APPENDIX C
COLOG HYDROPHYSICAL AND GEOPHYSICAL LOGGING RESULTS REPORT

HydroPhysical™ and Geophysical Logging Results
Camp Stanley Storage Facility

Book 1 of 1:
Geophysical and HydroPhysical™Logging Results

Prepared for
Parsons
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List of Acronyms

gpm – gallons per minute
FEC – Fluid Electrical Conductivity
ft – feet
min. – minute
cm – centimeters
s – second
μS – micro Siemons
HpL™ - HydroPhysical™ Logging
FWS – Full Waveform Sonic
VDL – Variable Density Log (sonic data)
DI – De-ionized, e.g., DI water
ftbgs – feet below ground surface
GS – Ground Surface
BIPS - Borehole Image Processing System

HydroPhysical™ and Geophysical Logging Results
Camp Stanley Storage Facility

I. Executive Summary

The results of the HydroPhysical™ and geophysical logging performed in four wellbores at the Camp Stanley Storage Facility identified similar patterns of fracture orientation, fracture-specific permeability and FEC. Fracture orientations were identified to be on average less than 20 degrees, however, numerous features among the four wellbores logged had of dip angle greater than 45 degrees. Estimated fracture-specific transmissivities, in general, range from 0.048 to 40.0 feet^2/day. In general, however, the fracture-specific transmissivities are estimated to be below 10 feet^2/day. Fracture-specific FEC ranged from 436 to 829 μS/cm. In general, fracture-specific FEC averaged around 600 μS/cm.

Ambient testing identified downward vertical gradients in all wellbores with the exception of wellbore WB-01 that exhibited both ambient horizontal and downward vertical flow. A Specific discharge estimate was made from the observed velocity of horizontal flow in WB-01. This specific discharge, or Darcy velocity in the aquifer, estimate was 1.22 feet/day.

Please refer to Table SUMMARY:1 for a complete summary of the HydroPhysical™ logging results. All depths reported herein are referenced to ground surface.

II. Introduction

In accordance with COLOG's proposal dated April 2, 2003, COLOG has applied HydroPhysical™ (HpL™) and geophysical logging methods to characterize the formation waters of four wellbores at the Camp Stanley Storage Facility. The objectives of the investigation were to:

1) Evaluate temperature and fluid electrical conductivity under pre-testing conditions.
2) Identify fractures and features intersecting the borehole and evaluate their orientation.
3) Characterize and quantify flow in the borehole under both non-stressed (ambient) and stressed (pumping) conditions.
4) Evaluate the vertical distribution of flow and interval-specific permeability for all identified water-producing fractures or intervals.
5) Evaluate the lithology in which the borehole penetrates and assist in correlating lithology and possible flow zones.

The four wellbores geophysically and hydrophysically logged at the Camp Stanley Storage Facility are: WB-01, WB-02, WB-03 and WB-04. The geophysical and hydrophysical investigations were typically performed in 4.0" diameter cored boreholes to a depth of approximately 310 feet with the exception of WB-04 which was to a depth of approximately 510 feet. The geophysical and hydrophysical logging methods used to achieve the objectives were: optical televiewer, HydroPhysical™ logging and heat pulse flow meter. The four wellbores were tested under both non-stressed, or ambient, conditions and stressed, or pumping, conditions to fully evaluate the water-bearing horizons intersecting the wellbore.

COLOG's logging of the four subject wellbores was performed over the period of July 16th through July 24th, 2003.

TABLE SUMMARY:1. SUMMARY OF HYDROPHYSICAL LOGGING RESULTS; PARSONS; CAMP STANLEY STORAGE FACILITY

Well ID	Water Bearing Interval #	Interval of Flow (feet)	Interval Specific Flow Rate During Ambient Testing (gpm)	Interval Specific Flow Rate During Pumping (gpm)	Interval Specific Hydraulic Conductivity (ft/day)	Transmissivity (ft^2/day)
WB-01	1	169.2 - 169.5	0.000	0.008	0.761	0.228
	2	170.0 - 170.8	0.004	0.013	0.321	0.257
	3	209.4 - 211.9	0.003	0.005	0.028	0.057
	4	218.8 - 221.4	0.000	0.013	0.143	0.371
	5	233.8 - 235.9	-0.034	0.264	4.05	8.50
	6	239.0 - 242.5	0.000	0.309	2.52	8.81
	7	271.5 - 272.9	0.000	0.034	0.693	0.970
	8	295.6 - 296.4	0.000	0.013	0.464	0.371
	9	305.5 - 308.1	-0.017	0.053	0.768	2.00
WB-02	1	301.4 - 303.8	-0.501	0.909	15.8	37.8
WB-03	1	106.2 - 109.6	0.053	NA	NA	NA
	2	112.0 - 112.8	0.437	NA	NA	NA
	3	133.5 - 137.5	0.053	0.076	0.063	0.233
	4	145.9 - 146.5	0.000	0.079	1.33	0.799
	5	152.6 - 153.9	0.000	0.053	0.413	0.536
	6	157.4 - 191.6	0.000	0.264	0.078	2.67
	7	196.6 - 198.0	0.000	0.062	0.448	0.627
	8	204.4 - 207.0	0.000	0.033	0.128	0.334
	9	209.2 - 210.0	0.000	0.031	0.392	0.314
	10	212.7 - 214.7	0.000	0.044	0.223	0.445
	11	220.3 - 221.6	0.000	0.049	0.381	0.496
	12	230.9 - 231.4	0.000	0.022	0.445	0.223
	13	234.2 - 234.8	0.000	0.036	0.607	0.364
	14	239.0 - 239.7	0.000	0.047	0.679	0.476
	15	243.0 - 306.0	-0.560	0.335	0.144	9.06

Note: Negative flow is outflow from the borehole to the aquifer, positive flow is inflow to the borehole.

TABLE SUMMARY:1. SUMMARY OF HYDROPHYSICAL LOGGING RESULTS; PARSONS; CAMP STANLEY STORAGE FACILITY

Well ID	Water Bearing Interval #	Interval of Flow (feet)	Interval Specific Flow Rate During Ambient Testing (gpm)	Interval Specific Flow Rate During Pumping (gpm)	Interval Specific Hydraulic Conductivity (ft/day)	Transmissivity (ft^2/day)
WB-04	1	177.6 - 179.5	0.024	NA	NA	NA
	2	208.2 - 210.8	0.030	0.033	0.019	0.048
	3	218.3 - 219.6	0.000	0.068	0.842	1.09
	4	227.9 - 229.0	0.009	0.198	2.77	3.04
	5	253.6 - 254.3	0.039	0.175	3.82	2.67
	6	309.2 - 310.7	0.074	0.313	2.57	3.85
	7	332.2 - 335.3	0.238	2.73	12.9	40.0
	8	360.0 - 362.6	0.005	1.00	6.16	16.0
	9	370.5 - 371.8	0.018	0.721	8.71	11.3
	10	375.6 - 376.7	0.159	0.165	0.088	0.097
	11	464.2 - 466.9	-0.597	0.264	5.13	13.9
	12	475.0 - 476.8	0.000	0.168	1.50	2.70
	13	486.3 - 489.5	0.000	0.012	0.060	0.193

Note: Negative flow is outflow from the borehole to the aquifer, positive flow is inflow to the borehole.

III. Methodology

A. HydroPhysical™ Logging (HpL™)

The HydroPhysical™ logging technique involves pumping the wellbore and then pumping while injecting into the Wellbore with deionized water (DI). During this process, profiles of the changes in fluid electrical conductivity of the fluid column are recorded. These changes occur when electrically contrasting formation water is drawn back into the borehole by pumping or by native formation pressures (for ambient flow characterization). A downhole wireline HydroPhysical™ tool, which simultaneously measures fluid electrical conductivity (FEC) and temperature is employed to log the physical/chemical changes of the emplaced fluid.

The computer programs FLOWCALC and/or BORE/BOREII (Hale and Tsang, 1988 and (Daughtery and Tsang, 2000) can be utilized to evaluate the inflow quantities of the formation water for each specific inflow location. FLOWCALC is used to estimate the interval-specific flow rates for the production test results based on "hand-picked" values of FEC and depth. The values are determined from the "Pumping" and "Pumping During DI Injection logs". Numerical modeling of the reported data is performed using code BORE/BOREII. These methods accurately reflect the flow quantities for the identified water bearing intervals.

In addition to conducting HydroPhysical™ logging for identification of the hydraulically conductive intervals and quantification of the interval specific flow rates, additional logging runs are also typically performed. Prior to emplacement of DI, ambient fluid electrical conductivity and temperature (FEC/T) logs are acquired to assess the ambient fluid conditions within the borehole. During these runs, no pumping or DI emplacement is performed, and precautions are taken to preserve the existing ambient geohydrological and geochemical regime. These ambient water quality logs are performed to provide baseline values for the undisturbed borehole fluid conditions prior to testing.

For interval-specific permeability estimations, COLOG utilizes Hvorslev's 1951 porosity equation in conjunction with the HpL™ results. Several assumptions are made for estimating the permeability of secondary porosity. First, the type of production test COLOG performs in the field may significantly affect the accuracy of the transmissivity estimation. The permeability equation is relatively sensitive to overall observed drawdown. For a high yield wellbore, drawdown will usually stabilize and an accurate observed drawdown can be estimated. However, for a low yield wellbore, drawdown usually does not stabilize but instead, water level continues to drop until it reaches the pump inlet and the test is complete. In this case COLOG utilizes the maximum observed drawdown. The inaccuracy arises in the fact that overall observed drawdown does not stabilize and therefore is more an arbitrary value dependent on the placement of the pump downhole. Secondly, in an environment where flow originates from secondary porosity the length of the interval is derived from the either the thickness of the fracture down to 0.1 feet or the thickness of the fracture network producing water. This assumption of a fracture network producing water versus a porous media is not how the permeability equation was designed to be used. In lieu of a more appropriate equation unknown to COLOG at this time, COLOG utilizes Hvorslev's 1951 porosity equation based on its sensitivity to interval-specific flow which can be measured accurately, drawdown which can be measured accurately in the case of a high yield wellbore and its insensitivity to effective radius. The insensitivity to effective radius is critical when an observation well is not available to measure drawdown at a known distance from the subject wellbore.

Sensitivity of Transmissivity to Effective Radius

An estimation of transmissivity (T) has be made for all identified water-bearing intervals using an equation after Hvorslev (1951) assuming steady-state radial flow in an unconfined aquifer:

$$T = KL = \frac{q_i}{2\pi\Delta h_w}\ln\left(\frac{r_e}{r_w}\right)$$

where K is the hydraulic conductivity, q_i is the interval specific inflow rate calculated using HpL™ results (or "Delta Flow" from the table which equals "Interval-Specific Flow Rate During Pumping Conditions" minus "Ambient Flow Rate" if any), r_w is the borehole radius, r_e is the effective pumping radius, Δh_w is the observed maximum drawdown and L is the thickness of the zone through which flow occurs. For this example the data from a generic wellbore is used. The thickness, or length of the interval is calculated using a combination of both the HpL™ data and the optical televiewer data. L can usually be estimated with a high degree of confidence based on both of those data sets. Q_i, or Delta Flow, can also be estimated accurately using code BOREII (see appendix B) for the HpL™ data sets. Δh_w is estimated with a high degree of confidence using A downhole pressure transducer and a laptop to record water-level data every 10 seconds. Additionally, the borehole radius is confirmed quite readily from the caliper data. For this wellbore, r_w equals 0.20 feet, r_e has been assumed to be approximately 50 feet and the observed maximum drawdown was estimated at 47.29 feet. By applying L and q_i from the HpL™ results under the two pressure conditions, the interval specific transmissivity can be calculated for each identified water-producing interval.

Colog utilizes Hvorslevs' 1951 equation when an observation well a known distance away with measurable drawdown is not available. Essentially, Hvorslevs' 1951 equation is similar to the prevalent Theis equation minus the observation well drawdown information. In replace of the observation well drawdown data Hvorslevs' equation uses an assumed "effective radius" divided by the borehole radius. One benefit to using Hvorslevs' 1951 equation when observation well data is unavailable is the insensitivity of the equation to the assumed effective radius as this is the only "unknown" variable in the equation. All other variables are known or calculated with a high degree of confidence. Only the effective radius is unproven, or unsupported, but its value can be estimated with some degree of accuracy.

The following example will illustrate the insensitivity of Hvorslevs' 1951 equation to the assumed effective radius of an aquifer. The greatest magnitude of change in this example between r_e of 50 feet and r_e of 300 feet is 2.90 $feet^2$/day transmissivity.

Interval (feet)	Length of Interval (feet)	Q_i - Delta Flow (gpm)	Borehole Radius (feet)	Transmissivity Using r_e of 50 Feet	Transmissivity Using r_e of 100 Feet	Transmissivity Using r_e of 300 Feet
87.6 – 89.5	1.9	0.660	0.20	2.36 x E^{00}	2.66 x E^{00}	3.13 x E^{00}
94.3 – 94.5	0.2	0.213	0.20	7.62 x E^{-01}	8.58 x E^{-01}	1.01 x E^{00}
97.9 – 99.3	1.4	0.246	0.20	8.80 x E^{-01}	9.91 x E^{-01}	1.17 x E^{00}
111.4 – 111.5	0.1	0.282	0.20	1.01 x E^{00}	1.14 x E^{00}	1.34 x E^{00}
116.8 – 119.2	2.4	0.205	0.20	7.34 x E^{-01}	8.26 x E^{-01}	9.72 x E^{-01}

B. **Optical Televiewer (BIPS)**

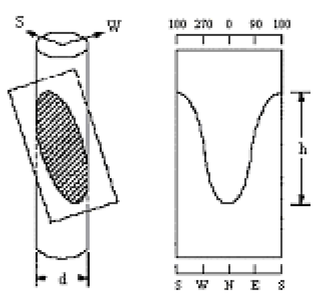
The optical televiewer, or the Borehole Image Processing System (BIPS), provides the highest resolution available for fracture and feature analysis in boreholes. This technology is based on direct optical observation of the borehole wall face. Precise measurements of dip angle and direction of bedding and joint planes, along with other geological analyses, are possible in both air and clear fluid filled boreholes.

Theory of Operation

A small light ring illuminates the borehole wall allowing a camera to directly image the borehole wall face. A conical mirror housed in a clear cylindrical window focuses a 360° optical "slice" of the borehole wall into the camera's lens. As the optical televiewer tool is lowered down the hole, the raw analog video signal from this camera is transmitted uphole via coaxial wireline to the optical televiewer surface instrumentation.

The analog signal is digitized in real time by capturing 360 pixels around a 0.5 mm ring from the conical image. The rings are stacked and unwrapped to a 2-D image of the borehole wall. A digital fluxgate magnetometer is used to determine the orientation of the digital image. A secondary mechanical compass is imaged along with the analog signal to insure proper orientation of the digital image.

The optical televiewer (BIPS) image is an oriented, 2-D picture of the borehole wall unwrapped from south to south (Figure 1). Planar features that intersect the borehole appear to be sinusoids on the unwrapped image. To calculate the dip angle of a fracture or bedding feature the amplitude of the sinusoid (h) and the borehole diameter (d) are required. The angle of dip is equal to the arc tangent of h/d, and the dip direction is picked at the trough of the sinusoid (Figure 1).



Dip Direction = Orientation of Sinusoid Minimum
Dip Angle = ArcTan h/d
where: h = height of sinusoid
d = borehole diameter

Figure 1: Geometric representation of a north dipping fracture plane and corresponding optical televiewer log.

Sinusoidal features were picked throughout wells by visual inspection of the digital optical televiewer images using interactive software. The software performed the orientation calculations and assigned depths to the fractures or bedding features at the inflection points (middles) of the sinusoids. Tadpoles represent individual features, where the tail points in the direction of dip (clockwise from the top, 0-359). The head is positioned vertically according to the median depth of the feature and positioned horizontally according to the feature dip angle (0-90 from horizontal). Features were subjectively ranked for flow potential using COLOG's Ranking System for Optical Televiewer Features included in this report on the following page. The features picked along with their assigned ranks, orientations and depths are presented in tables for each well. The qualitative ranks assigned to features are based solely on optical data and are not cross referenced with HydroPhysical™ or any other geophysical data. Orientations are based on magnetic north and are corrected for declination.

Rose Diagrams

A rose diagram is a polar diagram in which radial length of the petals indicates the relative frequency (percentage) of occurrence of a particular angle or fracture dip direction or range of angles or dip directions. Rose diagrams are used to identify patterns (if any) in the frequency of dip angles or directions for a particular data set. Figures 1 and 2 are example rose diagrams from an optical televiewer data set of fractures and features.

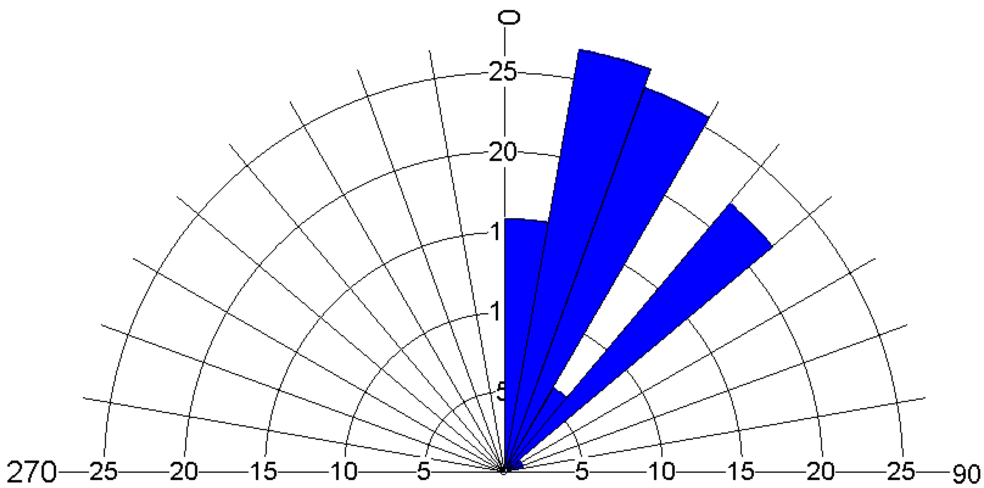


Figure 1: Example rose diagram from an optical televiewer data set illustrating the frequency (%) of dip angles.

Figure 1 above indicates, from the data set, that approximately 16 percent of the fractures/features have a dip angle between 0 and 10 degrees, approximately 27 percent of the fractures/features have a dip angle between 11 and 20 degrees, approximately 25.5 percent between 21 and 30 degrees, approximately 6 percent between 31 and 40 degrees and 22 percent between 41 and 50 degrees. A quick glance at Figure 1 identifies a pattern of dip angle where greater than 50 percent of the fracture/features identified have a dip angle between 11 and 30 degrees. Additionally, no high-angle (greater than 50 degrees) fractures/features were identified from this data set.

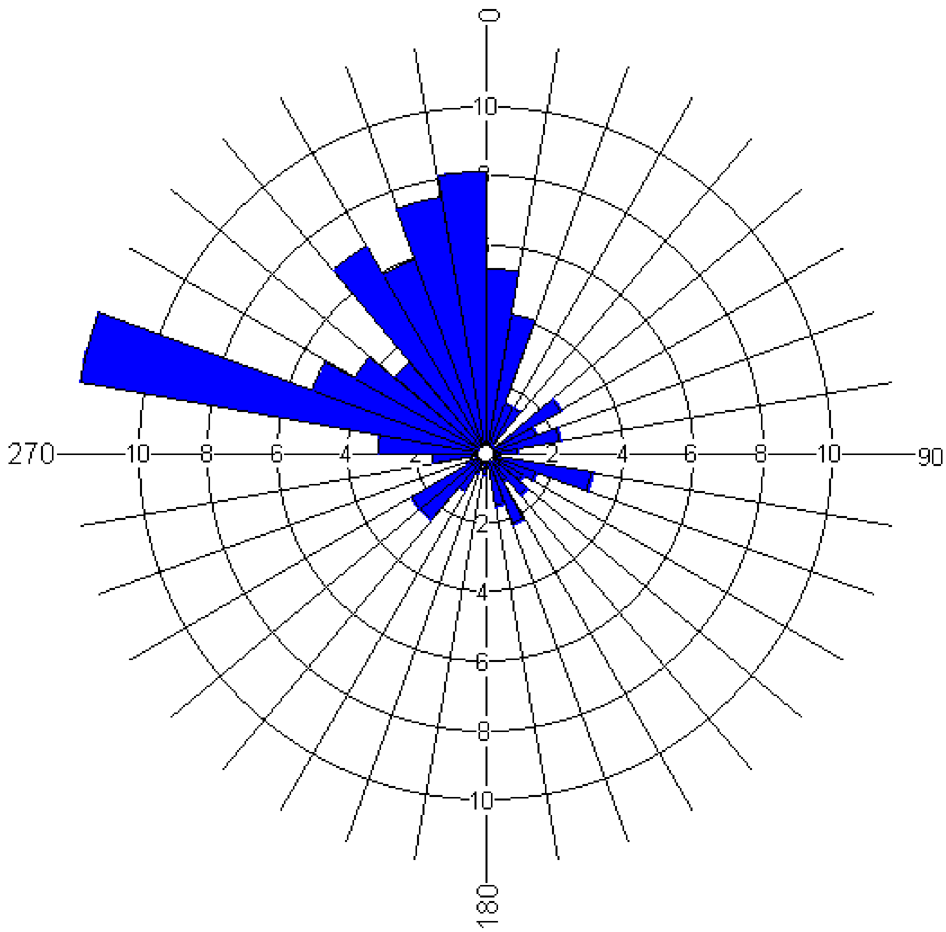


Figure 2: Example rose diagram from an optical televiewer data set illustrating the frequency (%) of dip direction.

Figure 2 above indicates, with a quick glance, that the majority of the fractures/features dip in the direction of northwest. Specifically, approximately 62 percent of the identified fractures/features have a dip direction of 280 degrees (west) to 20 degrees (north).

Stereonets

For stereonets, COLOG utilizes a Schmidt net, an equal-area plot of longitude and latitude used in plotting geologic data such as the direction of structural features. Here, the angle indicates dip direction and the distance from the center indicates the dip magnitude. The further from the center the shallower the dip angle. Figure 3 below is an example stereonet diagram from an optical televiewer data set of fractures and features.

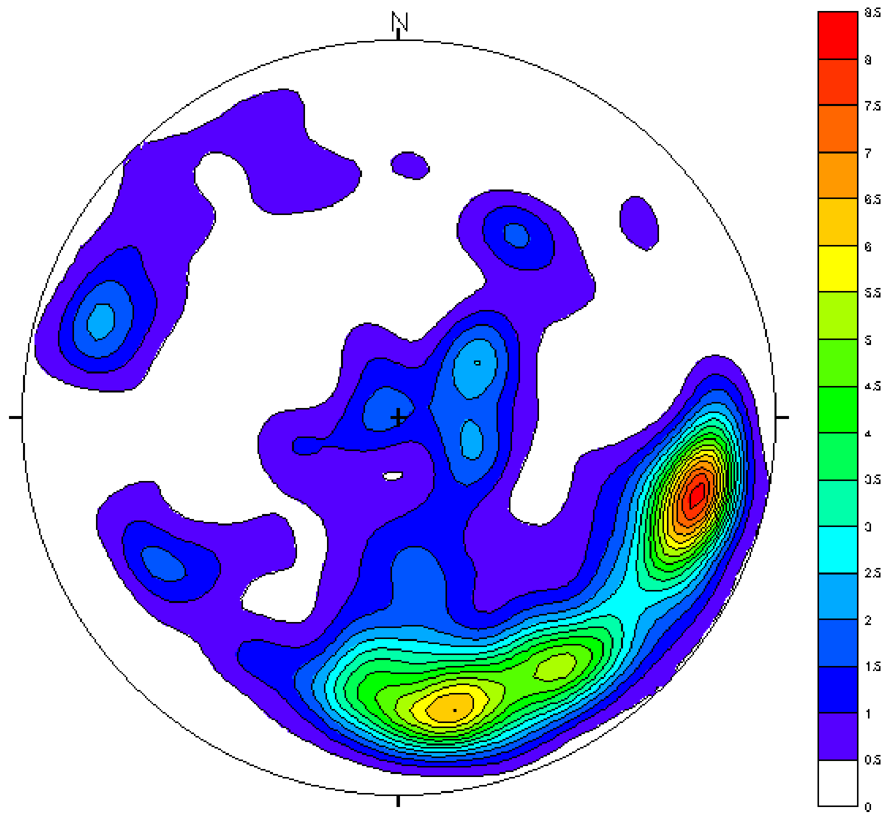


Figure 3: Example stereonet from an optical televiewer data set illustrating the frequency (%) of dip direction and dip angle in 2-D space.

Figure 3 above indicates, with a quick glance, that two distinct patterns exist in the subject data set. A cluster of fractures/features with similar dip direction of approximately 110 degrees and similar shallow dip angles is apparent. A second cluster, slightly less dense, is apparent with similar dip directions of approximately 170 degrees (almost due south) and similarly shallow dip angles.

C. Heat-Pulse Flow Meter

MSI's Heat Pulse Flowmeter (HFP-4293) is a high-resolution device for measuring vertical fluid movement within the borehole. This flowmeter is based upon the proven USGS design and works on the thermal fluid tracer concept. Borehole fluid is heated or thermally tagged by as much as 1° F with an electrical heater grid. The flow rate is determined by measuring the time between the grid discharge and the peak of the thermal pulse of water reaching an upper or lower thermistor sensor. MSI utilizes flow-concentrating diverters to direct fluid flowing in the borehole through the probe flow tube (Figure H-1).

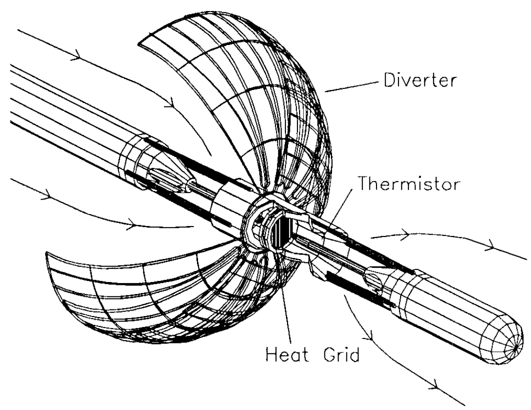


Figure H-1: Heat pulse flowmeter diverter diagram showing fluid flow

The HFP-4293 is calibrated in a flow chamber where flow rate can be controlled and measured. Values for response time are taken for a wide range of flow rates and applied in an empirical curve-fit solution (Figure H-2). The calibration coefficients are entered into the processing software to determine vertical flow rates in gallons/minute. Thermal buoyancy of the heat pulse imposes a small asymmetry on the flow calibration so that the device is slightly less sensitive to upflow than to downflow.

Presently the HFP measures flow from 0.01 to 1.5 gallons/minute (0.038 to 5.69 liters/min) with 0.005 gpm resolution using a 1.125 inch diameter flow tube and standard multi-layered flow diverter. The low end flow limit of 0.01 gpm is a function of the current calibration facility in which convective eddy currents as great as 0.01 gpm are generated by differences between water temperature in the calibration device and surrounding air. A more thermally insulated calibration chamber or smaller diameter probe flow tube could allow for significantly lower flow limit with this tool. Higher flow rates can be achieved by increasing thermistor spacing or flow tube and heating grid diameter.

In practice the HFP is run at discrete intervals within a borehole. Intervals are selected based upon review of fluid column logs (temperature, fluid resistivity, etc.), a caliper log and optimally a borehole imaging log (video or acoustic televiewer). Flow is measured at each interval and each test repeated until at least two measurements are recorded within given tolerances. Time to collect flow data is subject to the flow rate and number of intervals tested. While the actual time to record a flow rate of 0.01 gpm is less than 30 seconds, it may take up to 15 minutes per station for the borehole to stabilize and to obtain repeatable data. At higher flow rates, the borehole stabilizes more quickly and obtaining good data may take only a few minutes per station.

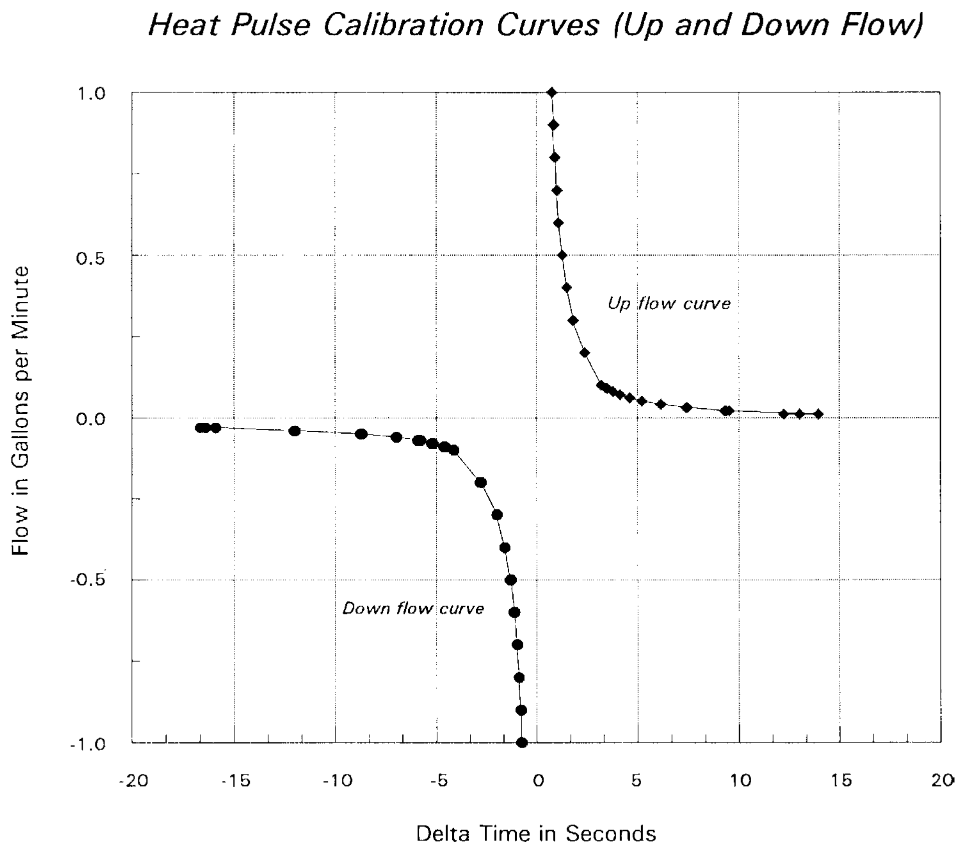


Figure H-2: Heat pulse flowmeter calibration curves used to translate response time to gpm.

A number of factors must be considered when interpreting high-resolution flow data including: 1) the effect of the open borehole on the flow regime in the vicinity of the well bore; 2) the effects of turbulent thermal convection and other secondary flow circulation's; 3) real flow regimes are often changing with time as measurements are being made; and, 4) not all permeable intervals may be producing vertical flow under ambient conditions. (Paillet et al, 1994)[1] describes these factors in detail which should be reviewed for a more through discussion.

Some of these factors can be minimized by using a flow concentrating diverter and by locating the diverter in a portion of the borehole that is not fractured or rugose (by analyzing the caliper and a borehole imaging log). More importantly, flow measurements should be collected in the same intervals under different head conditions. In areas where the flow regime is changing with time, a number of flow measurements should be measured at the same intervals over time and the resulting flow transients interpreted. Other variations include cross-borehole experiments where one borehole is pumped and the changes in flow are detected in the surrounding boreholes. This can provide a quick assessment of the hydraulic connections between boreholes.

IV. How to Interpret the Logs

[1] Pallet, Crowder and Hess, 1994, High-Resolution Flowmeter Logging - A Unique Combination of Borehole Geophysics and Hydraulics: Part II - Borehole Applications With the Heat-Pulse Flowmeter, Proceedings of the Symposium on the Application of Geophysics to Engineering and Environmental Problems, Boston, Massachusetts, pages 381-404.

How to Interpret HydroPhysical™ Logs

Figure HpL:1 below is a generic example HpL™ data set for ambient flow evaluation. The data represents HpL™ logs acquired immediately after deionized (DI) water emplacement for ambient flow evaluation. For ambient flow evaluation the wellbore fluids are first replaced with DI water (termed "emplacement"), then a series of fluid electrical conductivity (FEC) logs are acquired over a period of a time to monitor ground water entering the wellbore under natural pressures and migrating either vertically or horizontally through the wellbore. The wellbore fluids are replaced with DI water without disturbing the ambient free-water level by injecting DI water at the bottom of the wellbore and extracting wellbore water at exactly the same rate at the free-water surface. However, at the beginning of the DI water emplacement, a slightly depressed free-water level (approximately one tenth of a foot below ambient free water-level) is achieved and maintained throughout the test. This procedure is implemented to ensure that little to no DI water is able to enter the surrounding formation during DI water emplacement. By acquiring FEC logs during the emplacement of DI water and by continuously measuring water level with a downhole pressure transducer the emplacement can be properly monitored and controlled to minimize the disturbance of the recorded ambient water. After the wellbore fluids are replaced with DI water, the injection and extraction pumps are turned off and in most cases the downhole plumbing is removed from the wellbore. A check valve is installed in the pump standpipe to ensure water in the standpipe does not drain back into the wellbore. While the plumbing is removed from the wellbore DI water is injected from the top of the wellbore to maintain ambient water level. Often a baseline FEC log is acquired during the final stages of the emplacement of DI water to provide baseline conditions just before the ceasing of pumping. Figure HpL:1 illustrates ambient flow entering the wellbore at depths of 150.0 to 152.7, 138.8 to 139.0, 132.7 to 133.4, 122.3 to 123.1 and 118.0 to 118.1 feet. The location of these intervals is illustrated by the sharp increases or "spikes" in FEC. The increase in FEC over time at these four intervals is characteristic of ambient inflow. The upward vertical trend in this inflow is also apparent from the FEC logs. For example, the dominant inflowing zone at 138.8 to 139.0 feet illustrates a major growth in FEC above the inflow "spike", and little growth below the "spike." The zone at 118.0 to 118.1 feet is the termination of all inflow into the well. The sum of the four inflow zones make up the outflow of this zone, and this value, along with the value of the four inflow zones is computed using code BOREII.

COLOG uses three types of tests to identify the water-bearing intervals in a wellbore under stressed conditions. In the lowest yield environment (less than ~0.7 gpm) a slug test approach is utilized. In a relatively low-yield wellbore environment a pump after emplacement (PAE) test is conducted, and in a relatively medium to high-yield wellbore environment a pump and inject (PNI) test is conducted. The decision on the type of test to perform on a specific wellbore is made in the field based on the ability of the wellbore to recover to ambient free-water level when a disturbance in water level is introduced into the well, i.e. inserting tools and/or pluming into the well.

In a low-yield wellbore environment a slug or PAE test is utilized to identify the water-bearing intervals under stressed conditions. These tests are similar in protocol and involve first a replacement of wellbore fluids with DI water in a manner identical to that of the emplacement during an ambient flow evaluation. Often a baseline FEC log is acquired during the final stages of the emplacement of DI water to provide baseline conditions just before the ceasing of injection pumping. Following the cessation of injection pumping, the extraction pump is used to either pull an instantaneous slug (slug test) or is used to pump at a relatively steady low rate of flow in the wellbore (approximately 1-2 gpm). During this time numerous FEC logs are acquired over time. The location of water-bearing intervals is apparent by the sharp increases or “spikes” in FEC over time. The rate at which these intervals inflow is calculated using BOREII and is based on the rate of increase of mass (area under the curve using the FEC log as the curve). Flow direction is easily determined by tracking the center of mass of the area under the curve. In most cases, if pumping is being conducted flow is traveling up the wellbore towards the pump which is situated inside casing.

