller amounts as the averaging period (time constant) is increased from 1 to 20 s.

FIG. 3 Example of Natural Statistical Fluctuation of Gamma Counts From a Test Source of Given Strength

6.5 Geologic conditions include high levels of radiation which can degrade the efficiency of gamma counting through the dead time effect, energy level of emitted gammas, formation density, and lithologic bed geometry.

7. Apparatus

7.1 A geophysical logging system has been described in the general guide (the Apparatus section of Guide D 5753).

7.2 Gamma logs are collected with probes using scintillation detectors.

7.2.1 The most common gamma detectors are sodium iodide (NaI).

7.2.2 Other gamma detectors include cesium iodide (CsI) and bismuth germanate (BGO).

7.3 Gamma probes generate nuclear counts as pulses of voltage that are amplified and clipped to a uniform amplitude.

7.3.1 Gamma probes used for geotechnical applications typically can be logged inside of a 2-in. (5-cm) diameter monitoring well.

7.4 The volume of investigation and depth of investigation are determined by the density of the material near the probe, which controls the average distance a gamma photon can travel before being absorbed.

7.4.1 The volume of investigation for gamma logs is generally considered spherical with a radius of 0.5 to 1.0 ft (15 to 30 cm) from the center of the detector in typical geological formations. The volume becomes elongated when detector length exceeds approximately 0.5 ft (15 cm).

7.4.2 The depth of investigation for gamma logs is generally considered to be 0.5 to 1.0 ft (15 to 30 cm).

7.5 Vertical resolution of gamma logs is determined by the size of the volume from which gammas can reach a nuclear detector suspended in the borehole. In typical geological formations surrounding a fluid-filled borehole, this is a roughly spherical volume about 1 to 2 ft (30 to 60 cm) in diameter. Excessive logging speed can decrease vertical resolution.

7.6 Measurement resolution of gamma probes is determined by the counting efficiency of the nuclear detector being used in the probe. Typical measurement resolution is 1 cps.

7.7 A variety of gamma logging equipment is available for geotechnical investigations. It is not practical to list all of the sources of potentially acceptable equipment.

8. Calibration and Standardization of Gamma Logs

8.1 *General*:

8.1.1 National Institute of Standards and Technology (NIST) calibration and standardization procedures do not exist for gamma logging.

8.1.2 Gamma logs can be used in a qualitative (for example, comparative) or quantitative (for example, estimating radioisotope concentration) manner depending upon the project objectives.

8.1.3 Gamma calibration and standardization methods and frequency shall be sufficient to meet project objectives.

8.1.3.1 Calibration and standardization should be performed each time a gamma probe is suspected to be damaged, modified, repaired, and at periodic intervals.

8.2 Calibration is the process of establishing values for gamma response associated with specific levels of radioisotope concentration in the sampled volume and is accomplished with a representative physical model. Calibration data values related to the physical properties (for example, radioisotope concentration) may be recorded in units (for example, cps), that can be converted to units of radioactive element concentration (for example, ppm Radium-226 or percent Uranium-238 equivalents).

8.2.1 Calibration is performed by recording gamma log response in cps in boreholes centered within volumes containing known homogenous concentrations of radioactivity elements.

8.2.2 Calibration volumes should be designed to contain material as close as possible to that in the environment where the logs are to be obtained to allow for effects such as gamma energy level, formation density, and activity of daughter isotopes on the calibration process.

8.3 Standardization is the process of checking logging response to show evidence of repeatability and consistency, and to ensure that logging probes with different detector efficiencies measure the same amount of gamma activity in the same formation. The response in cps of every gamma detector is different for the same radioactive environment.

8.3.1 Calibration ensures standardization.

8.3.2 The American Petroleum Institute maintains a borehole in Houston, Texas, where two formations have been fabricated to provide homogeneous levels of gamma activity so that probes can be standardized on the basis of the response in these boreholes. 1 API gamma unit is $1/200^{th}$ of the full scale response in the representative shale model in this borehole (see Guide D 5753).

8.3.3 For geotechnical applications, gamma logs should be presented in API units for standardization.

8.3.4 A representative borehole may be used to periodically check gamma probe response providing the borehole and surrounding environment does not change with time or their effects on gamma response can be documented.