Figure HpL:2 is a generic example data set for a pump and inject test (PNI). The set of FEC logs on the right of this figure (FEC1303, FEC1310, FEC1320, and FEC1329) illustrate the condition of the wellbore during development pumping. In the case of this example, the wellbore was stressed at a rate of approximately 10 gpm until a relatively steady-state condition was achieved in the wellbore. A steady-state condition is apparent when the FEC logs begin to repeat as they do in figure HPL:2. Repeatable FEC logs indicate that the hydrochemistry of the water inflowing to the wellbore is not changing over time (steady-state) and that the flow rates of all inflow zones is also not changing over time. Additionally, the drawdown is monitored continuously to observe a “slowing down” in the rate of increase of drawdown. When drawdown (water level) is stable, the inflow rates of the various inflow zones are assumed to be steady. By contrast, if DI water injection is begun in the early stages of pumping when drawdown is still increasing, i.e. water level is dropping rapidly, the inflow rates of the various inflow zones would increase with time as less wellbore storage is used to maintain a particular pumping rate. The remaining FEC logs (FEC1435, FEC1450, FEC1503, and FEC1516) illustrate the conditions in the wellbore during pumping and injection procedures. Fluid was extracted from the wellbore at a rate of approximately twelve gpm while DI water was simultaneously injected at the bottom of the wellbore at a rate of approximately two gpm, until a relatively steady-state condition existed in the well. Water-bearing intervals in the wellbore are identified by changes or “steps” in FEC throughout the FEC logs. The flow rate of these intervals is computed using BOREII and/or Flowcalc software. Every location that the FEC increases in these logs is a zone of inflow. Similarly, where the logs decrease in FEC indicates a zone of inflow with water lower in FEC than the water in the wellbore. A zone exhibiting a decrease in FEC on the injection logs should also decrease at the same depth on the development (pre-DI water injection) logs. Please see Appendix B for a detailed discussion of code BOREII used to numerically model the reported field FEC logs.

WB-01 Logging Results

1.0 HydroPhysical™ Logging

1.1 Ambient Fluid Electrical Conductivity and Temperature Log: WB-01

At 0922 hours on July 16, 2003, after a calibration check of the fluid electrical conductivity (FEC) and temperature logging tool, the fluid column was logged for FEC and temperature profiles with COLOG's 1.5-inch diameter HpL™ tool. These logs were performed prior to the installation of any pumping equipment. Please refer to Figure WB-01:1. The ambient FEC/temperature profiles indicate slight changes throughout the length of the borehole. At a depth of approximately 209 feet an inflection is observed in the ambient FEC profile. This inflection corresponds well with a water-bearing interval identified during ambient testing at this depth. The ambient temperature log recorded an increase in temperature in the upper portion of the log. This increase is most likely due to groundwater entering the wellbore from above ambient water level. The remainder of the temperature log indicates a gradual increase in temperature with depth. In vertically flowing conditions, where water enters the borehole, termed inflow, a change in either FEC and/or temperature is typically seen.

1.2 Ambient Flow Characterization: WB-01

On July 16, 2003, an ambient flow characterization was conducted in boring WB-01. For ambient flow assessment, the fluid column in the borehole was replaced with de-ionized water (DI) and the boring left in an undisturbed state to allow any natural flow to occur. The pump was removed from the boring to insure that water in the pump standpipe would not drain back into the boring. Prior to this period and throughout all HpL™ testing, water levels and flow rates were monitored and recorded digitally every ten seconds. Ambient flow evaluation is reported for the period after the water surface returned to near pre-DI water emplacement levels. A series of FEC and temperature logs were then conducted over the duration of testing to identify changes in the fluid column associated with ambient flow. Ambient flow characterization is conducted to evaluate the presence of both vertical and horizontal flow.

On July 16, 2003, at 1129 hours (t=0 minutes, elapsed time of test), dilution of the fluid column was complete. Minimal to no DI water was lost to the formation due to the slightly depressed head maintained during DI water emplacement procedures. During the 20.2 hours following the emplacement of DI water, multiple logs were conducted. Of these logs, nine are presented in Figure WB-01:2, with the first log (FEC1121) occurring during emplacement. The designation of each logging with the FEC tool is indicated in the figure legend by the time of logging (e.g., FEC1121 versus a subsequent logging at FEC1241), thus the progressing of curves to the right in this figure represents changes in FEC over the total logging period. The last four digits of each log ID corresponds to the time at which that particular log was started. Only logs acquired during logging in the downward direction are presented as the design of the FEC/temperature probe allows for the most accurate data to be collected in the downward direction. The logs acquired in the upward logging direction are not representative of downhole conditions and are therefore omitted. These logs illustrate changes in FEC at several intervals throughout the length of the borehole. These changes in the FEC profiles with respect to time are associated with ambient vertical and horizontal flow occurring within these intervals.

Formation water migration caused by downward vertical and horizontal flow within the fluid column is indicated by the increase in FEC over time in Figure WB-01:2. The uppermost interval(s) of inflow is located above ambient water level (139.15 ftbgs). Once the inflowing groundwater enters the fluid column in the wellbore, it is possible to track its movement. Numeric modeling of the reported field data for this interval suggests downflow is occurring at a rate of 0.034 gpm. This vertical downflow combines with inflow at 170.0 to 170.8 and 209.4 to 211.9 feet, and the combined flow migrates down the borehole. Numeric modeling of the reported field data for these intervals suggest inflow is occurring at rates of 0.004 and 0.003 gpm, respectively. The aggregate ambient downflow continues to migrate down the borehole at a rate of 0.041 gpm. At a depth of 233.8 to 235.9 feet groundwater is observed to both enter and exit the wellbore. Numeric modeling of the reported field data for this interval suggests flow is entering the wellbore at a rate of 0.011 gpm and exiting the wellbore at a rate of 0.034 gpm. All flow rates are based on the rate of increase of mass at their respective intervals. Correcting for convergence of flow at the wellbore and factoring the length of the interval, the flow rate of the groundwater entering the wellbore at 233.8 to 235.9 feet equates to a Darcy velocity, or specific discharge of groundwater in the aquifer of 1.22 ft/day. All inflow that does not exit the wellbore at 233.8 to 235.9 feet migrates down the wellbore at a rate of 0.017 gpm and exits at 305.5 to 308.1 feet. Please refer to Table WB-01:1 and SUMMARY:1 for a complete summary of the HydroPhysical™ logging results. Please refer to Appendix B for a discussion of the methodology and code used to calculate these values. The ambient depth to water at the time of testing was 139.15 ftbgs.

1.3 Flow Characterization During 0.7 GPM Production Test: WB-01

Low-rate pumping of wellbore fluids after DI water emplacement was conducted at one pumping rate to establish the inflow locations and evaluate the interval-specific inflow rates. Low-rate pumping at a given rate after DI water emplacement is conducted when the subject wellbore cannot sustain more than approximately 2-3 gpm yield. For DI water emplacement, DI water is injected at the bottom of the wellbore while simultaneous extraction pumping is conducted near water surface at the same rate. Water levels and flow rates are monitored and recorded digitally continuously to ensure minimal to no DI water is lost to the formation. This is achieved by maintaining water level at or below the recorded ambient level. After DI water emplacement is complete low-rate pumping is conducted to stress the aquifer(s) and draw groundwater into the wellbore where it is contrasted by the DI water in the wellbore. Continuous FEC profiling over time yields the depth and rate of influx of groundwater during pumping. These procedures were conducted at a time-averaged pumping rate of 0.73 gpm.

On July 17, 2003 at 1255 hours (t = 0 minutes elapsed time of testing), pumping was initiated at approximately 0.7 gpm. Prior to initiating pumping, the ambient depth to water was recorded at 139.94 ftbgs. Time dependent depth to water, totals and flow rate information were recorded and are presented in Figure WB-01:3. Low-rate pumping was maintained at a time-averaged rate of 0.73 gpm until 1606 hours (t = 191 minutes, elapsed time of testing). During this period drawdown was observed to steadily decrease until water level relatively stabilized at approximately 6.14 feet below ambient water level. At the conclusion of the test the extraction rate was increased approximately 5 gpm to additionally stress the aquifer and therefore better identify water-bearing intervals. During the period of testing, multiple loggings were conducted. Of these logs nine FEC traces are presented in Figure WB-01:4 with the first log, FEC1250 occurring during DI water emplacement procedures to serve as a baseline of downhole conditions. These logs clearly illustrate specific intervals of dramatic increase in FEC with respect to time. The depth at which the peak value for a given interval occurs is indicative of a water-bearing interval. The data presented in Figure WB-01:4 suggest the presence of nine hydraulically conductive intervals, with the dominant water-bearing interval at 239.0 to 242.5 feet. Numerical modeling of the reported field data was performed using code BORE and/or BOREII (Hale and Tsang, 1988, Tsang et.al. 1990, Daughtery and Tsang, 2000). This modeling was performed to estimate the rate of inflow and FEC for each identified hydraulically conductive interval during the pumping. The results of the modeling and analysis are presented in Table WB-01:1. In summary, the interval of 239.0 to 242.5 feet dominated inflow producing 0.309 gpm, or 42 percent of the total inflow during production testing. Please refer to Table WB-01:1 for a listing of the depths of water-bearing zones and their interval-specific inflow rate during testing. The water bearing interval(s) that inflow above ambient water level was assumed to contribute the same amount of flow (0.034 gpm) during the development of the well as they did during ambient testing.

1.4 Estimation of Interval Specific Transmissivity: WB-01

An estimation of transmissivity (T) can be made using an equation after Hvorslev (1951) assuming steady-state radial flow in an unconfined aquifer:

$$T = KL = \frac{q_i}{2\pi\Delta h_w} \ln\left(\frac{r_e}{r_w}\right)$$

where K is the hydraulic conductivity, q_i is the interval specific inflow rate calculated by HpL™ results, r_w is the borehole radius (0.17 ft), r_e is the effective pumping radius , Δh_w is the observed maximum drawdown (6.14 feet) and L is the thickness of the zone through which flow occurs. For our calculations, COLOG used r_e of 50 feet (assumed). By applying L and q_i from the HpL™ results under the two pressure conditions, the interval specific hydraulic conductivity can be calculated for each identified water producing interval. These calculations were made at each identified interval and are presented in Table WB-01:1. In summary, the interval at 233.8 to 235.9 feet registered the highest transmissivity at 3.59 feet^2/day.

2.0 Geophysical Logging

On July 16 and 17, 2003, downhole geophysical investigations were performed in boring WB-01. The geophysical logs performed were: optical televiewer (BIPS) and heat pulse flowmeter. The data for these logs is presented in the WB-01 Geophysical Summary Plot. A contractor other than COLOG conducted additional geophysical logging in wellbore WB-01. This data is presented in the WB-01 Geophysical Summary Plot.

3.0 Data Summary

Processing and interpretation of the geophysical and HydroPhysical™ logs for WB-01 suggest the presence of nine producing intervals for this borehole. Numerical modeling of the reported HydroPhysical™ field data was performed using computer programs FLOWCALC and/or BOREII. These analyses were performed to estimate the rate of inflow for each identified hydraulically conductive borehole interval during DI injection procedures. The results of these analyses are presented in Table WB-01:1. These identified producing intervals correlate well with water-bearing zones identified during ambient testing. In summary, the interval 239.0 to 242.5

feet dominated inflow during the production test, producing 0.309 gpm, or 42 percent of the total flow during the production test.

During ambient testing, boring WB-01 exhibited both vertical and horizontal flow. Five water-bearing zones were identified under ambient conditions. The uppermost interval was above ambient water level, therefore, its exact location is unknown. A downward vertical pressure gradient was observed in the wellbore under ambient conditions. One interval of horizontal flow at a rate of 0.011 gpm was identified at 233.8 to 235.9 feet. Correcting for convergence of flow at the wellbore and factoring the length of the interval, this flow rate equates to a Darcy velocity, or specific discharge of groundwater in the aquifer of 1.22 ft/day.

Additionally, the wellbore was logged under ambient conditions with the heat pulse flowmeter on July 17, 2003. The data acquired by the heat pulse flowmeter suggests the presence of a downward vertical gradient present in the wellbore at the time of testing. Ambient flow is observed to enter the wellbore above 225 feet at approximately 0.05 gpm and migrate downward. At 260 feet ambient downflow of 0.02 gpm was observed, suggesting 0.03 gpm was thieved, or exited, the borehole between 225 and 260 feet. At 290 and 300 feet ambient downflow of 0.02 gpm was observed.

The optical televiewer identified features at depths correlating well with the HpL™ data. The features observed by the optical televiewer at water-bearing intervals identified from the HpL™ data had apparent aperture. Sixty-eight high-angle features (features of dip angle greater than 45 degrees) were identified from the optical televiewer data. Additionally, ten of the features are qualitatively ranked greater than one, suggesting the features have flow potential. Four of the high angle features that ranked qualitatively greater than one corresponded relatively well with flow intervals identified by HydroPhysical™ testing at 239.0 to 242.5, 271.5 to 272.9 and 305.5 to 308.1 feet.

The nine interval-specific estimated transmissivities in WB-01 ranged from 0.057 to 8.81 square feet per day with the interval of 239.5 to 242.5 feet registering the highest transmissivity. The nine interval-specific transmissivity estimates do not differ significantly with respect to each other.

Fracture inter-connectiveness in the immediate vicinity of a wellbore can be inferred by the similarity, or lack there of, of parameters such as interval-specific transmissivity estimates and interval-specific FEC, along with the presence of high-angle fractures and pressure differentials within the borehole. Similar transmissivity and FEC estimates would suggest an inter-connected network of fractures or aquifers in the immediate vicinity of the wellbore. A pressure differential present in the wellbore would suggest the driving force for vertical communication is present and high-angle fractures with aperture may provide the conduit for vertical communication.

The data acquired in WB-01 exhibited similar interval-specific transmissivity and similar FEC estimates. A downward vertical gradient is observed in the wellbore, however, the bulk of the downward vertical flow in the wellbore originated from above ambient water level. Major high angle features were identified in the wellbore to provide a conduit for vertical communication. The low flow rates identified in this wellbore under pumping and ambient conditions may contribute to the similar transmissivity estimates. The data suggest the fractures intersecting the wellbore are possibly interconnected in the immediate vicinity of the wellbore. Please see Tables WB-01:1 and SUMMARY:1 for a summary that includes the locations, flow rates and hydraulic conductivity estimates assessed by COLOG.

FIGURE WB-01:1. AMBIENT TEMPERATURE AND FLUID ELECTRICAL CONDUCTIVITY; PARSONS; CAMP STANLEY STORAGE FACILITY; SAN ANTONIO; TX; WELLBORE: WB-01.

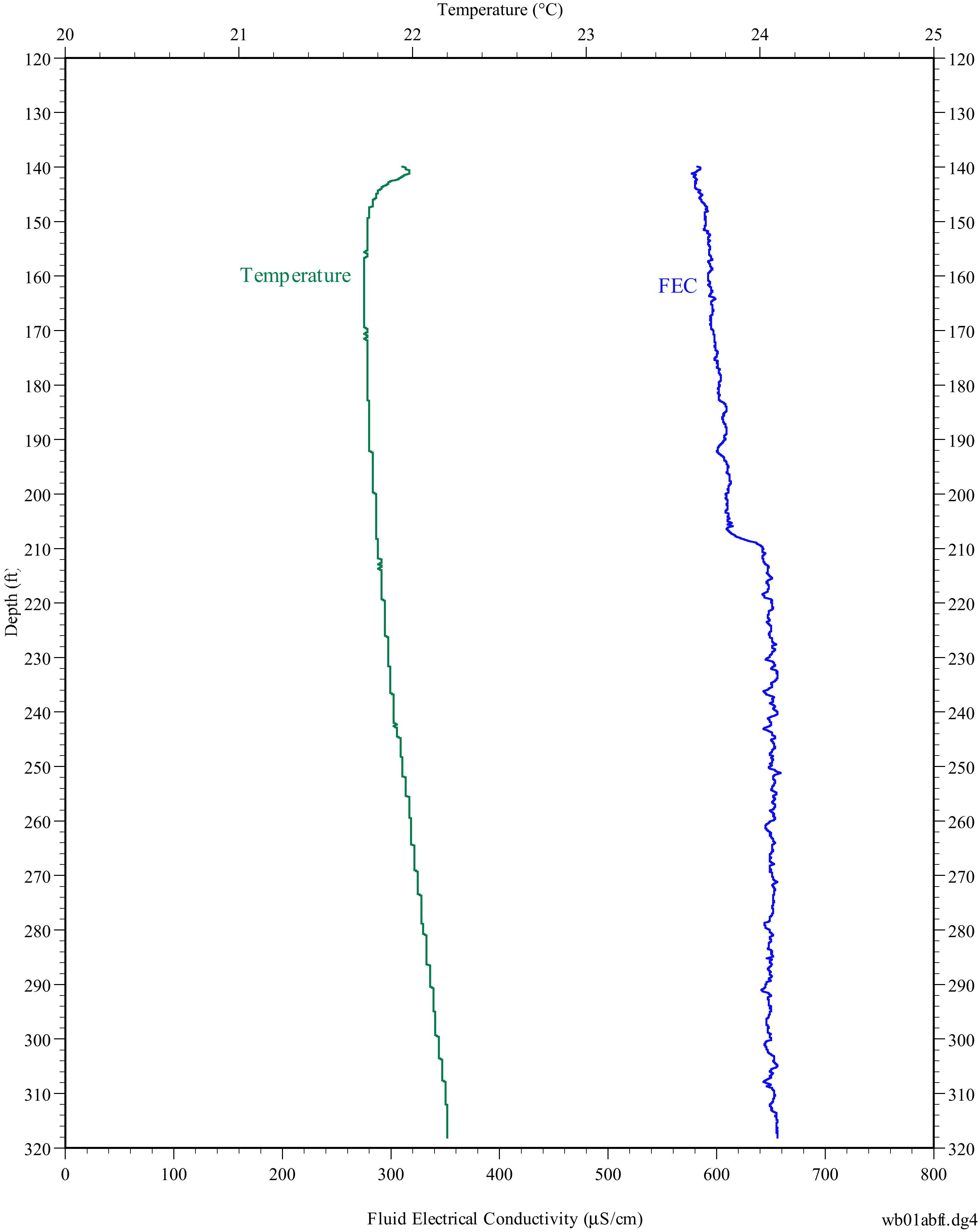


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FIGURE WB-01:2 SUMMARY OF HYDROPHYSICAL LOGS DURING AMBIENT FLOW CHARACTERIZATION; PARSONS; CAMP STANLEY STORAGE FACILITY; SAN ANTONIO, TX; WELLBORE: WB-01.

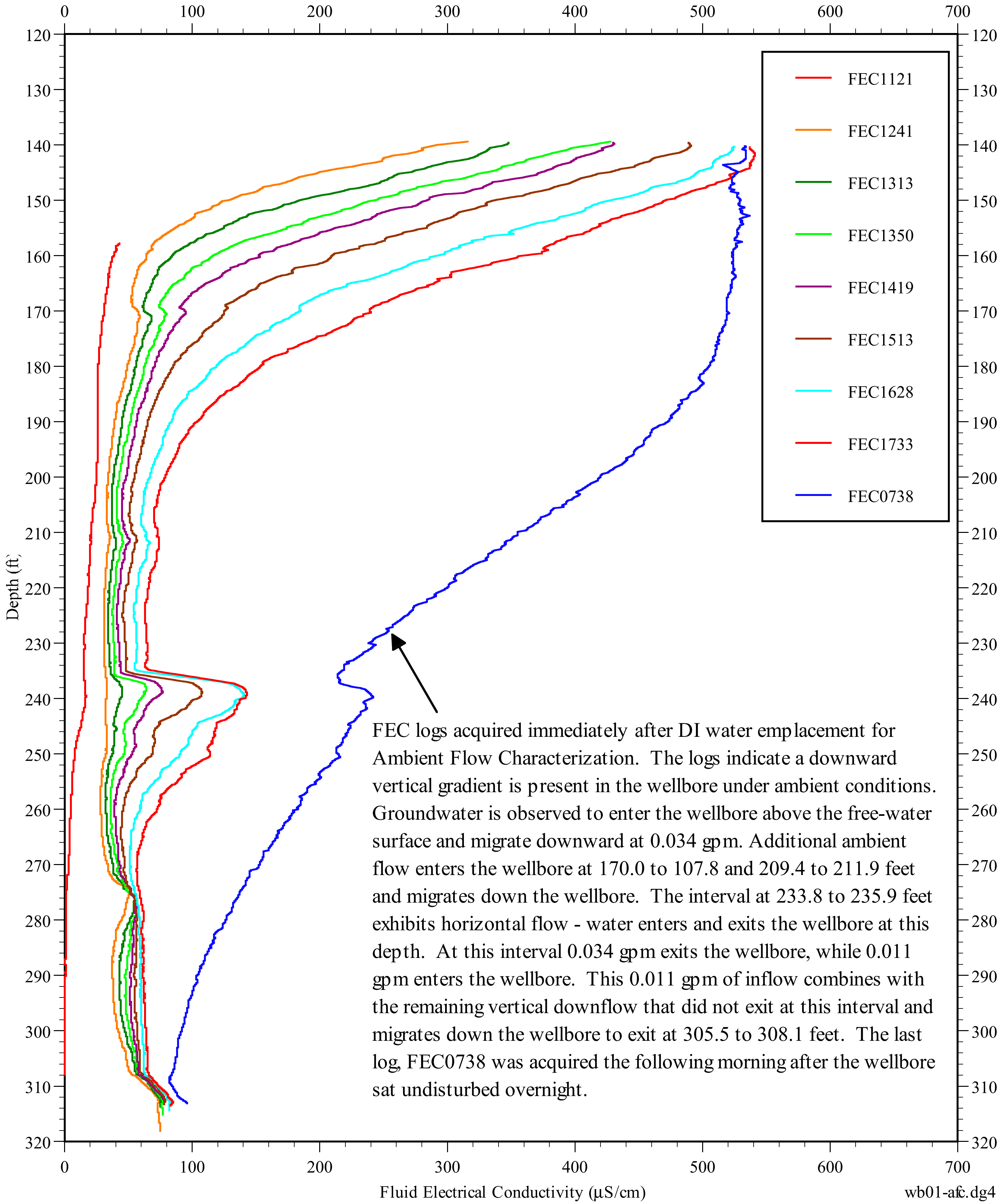

FIGURE WB-01:3. PUMPING AND DRAWDOWN DATA DURING 0.7 GPM PRODUCTION TEST; PARSONS; CAMP STANLEY STORAGE FACILITY; SAN ANTONIO, TX; BOREHOLE: WB-01.

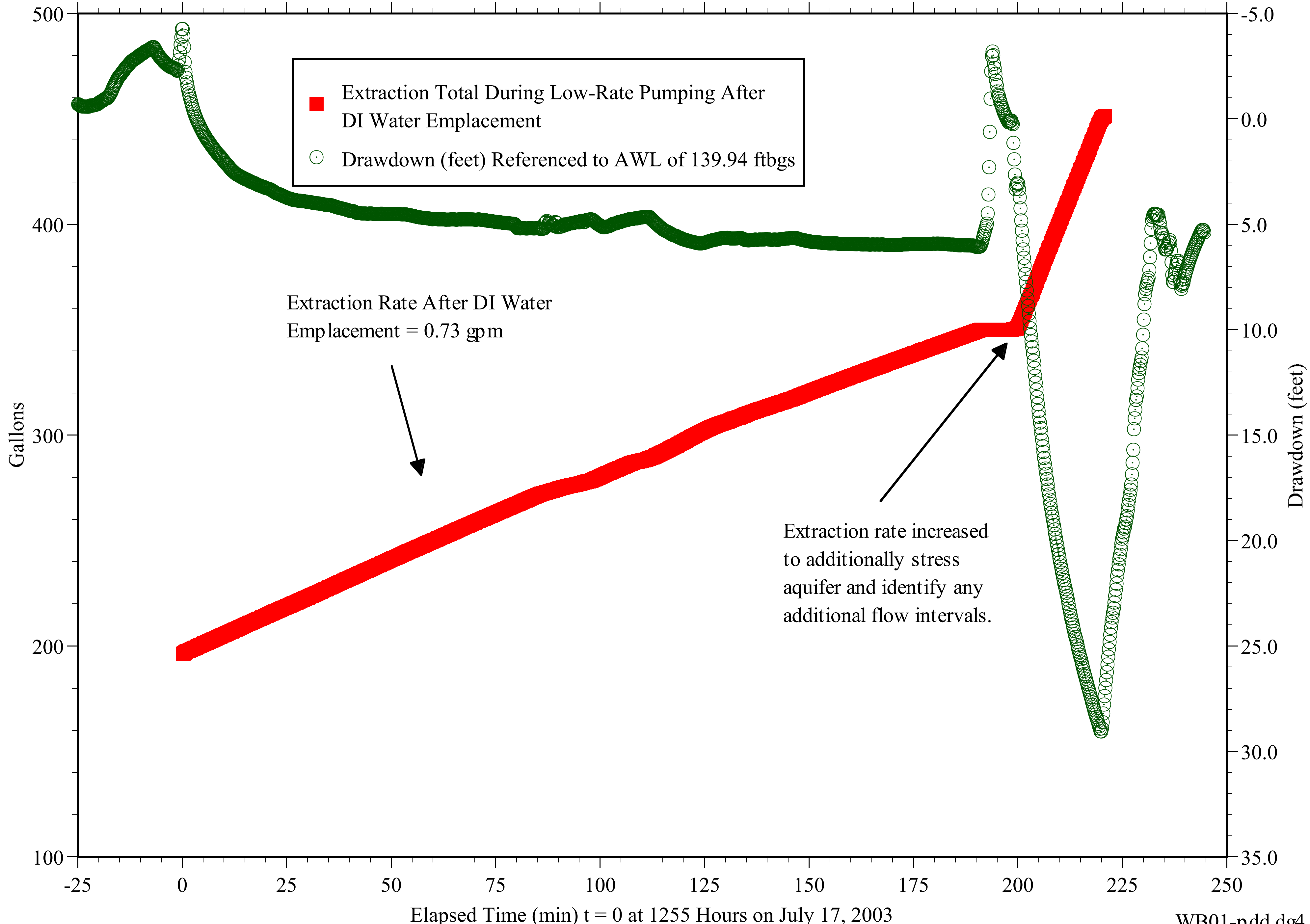

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FIGURE WB-01:4. SUMMARY OF HYDROPHYSICAL LOGS DURING LOW-RATE PRODUCTION TEST; PARSONS; CAMP STANLEY STORAGE FACILITY; SAN ANTONIO, TX; WELL: WB-01.

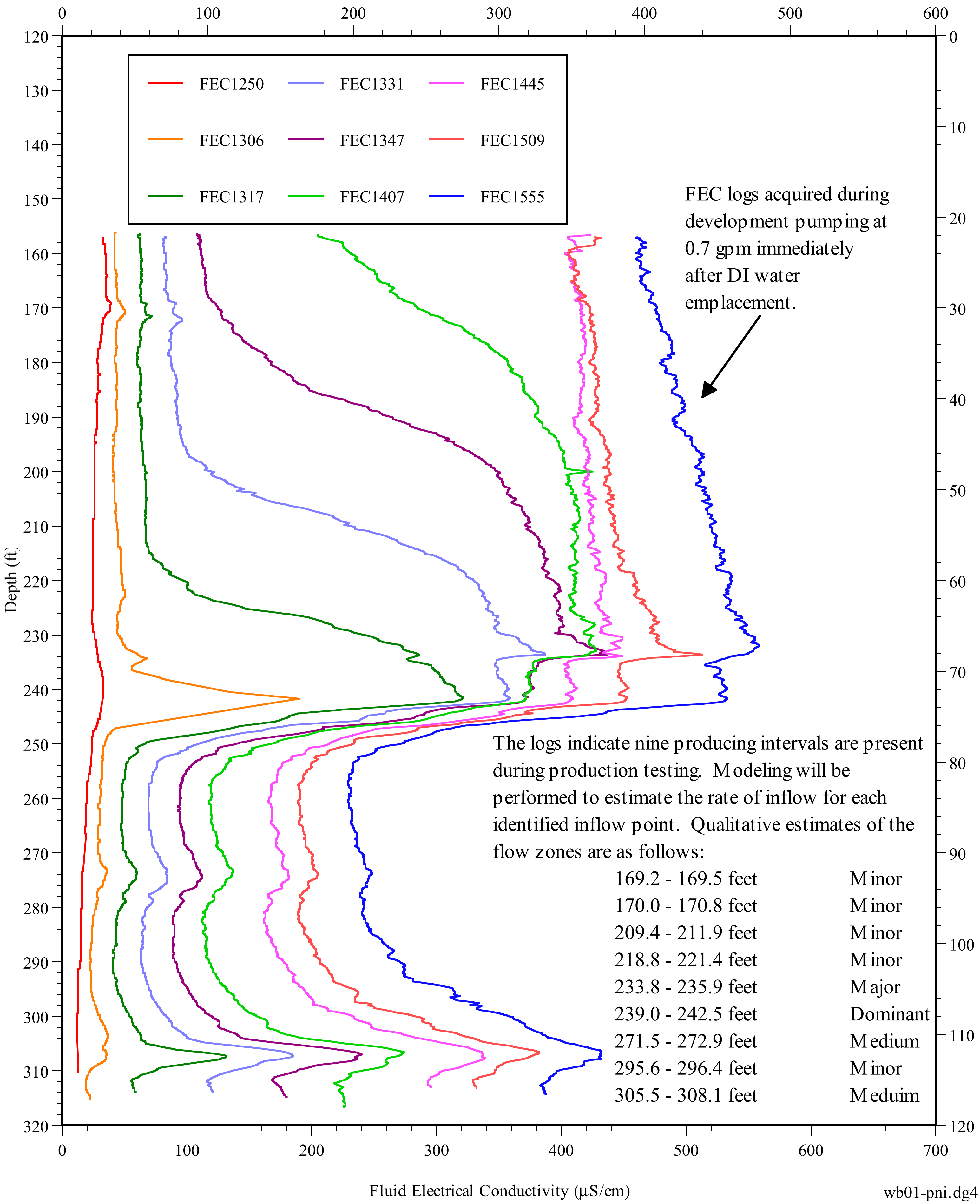


TABLE WB-01:1. SUMMARY OF HYDROPHYSICAL™ LOGGING RESULTS WITH HYDRAULIC CONDUCTIVITY AND TRANSMISSIVITY ESTIMATIONS; PARSONS; CAMP STANLEY STORAGE FACILITY; WELL: WB-01.

Well name	WB-01
Ambient Depth to water (ft)	139.94
Diameter of Borehole (ft)	0.33
Maximum Drawdown (ft)	6.14
Effective Radius (ft)	50

Interval No.	Top of Interval (ft)	Bottom of Interval (ft)	Length of Interval (ft)	Ambient Flow[1] (gpm)	Darcy Velocity in Aquifer[2] (Specific Discharge) (ft/day)	Interval Specific Flow Rate (gpm)	Delta Flow[3] (gpm)	Delta Flow (ft^3/min.)	Interval Specific Hydraulic Conductivity[4] (ft/day)	Transmissivity (ft2/day)	Interval Specific Fluid Electrical Conductivity (microS/cm)
1	169.2	169.5	0.3	0.000	NA	0.008	0.008	0.00107	7.61E-01	2.28E-01	582
2	170.0	170.8	0.8	0.004	NA	0.013	0.009	0.00120	3.21E-01	2.57E-01	596
3	209.4	211.9	2.5	0.003	NA	0.005	0.002	0.00027	2.28E-02	5.71E-02	645
4	218.8	221.4	2.6	0.000	NA	0.013	0.013	0.00174	1.43E-01	3.71E-01	647
5	233.8	235.9	2.1	-0.034	1.22	0.264	0.298	0.03984	4.05E+00	8.50E+00	650
6	239.0	242.5	3.5	0.000	NA	0.309	0.309	0.04131	2.52E+00	8.81E+00	650
7	271.5	272.9	1.4	0.000	NA	0.034	0.034	0.00455	6.93E-01	9.70E-01	649
8	295.6	296.4	0.8	0.000	NA	0.013	0.013	0.00174	4.64E-01	3.71E-01	654
9	305.5	308.1	2.6	-0.017	NA	0.053	0.070	0.00936	7.68E-01	2.00E+00	656

[1] All ambient flow identified for this wellbore is either downward or horizontal flow. A majority of the inflowing fluid enters the wellbore above ambient water level (139.94 ftbgs), and migrates downward at 0.034 gpm. The flow interval at 233.8 to 235.9 feet is the exit interval for a majority of the flow in the wellbore, however, this interval also contributes inflow at 0.011 gpm.

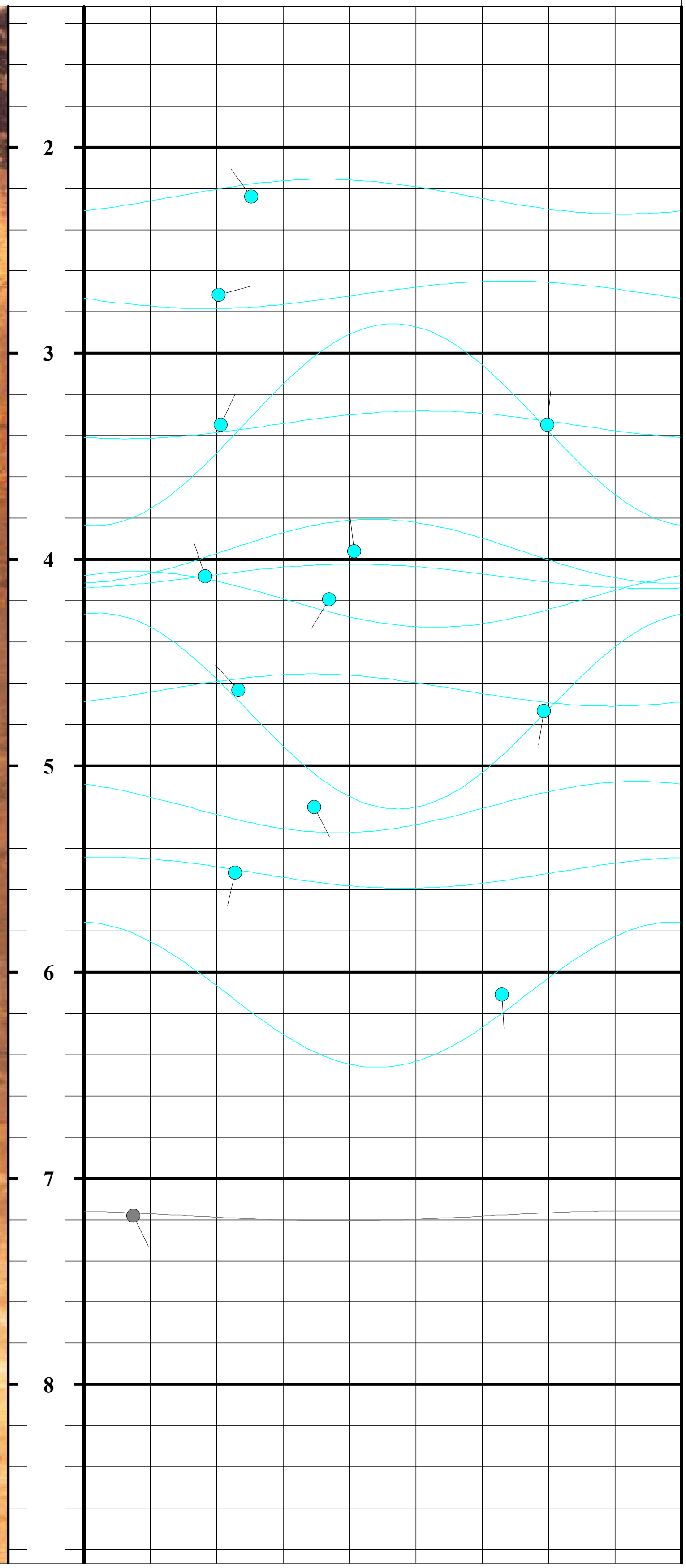
[2] Darcy Velocity is calculated using the observed volumetric flow rate, the cross-sectional area of the flow interval in the wellbore and a wellbore convergence factor of 2.5 (Drost, 1968). The Darcy Velocity is only applicable to ambient horizontal flow.

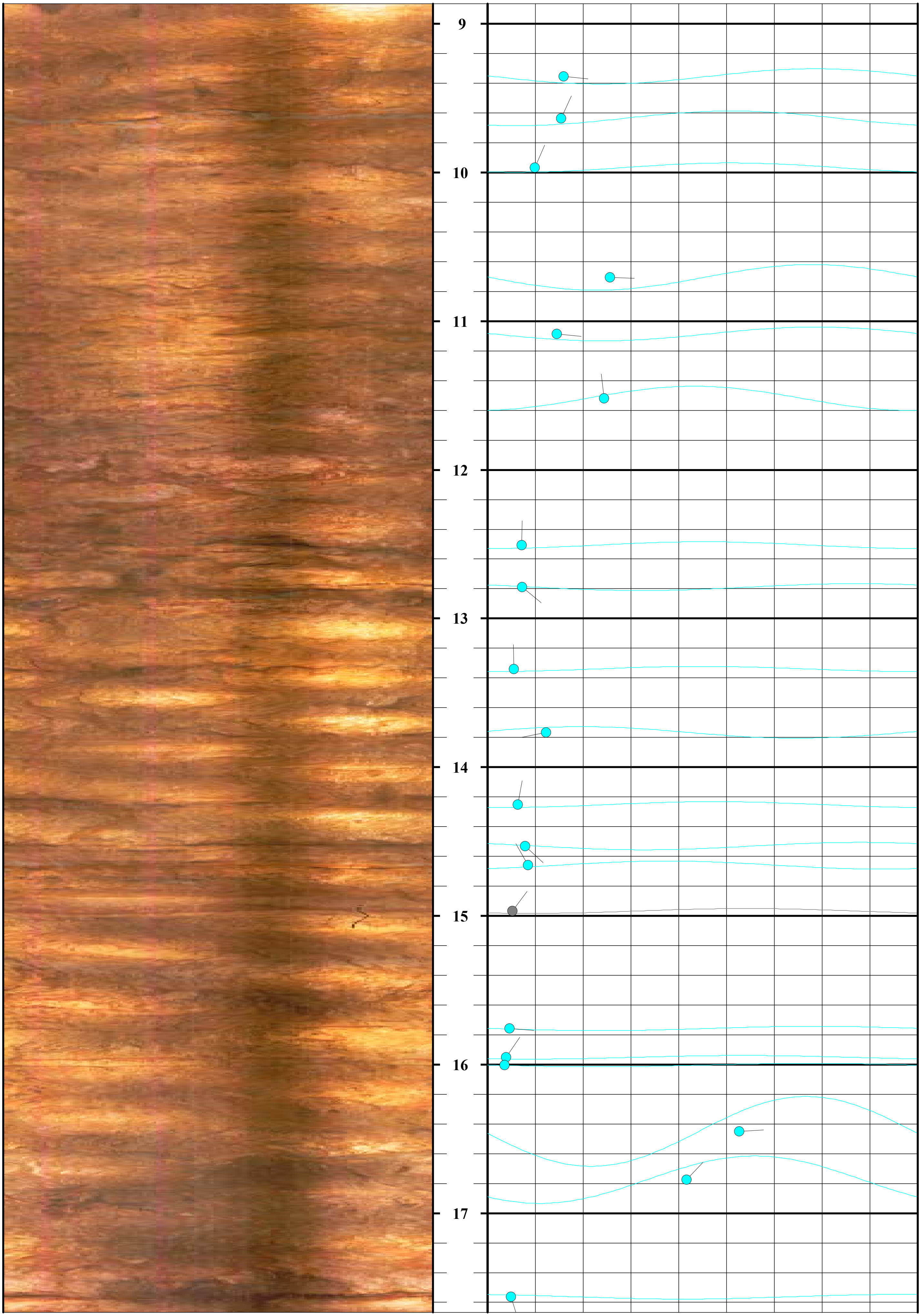
[3] Delta Flow is the difference between Interval-Specific Flow Rate (during pumping) and Ambient Flow Rate.

[4] Hydraulic conductivity and transmissivity estimates are based on single well drawdown data, a porus-medium equivilent model and Hvorslev's 1951 porosity equation.

COLOG — Borehole Geophysics & Hydrophysics — A Division of Layne Christensen Company	**Optical Borehole Image Plot**		COLOG Main Office
	COMPANY: Parsons	PROJECT: Camp Stanley	17301 W.Colfax Ave, Ste 265, Golden, CO 80401
	DATE LOGGED: 17 July 2003	WELL: WB-01	Phone: (303) 279-0171, Fax: (303) 278-0135 www.colog.com

Optical Televiewer (BIPS)	Depth	Projection
0° 90° 180° 270° 0°		0° 90° 180° 270° 0°
		Tadpole (Degrees)
		0 90