8.3.5 A small radioactive source(s) (thorium-treated lantern mantles, small bottles of potassium chloride, laboratory radioactive test sources, or sleeves containing natural radioisotopes (phosphate sands, etc.)) placed over the gamma detector can be used to check calibration if the sources have been related to a calibration facility.

8.4 Gamma log output needs to be corrected for dead time when logging in formations with unusually large count rates, such as uranium-rich pegmatites or phosphatic sands, and areas contaminated with radioactive waste.

8.4.1 Dead time corrections are usually negligible under typical logging conditions when measured gamma counts are less than a few hundred counts per second.

8.4.2 Dead time corrections are estimated by comparing the gamma log response under the influence of two similar radioactive sources. The measured count rate would approximately double over that with one source when both sources are placed in the sample volume of the logging tool. The dead time causes the count rates to be slightly less than double. Dead time is given by the formula:

$$\text{Dead Time} = t_0 = 2(N_1 + N_2 - N_{12})/(N_{12}(N_1 + N_2)) \quad (1)$$

$$\text{Corrected count rate} = N^* = N/(1 - N\,t_0)$$

where:

N_1, N_2 = the count rates measured using each of the two similar sources,
N_{12} = the count rate obtained using both of the similar sources in counts per second,
t_0 = the dead time correction in seconds,
N = the measured count rate in a formation in counts per second, and
N^* = the count rate after correction for the dead time effect.

t_0 is usually found to be a few microseconds for most gamma logging equipment.

9. Procedure

9.1 See the Procedure section of Guide D 5753 for planning a logging program, data formats, personnel qualifications, field documentation, and header documentation.

9.1.1 Document gamma specific information (for example, crystal size, type, and location).

9.2 Identify gamma logging objectives. Select appropriate equipment to meet objectives.

9.3 Gamma logs are commonly run with other logging measurements in combination probes for correlation purposes. This is most often done by equipping other classes of logging probes (electric, indication, neutron porosity, etc.) with gamma detectors (see Fig. 4).

9.3.1 Detector location on the probe needs to be appropriate to meet the project objectives. Long combination probe strings with the gamma detector located at a significant distance from the bottom of the probe may be inappropriate. Gamma detection position on the logging probe is especially important in shallow boreholes where over drilling the borehole is not possible.

9.3.2 Gamma probes are usually run free-hanging where the probe lies against one side of the borehole that is, as a mandrel. However, gamma detectors are sometimes included with combination probes that are run centralized or decentralized in the borehole. Gamma response may be somewhat different depending upon the method used (for example, free-hanging or centralized) in a given geologic environment.

9.3.3 Gamma equipment decontamination is addressed according to project specifications (see Practice D 5088 for non-radioactive waste sites and Practice D 5608 for low level radioactive waste sites).

9.4 Select when the gamma probe is to be run in the logging sequence (see 8.2.2.1 of Guide D 5753).

9.4.1 Gamma probes are run after or in combination with any television camera and fluid property probes to insure that there is minimum disturbance to the borehole fluid that can degrade those logs.

9.4.2 Gamma probes are run before any probe utilizing nuclear sources and more expensive centralized probes to ensure borehole stability possible.

9.4.3 Whenever possible, gamma probes should be run open hole or through the least amount of completion material to minimize well construction effects and to provide a base line for comparing subsequent logs.

9.5 Gamma probe operation is typically checked before the start of each run to insure that equipment is operating and that nuclear counters are producing output.

9.5.1 Gamma operation may be checked by placing a small radioactive source over the gamma detector. Common materials, such as thorium-treated lantern mantles, small bottles of potassium chloride, laboratory radioactive test sources, or sleeves containing natural radioisotopes (phosphatic sands, etc.), are frequently used.

9.6 Select and document the depth reference point.

9.6.1 The selected depth reference needs to be stable and accessible (for example, top of borehole casing).

9.7 Determine and document probe zero reference point (for example, top of probe or cablehead) and depth offset to gamma measurement point.

9.7.1 The measurement point of the gamma logging probe is the distance along the probe corresponding with the center of the crystal within the logging tool; this position is not visible unless the position is marked on the outside of the tool or the operator has information specifying that position with respect to a prominent reference point on the probe housing.

9.7.2 Position the probe zero reference point to the depth reference point (ground level, top of casing, etc.) and initialize depth recording/display systems.