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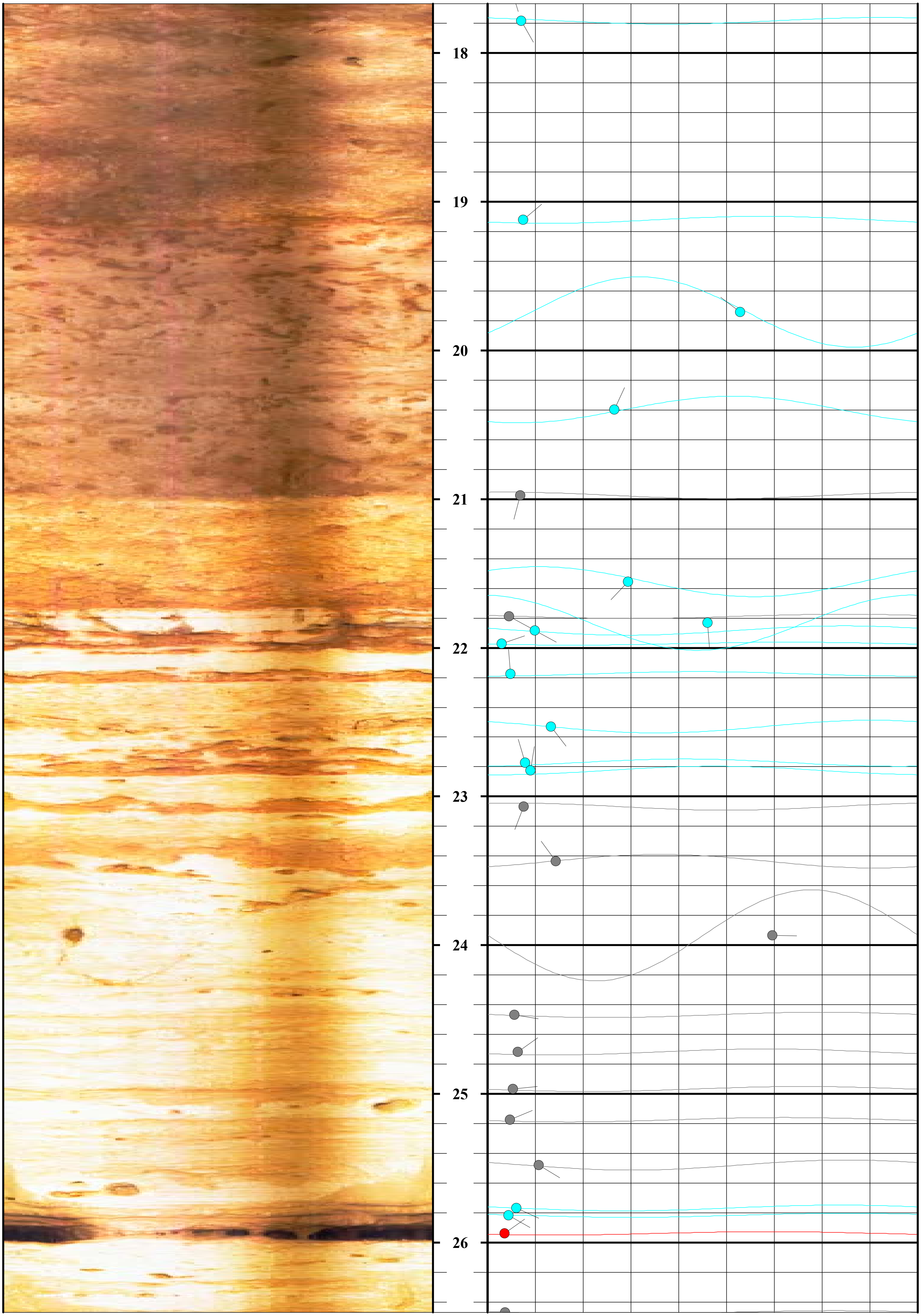
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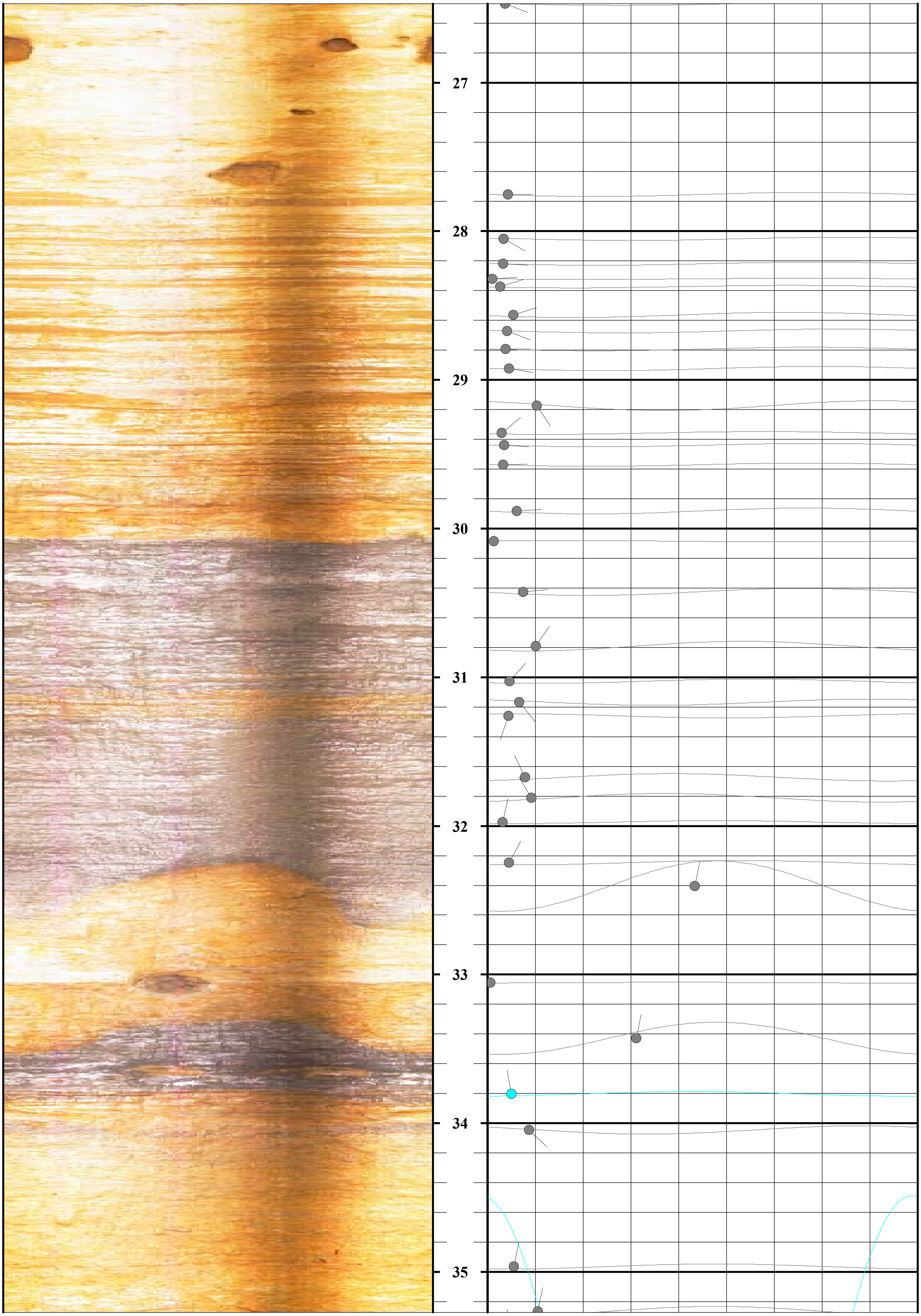
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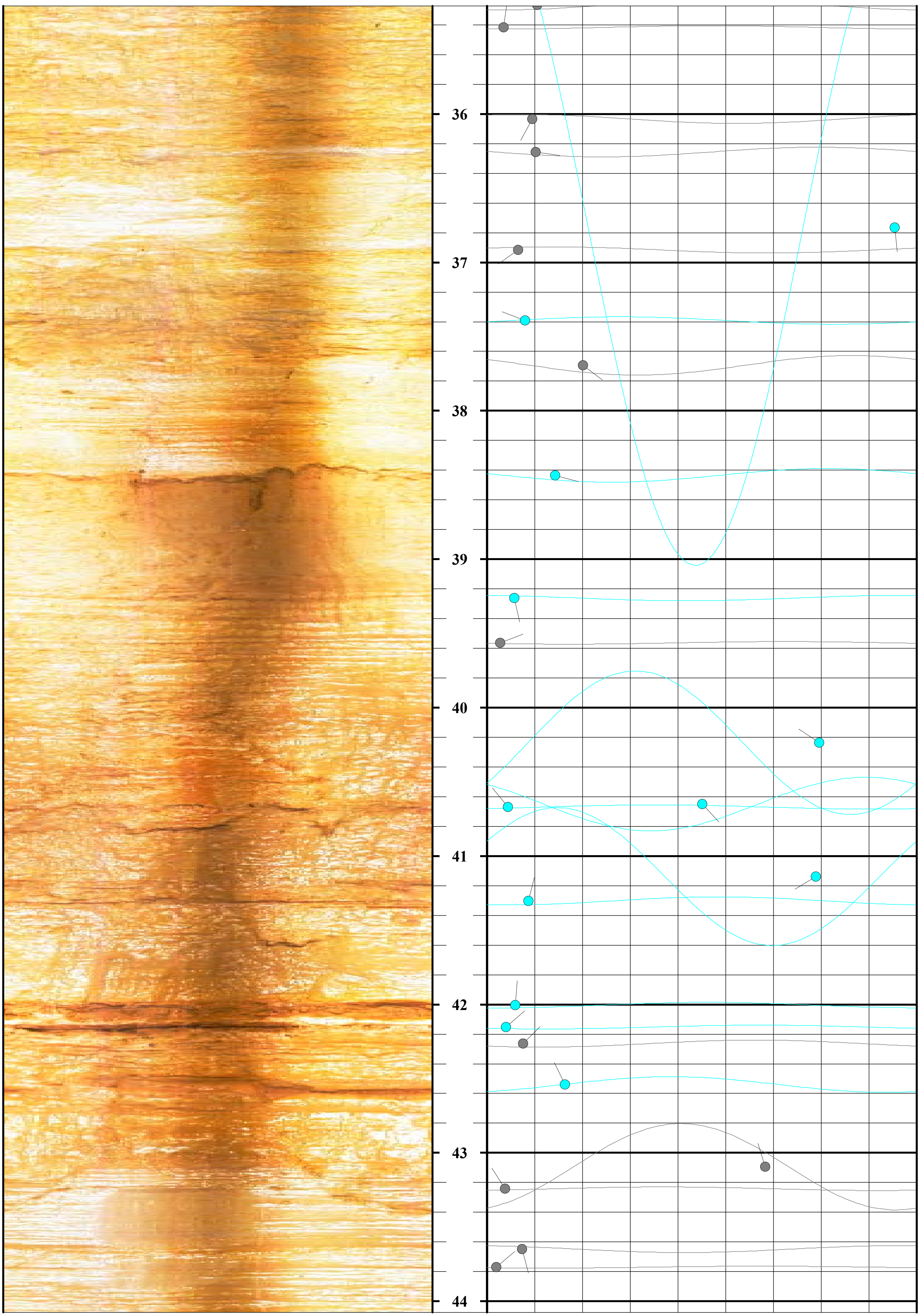
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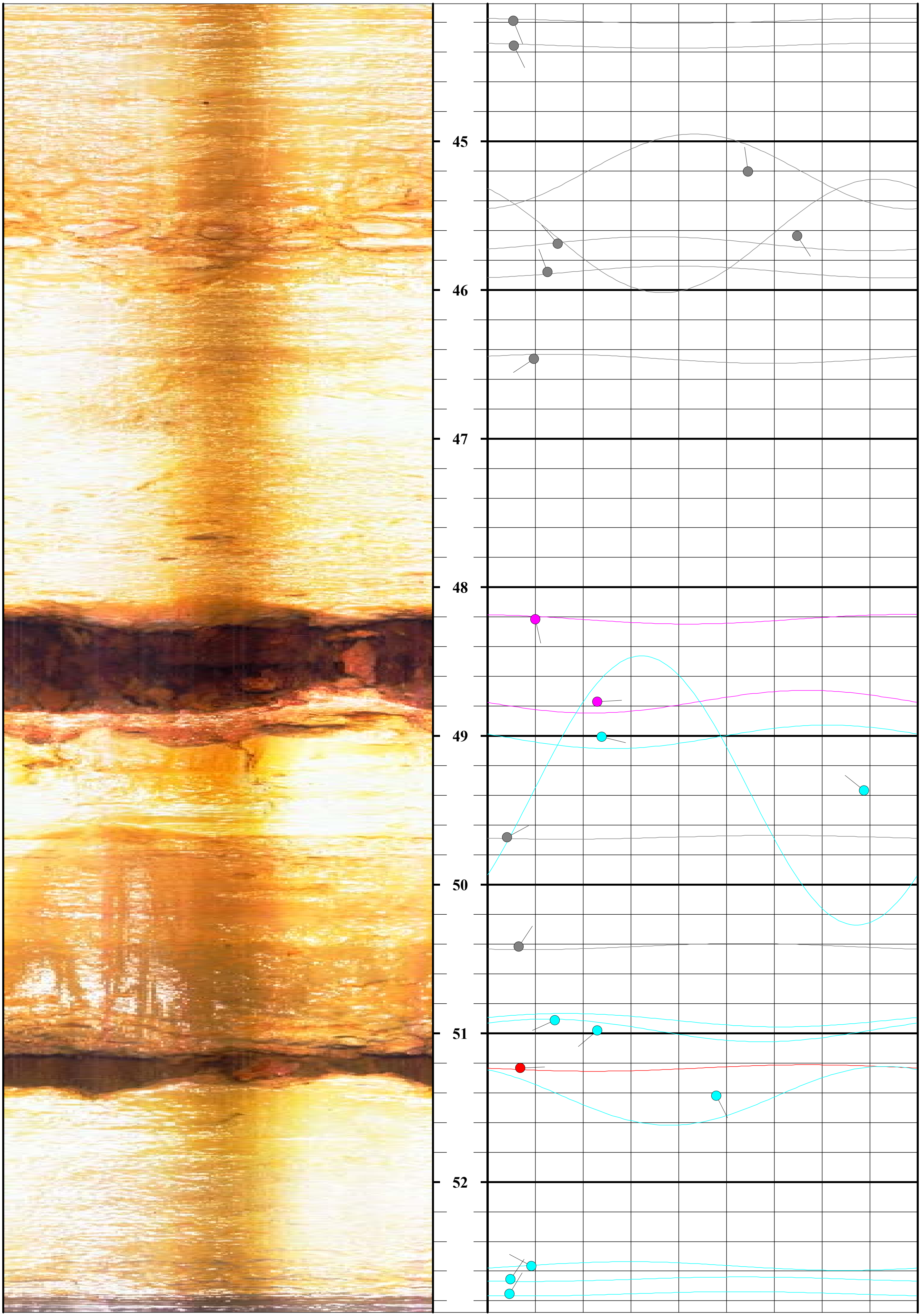
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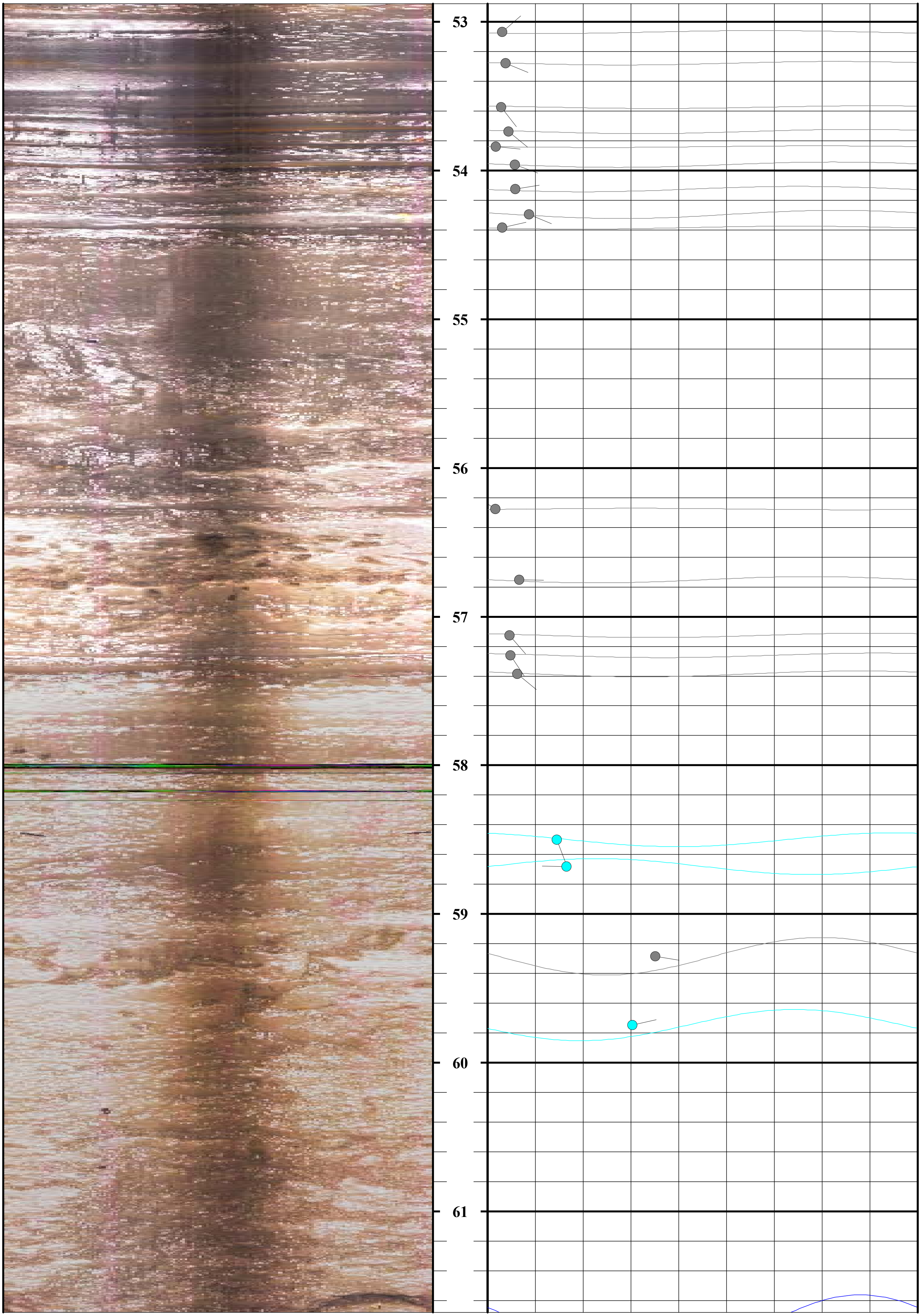
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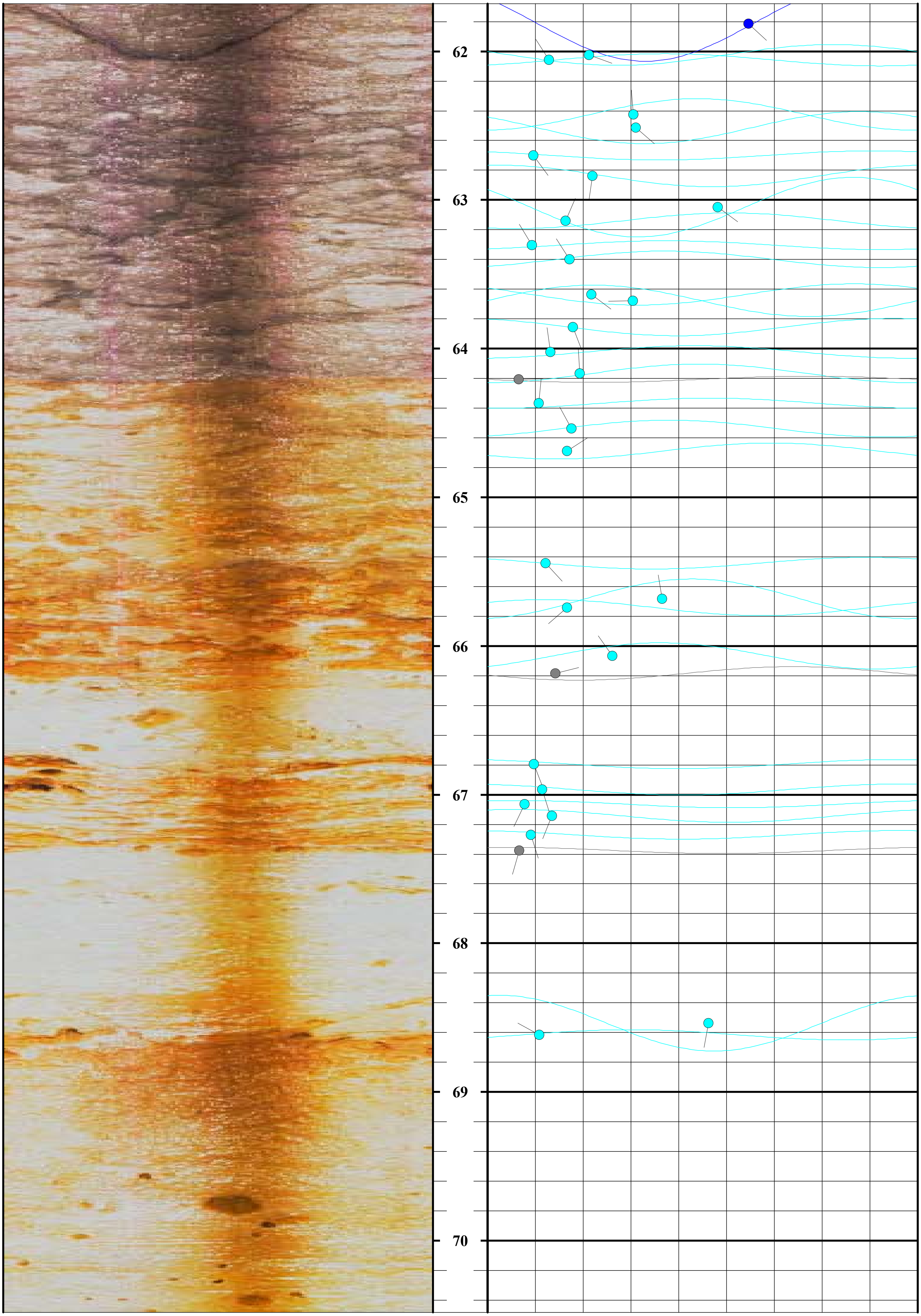
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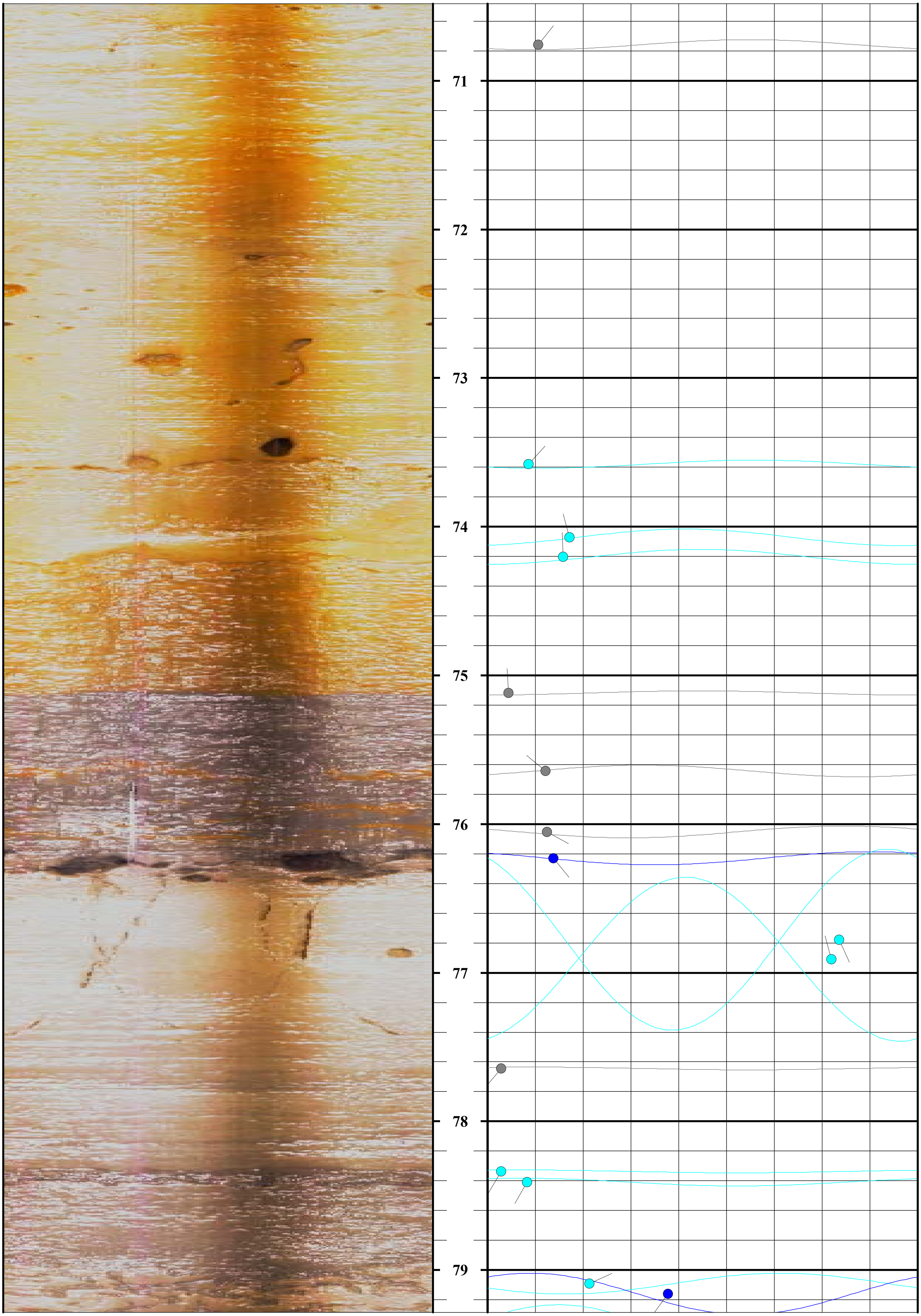
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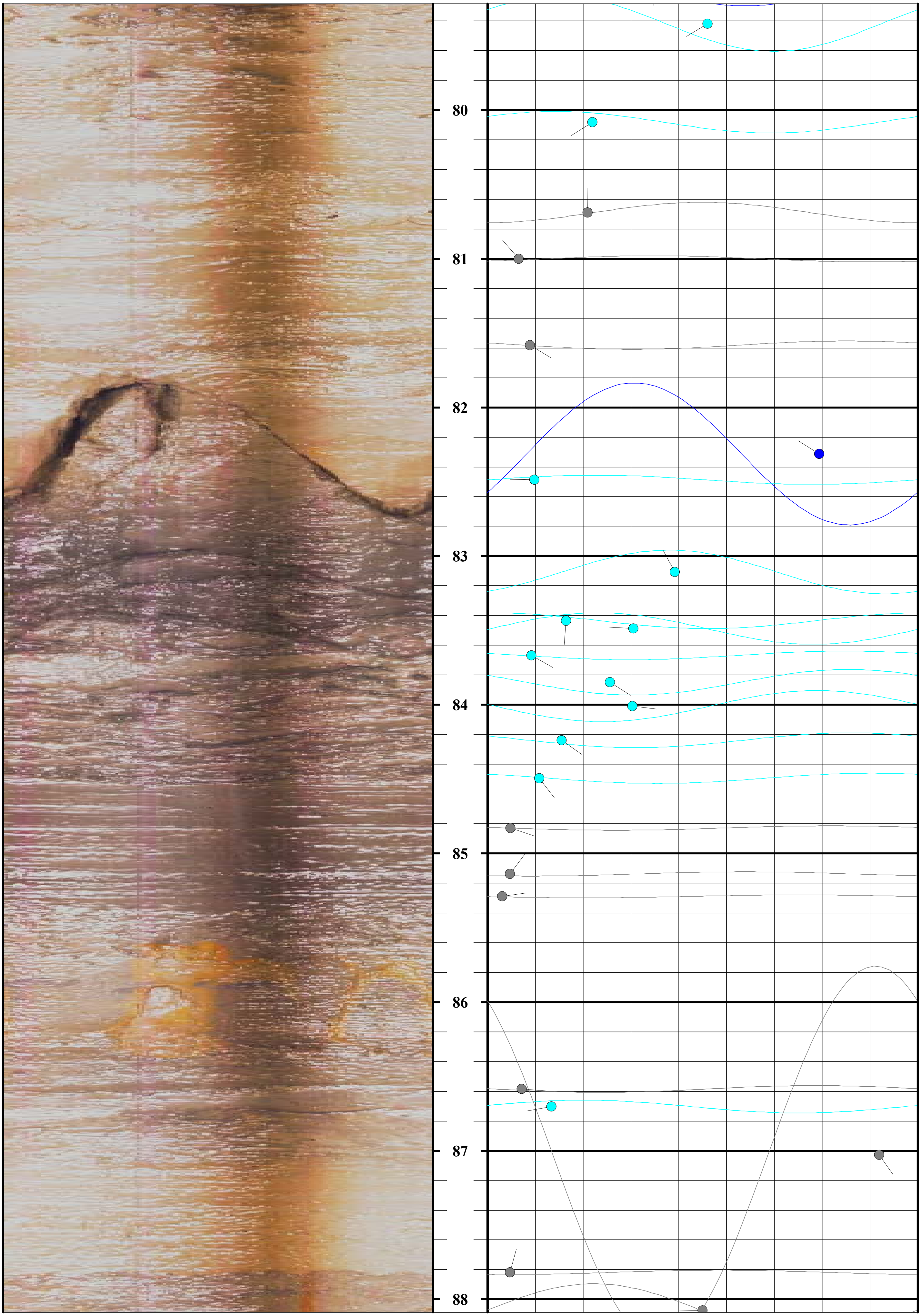
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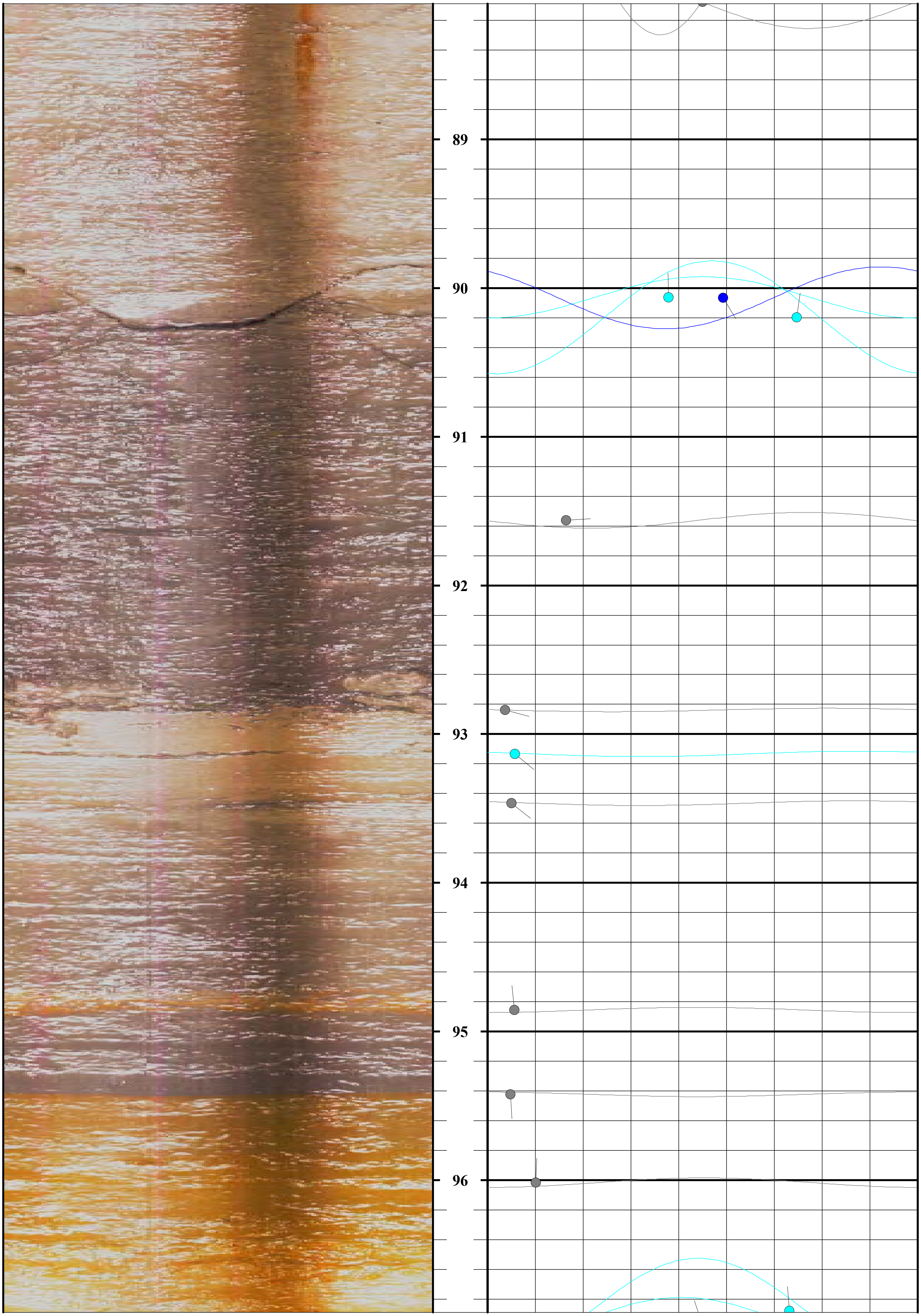
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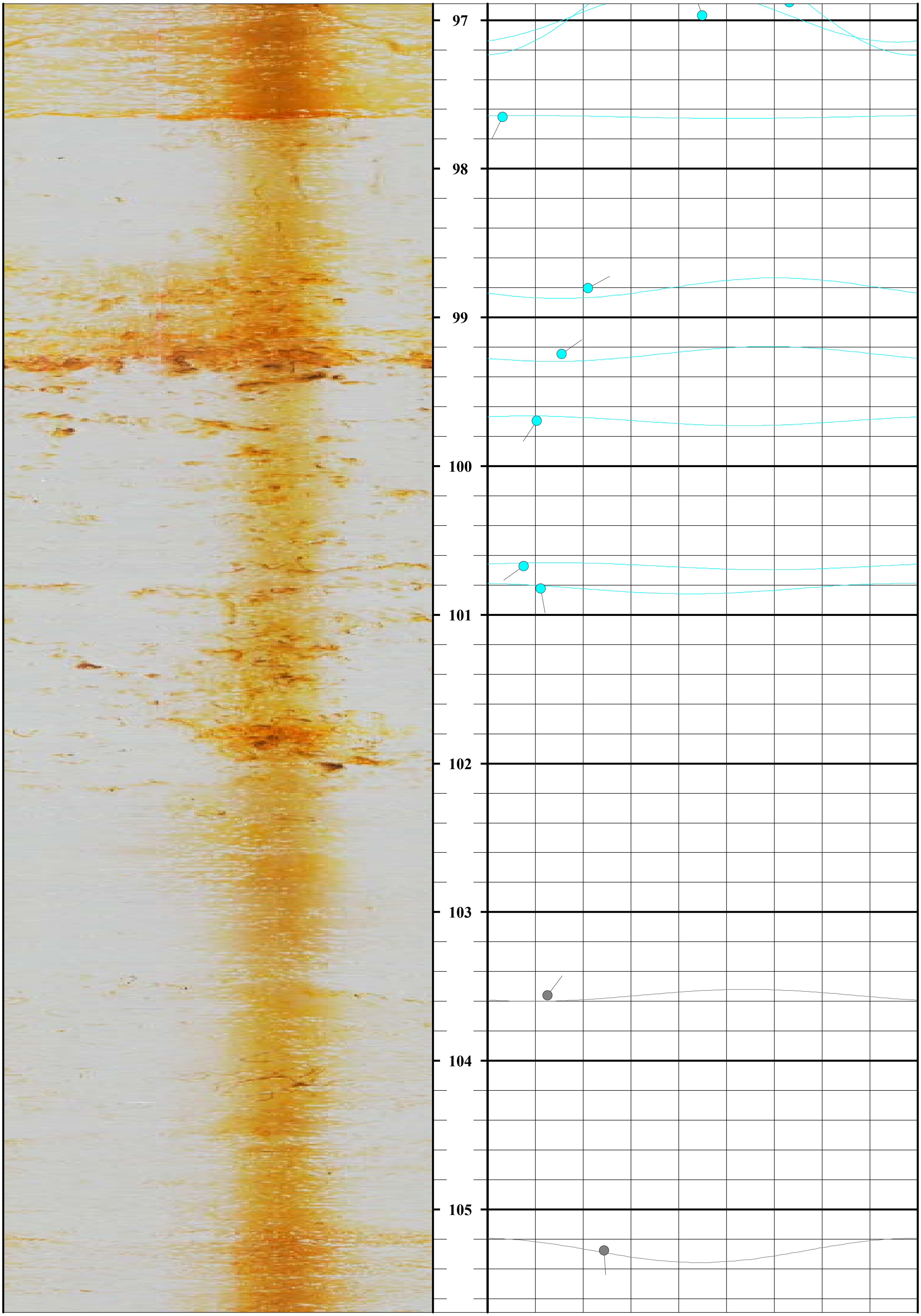
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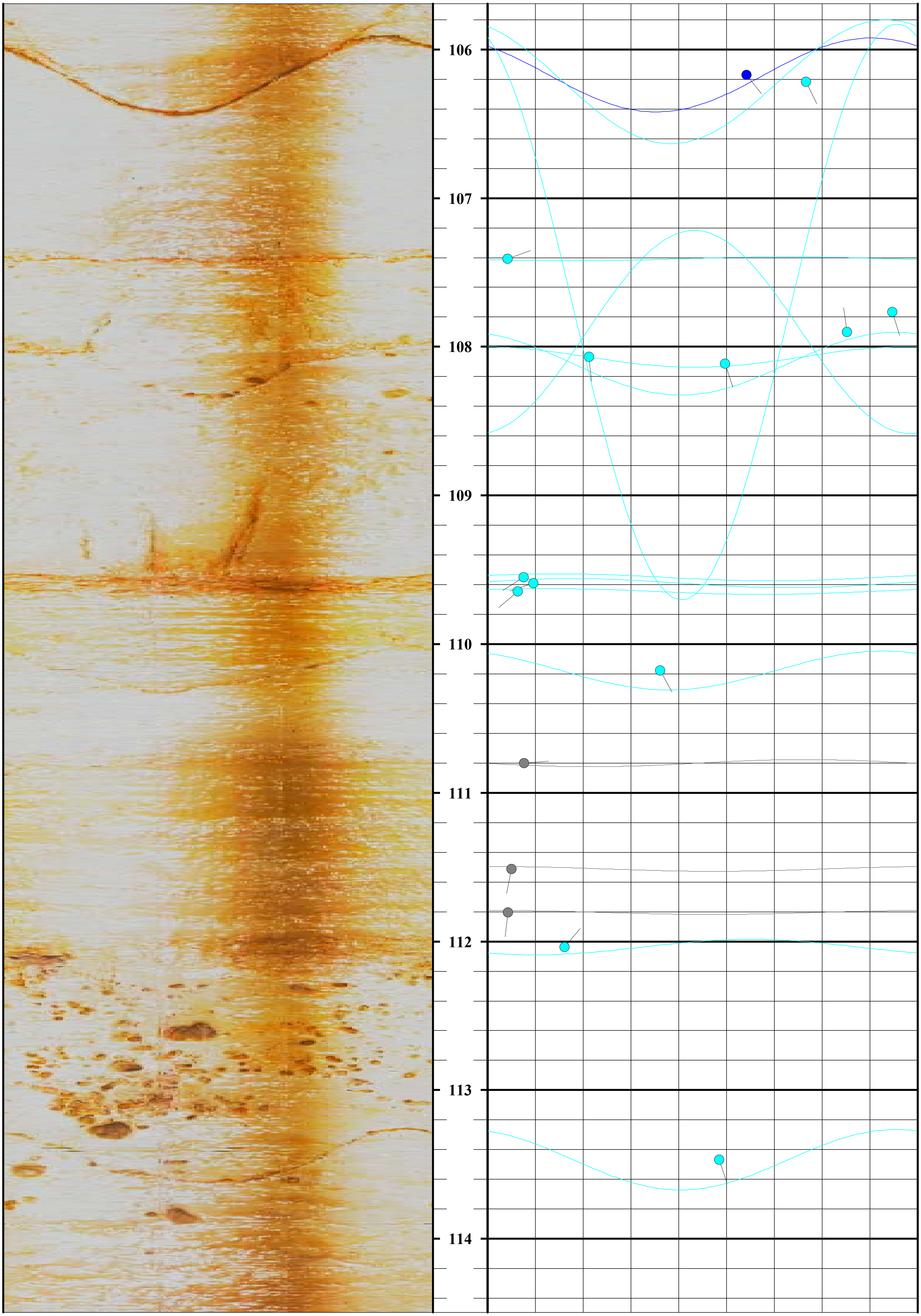
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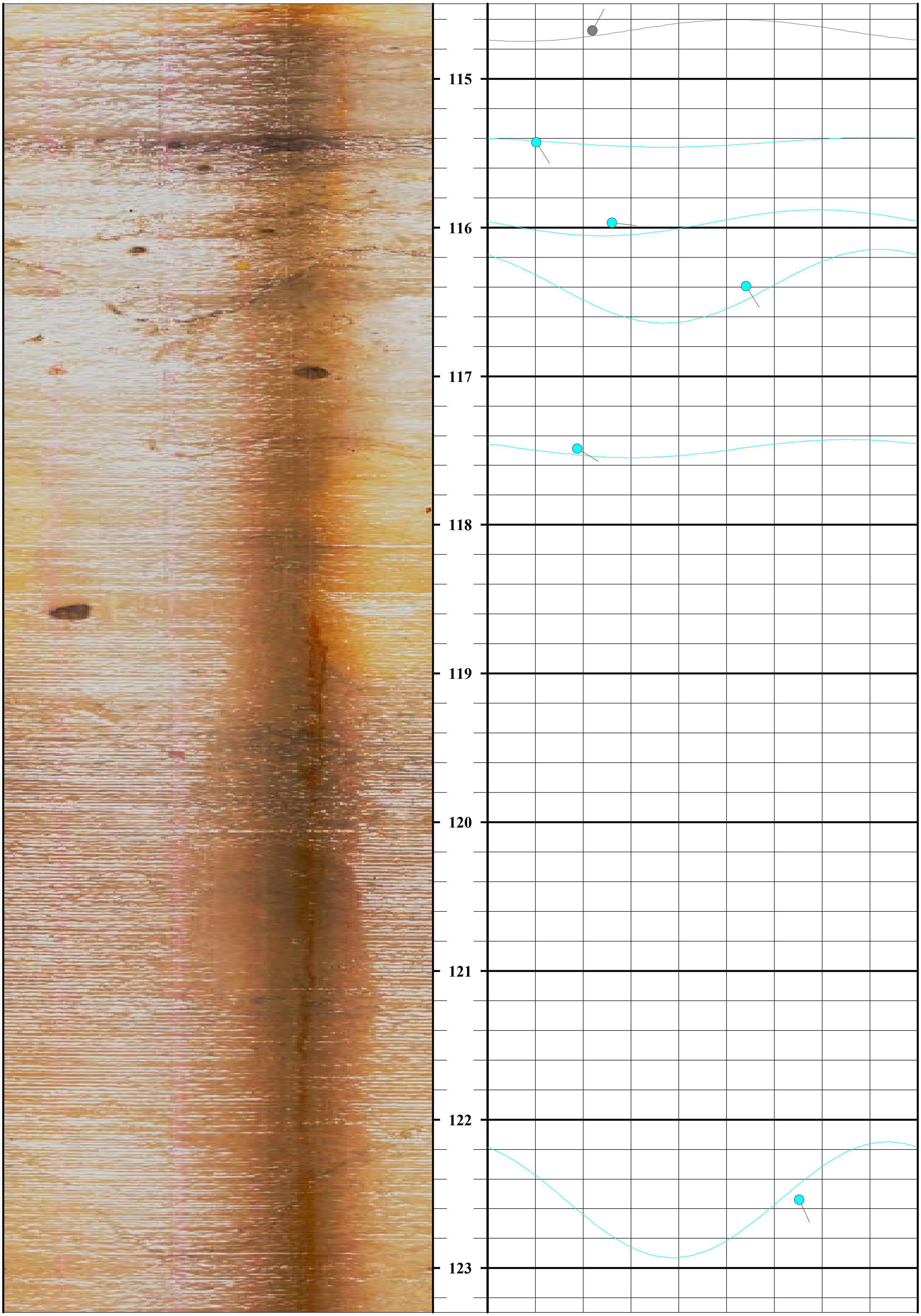
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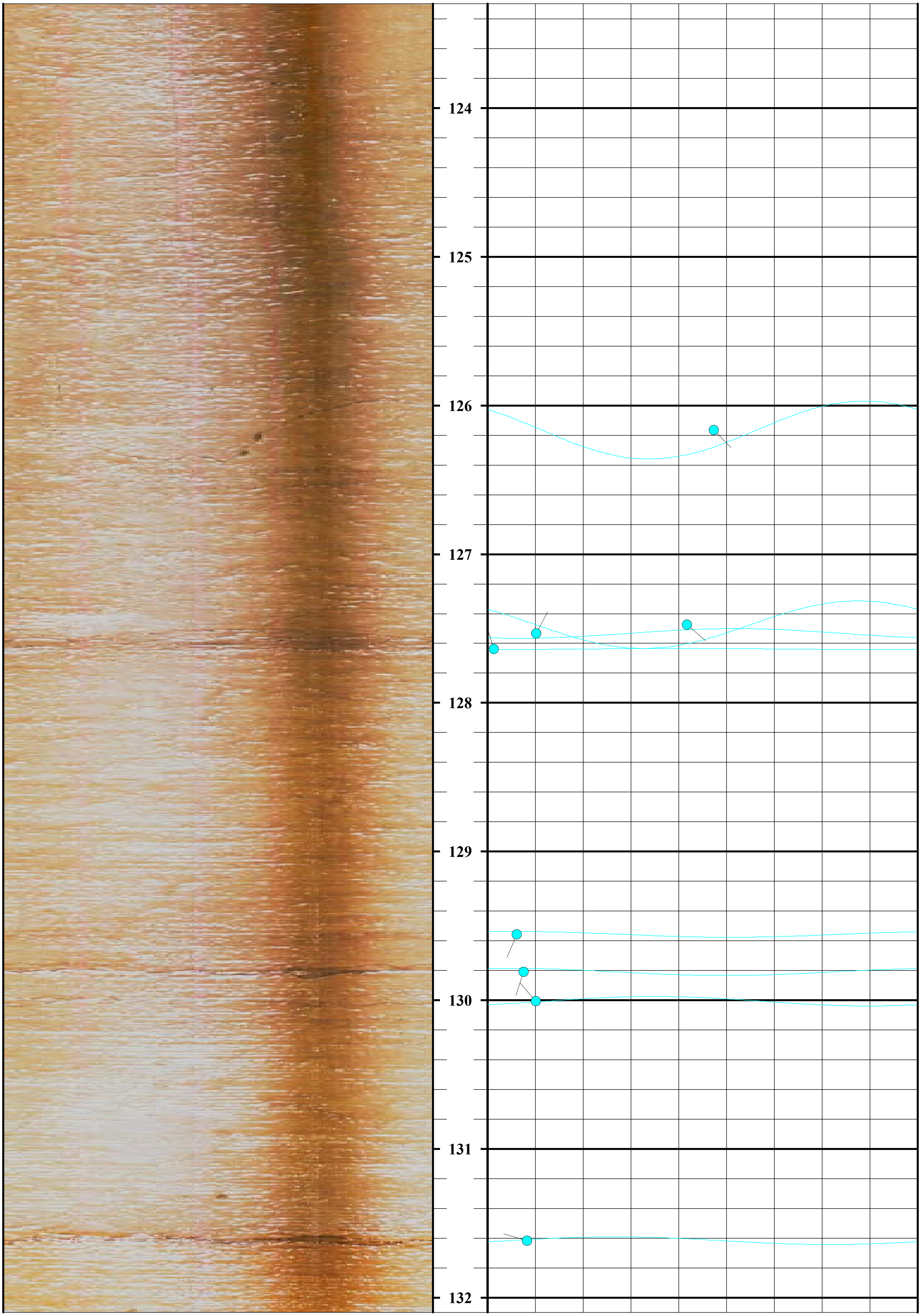
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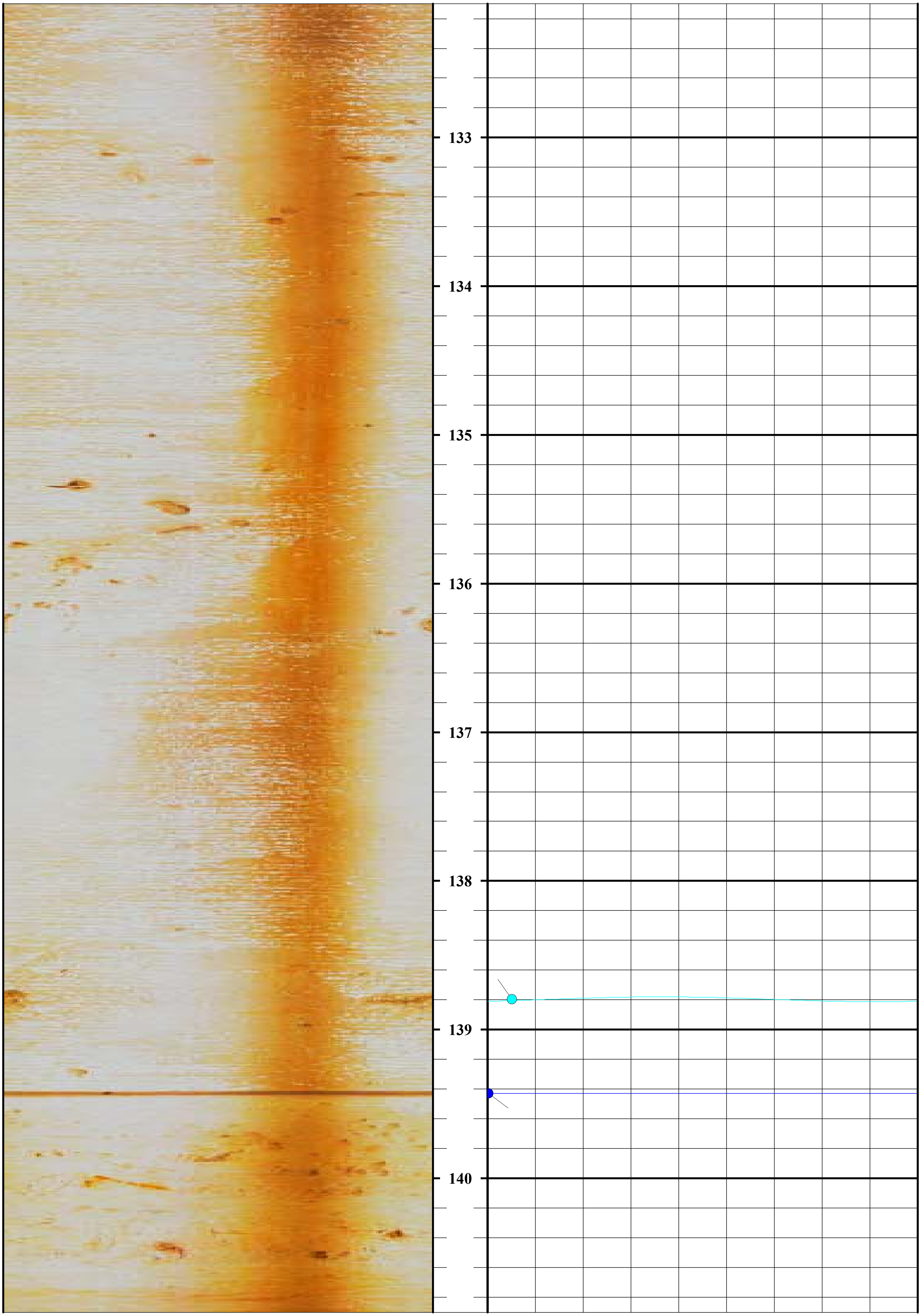
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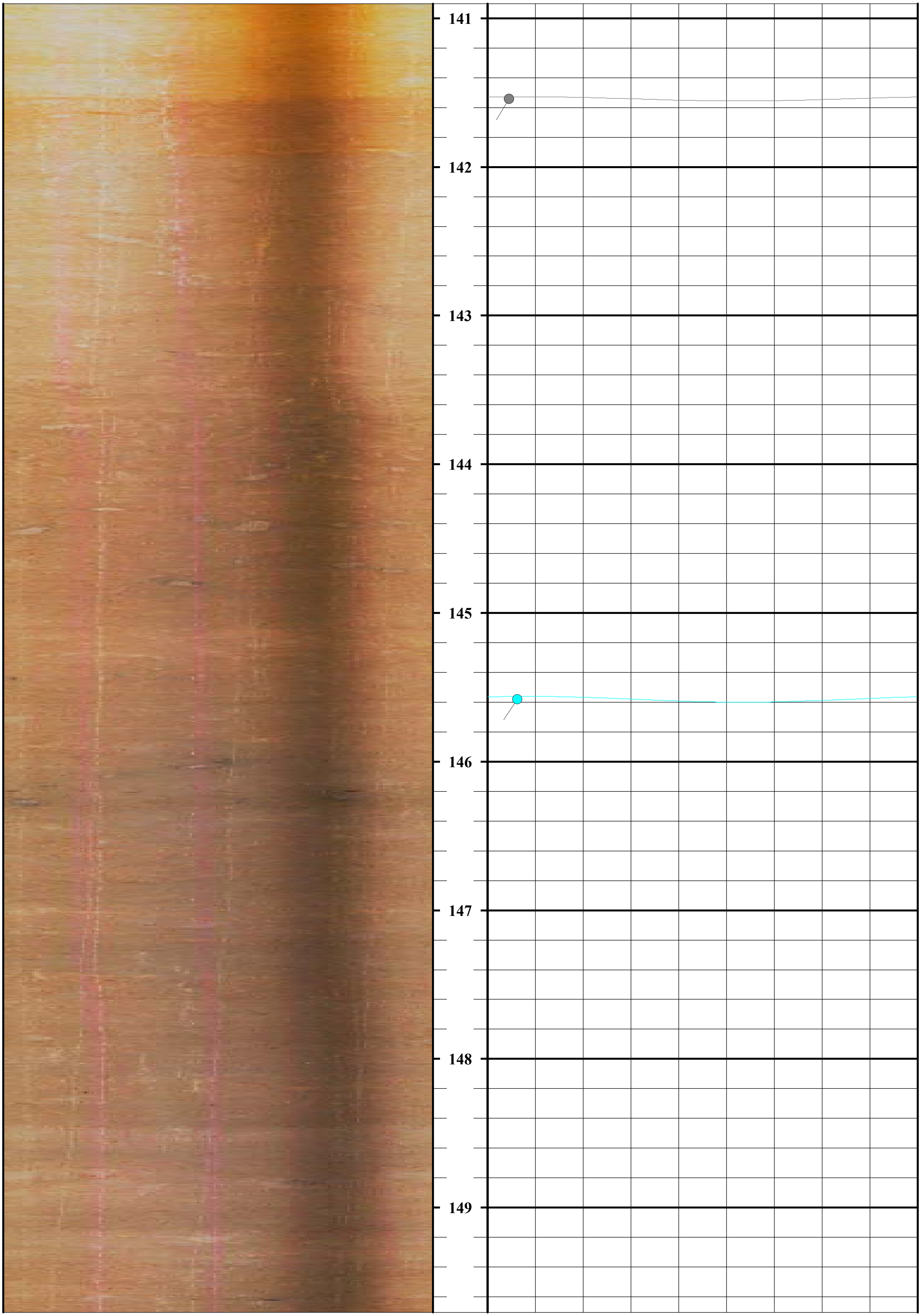
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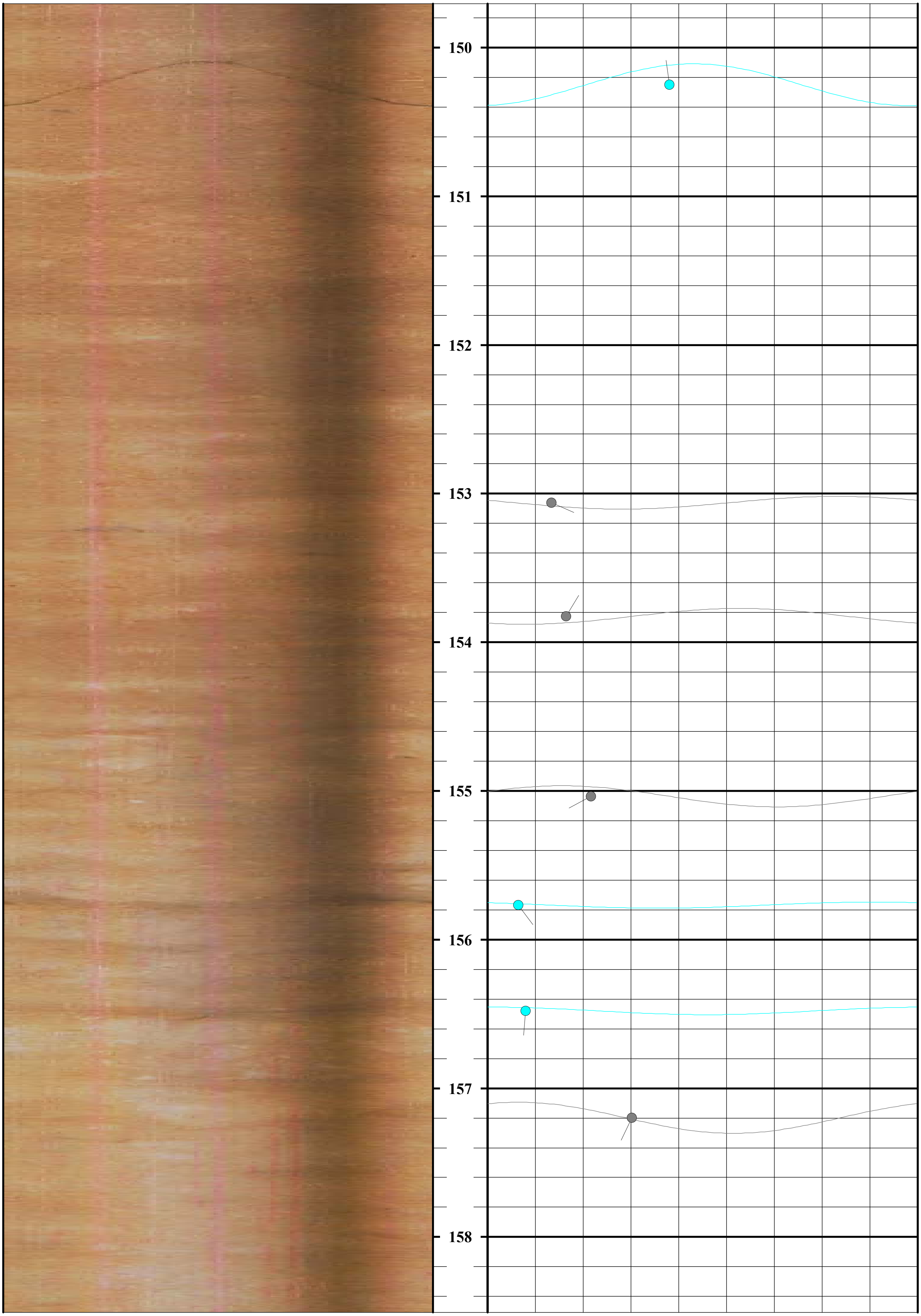
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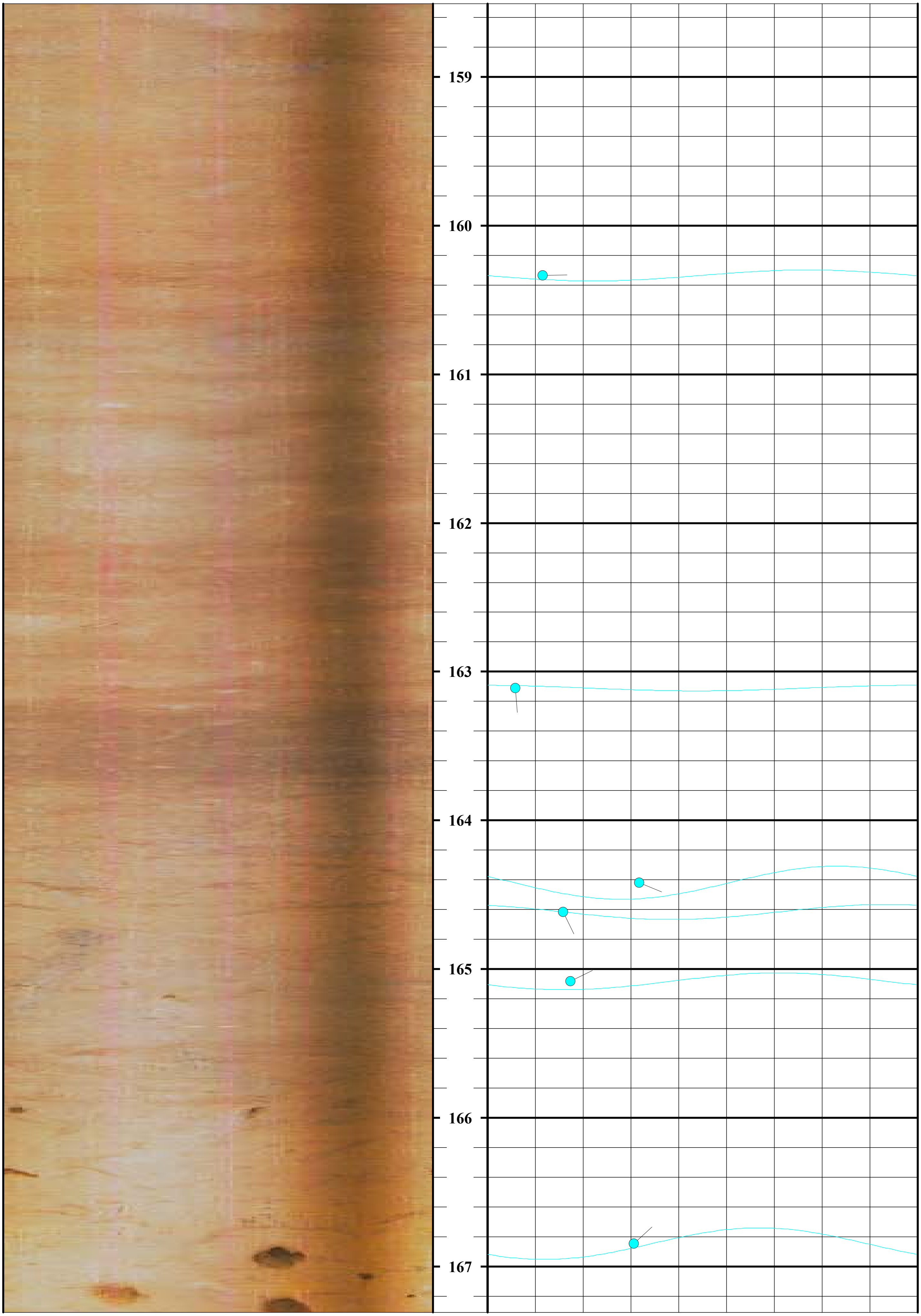
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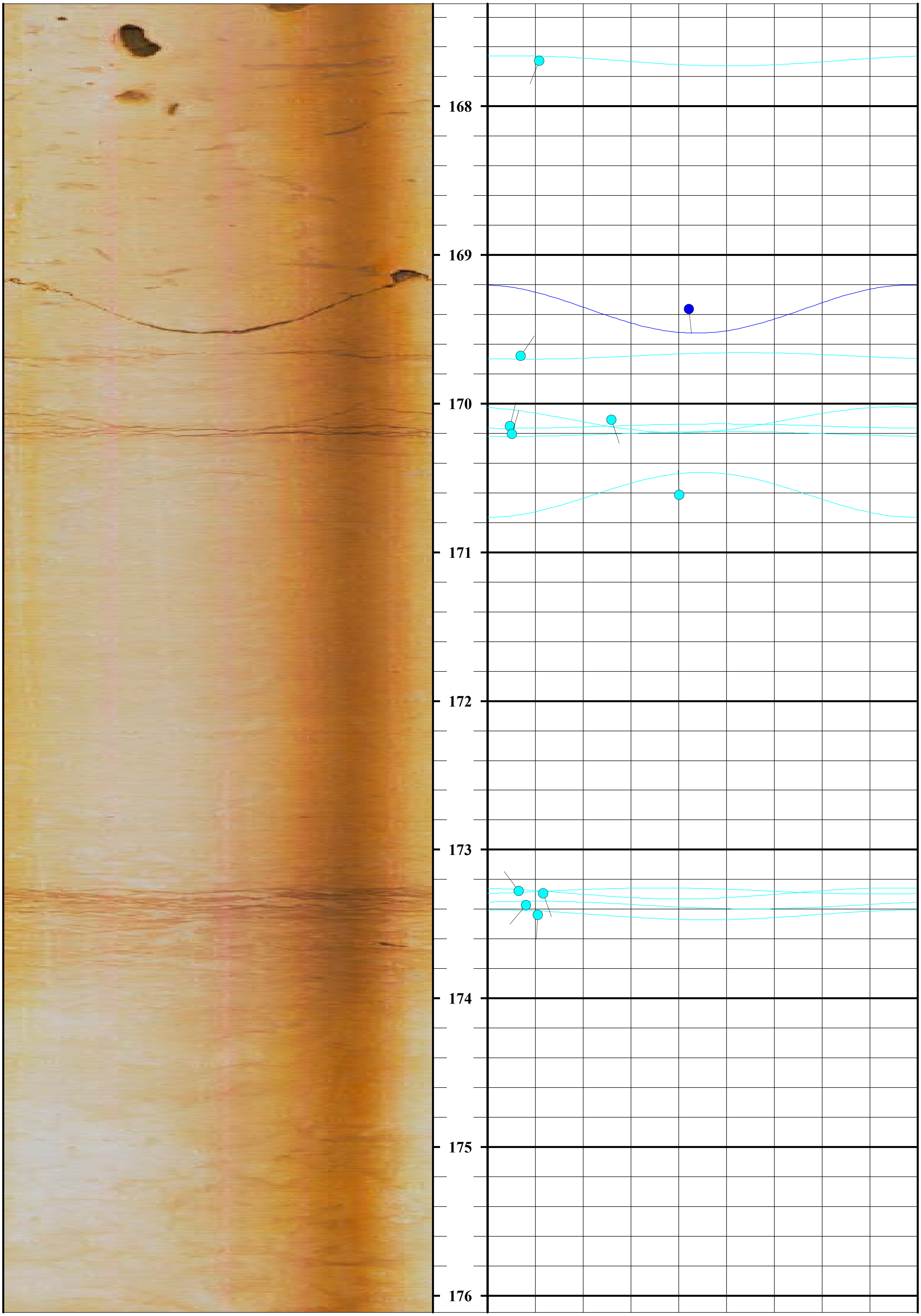
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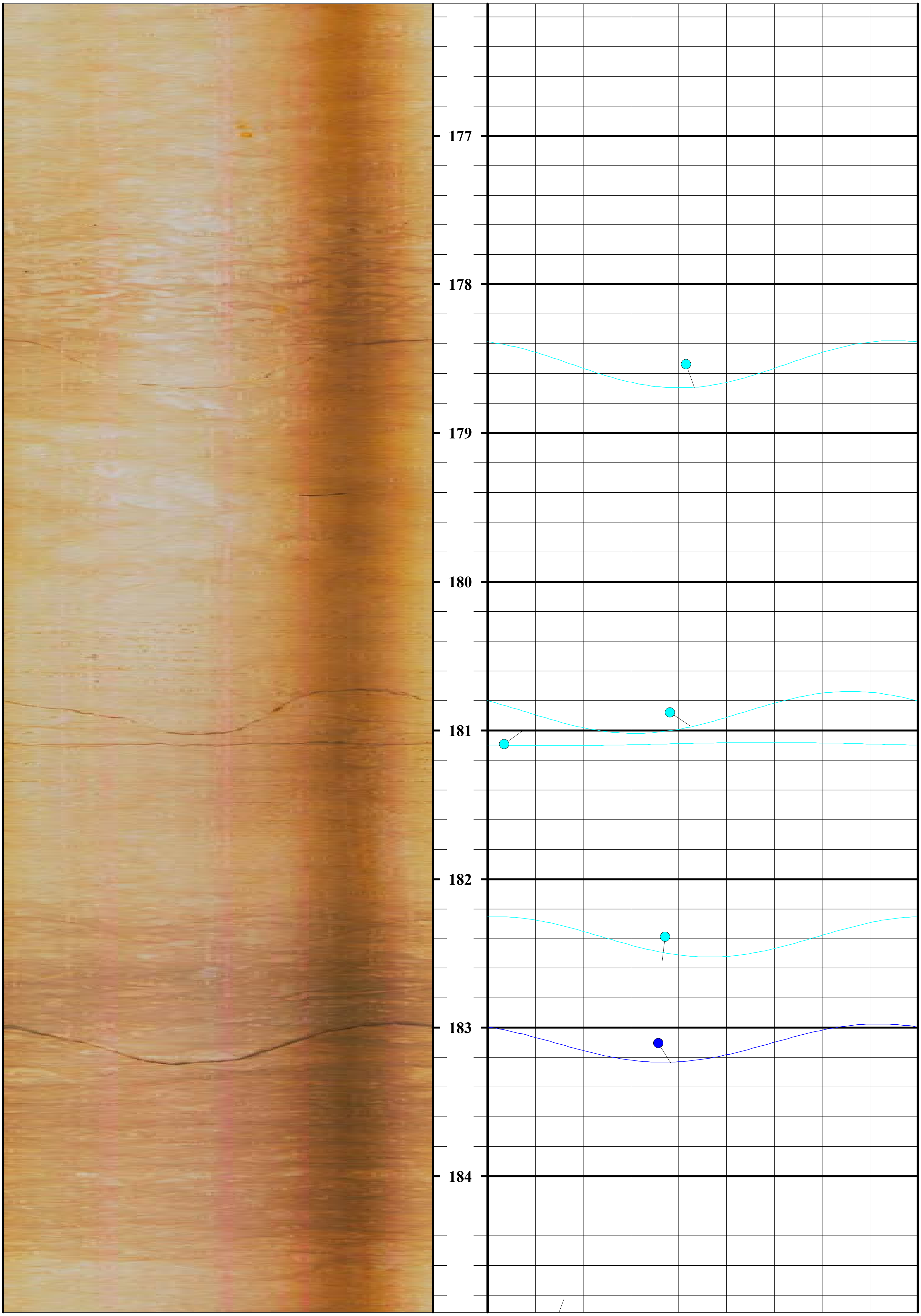
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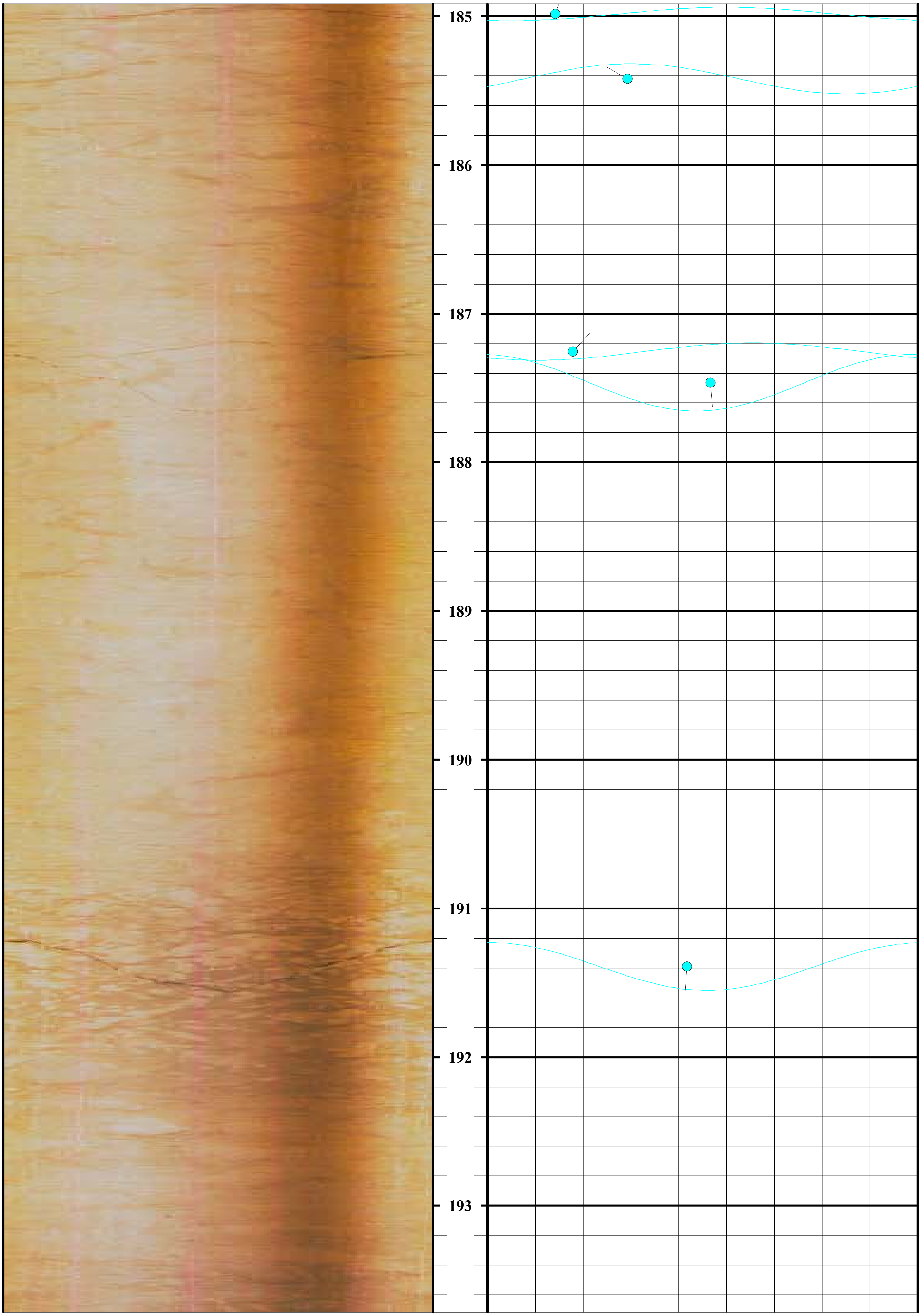
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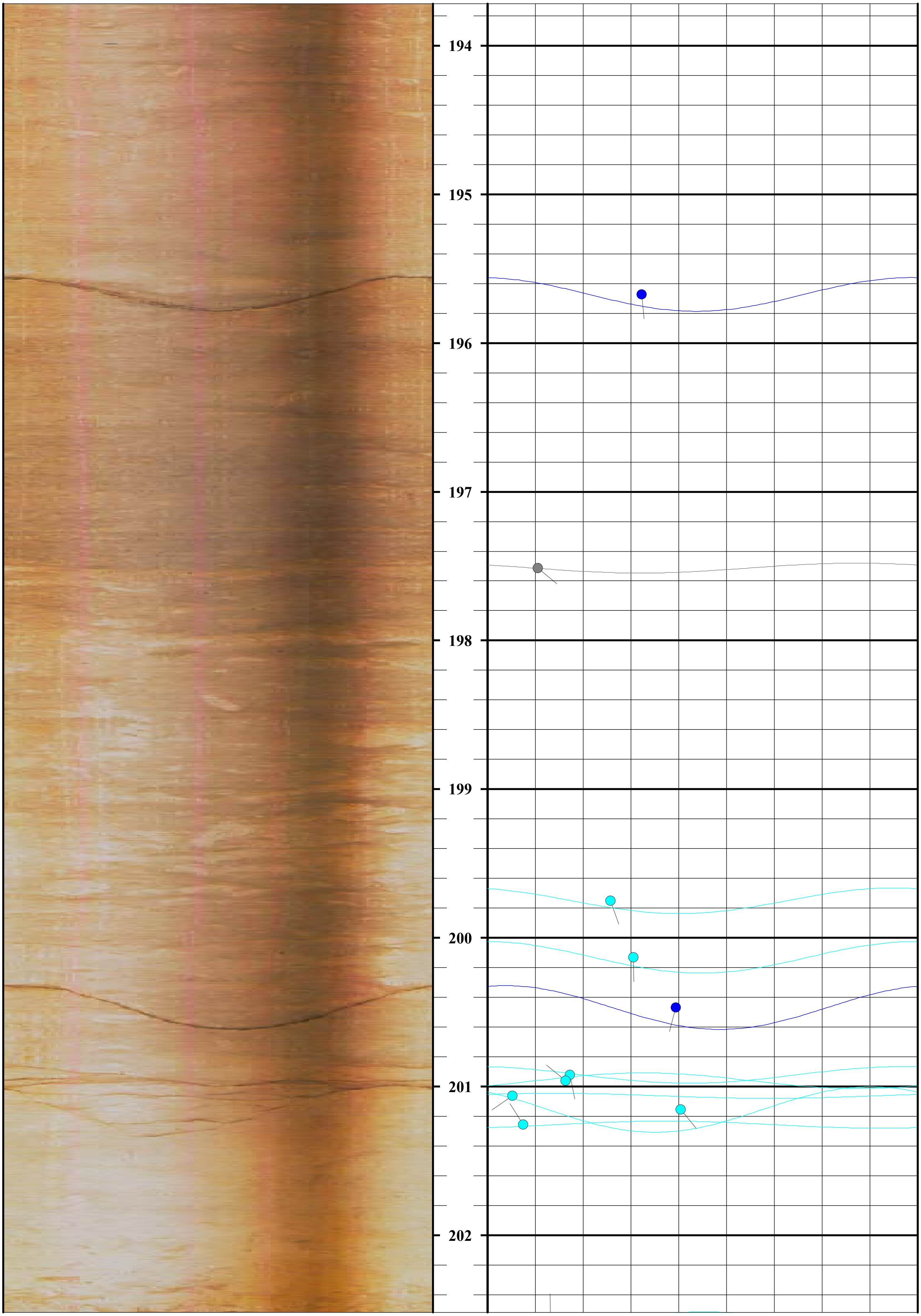
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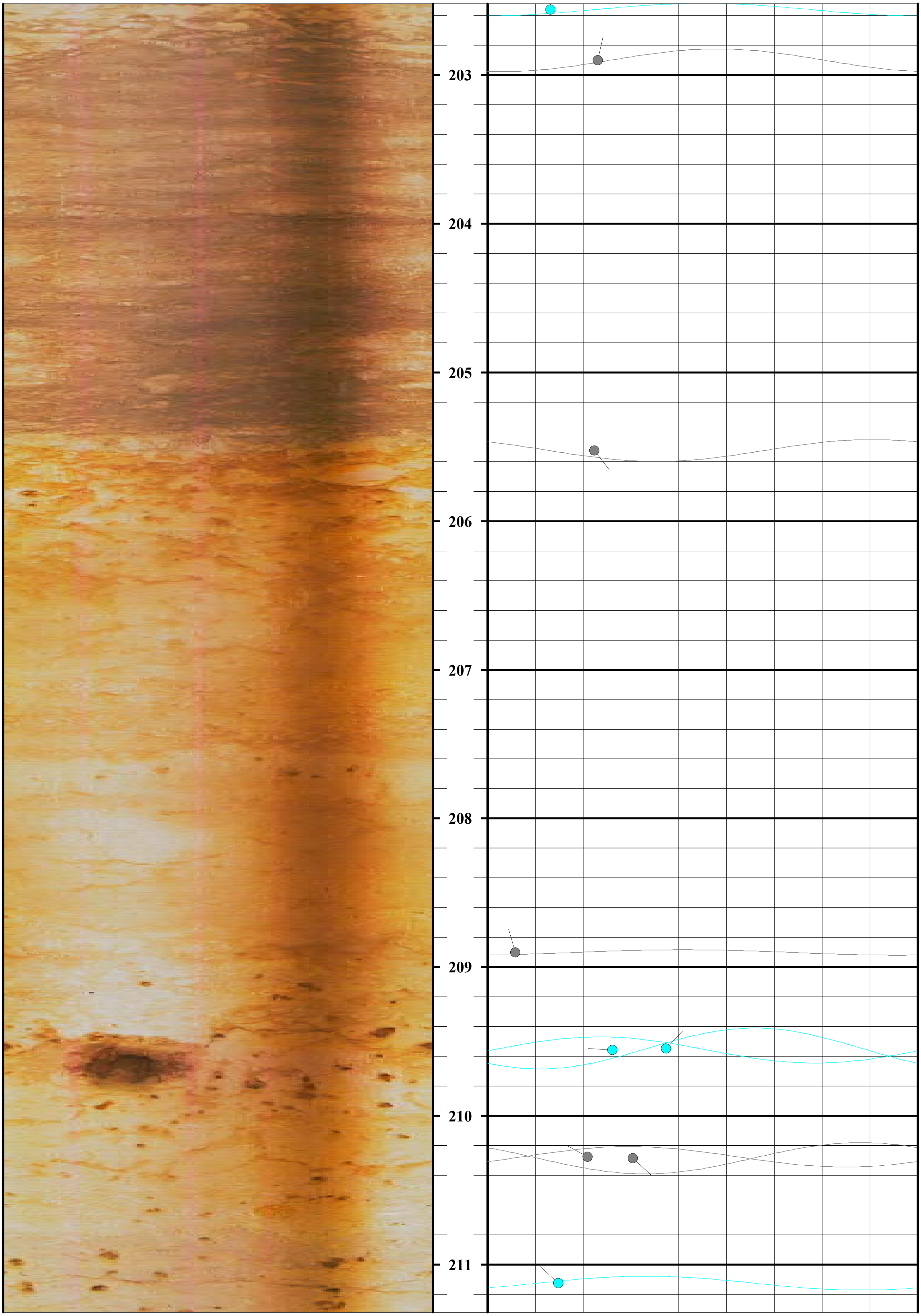
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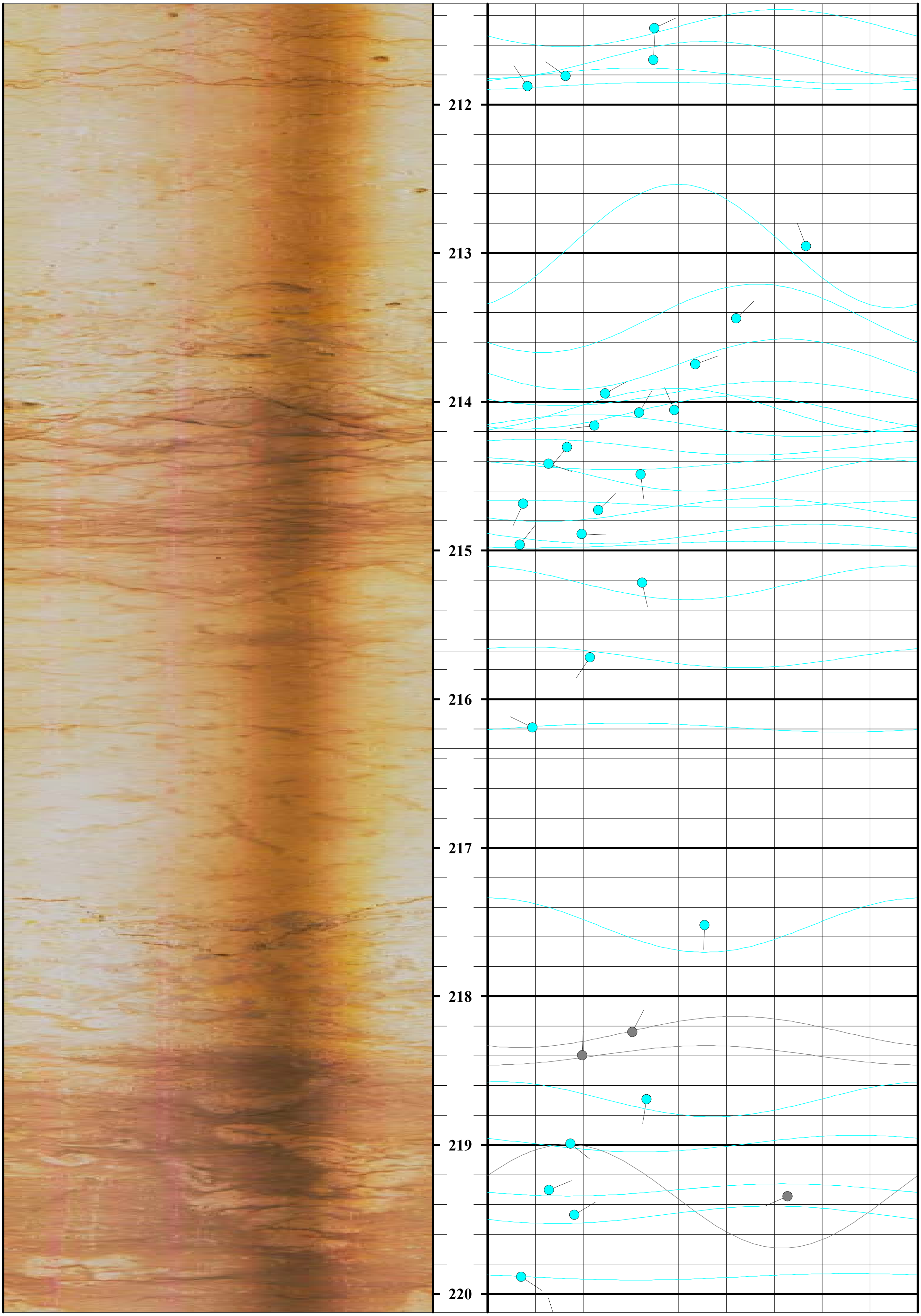
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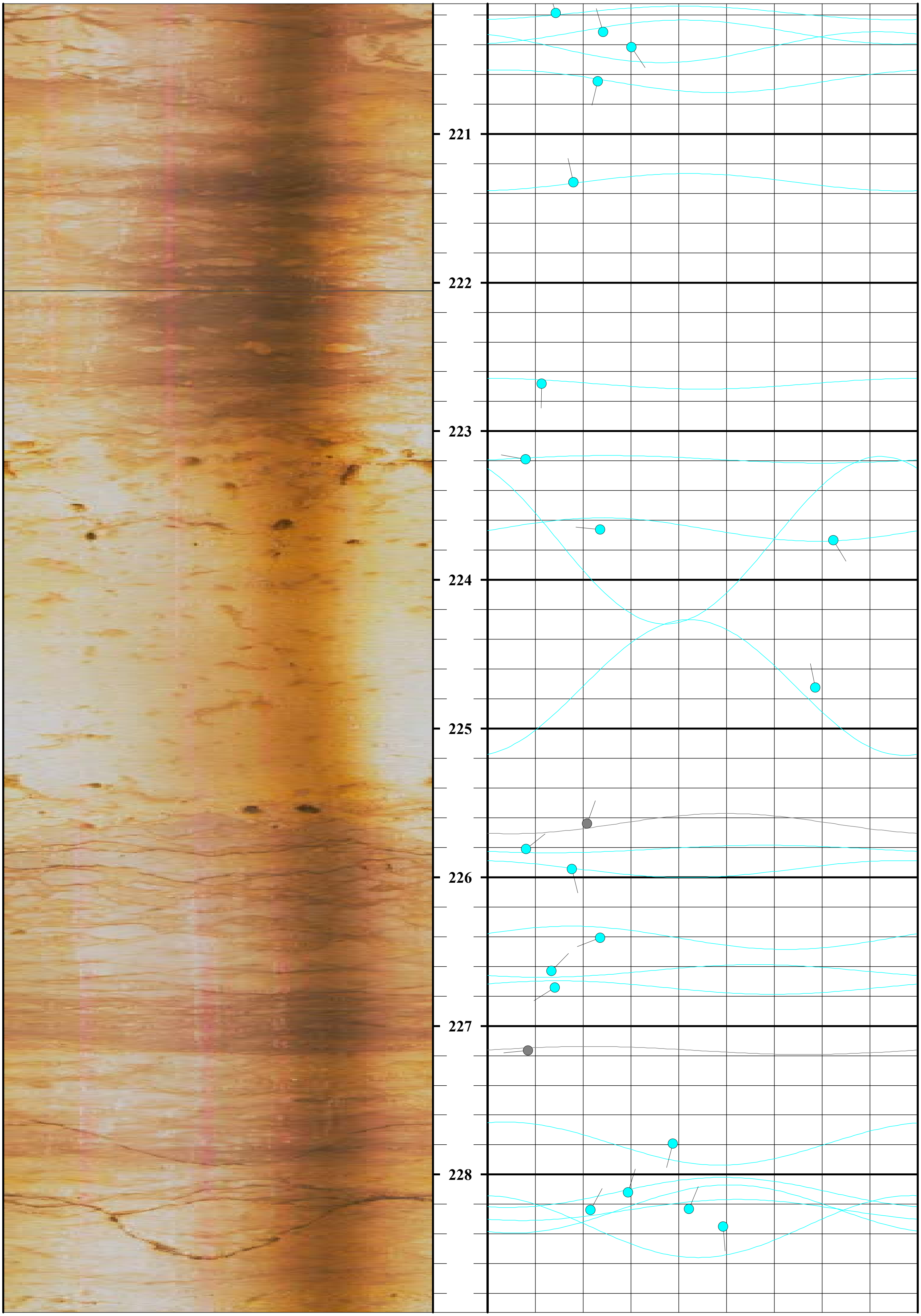
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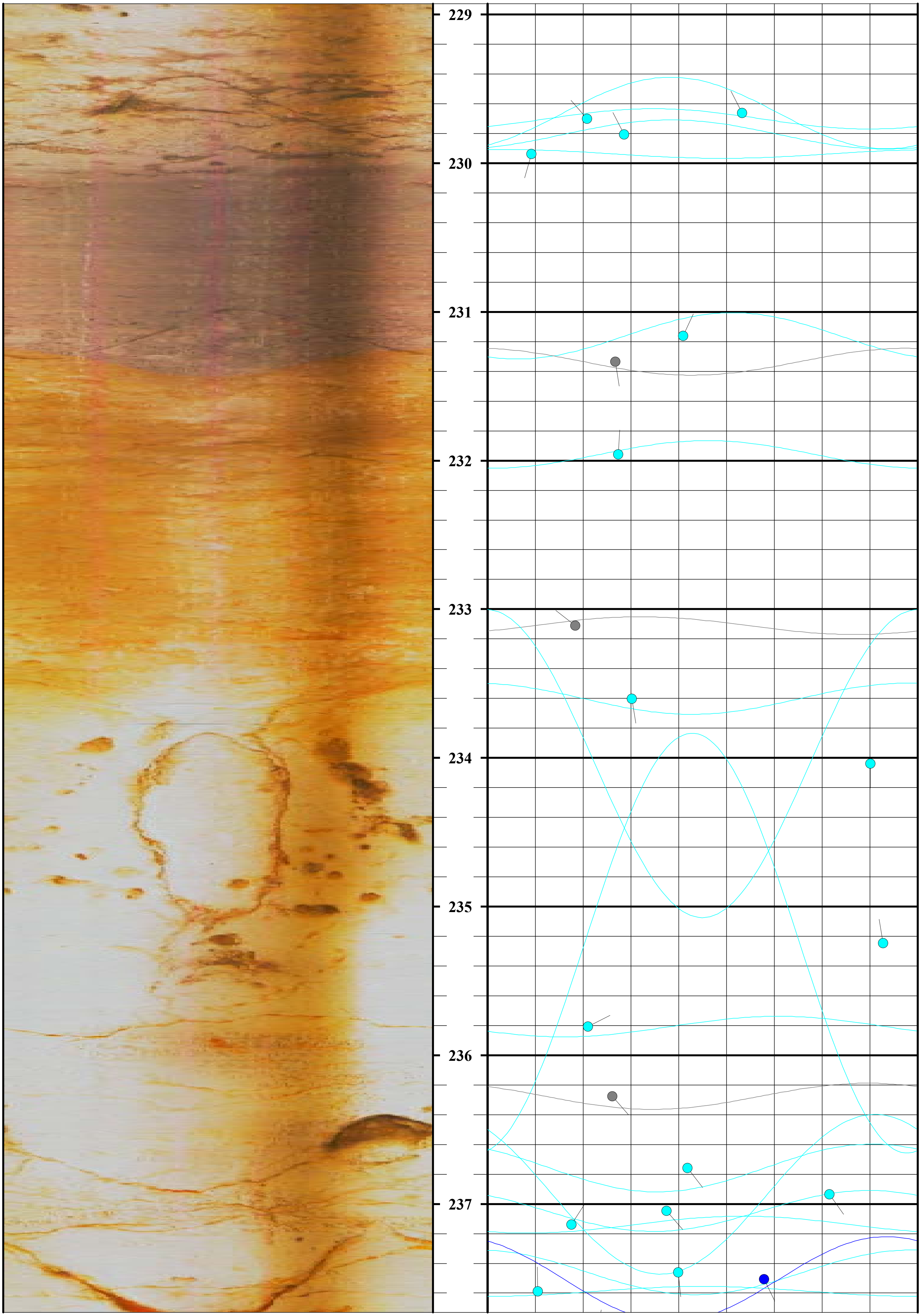
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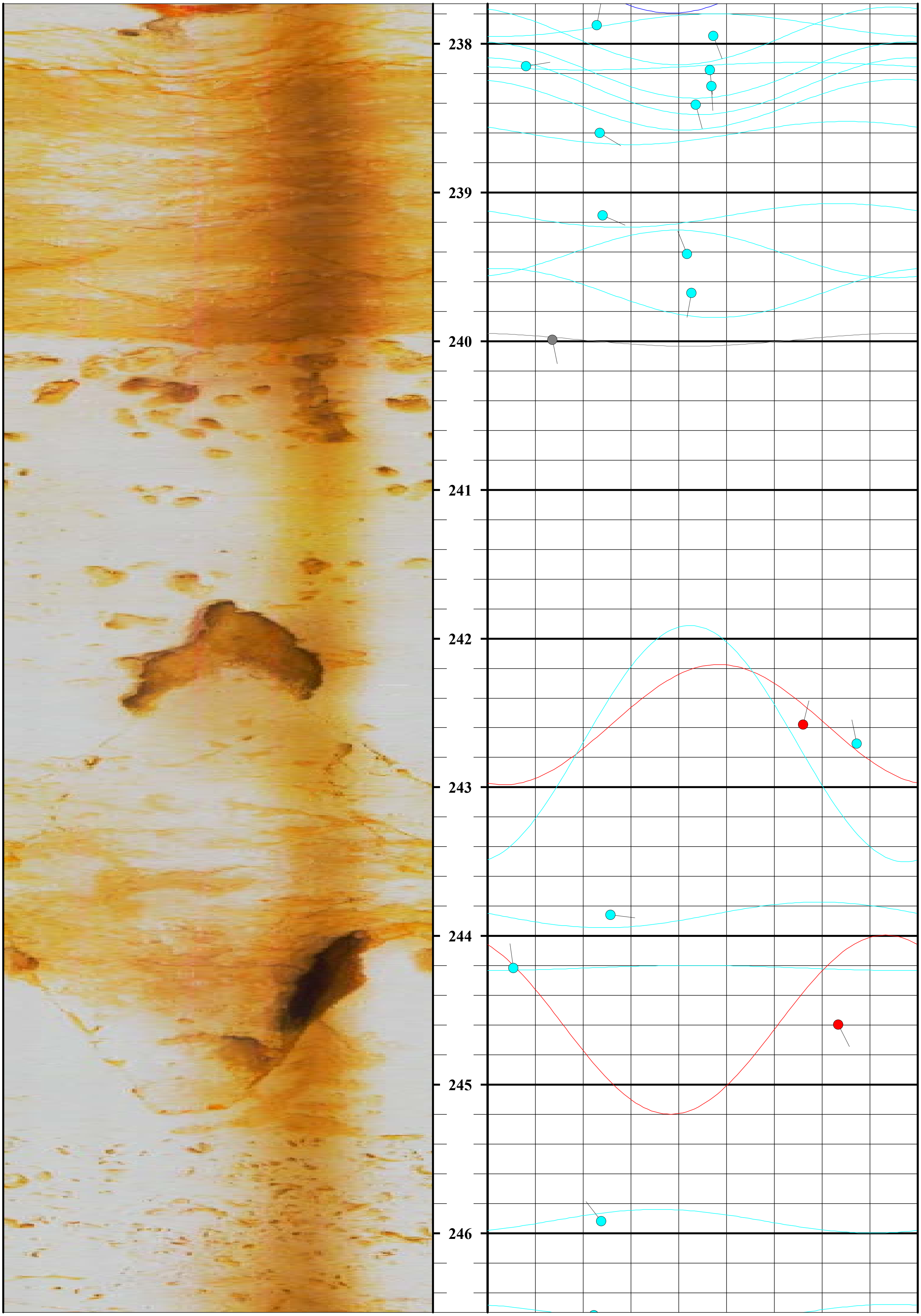
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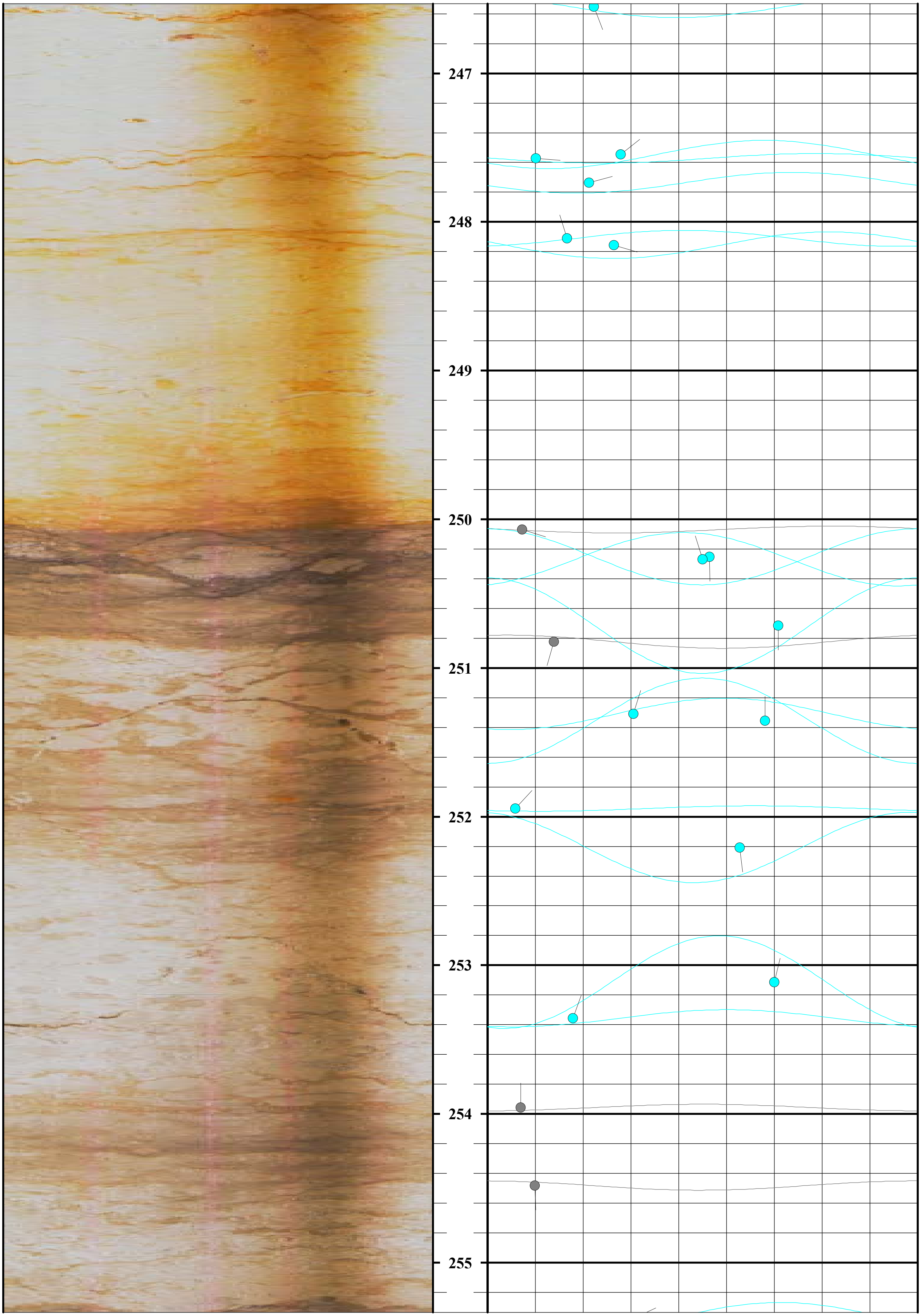
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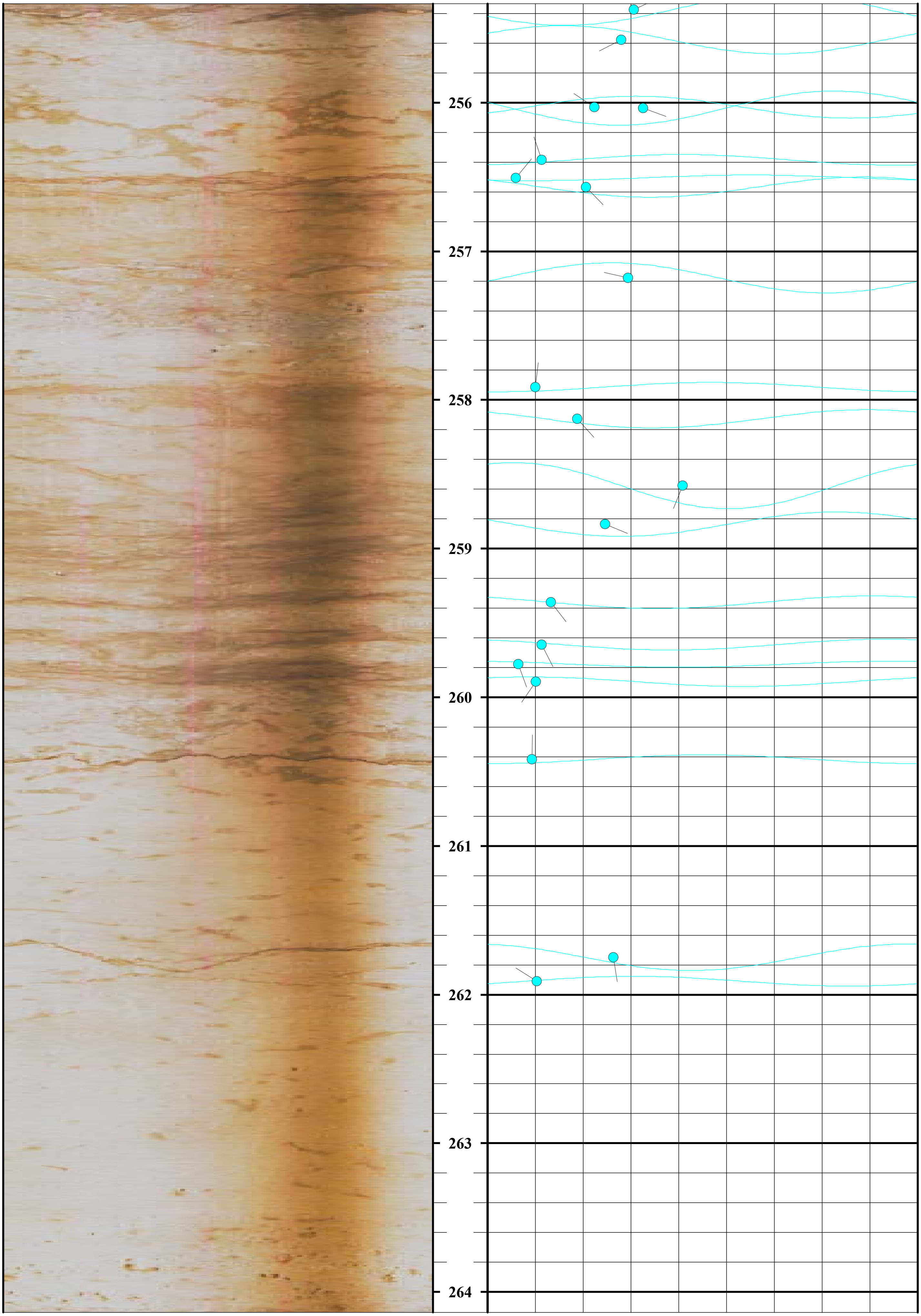
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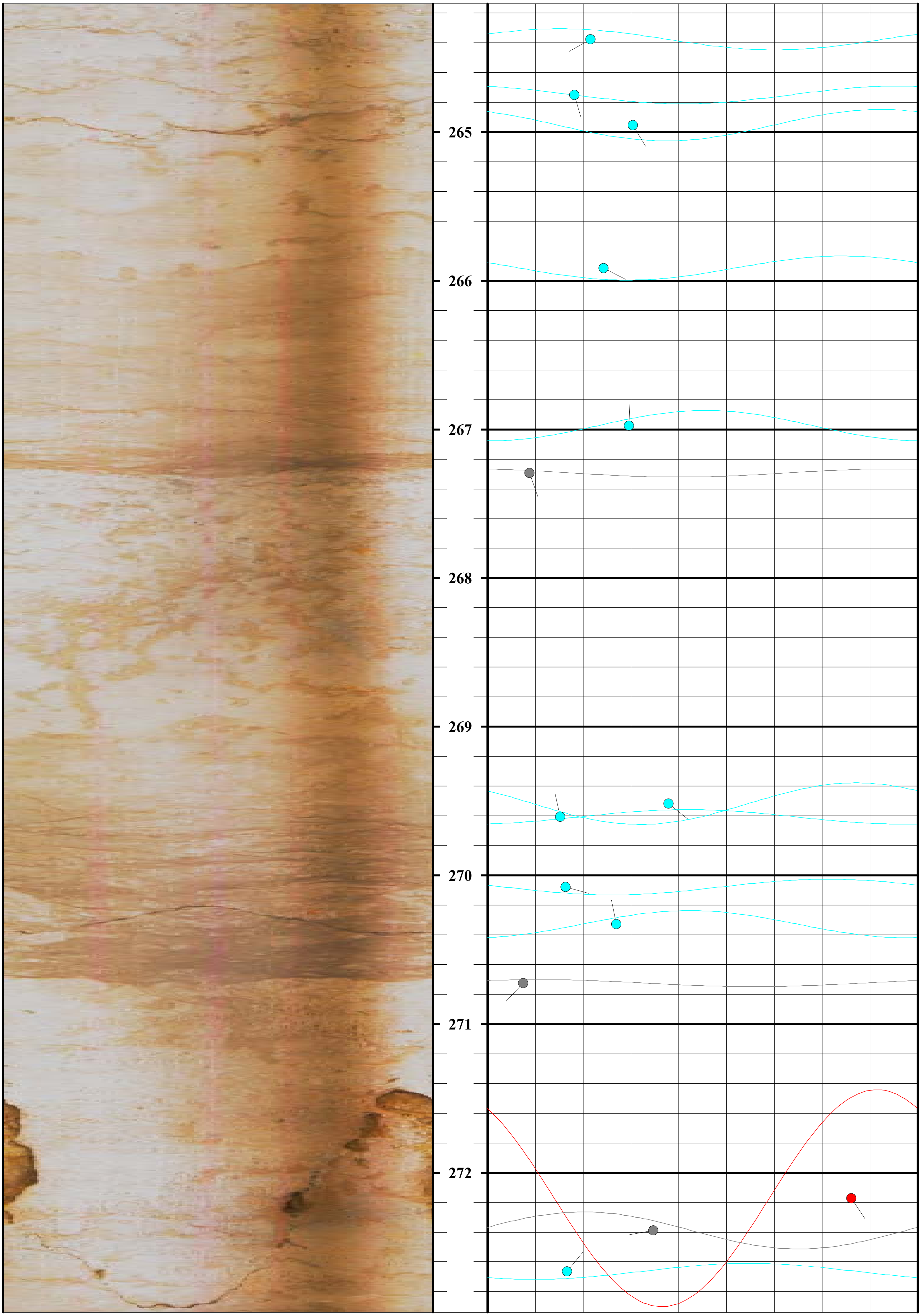
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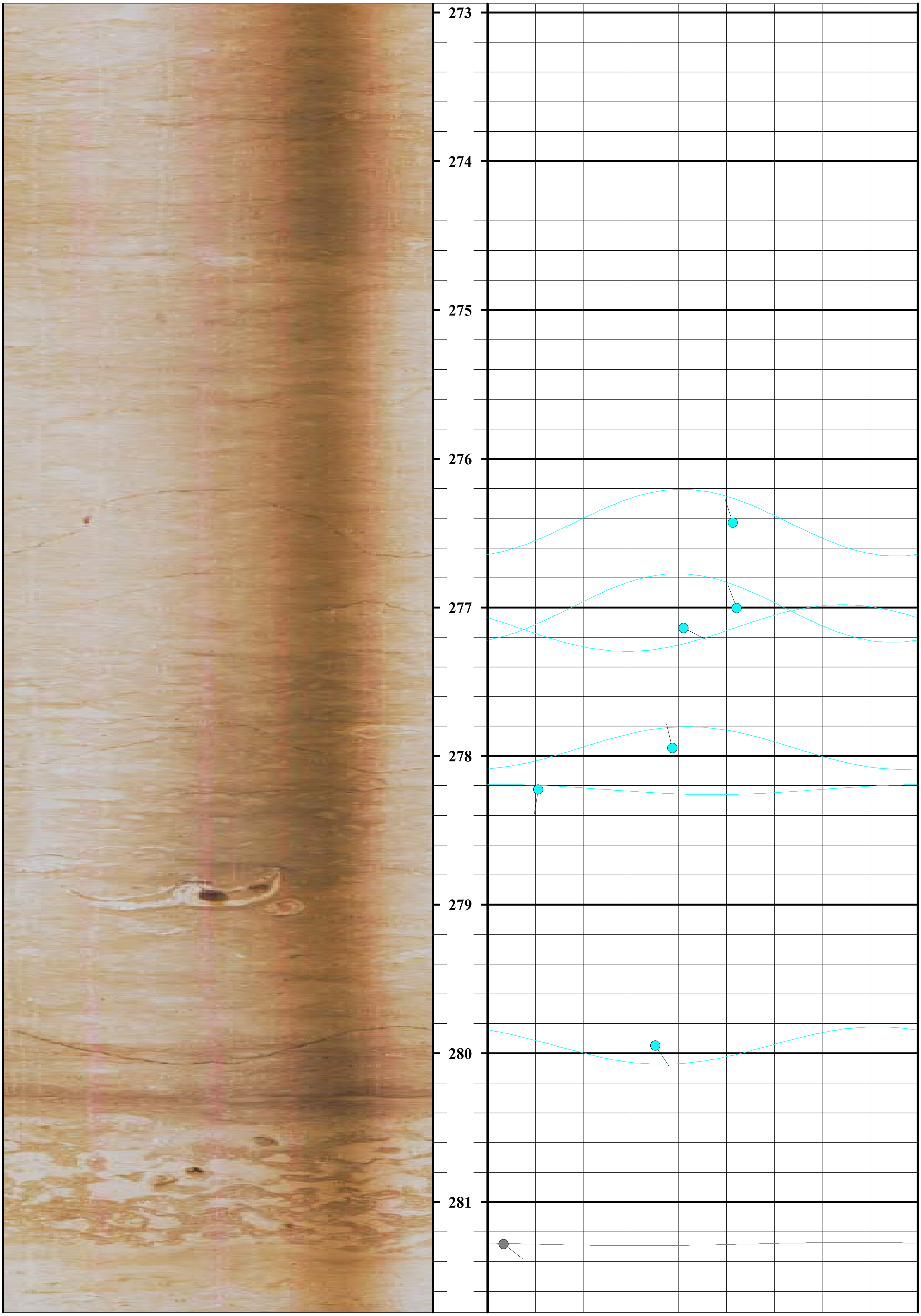
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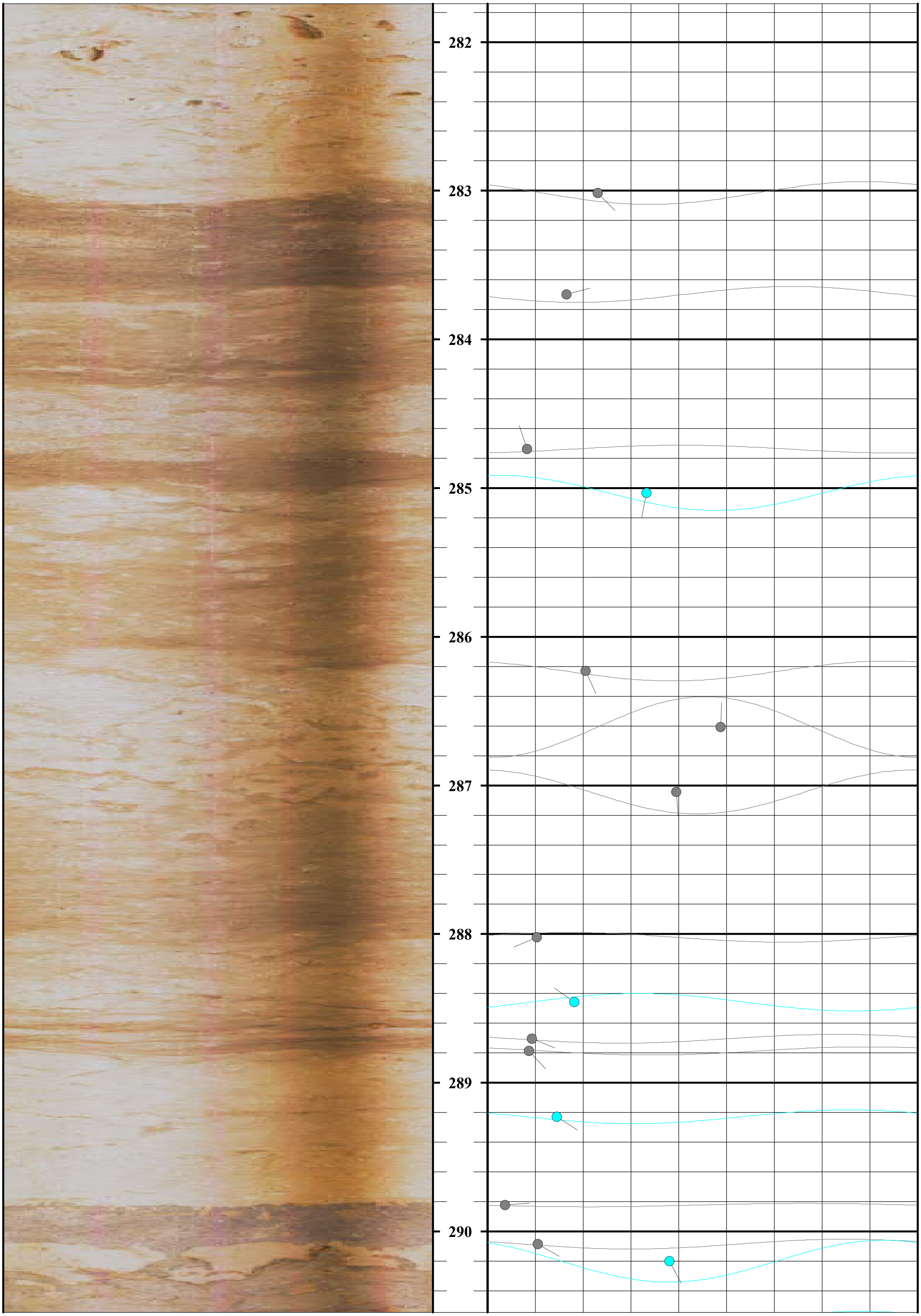
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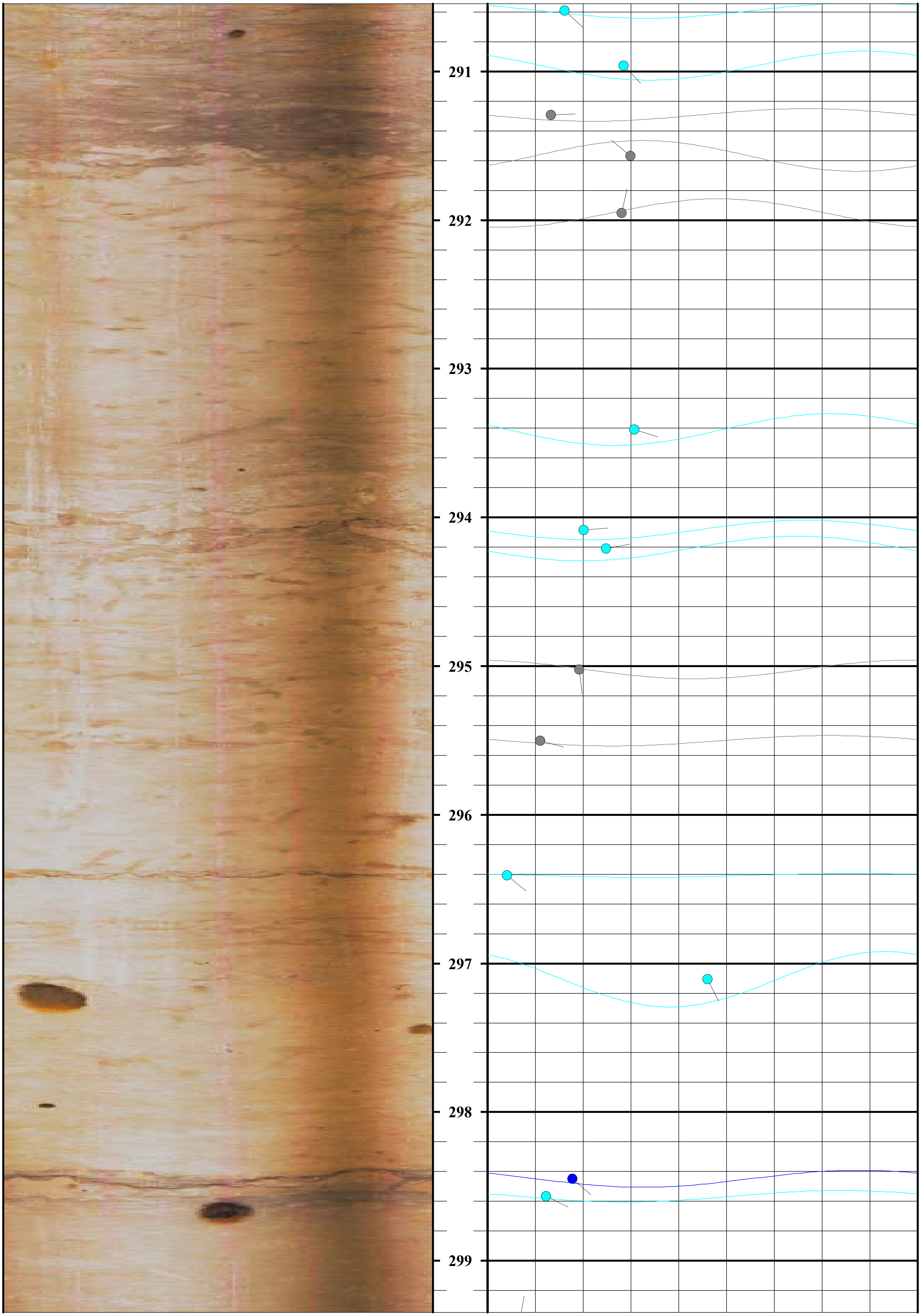
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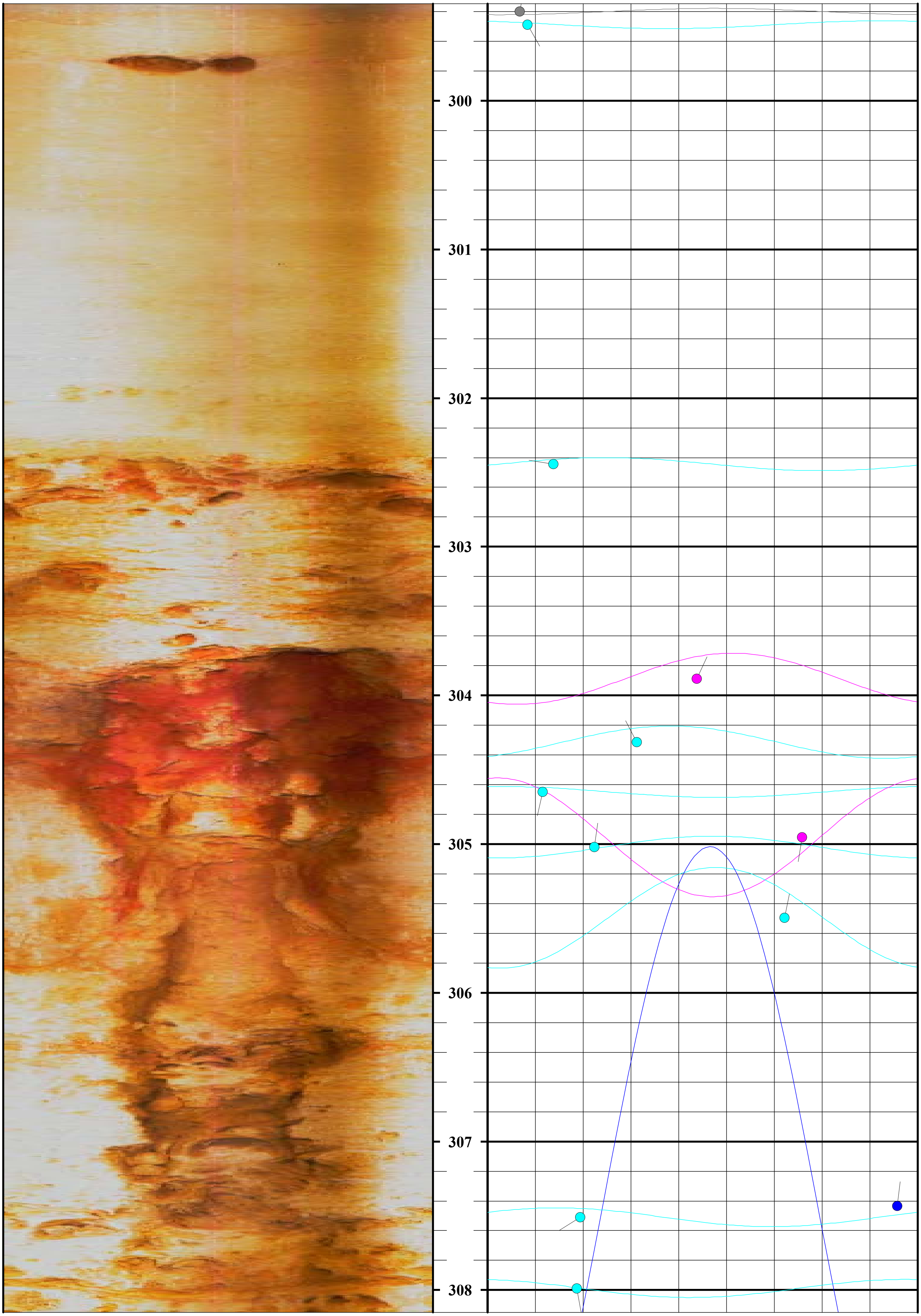
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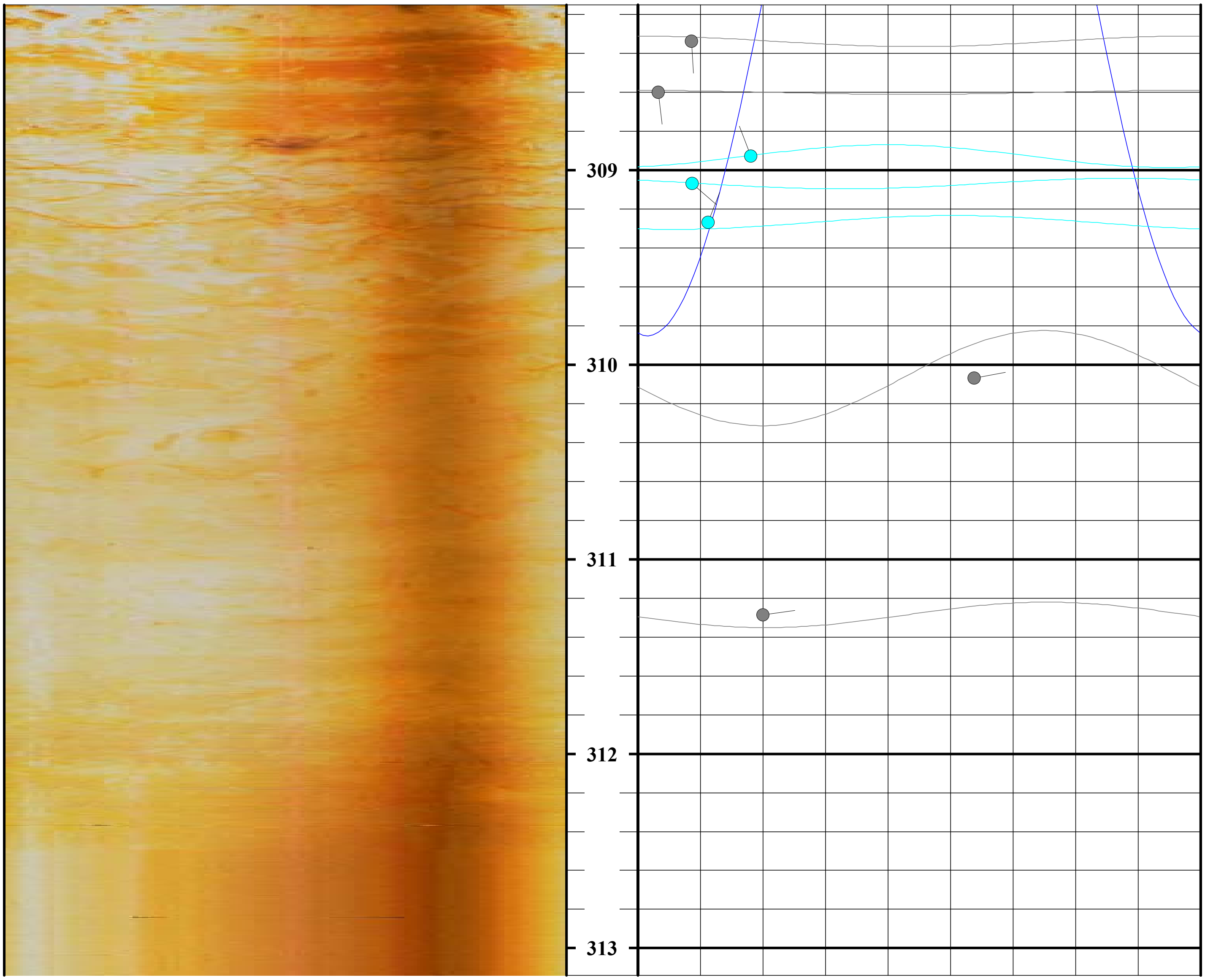
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Orientation Summary Table
Optical Image Features
Camp Stanley Storage Facility, Wellbore: WB-01
Parsons
July 17, 2003

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
1	0.68	2.2	325	25	1
2	0.83	2.7	75	20	1
3	1.02	3.4	6	70	1
4	1.02	3.4	25	21	1
5	1.21	4.0	354	41	1
6	1.24	4.1	342	18	1
7	1.28	4.2	211	37	1
8	1.41	4.6	317	23	1
9	1.44	4.7	189	69	1
10	1.58	5.2	153	35	1
11	1.68	5.5	193	23	1
12	1.86	6.1	177	63	1
13	2.19	7.2	154	8	0
14	2.85	9.4	95	16	1
15	2.94	9.6	24	15	1
16	3.04	10.0	24	10	1
17	3.26	10.7	92	26	1
18	3.38	11.1	95	15	1
19	3.51	11.5	353	24	1
20	3.81	12.5	1	7	1
21	3.90	12.8	128	7	1
22	4.07	13.3	359	6	1
23	4.20	13.8	259	12	1
24	4.34	14.3	10	6	1
25	4.43	14.5	131	8	1
26	4.47	14.7	331	9	1
27	4.56	15.0	36	5	0
28	4.80	15.8	94	5	1
29	4.86	16.0	34	4	1
30	4.88	16.0	91	4	1
31	5.01	16.5	87	53	1
32	5.11	16.8	44	42	1
33	5.35	17.6	163	5	1
34	5.42	17.8	150	7	1
35	5.83	19.1	50	7	1
36	6.02	19.7	307	53	1
37	6.22	20.4	25	27	1
38	6.39	21.0	195	7	0
39	6.57	21.6	223	29	1
40	6.64	21.8	119	5	0
41	6.65	21.8	176	46	1
42	6.67	21.9	118	10	1
43	6.70	22.0	72	3	1
44	6.76	22.2	356	5	1