9.8 Select horizontal and vertical scales for log display to meet project objectives.

9.8.1 Preferred horizontal scale divisions are multiples of two or five inches, such that the log value is easily determined on the plot (for example, 0 to 100, 0 to 200, 50 to 150, etc.).

9.8.2 Preferred vertical scales are multiples of two or five, such that depth can be easily determined on a log plot (for example, 1/5, 1/10...1/100, etc.).

9.9 Select digitizing interval (or sample rate if applicable) to meet project objectives (see 8.3.1.2 of Guide D 5753).

9.9.1 Digitizing interval needs to be at least as small as the vertical resolution of the gamma probe, that is typically about 1 ft (30 cm).

9.9.2 Typically, this interval is no larger than 0.5 ft (15 cm) to ensure that the optimum vertical resolution is achieved.

9.9.3 Even though field plots may be generated with smoothing, the rawest (non-filtered) form of the data should be recorded.

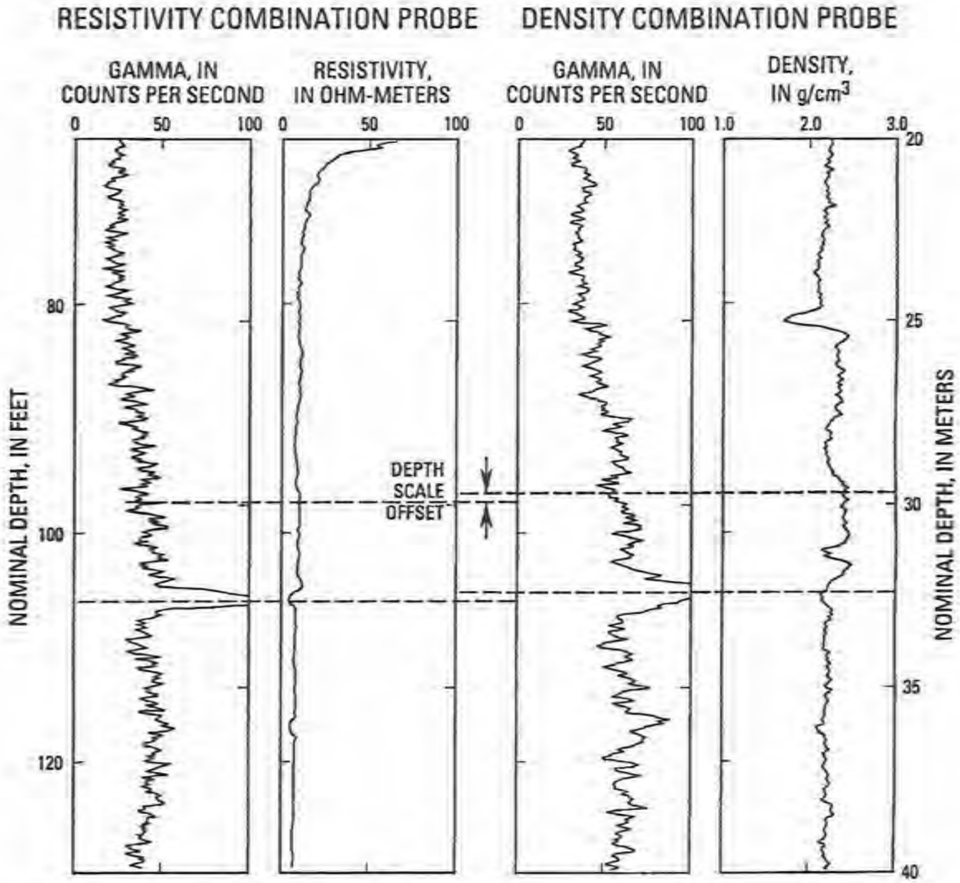
9.10 The gamma probe is lowered to the bottom of the borehole.

9.10.1 Gamma counts should be monitored as the probe is lowered because knowledge of the average count rates produced by the formation is important in determining proper logging speed. Gamma value range is also needed to determine proper horizontal scale and with some instrumentation, to determine sensitivity/gain settings.

9.10.2 Selection of probe speed while lowering is based on knowledge of borehole depth, stability, and other conditions; tension on the measuring wheel and smoothness of probe descent should be monitored to ensure that depth errors are not being introduced.