All directions are with respect to magnetic north.

Orientation Summary Table
Optical Image Features
Camp Stanley Storage Facility, Wellbore: WB-01
Parsons
July 17, 2003

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
45	6.87	22.5	141	13	1
46	6.94	22.8	345	8	1
47	6.96	22.8	10	9	1
48	7.03	23.1	200	8	0
49	7.14	23.4	324	14	0
50	7.29	23.9	90	60	0
51	7.46	24.5	99	6	0
52	7.53	24.7	54	6	0
53	7.61	25.0	84	5	0
54	7.67	25.2	68	5	0
55	7.77	25.5	121	11	0
56	7.85	25.8	114	6	1
57	7.87	25.8	119	4	1
58	7.91	25.9	55	4	3
59	8.07	26.5	111	4	0
60	8.46	27.8	90	4	0
61	8.55	28.1	119	3	0
62	8.60	28.2	93	3	0
63	8.63	28.3	87	1	0
64	8.65	28.4	73	3	0
65	8.71	28.6	72	5	0
66	8.74	28.7	111	4	0
67	8.78	28.8	90	4	0
68	8.81	28.9	98	5	0
69	8.89	29.2	147	10	0
70	8.95	29.4	50	3	0
71	8.97	29.4	93	4	0
72	9.01	29.6	89	3	0
73	9.11	29.9	87	6	0
74	9.17	30.1	253	1	0
75	9.28	30.4	84	8	0
76	9.38	30.8	34	10	0
77	9.46	31.0	42	5	0
78	9.50	31.2	141	7	0
79	9.53	31.3	200	4	0
80	9.65	31.7	334	8	0
81	9.70	31.8	329	9	0
82	9.74	32.0	13	3	0
83	9.83	32.3	29	5	0
84	9.88	32.4	12	43	0
85	10.07	33.1	336	1	0
86	10.19	33.4	12	31	0
87	10.30	33.8	350	5	1
88	10.38	34.1	133	9	0

All directions are with respect to magnetic north.

Orientation Summary Table
Optical Image Features
Camp Stanley Storage Facility, Wellbore: WB-01
Parsons
July 17, 2003

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
89	10.66	35.0	12	6	0
90	10.75	35.3	11	11	0
91	10.80	35.4	8	4	0
92	10.98	36.0	209	10	0
93	11.05	36.3	97	10	0
94	11.20	36.8	175	86	1
95	11.25	36.9	235	7	0
96	11.40	37.4	291	8	1
97	11.49	37.7	126	20	0
98	11.71	38.4	104	14	1
99	11.97	39.3	167	6	1
100	12.06	39.6	69	3	0
101	12.27	40.2	304	70	1
102	12.39	40.7	137	45	1
103	12.40	40.7	321	4	1
104	12.54	41.1	239	69	1
105	12.59	41.3	14	9	1
106	12.80	42.0	5	6	1
107	12.85	42.2	49	4	1
108	12.88	42.3	45	8	0
109	12.97	42.5	334	16	1
110	13.13	43.1	343	58	0
111	13.18	43.2	328	4	0
112	13.30	43.7	165	7	0
113	13.34	43.8	50	2	0
114	13.47	44.2	158	5	0
115	13.52	44.4	153	6	0
116	13.78	45.2	353	55	0
117	13.91	45.6	147	65	0
118	13.93	45.7	320	15	0
119	13.98	45.9	339	13	0
120	14.16	46.5	236	10	0
121	14.69	48.2	167	10	4
122	14.87	48.8	87	23	4
123	14.94	49.0	104	24	1
124	15.05	49.4	309	79	1
125	15.14	49.7	61	4	0
126	15.37	50.4	34	7	0
127	15.52	50.9	246	14	1
128	15.54	51.0	230	23	1
129	15.61	51.2	88	7	3
130	15.67	51.4	152	48	1
131	16.02	52.6	298	9	1
132	16.05	52.7	34	5	1

All directions are with respect to magnetic north.

Orientation Summary Table
Optical Image Features
Camp Stanley Storage Facility, Wellbore: WB-01
Parsons
July 17, 2003

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
133	16.08	52.8	31	5	1
134	16.18	53.1	49	3	0
135	16.24	53.3	112	4	0
136	16.33	53.6	142	3	0
137	16.38	53.7	129	4	0
138	16.41	53.8	95	2	0
139	16.45	54.0	109	6	0
140	16.50	54.1	80	6	0
141	16.55	54.3	112	9	0
142	16.58	54.4	78	3	0
143	17.15	56.3	305	2	0
144	17.30	56.8	91	7	0
145	17.41	57.1	139	5	0
146	17.45	57.3	146	5	0
147	17.49	57.4	129	6	0
148	17.83	58.5	159	15	1
149	17.89	58.7	271	17	1
150	18.07	59.3	99	35	0
151	18.21	59.8	77	30	1
152	18.84	61.8	132	55	2
153	18.90	62.0	109	21	1
154	18.92	62.1	328	13	1
155	19.03	62.4	356	31	1
156	19.05	62.5	131	31	1
157	19.11	62.7	143	10	1
158	19.15	62.8	188	22	1
159	19.22	63.1	126	48	1
160	19.25	63.1	23	16	1
161	19.29	63.3	329	9	1
162	19.32	63.4	328	17	1
163	19.39	63.6	126	22	1
164	19.41	63.7	269	30	1
165	19.46	63.9	159	18	1
166	19.51	64.0	353	13	1
167	19.56	64.2	357	19	1
168	19.57	64.2	89	7	0
169	19.62	64.4	6	11	1
170	19.67	64.5	332	18	1
171	19.72	64.7	57	17	1
172	19.95	65.4	137	12	1
173	20.02	65.7	352	37	1
174	20.04	65.7	229	17	1
175	20.14	66.1	325	26	1
176	20.17	66.2	76	14	0

All directions are with respect to magnetic north.

Orientation Summary Table
Optical Image Features
Camp Stanley Storage Facility, Wellbore: WB-01
Parsons
July 17, 2003

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
177	20.36	66.8	159	10	1
178	20.41	67.0	162	11	1
179	20.44	67.1	205	8	1
180	20.46	67.1	202	14	1
181	20.50	67.3	163	9	1
182	20.54	67.4	196	7	0
183	20.89	68.5	190	46	1
184	20.92	68.6	299	11	1
185	21.57	70.8	39	11	0
186	22.43	73.6	43	9	1
187	22.58	74.1	345	17	1
188	22.62	74.2	358	16	1
189	22.90	75.1	357	4	0
190	23.06	75.6	310	12	0
191	23.18	76.1	118	13	0
192	23.23	76.2	141	14	2
193	23.40	76.8	155	74	1
194	23.44	76.9	346	72	1
195	23.67	77.7	220	3	0
196	23.88	78.3	210	3	1
197	23.90	78.4	209	8	1
198	24.11	79.1	66	21	1
199	24.13	79.2	215	38	2
200	24.21	79.4	239	46	1
201	24.41	80.1	238	22	1
202	24.59	80.7	359	21	0
203	24.69	81.0	319	7	0
204	24.87	81.6	121	9	0
205	25.09	82.3	303	69	2
206	25.14	82.5	271	10	1
207	25.33	83.1	332	39	1
208	25.43	83.4	184	17	1
209	25.45	83.5	273	31	1
210	25.50	83.7	119	9	1
211	25.56	83.9	122	26	1
212	25.61	84.0	96	30	1
213	25.68	84.2	124	16	1
214	25.75	84.5	142	11	1
215	25.86	84.8	108	5	0
216	25.95	85.1	36	5	0
217	26.00	85.3	82	3	0
218	26.39	86.6	94	7	0
219	26.43	86.7	260	13	1
220	26.53	87.0	145	82	0

All directions are with respect to magnetic north.