9.11 Select logging speed.

9.11.1 Logging speed should be determined by the application of the data acquired to meet project objectives.



NOTE 1—This figure shows a small depth offset that should be removed by adjusting the depth scale on one of the logs; note that the average count rates for the two different gamma detectors differ as a result of different detector efficiencies.

FIG. 4 Example of Gamma Logs From Gamma Detectors in Two Different Logging Tools (Electrical Resistivity on Density)

9.11.2 Typical gamma logging speed is approximately 20 ft/min (6 m/min), but slower speeds may be needed if formation gamma activity is low.

9.11.3 Proper logging speed is indicated by gamma logs that show distinct beds, which correlate with other information such as core descriptions or driller's logs, and where there is relatively little random fluctuation within beds (see Fig. 1).

9.11.4 If the operator is concerned about whether logging speed is affecting the quality of the gamma log, the operator should repeat a representative section of the log (representative of the geologic variation in the borehole) using the same speed; if the log reproduces interpreted bed boundaries that agree with other log and geologic data and the initial run, then the logging speed is adequate. If there are significant changes in the interpreted bed boundaries or if bed boundaries (lithologic contacts) are not indicated, the operator should try logging at a reduced speed.

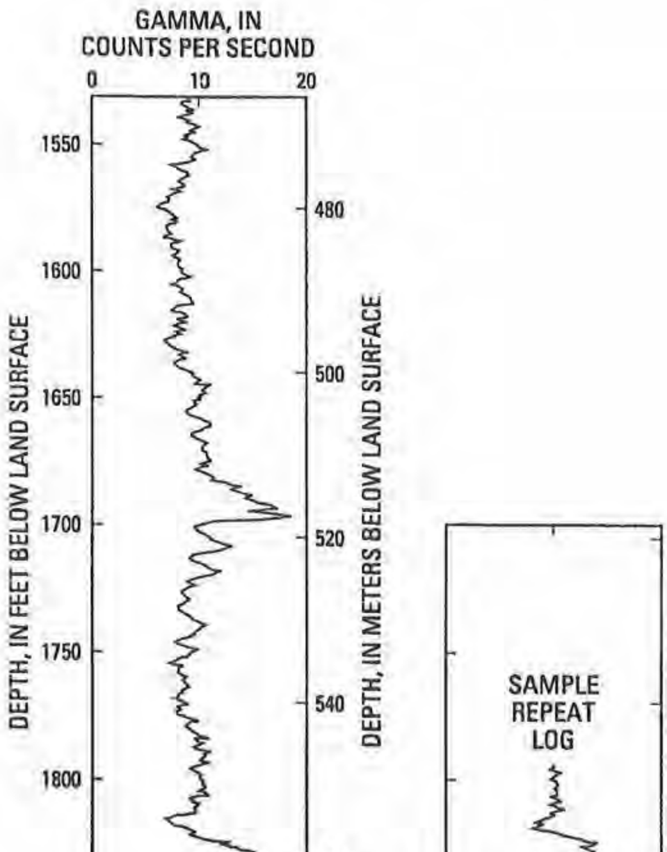
9.11.5 In situations where gamma activity is extremely low, such as in many basalts and some carbonate and quartzite formations, the operator can estimate the maximum logging speed from the formula:

$$S_f < 0.50G \quad \text{or} \quad S_m < 0.15G \qquad (2)$$

where:

S_f = the logging speed in feet per minute,
S_m = the logging speed in metres per minute, and
G = the average measured gamma activity of the interval or intervals of interest in counts per second.

This formula gives the logging speed required to ensure that the standard nuclear statistical error is less than about 5 %. In some situations, the available time and budget and the length of borehole to be logged may indicate that a trade-off be made between statistical errors and log resolution; an effective trade-off for a given situation can be made by experimenting



NOTE 1—In this figure, experimentation with logging speed demonstrates that a 10 ft (m) per minute logging speed generates useful and repeatable gamma logs with statistical errors somewhat greater than 5 %, but where beds can be effectively detected.

FIG. 5 Example of a Gamma Log From a Basalt Formation of Very Low Gamma Activity

with repeat logging runs over representative intervals containing bed contacts (see Fig. 5).