Orientation Summary Table
Optical Image Features
Camp Stanley Storage Facility, Wellbore: WB-01
Parsons
July 17, 2003

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
221	26.77	87.8	15	5	0
222	26.84	88.1	269	45	0
223	27.45	90.1	360	38	1
224	27.45	90.1	149	49	2
225	27.49	90.2	8	65	1
226	27.91	91.6	87	16	0
227	28.30	92.8	104	4	0
228	28.39	93.1	129	6	1
229	28.49	93.5	128	5	0
230	28.91	94.9	354	6	0
231	29.08	95.4	177	5	0
232	29.27	96.0	2	10	0
233	29.53	96.9	357	63	1
234	29.56	97.0	342	45	1
235	29.76	97.7	206	3	1
236	30.11	98.8	61	21	1
237	30.25	99.3	55	16	1
238	30.39	99.7	214	10	1
239	30.68	100.7	235	8	1
240	30.73	100.8	169	11	1
241	31.57	103.6	37	13	0
242	32.09	105.3	177	24	0
243	32.36	106.2	141	54	2
244	32.38	106.2	153	67	1
245	32.74	107.4	70	4	1
246	32.85	107.8	163	85	1
247	32.89	107.9	353	75	1
248	32.94	108.1	174	21	1
249	32.95	108.1	162	50	1
250	33.39	109.6	238	8	1
251	33.40	109.6	252	10	1
252	33.42	109.7	230	6	1
253	33.58	110.2	151	36	1
254	33.77	110.8	86	8	0
255	33.99	111.5	190	5	0
256	34.08	111.8	187	4	0
257	34.15	112.0	40	16	1
258	34.59	113.5	162	49	1
259	34.95	114.7	29	22	0
260	35.18	115.4	147	10	1
261	35.35	116.0	96	26	1
262	35.48	116.4	148	54	1
263	35.81	117.5	121	19	1
264	37.35	122.5	155	65	1

All directions are with respect to magnetic north.

Orientation Summary Table
Optical Image Features
Camp Stanley Storage Facility, Wellbore: WB-01
Parsons
July 17, 2003

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
265	38.46	126.2	135	47	1
266	38.85	127.5	130	42	1
267	38.87	127.5	28	10	1
268	38.90	127.6	343	1	1
269	39.49	129.6	203	6	1
270	39.57	129.8	198	8	1
271	39.63	130.0	320	10	1
272	40.12	131.6	287	8	1
273	42.31	138.8	325	5	1
274	42.50	139.4	126	0	2
275	43.14	141.5	211	5	0
276	44.37	145.6	213	6	1
277	45.80	150.3	352	38	1
278	46.65	153.1	112	13	0
279	46.89	153.8	32	16	0
280	47.26	155.0	242	22	0
281	47.48	155.8	143	7	1
282	47.70	156.5	184	8	1
283	47.91	157.2	206	30	0
284	48.87	160.3	88	12	1
285	49.72	163.1	176	6	1
286	50.12	164.4	112	32	1
287	50.18	164.6	153	16	1
288	50.32	165.1	64	17	1
289	50.86	166.9	47	31	1
290	51.11	167.7	202	11	1
291	51.62	169.4	175	42	2
292	51.72	169.7	34	7	1
293	51.85	170.1	161	26	1
294	51.86	170.2	14	5	1
295	51.88	170.2	17	5	1
296	52.00	170.6	359	40	1
297	52.82	173.3	324	7	1
298	52.82	173.3	160	12	1
299	52.84	173.4	220	8	1
300	52.86	173.4	183	11	1
301	54.42	178.5	160	42	1
302	55.13	180.9	124	38	1
303	55.20	181.1	54	3	1
304	55.59	182.4	186	37	1
305	55.81	183.1	148	36	2
306	56.38	185.0	20	14	1
307	56.52	185.4	301	29	1
308	57.07	187.3	42	18	1

All directions are with respect to magnetic north.

Orientation Summary Table
Optical Image Features
Camp Stanley Storage Facility, Wellbore: WB-01
Parsons
July 17, 2003

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
309	57.14	187.5	175	47	1
310	58.34	191.4	184	42	1
311	59.64	195.7	175	32	2
312	60.20	197.5	128	11	0
313	60.88	199.8	161	26	1
314	61.00	200.1	178	31	1
315	61.10	200.5	194	39	2
316	61.24	200.9	169	17	1
317	61.25	201.0	310	16	1
318	61.28	201.1	235	5	1
319	61.31	201.2	140	41	1
320	61.34	201.3	329	8	1
321	61.74	202.6	360	13	1
322	61.84	202.9	12	23	0
323	62.65	205.5	142	22	0
324	63.67	208.9	344	6	0
325	63.87	209.6	43	37	1
326	63.87	209.6	274	26	1
327	64.09	210.3	299	21	0
328	64.09	210.3	132	30	0
329	64.35	211.1	312	15	1
330	64.46	211.5	65	35	1
331	64.53	211.7	4	35	1
332	64.56	211.8	305	16	1
333	64.58	211.9	327	8	1
334	64.91	213.0	339	67	1
335	65.06	213.4	46	52	1
336	65.15	213.8	70	44	1
337	65.21	213.9	61	25	1
338	65.24	214.1	336	39	1
339	65.25	214.1	30	32	1
340	65.28	214.2	264	22	1
341	65.32	214.3	219	17	1
342	65.36	214.4	108	13	1
343	65.38	214.5	174	32	1
344	65.43	214.7	204	7	1
345	65.45	214.7	47	23	1
346	65.50	214.9	92	20	1
347	65.52	215.0	39	7	1
348	65.60	215.2	167	32	1
349	65.75	215.7	213	21	1
350	65.89	216.2	296	9	1
351	66.30	217.5	182	46	1
352	66.52	218.2	27	30	0

All directions are with respect to magnetic north.

Orientation Summary Table
Optical Image Features
Camp Stanley Storage Facility, Wellbore: WB-01
Parsons
July 17, 2003

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
353	66.57	218.4	3	20	0
354	66.66	218.7	189	33	1
355	66.75	219.0	128	17	1
356	66.84	219.3	67	13	1
357	66.86	219.4	247	63	0
358	66.89	219.5	58	18	1
359	67.02	219.9	124	7	1
360	67.11	220.2	343	14	1
361	67.15	220.3	344	24	1
362	67.18	220.4	146	30	1
363	67.25	220.7	194	23	1
364	67.46	221.3	348	18	1
365	67.87	222.7	181	11	1
366	68.03	223.2	280	8	1
367	68.17	223.7	276	24	1
368	68.19	223.7	149	72	1
369	68.49	224.7	349	69	1
370	68.78	225.6	19	21	0
371	68.83	225.8	52	8	1
372	68.87	225.9	167	18	1
373	69.01	226.4	249	24	1
374	69.08	226.6	45	13	1
375	69.11	226.7	238	14	1
376	69.24	227.2	265	9	0
377	69.43	227.8	194	39	1
378	69.53	228.1	17	29	1
379	69.56	228.2	22	42	1
380	69.57	228.2	28	22	1
381	69.60	228.4	176	49	1
382	70.00	229.7	333	53	1
383	70.01	229.7	319	21	1
384	70.05	229.8	334	29	1
385	70.09	229.9	196	9	1
386	70.46	231.2	25	41	1
387	70.51	231.3	171	27	0
388	70.70	232.0	4	27	1
389	71.05	233.1	308	18	0
390	71.20	233.6	171	30	1
391	71.34	234.0	180	80	1
392	71.70	235.3	351	83	1
393	71.87	235.8	63	21	1
394	72.02	236.3	138	26	0
395	72.16	236.8	142	42	1
396	72.22	236.9	144	72	1

All directions are with respect to magnetic north.

Orientation Summary Table
Optical Image Features
Camp Stanley Storage Facility, Wellbore: WB-01
Parsons
July 17, 2003

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
397	72.25	237.1	139	38	1
398	72.28	237.1	33	18	1
399	72.38	237.5	174	40	1
400	72.39	237.5	154	58	2
401	72.42	237.6	360	11	1
402	72.50	237.9	10	23	1
403	72.53	238.0	159	47	1
404	72.59	238.2	81	8	1
405	72.60	238.2	174	47	1
406	72.63	238.3	177	47	1
407	72.67	238.4	165	44	1
408	72.73	238.6	120	23	1
409	72.89	239.2	113	24	1
410	72.97	239.4	339	42	1
411	73.05	239.7	190	43	1
412	73.15	240.0	168	14	0
413	73.94	242.6	13	66	3
414	73.98	242.7	349	77	1
415	74.33	243.9	97	26	1
416	74.44	244.2	353	5	1
417	74.55	244.6	153	73	3
418	74.96	245.9	322	24	1
419	75.15	246.6	159	22	1
420	75.45	247.6	52	28	1
421	75.46	247.6	95	10	1
422	75.51	247.7	75	21	1
423	75.62	248.1	344	17	1
424	75.64	248.2	105	27	1
425	76.22	250.1	107	7	0
426	76.28	250.3	179	47	1
427	76.28	250.3	344	45	1
428	76.42	250.7	180	61	1
429	76.45	250.8	196	14	0
430	76.60	251.3	18	31	1
431	76.61	251.4	0	58	1
432	76.79	252.0	43	6	1
433	76.87	252.2	173	53	1
434	77.15	253.1	14	60	1
435	77.22	253.4	20	18	1
436	77.41	254.0	0	7	0
437	77.57	254.5	177	10	0
438	77.84	255.4	65	31	1
439	77.90	255.6	243	28	1
440	78.04	256.0	303	22	1

All directions are with respect to magnetic north.

Orientation Summary Table
Optical Image Features
Camp Stanley Storage Facility, Wellbore: WB-01
Parsons
July 17, 2003

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
441	78.04	256.0	110	33	1
442	78.14	256.4	342	11	1
443	78.18	256.5	39	6	1
444	78.20	256.6	135	21	1
445	78.39	257.2	283	29	1
446	78.61	257.9	7	10	1
447	78.68	258.1	138	19	1
448	78.82	258.6	202	41	1
449	78.89	258.8	112	25	1
450	79.05	259.4	142	13	1
451	79.14	259.7	152	11	1
452	79.18	259.8	160	6	1
453	79.22	259.9	215	10	1
454	79.38	260.4	1	9	1
455	79.78	261.8	171	26	1
456	79.83	261.9	302	10	1
457	80.58	264.4	241	22	1
458	80.70	264.8	163	18	1
459	80.76	265.0	149	30	1
460	81.05	265.9	117	24	1
461	81.37	267.0	2	30	1
462	81.47	267.3	161	9	0
463	82.15	269.5	128	38	1
464	82.18	269.6	347	15	1
465	82.32	270.1	104	16	1
466	82.40	270.3	349	27	1
467	82.52	270.7	223	8	0
468	82.96	272.2	146	76	3
469	83.02	272.4	260	35	0
470	83.11	272.7	39	17	1
471	84.26	276.4	342	51	1
472	84.43	277.0	339	52	1
473	84.47	277.1	117	41	1
474	84.72	278.0	347	39	1
475	84.80	278.2	189	11	1
476	85.33	280.0	146	35	1
477	85.73	281.3	127	3	0
478	86.26	283.0	136	23	0
479	86.47	283.7	75	17	0
480	86.79	284.7	342	8	0
481	86.88	285.0	191	33	1
482	87.24	286.2	155	21	0
483	87.36	286.6	2	49	0
484	87.49	287.0	176	40	0

All directions are with respect to magnetic north.

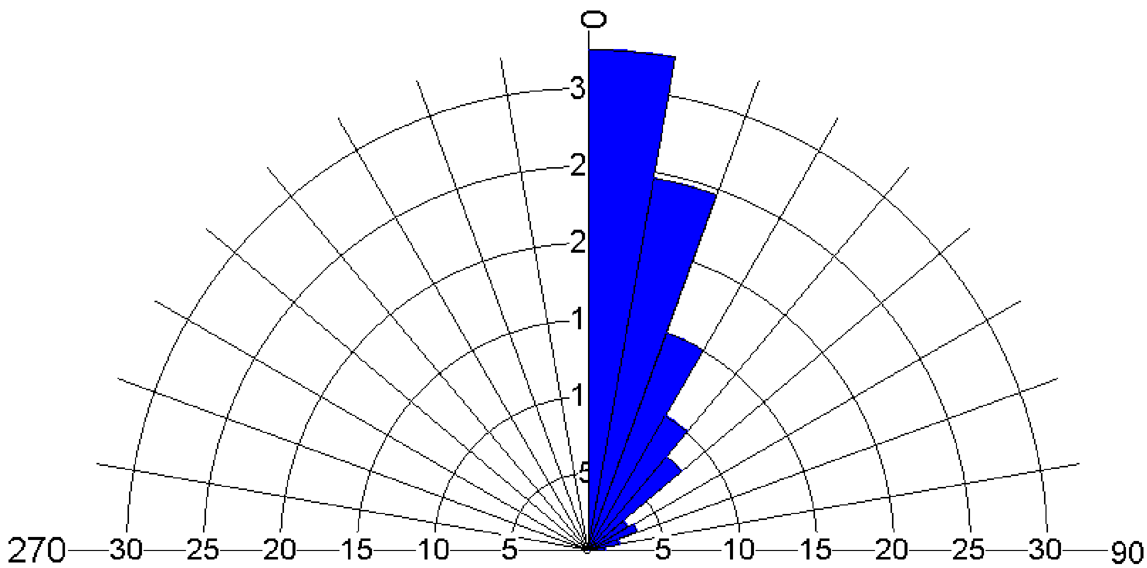
Orientation Summary Table
Optical Image Features
Camp Stanley Storage Facility, Wellbore: WB-01
Parsons
July 17, 2003

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
485	87.79	288.0	248	10	0
486	87.92	288.5	306	18	1
487	88.00	288.7	111	9	0
488	88.02	288.8	137	9	0
489	88.16	289.2	122	15	1
490	88.34	289.8	85	4	0
491	88.42	290.1	120	11	0
492	88.45	290.2	152	38	1
493	88.57	290.6	132	16	1
494	88.68	291.0	135	29	1
495	88.79	291.3	88	13	0
496	88.87	291.6	309	30	0
497	88.99	292.0	13	28	0
498	89.43	293.4	107	31	1
499	89.64	294.1	85	20	1
500	89.68	294.2	79	25	1
501	89.92	295.0	173	19	0
502	90.07	295.5	105	11	0
503	90.35	296.4	129	4	1
504	90.56	297.1	153	46	1
505	90.97	298.5	130	18	2
506	91.00	298.6	115	12	1
507	91.26	299.4	10	7	0
508	91.28	299.5	151	8	1
509	92.18	302.4	279	14	1
510	92.63	303.9	25	44	4
511	92.75	304.3	333	31	1
512	92.86	304.7	192	12	1
513	92.95	305.0	188	66	4
514	92.97	305.0	8	22	1
515	93.12	305.5	11	62	1
516	93.70	307.4	6	86	2
517	93.73	307.5	238	19	1
518	93.88	308.0	169	19	1
519	93.98	308.3	177	9	0
520	94.06	308.6	173	3	0
521	94.16	308.9	340	18	1
522	94.20	309.1	131	9	1
523	94.27	309.3	21	11	1
524	94.51	310.1	79	54	0
525	94.88	311.3	82	20	0

All directions are with respect to magnetic north.

Figure WB-01:5
Rose Diagram of Optical Televiewer Features
Parsons
Camp Stanley Storage Facility: Wellbore WB-01
June 17, 2003

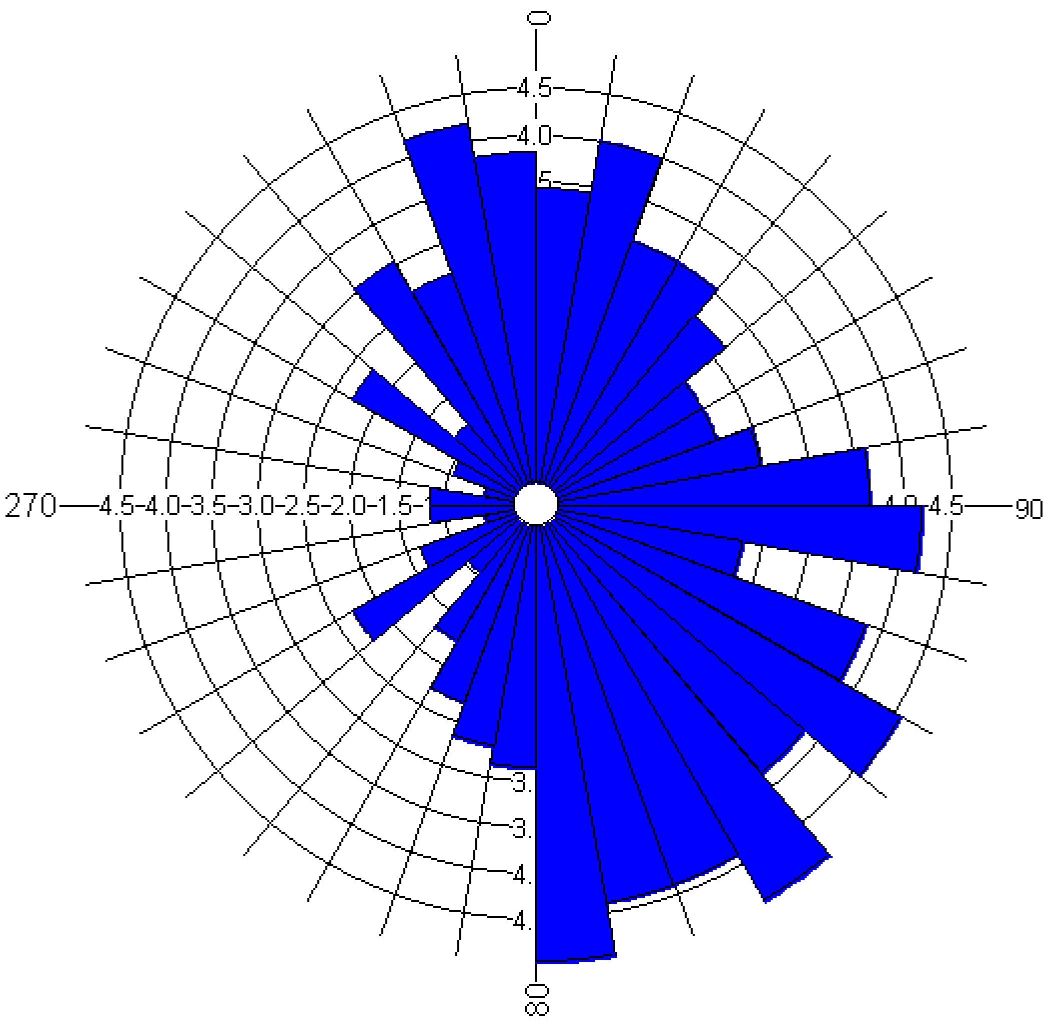
Dip Angles



Shown as *percent* of features with observed dip angle

Figure WB-01:6
Rose Diagram of Optical Televiewer Features
Parsons
Camp Stanley Storage Facility: Wellbore WB-01
June 17, 2003

Dip Direction

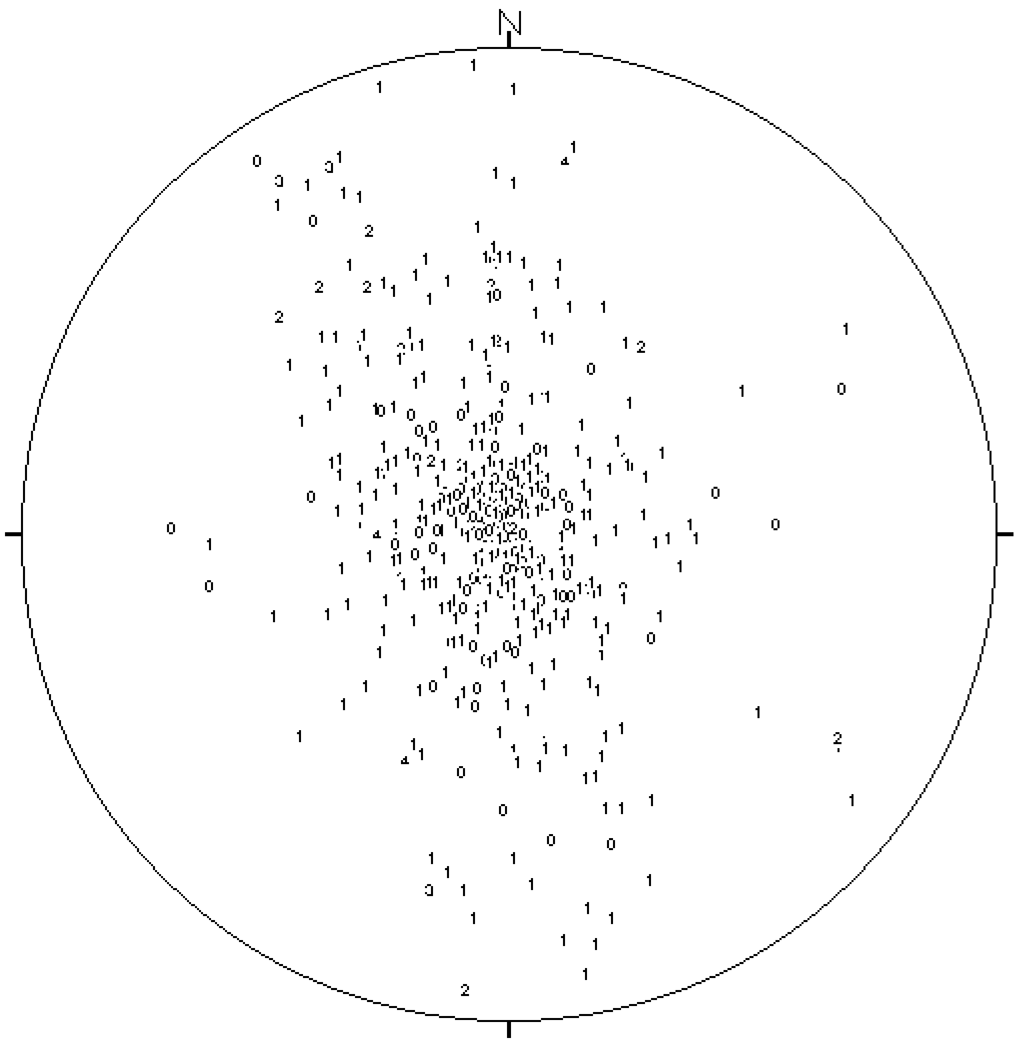


Shown as *percent* of features with observed dip direction

All directions are with respect to magnetic north.

Figure WB-01:7
Stereonet of Optical Televiewer Features
Parsons
Camp Stanley Storage Facility: Wellbore WB-01
June 17, 2003

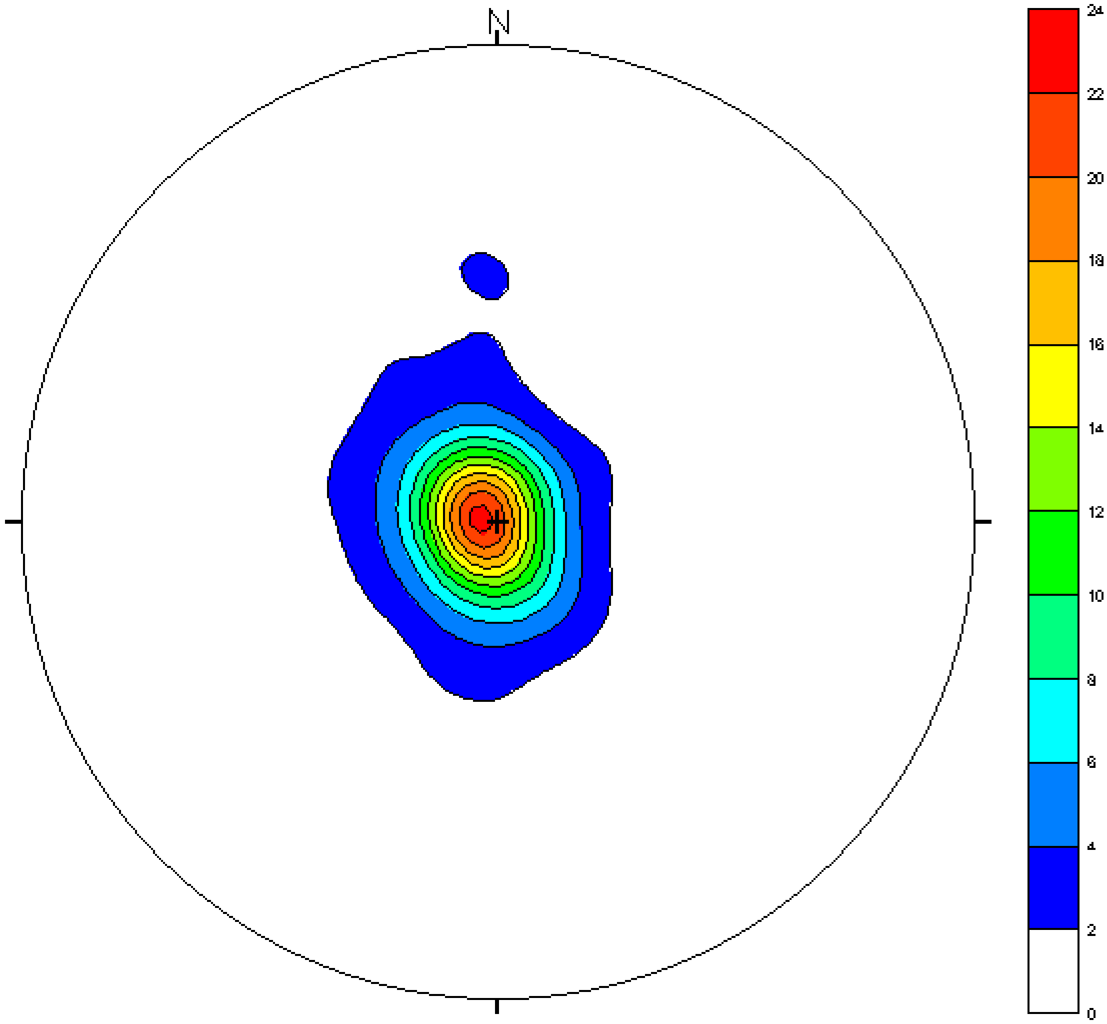
Schmidt Projection with Feature Ranks



All directions are with respect to magnetic north.

Figure WB-01:8
Stereonet of Optical Televiewer Features
Parsons
Camp Stanley Storage Facility: Wellbore WB-01
July 17, 2003

Schmidt Projection with Contours



All directions are with respect to magnetic north.

Geophysical Summary Plot

BOREHOLE GEOPHYSICS & HYDROPHYSICS
COLOG
A DIVISION OF LAYNE CHRISTENSEN COMPANY

COMPANY: Parsons	PROJECT: Camp Stanley
DATE LOGGED: 17 July 2003	WELL: WB-01

COLOG Main Office
17301 W.Colfax Ave, Ste 265, Golden, CO 80401
Phone: (303) 279-0171, Fax: (303) 278-0135
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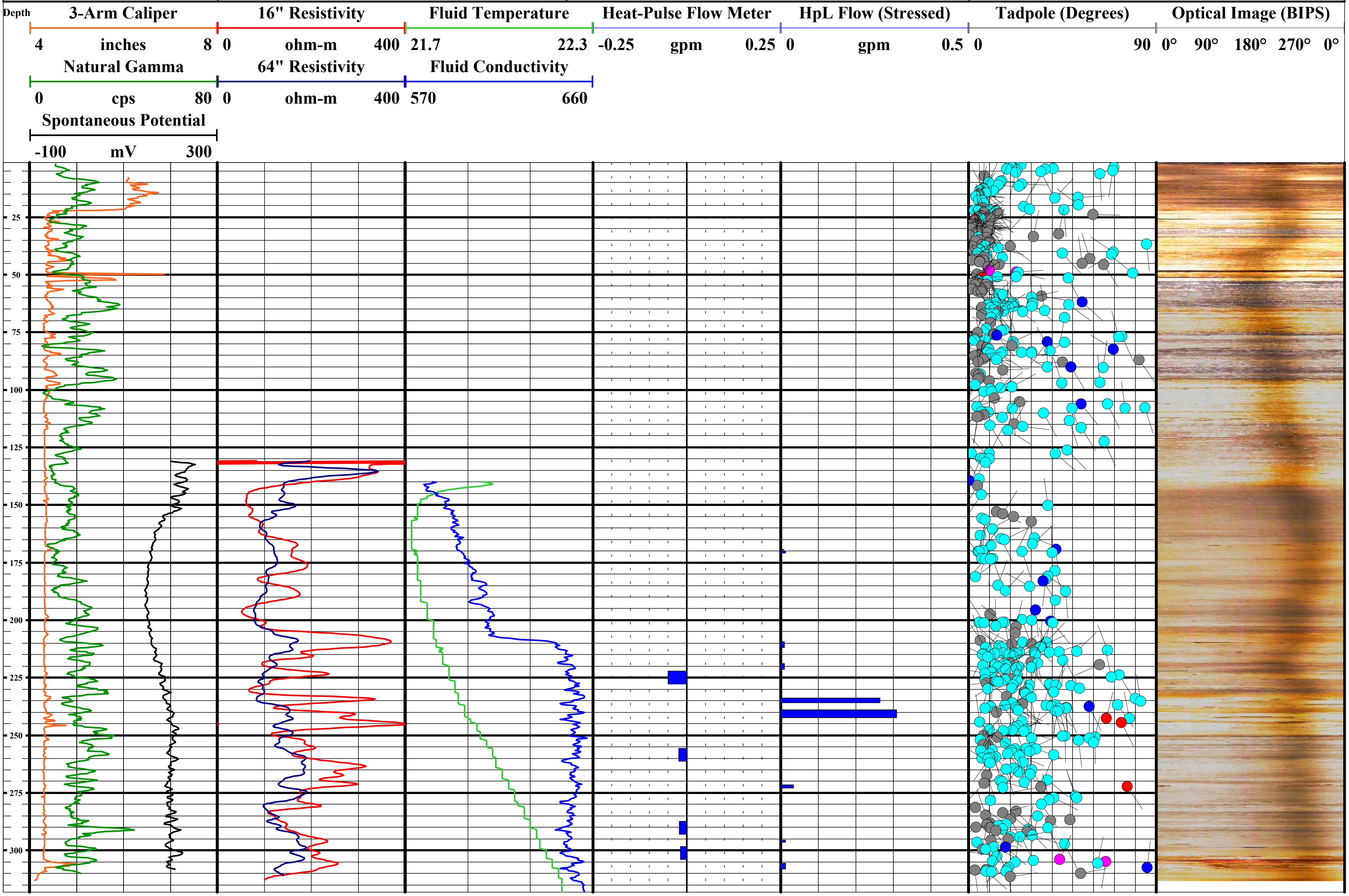


WB-02 Logging Results

1.0 HydroPhysical™ Logging

1.1 Ambient Fluid Electrical Conductivity and Temperature Log: WB-02

At 0843 hours on July 21, 2003, after a calibration check of the fluid electrical conductivity (FEC) and temperature logging tool, the fluid column was logged for FEC and temperature profiles with COLOG's 1.5-inch diameter HpL™ tool. These logs were performed prior to the installation of any pumping equipment. Please refer to Figure WB-02:1. The ambient FEC/temperature profiles indicate slight changes throughout the length of the borehole. The FEC profile indicates a gradual increase in FEC with depth. The ambient temperature log recorded a decrease in temperature in the upper portion of the log. This decrease is possibly due to groundwater entering the wellbore from above ambient water level. The remainder of the temperature log indicates relatively constant temperature with depth. In vertically flowing conditions, where water enters the borehole, termed inflow, a change in either FEC and/or temperature is typically seen.

1.2 Ambient Flow Characterization: WB-02

On July 21, 2003, an ambient flow characterization was conducted in boring WB-02. For ambient flow assessment, the fluid column in the borehole was replaced with de-ionized water (DI) and the boring left in an undisturbed state to allow any natural flow to occur. The pump was removed from the boring to insure that water in the pump standpipe would not drain back into the boring. Prior to this period and throughout all HpL™ testing, water levels and flow rates were monitored and recorded digitally every ten seconds. Ambient flow evaluation is reported for the period after the water surface returned to near pre-DI water emplacement levels. A series of FEC and temperature logs were then conducted over the duration of testing to identify changes in the fluid column associated with ambient flow. Ambient flow characterization is conducted to evaluate the presence of both vertical and horizontal flow.

On July 21, 2003, at 1344 hours (t=0 minutes, elapsed time of test), dilution of the fluid column was complete. During the 3.3 hours following the emplacement of DI water, multiple logs were conducted. Of these logs, 17 are presented in Figure WB-02:2, with the first log (FEC1330) occurring during emplacement. The designation of each logging with the FEC tool is indicated in the figure legend by the time of logging (e.g., FEC1330 versus a subsequent logging at FEC1344), thus the progressing of curves to the right in this figure represents changes in FEC over the total logging period. The last four digits of each log ID corresponds to the time at which that particular log was started. Only logs acquired during logging in the downward direction are presented as the design of the FEC/temperature probe allows for the most accurate data to be collected in the downward direction. The logs acquired in the upward logging direction are not representative of downhole conditions and are therefore omitted. These logs illustrate changes in FEC at several intervals throughout the length of the borehole. These changes in the FEC profiles with respect to time are associated with ambient vertical flow occurring within these intervals.

Formation water migration caused by downward vertical flow within the fluid column is indicated by the increase in FEC over time in Figure WB-02:2. The uppermost interval(s) of inflow is located above ambient water level (156 ftbgs). Once the inflowing groundwater enters the fluid column in the wellbore, it is possible to track its movement. Numeric modeling of the reported field data for this interval suggests downflow is occurring at a rate of 0.501 gpm. This vertical flow migrates down the wellbore to exit at 301.4 to 303.8 feet. All flow rates are based on the rate of increase of mass at their respective intervals. Please refer to Table WB-02:1 and SUMMARY:1 for a complete summary of the HydroPhysical™ logging results. Please refer to Appendix B for a discussion of the methodology and code used to calculate these values. The ambient depth to water at the time of testing was 156 ftbgs.

1.3 Flow Characterization During 1.4 GPM Production Test: WB-02

Low-rate pumping of wellbore fluids after DI water emplacement was conducted at one pumping rate to establish the inflow locations and evaluate the interval-specific inflow rates. Low-rate pumping at a given rate after DI water emplacement is conducted when the subject wellbore cannot sustain more than approximately 2-3 gpm yield. For wellbore WB-02, an alternative method of DI water emplacement was used. DI Water was injected down the top of the wellbore, allowed to travel down the length of the wellbore and exit at 301.4 to 303.8 feet. This method was utilized because the narrow diameter of the wellbore restricted the standard equipment from being placed in the wellbore. After DI water emplacement is complete, low-rate pumping is conducted to stress the aquifer(s) and draw groundwater into the wellbore where it is contrasted by the DI water in the wellbore. Continuous FEC profiling over time yields the depth and rate of influx of groundwater during pumping. These procedures were conducted at a time-averaged pumping rate of 1.41 gpm.