9.12 Collect gamma log data while the probe is moving up the borehole; data collection while logging upward ensures that the probe is retrieved smoothly and continuously.

9.12.1 In unstable boreholes, it is sometimes advantageous to collect data both while probe is being lowered and being pulled up the borehole.

9.13 When the probe reaches the top of the borehole:

9.13.1 Check depth reference and document after survey depth error (ASDE).

9.13.2 Determine if ASDE meets project objectives.

9.13.3 Typical tolerance for ASDE is ±0.4 per 100-ft interval logged (±0.4 m per 100-m).

9.13.4 Typical depth tolerance for repeat logs is within 0.4 %.

9.14 Selected borehole intervals should be repeated (that is, relogged) under similar logging parameters as the initial log. Repeat logs verify that the gamma electronics are functioning correctly, and that the logging speed (effect of nuclear statistical fluctuations) is adequate for project objectives. The interval repeated should have enough variability, if possible, to check repeatability and resolution; also note that nuclear statistical noise is most likely to affect intervals with relatively low gamma count rates.

9.14.1 Repeat logs should be compared with the original log to ensure correct operation of the probe prior to ending a logging event.

9.14.2 Repeat sections may not repeat exactly because of the statistical nature of nuclear activity that introduces some random fluctuation into the measured count rate. Individual log values should typically repeat within one standard deviation, and the character and shape of the logs should be similar. Note that the importance of high count rates to reduce the statistical variations between log runs.

9.14.3 Repeat sections may not repeat exactly due to a different orientation of the logging probe on the repeat run or changes in the borehole between logging runs (see Section 6, Interferences).

9.15 Evaluate the quality of field logs and compare logs with drilling and completion information.

9.16 Gamma logs are usually smoothed by filtering (in hardware or software) with an N-point averaging window (for example, running average, weighted average, etc.) to minimize the effects of statistical variation caused by radioactive decay. The window width:

$$(N-1)\Delta z \qquad (3)$$

where:

N = the number of points, and

Δz = the digitizing interval, which should correspond with the vertical resolution, which is typically about 1 ft (30 cm) in most geological formations.

9.16.1 Larger filters are frequently applied to gamma logs for presentation purposes (compression of the vertical scale); however, this filtering generally results in loss of some log information.

9.16.2 The rawest form of the gamma data and the filtered data should be saved.

9.17 Post-acquisitions calibration checks may be required to meet the objectives of the logging program to verify gamma log standardization and dead time correction.

10. Interpretation of Results

10.1 See the Log Interpretation section of Guide D 5753 for procedures on log interpretation.

10.2 A valid gamma log is important to establish the distribution of lithology and bedding within a borehole for correlation purposes, for different logs run in the same borehole (see Fig. 4), and for the extrapolation of results between boreholes (see Fig. 2).

10.2.1 Except at sites contaminated by radioactive waste, the measured gamma photons originate from the radioactive decay of naturally-occurring isotopes of Potassium-40 and daughter products of Uranium-238 and Thorium-232 (see Fig. 6).

10.2.2 Gamma logs can be analyzed individually (that is, borehole lithology).

10.2.3 Gamma logs can be analyzed as part of a suite to take advantage of the synergistic nature of log data.

10.3 The gamma log should be depth correlated with the other geophysical logs as the first step to interpretation. This is especially important for logs that use the gamma data for depth adjustment.

10.3.1 The gamma log data may be filtered, edited, combined, and merged with other log values.

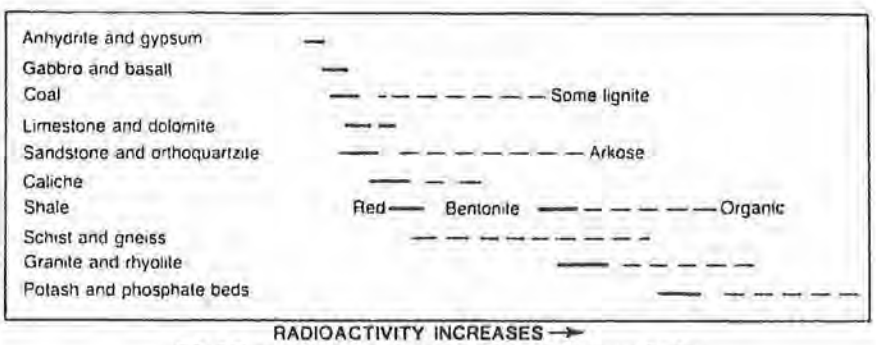


FIG. 6 Range of Relative Gamma Activity of Common Rocks

10.3.2 Final log headers are filled out and attached to the data.

10.3.3 The gamma log may be plotted at different scales for the purpose of interpreting, summarizing, and presenting the final data.

10.4 Other pertinent information, including borehole construction (casing size), drilling history (hole size, drill method, penetration rate, core loss, fluid loss, etc.), and geologic information should be integrated with the gamma log data.

10.4.1 Many of the borehole effects on the gamma log, such as correction for attenuation of steel casing and borehole fluid, can be normalized with empirical data to facilitate interpretation. This is especially important in comparing gamma logs from boreholes logged with different completion designs.

10.4.2 It is also possible to normalize the gamma log for well construction if it is possible to log a similar borehole prior to completion and again after a similar scheme.

10.5 Gamma logs commonly are the primary indicator of geologic structure and stratigraphy to be used as a guide in installing well screens, positioning cement plugs, bentonite seals or packers, etc.

10.5.1 When gamma logs are used as indicators of bed boundaries, the bed contact is usually identified as the point where the log measures half of the total change in amplitude across the bed contact (see Fig. 5).

10.6 Gamma logs obtained for depth correlation on logging runs using different probes may not produce the same count rates at each depth because of differences in detector efficiencies and probe designs.

10.7 Gamma logs may be applied to correlate lithology between boreholes based upon the characteristic gamma activity of specific beds or formations (See Fig. 6). Gamma logs can be used to determine the continuity of lithology, strike, and dip of beds between boreholes, and to infer the existence of faults and other discontinuities.

10.8 The primary application of gamma logs for geotechnical applications assumes a correlation between gamma activity and the proportion of fine-grained material in the formation. The gamma log may be used to calculate a clay volume or percentage. This assumption is frequently not valid (for example, phosphatic sands, arkosic sands, non-sedimentary environments, areas of natural radioactive mineralization, etc.) and should be tested in the project area. This testing may consist of cross plots, principal component analysis, and other multivariate statistical techniques. The application of gamma log analysis in the estimation of clay fraction may also be complicated by the presence of more than one clay type, each of which has a distinctly different level of gamma activity.

10.9 Gamma logs can be used to detect the presence of radioisotopes in borehole tracer studies, calibrated in units of radioisotope concentration to assess the degree of radioisotope contamination at radioactive waste sites, and used to locate source rocks in natural radium and radon hazard assessment studies.

11. Report

11.1 The Report section of Guide D 5753 should be consulted for requirements of the report.

11.2 Providers of gamma logs shall describe the components of the gamma logging system, the principles of the methods used, methods and results of calibration and standardization, performance verification (repeat sections, ASDE, correlation with other logs and key features such as bottom of steel casing, etc.), and uniqueness of interpretation.

11.3 Information on the software and algorithms used should be documented.

11.4 Any deviations from this guide should be documented.

11.5 Presentation of gamma logs should be designed to meet project objectives. At a minimum, depth (y-axis) and units of measurement (x-axis) scales should be clearly marked. There may be a difference between presentations of data collected in the field versus in the final report. Any scale "wraps" should be clearly marked (see Fig. 1).

11.5.1 Gamma logs are typically displayed with linear scales in counts per second or API units (see Fig. 1).

11.5.2 The digital data should be provided in ASCII format and include depth referenced gamma values and all pertinent header and calibration information; for example, Log ASCII Standard format (LAS).

11.5.3 Field plots typically are generated at the time of logging or immediately upon completion of data acquisition. These plots may be delivered in the field or may be discarded at some point later in the project. They are not typically included in the report.

11.5.4 Final log plots are typically generated post acquisition. They consist of the filtered and edited gamma data combined and merged with logical combinations of other log data. Final log plots are typically plotted in an industry standard format such as API format and may be included in the report.

11.5.5 Summary log plots may be generated (typically at reduced scales) to incorporate other logs, relevant data, and interpretations. These plots are generally included in the report.

12. Keywords

12.1 borehole geophysics; dead time correction; gamma log; natural gamma log; nuclear statistics; radioisotope; well construction; well logging

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