On July 22, 2003 at 1329 hours (t = 0 minutes elapsed time of testing), pumping was initiated at approximately 1.4 gpm. Prior to DI water emplacement, the ambient depth to water was recorded at 156 ftbgs. Time dependent depth to water, totals and flow rate information were recorded and are presented in Figure WB-02:3. Low-rate pumping was maintained at a time-averaged rate of 1.41 gpm until 1750 hours (t = 261 minutes, elapsed time of testing). During this period drawdown was observed to steadily decrease until water level relatively stabilized at approximately 6.53 feet below ambient water level. During the period of testing, multiple loggings were conducted. Of these logs eight FEC traces are presented in Figure WB-02:4 with the first log, FEC1321 occurring during DI water emplacement procedures to serve as a baseline of downhole conditions. These logs clearly illustrate a specific interval of dramatic increase in FEC with respect to time. The depth at which the peak value for a given interval occurs is indicative of a water-bearing interval. The data presented in Figure WB-02:4 suggest the presence of one hydraulically conductive interval at 301.4 to 303.8 feet. Numerical modeling of the reported field data was performed using code BORE and/or BOREII (Hale and Tsang, 1988, Tsang et.al. 1990, Daughtery and Tsang, 2000). This modeling was performed to estimate the rate of inflow and FEC for each identified hydraulically conductive interval during the pumping. The results of the modeling and analysis are presented in Table WB-02:1. In summary, the interval of 301.4 to 303.8 feet dominated inflow producing 0.909 gpm, or 64 percent of the total inflow during production testing. Please refer to Table WB-02:1 for a listing of the depths of water-bearing zones and their interval-specific inflow rate during testing. The water bearing interval(s) that inflow above ambient water level was assumed to contribute the same amount of flow (0.501 gpm) during the development of the well as they did during ambient testing.

1.4 Estimation of Interval Specific Transmissivity: WB-02

An estimation of transmissivity (T) can be made using an equation after Hvorslev (1951) assuming steady-state radial flow in an unconfined aquifer:

$$T = KL = \frac{q_i}{2\pi\Delta h_w} \ln\left(\frac{r_e}{r_w}\right)$$

where K is the hydraulic conductivity, q_i is the interval specific inflow rate calculated by HpL™ results, r_w is the borehole radius (0.17 ft), r_e is the effective pumping radius , Δh_w is the observed maximum drawdown (6.53 feet) and L is the thickness of the zone through which flow occurs. For our calculations, COLOG used r_e of 50 feet (assumed). By applying L and q_i from the HpL™ results under the two pressure conditions, the interval specific transmissivity can be calculated for each identified water-producing interval. These calculations were made at each identified interval and are presented in Table WB-02:1. In summary, the interval at 301.4 to 303.8 feet registered the highest transmissivity at 37.8 $feet^2$/day.

2.0 Geophysical Logging

On July 20 and 22, 2003, downhole geophysical investigations were performed in boring WB-02. The geophysical logs performed were: optical televiewer (BIPS) and heat pulse flowmeter. The data for these logs is presented in the WB-02 Geophysical Summary Plot. A contractor other than COLOG conducted additional geophysical logging in wellbore WB-02. This data is presented in the WB-02 Geophysical Summary Plot.

3.0 Data Summary

Processing and interpretation of the geophysical and HydroPhysical™ logs for WB-02 suggest the presence of one producing interval below ambient water level, for this borehole. Numerical modeling of the reported HydroPhysical™ field data was performed using computer programs FLOWCALC and/or BOREII. These analyses were performed to estimate the rate of inflow for each identified hydraulically conductive borehole interval during DI injection procedures. The results of these analyses are presented in Table WB-02:1. This identified producing intervals correlate well with water-bearing zones identified during ambient testing. In summary, the interval 301.4 to 303.8 feet dominated inflow during the production test, producing 0.909 gpm, or 64 percent of the total flow during the production test.

During ambient testing, boring WB-02 exhibited vertical flow. One water-bearing zone was identified under ambient conditions. The uppermost interval(s) was above ambient water level, therefore, its exact location is unknown. Groundwater enters the wellbore at this interval, and migrates down the wellbore to exit at 301.4 to 303.8 feet. A downward vertical pressure gradient was observed in the wellbore under ambient conditions.

Additionally, the wellbore was logged under ambient conditions with the heat pulse flowmeter on July 22, 2003. The data acquired by the heat pulse flowmeter suggests the presence of a downward vertical gradient present in the wellbore at the time of testing. Ambient flow is observed to enter the wellbore above 168 feet at approximately 0.50 gpm and migrate downward. Additional heat-pulse flow meter test stations were conducted at 178, 191, 231, and 295. At 305 feet, no ambient flow was observed. Based on the lack of evidence for flow originating at intervals other than 301.4 to 303.8 feet during HpL testing, the flow measurements by the heat pulse flow meter are assumed to be statistically the same.

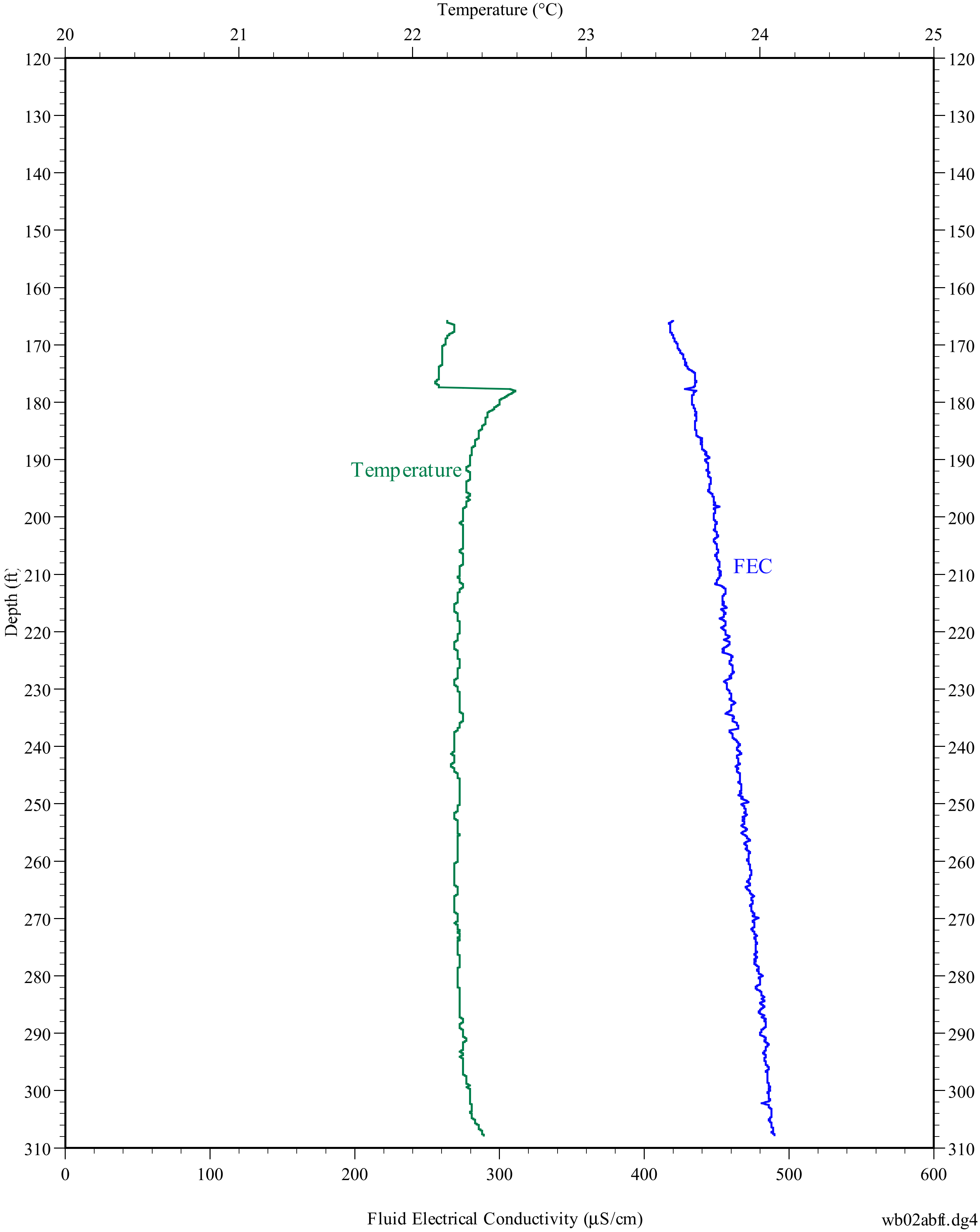
The optical televiewer identified features at depths correlating well with the HpL™ data. The features observed by the optical televiewer at water-bearing intervals identified from the HpL™ data had apparent aperture. Twenty-one high-angle features (features of dip angle greater than 45 degrees) were identified from the optical televiewer data. Additionally, six of the features are qualitatively ranked greater than one, suggesting the features to have flow potential. While logging the optical televiewer the approximate location of an inflow interval above ambient water level was identified at approximately 135 feet.

The single interval-specific estimated transmissivity in WB-02 was 37.8 square feet per day at the interval from 37.8 feet.

Fracture inter-connectiveness in the immediate vicinity of a wellbore can be inferred by the similarity, or lack there of, of parameters such as interval-specific transmissivity estimates and interval-specific FEC, along with the presence of high-angle fractures and pressure differentials within the borehole. Similar transmissivity and FEC estimates would suggest an inter-connected network of fractures or aquifers in the immediate vicinity of the wellbore. A pressure differential present in the wellbore would suggest the driving force for vertical communication is present and high-angle fractures with aperture may provide the conduit for vertical communication.

The data acquired in WB-02 suggest a downward vertical gradient is present in the wellbore, however, all of the downward vertical flow in the wellbore originated from above ambient water level. Major high angle features were identified in the wellbore to provide a conduit for vertical communication. The data is inconclusive as to weather the fractures intersecting the wellbore are, or are not interconnected in the immediate vicinity of the wellbore. This conclusion is largely based on the lack of hydrostatic head on the uppermost inflowing interval(s). Please see Tables WB-02:1 and SUMMARY:1 for a summary that includes the locations, flow rates and hydraulic conductivity estimates assessed by COLOG.

FIGURE WB-02:1. AMBIENT TEMPERATURE AND FLUID ELECTRICAL CONDUCTIVITY; PARSONS; CAMP STANLEY STORAGE FACILITY; SAN ANTONIO; TX; WELLBORE: WB-02.



wb02abft.dg4

FIGURE WB-02:2 SUMMARY OF HYDROPHYSICAL LOGS DURING AMBIENT FLOW CHARACTERIZATION; PARSONS; CAMP STANLEY STORAGE FACILITY; SAN ANTONIO, TX; WELLBORE: WB-02.

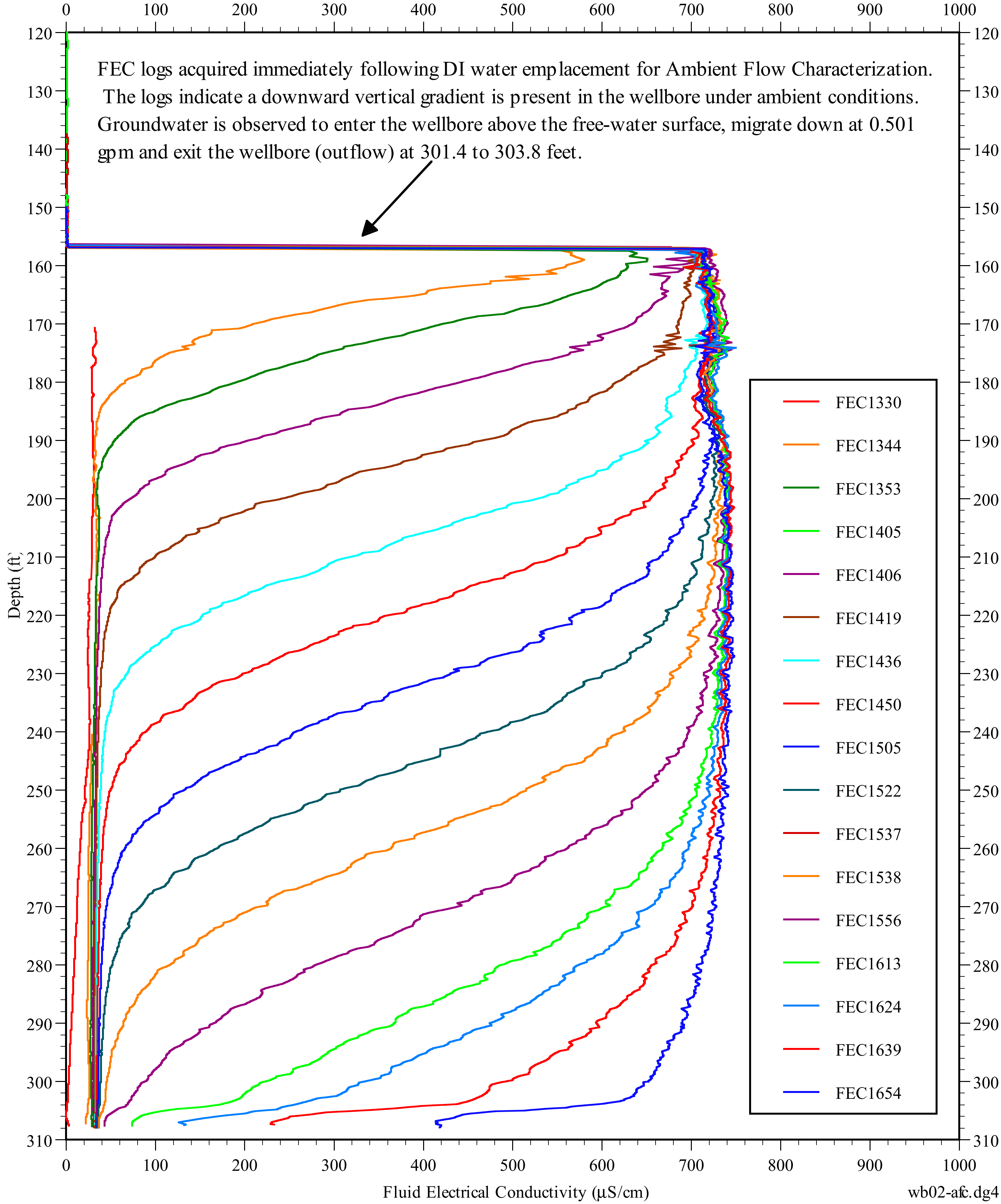
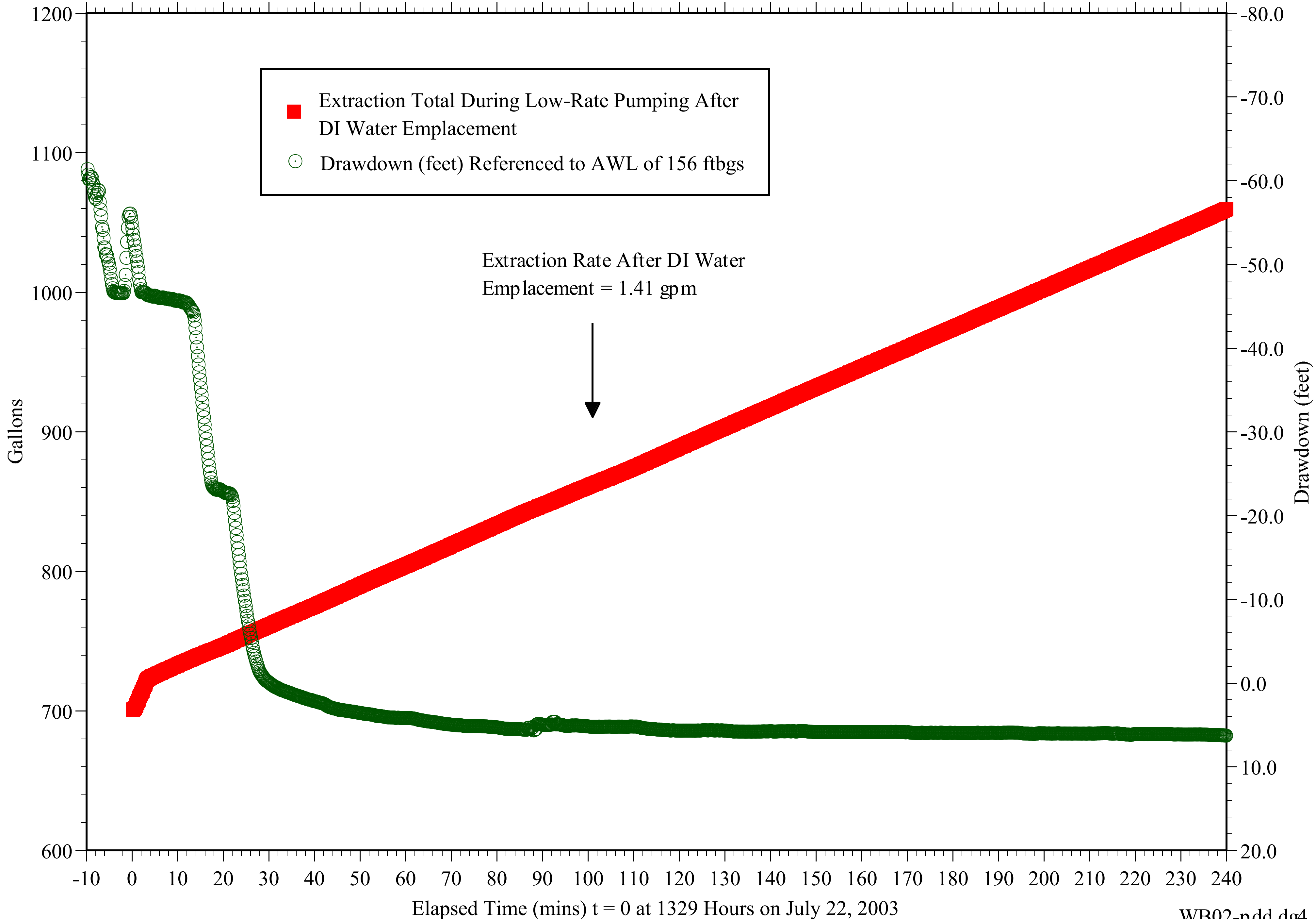
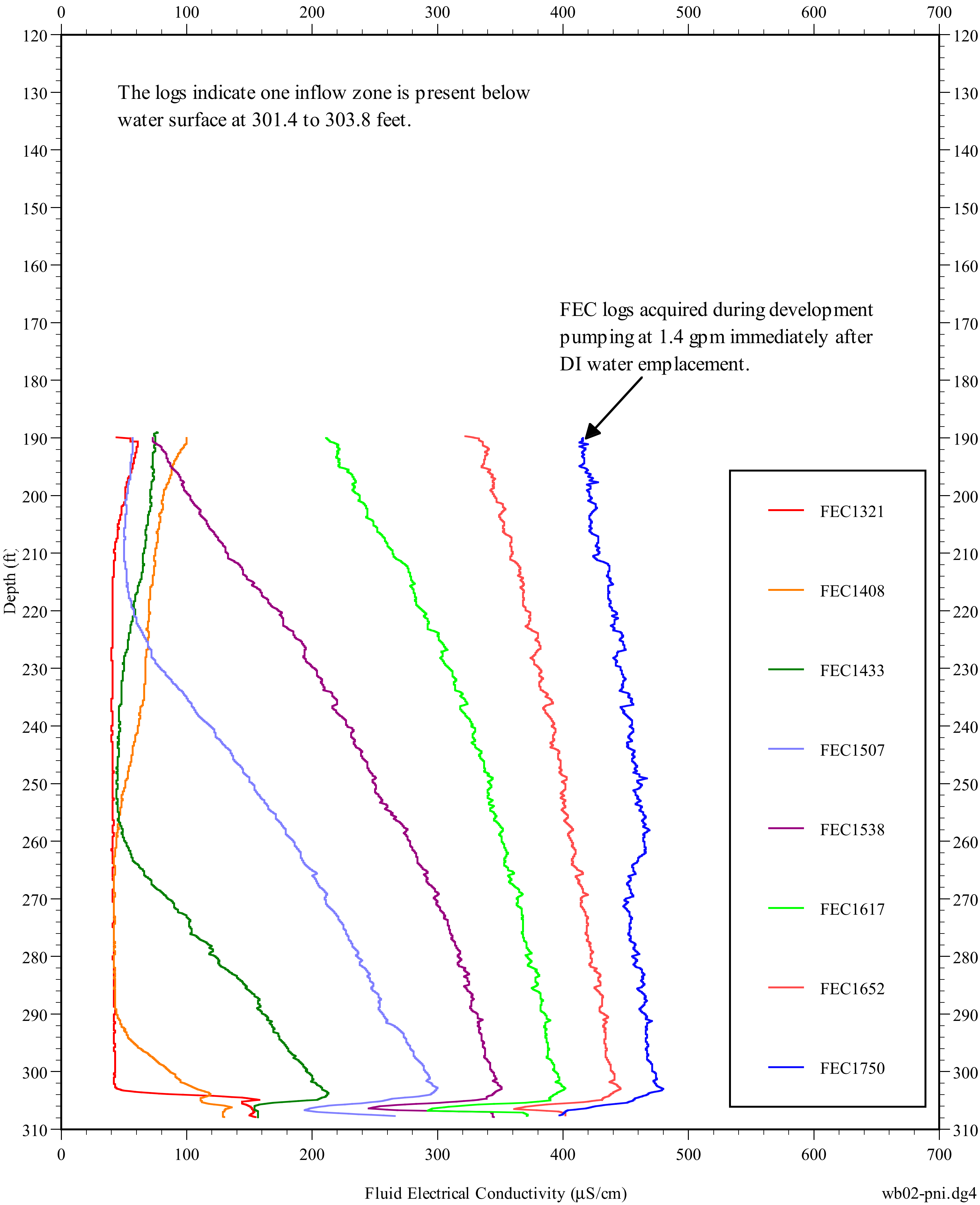


FIGURE WB-02:3. PUMPING AND DRAWDOWN DATA DURING 1.4 GPM PRODUCTION TEST; PARSONS; CAMP STANELY STORAGE FACILITY; SAN ANTONIO, TX; BOREHOLE: WB-02.



WB02-pdd.dg4

FIGURE WB-02:4. SUMMARY OF HYDROPHYSICAL LOGS DURING LOW-RATE PRODUCTION TEST; PARSONS; CAMP STANLEY STORAGE FACILITY; SAN ANTONIO, TX; WELL: WB-02.



wb02-pni.dg4

TABLE WB-02:1. SUMMARY OF HYDROPHYSICAL™ LOGGING RESULTS WITH HYDRAULIC CONDUCTIVITY AND TRANSMISSIVITY ESTIMATIONS; PARSONS; CAMP STANLEY STORAGE FACILITY; WELL: WB-02.

Well name	WB-02
Ambient Depth to water (ft)	156.00
Diameter of Borehole (ft)	0.33
Maximum Drawdown (ft)	6.53
Effective Radius (ft)	50

Interval No.	Top of Interval (ft)	Bottom of Interval (ft)	Length of Interval (ft)	Ambient Flow[1] (gpm)	Darcy Velocity in Aquifer[2] (Specific Discharge) (ft/day)	Interval Specific Flow Rate (gpm)	Delta Flow[3] (gpm)	Delta Flow (ft^3/min.)	Interval Specific Hydraulic Conductivity[4] (ft/day)	Transmissivity (ft2/day)	Interval Specific Fluid Electrical Conductivity (microS/cm)
1	301.4	303.8	2.4	-0.501	NA	0.909	1.410	0.18850	1.58E+01	3.78E+01	486

[1] All ambient flow identified for this wellbore is downward flow. All inflow enters the wellbore above ambient water level (138 ftbgs) at the time of testing.

[2] Darcy Velocity is calculated using the observed volumetric flow rate, the cross-sectional area of the flow interval in the wellbore and a wellbore convergence factor of 2.5 (Drost, 1968). The Darcy Velocity is only applicable to ambient horizontal flow.

[3] Delta Flow is the difference between Interval-Specific Flow Rate (during pumping) and Ambient Flow Rate.

[4] Hydraulic conductivity and transmissivity estimates are based on single well drawdown data, a porus-medium equivilent model and Hvorslev's 1951 porosity equation.

Optical Borehole Image Plot

COMPANY: Parsons	PROJECT: Camp Stanley
DATE LOGGED: 20 July 2003	WELL: WB-02

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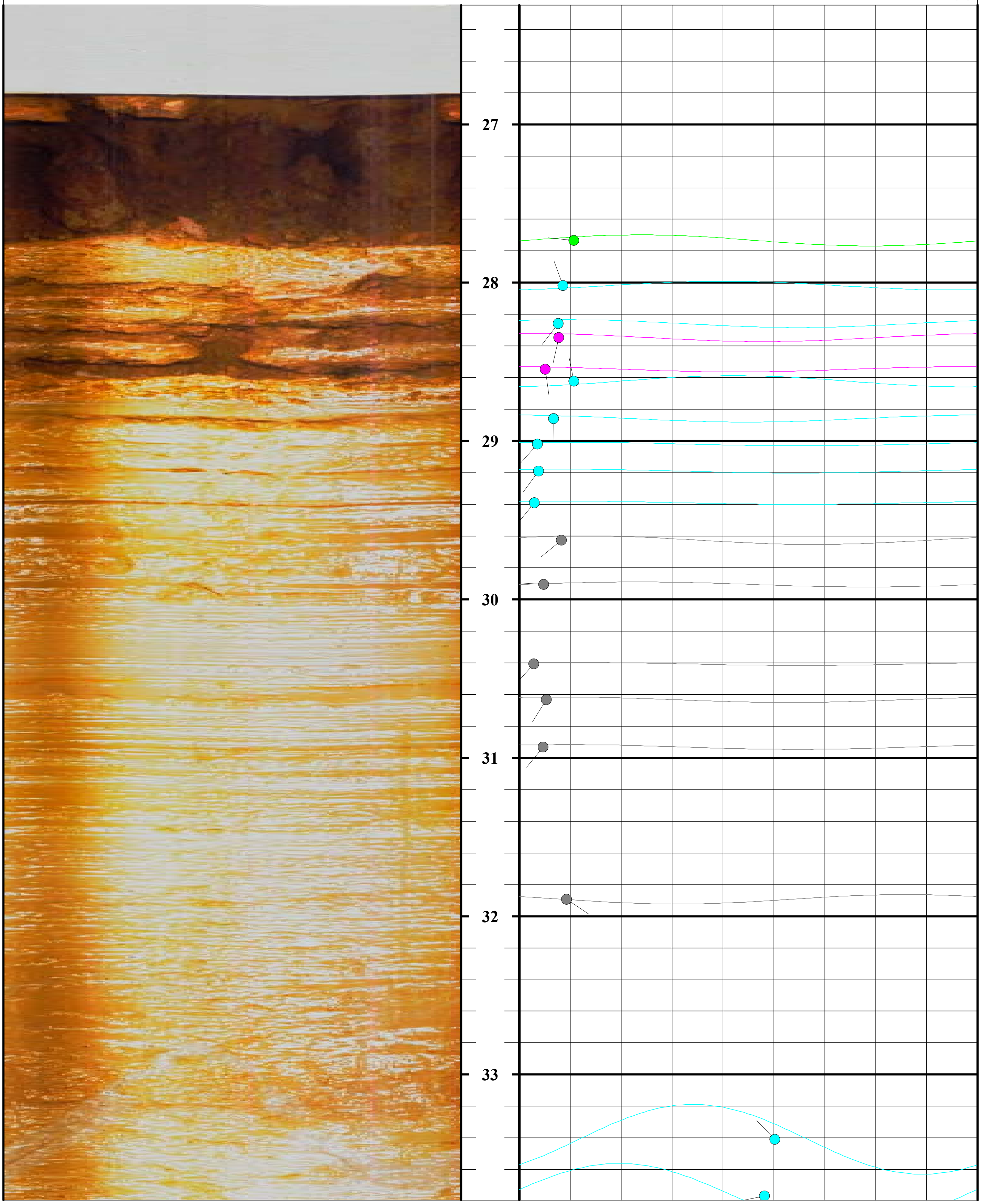
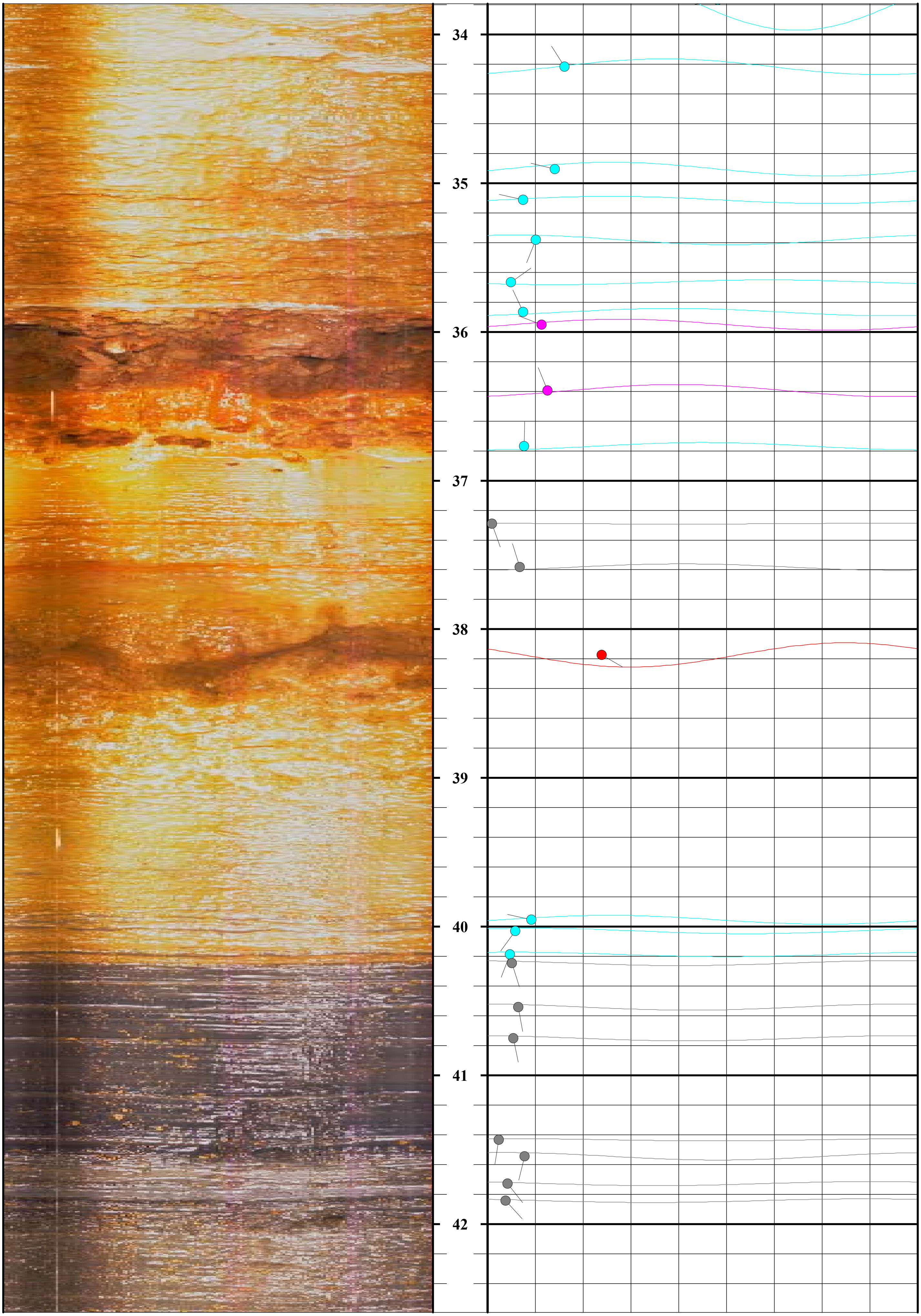
Optical Televiewer (BIPS)	Depth	Projection
0° 90° 180° 270° 0°		0° 90° 180° 270° 0°
		Tadpole (Degrees)
		0 90

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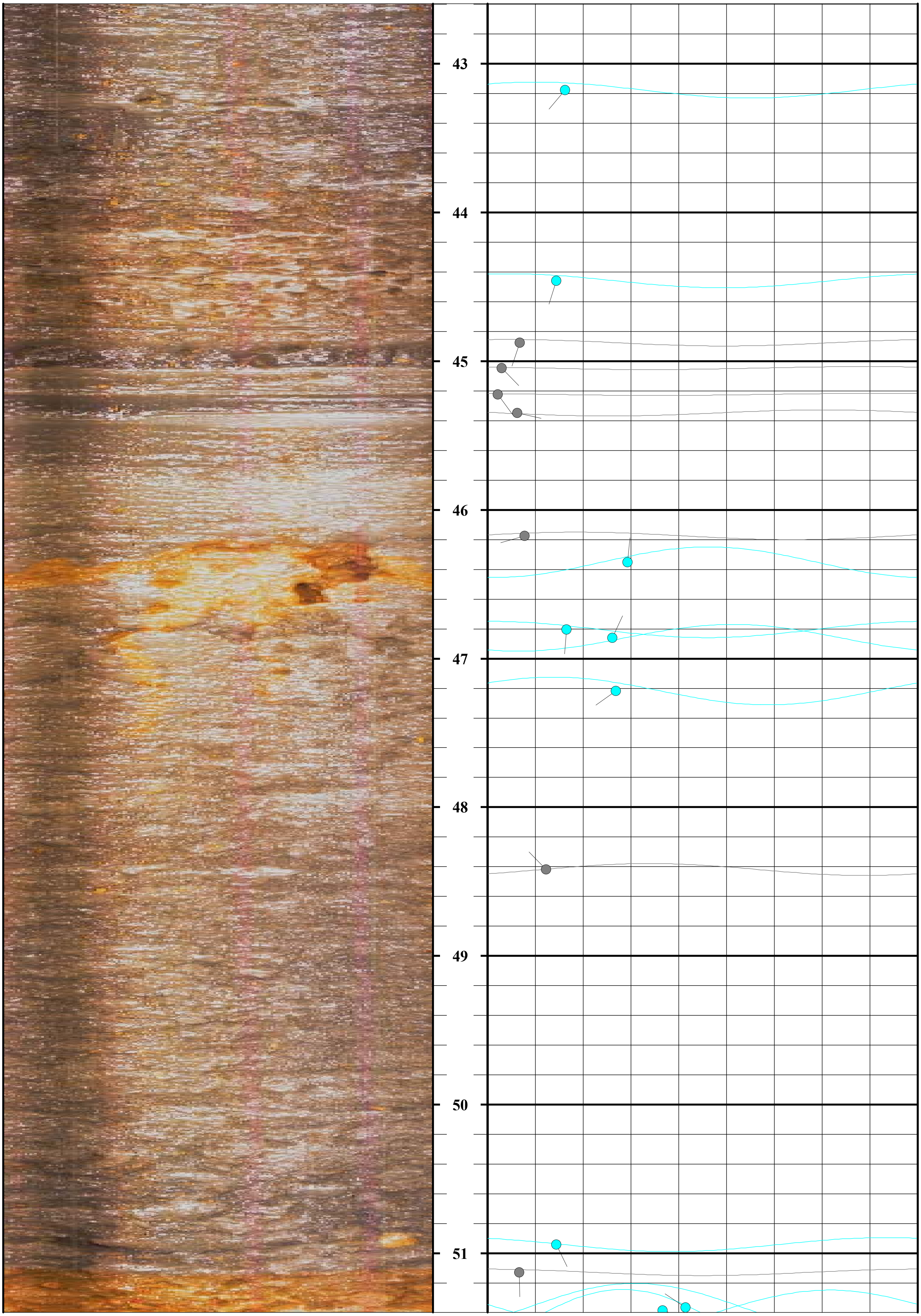
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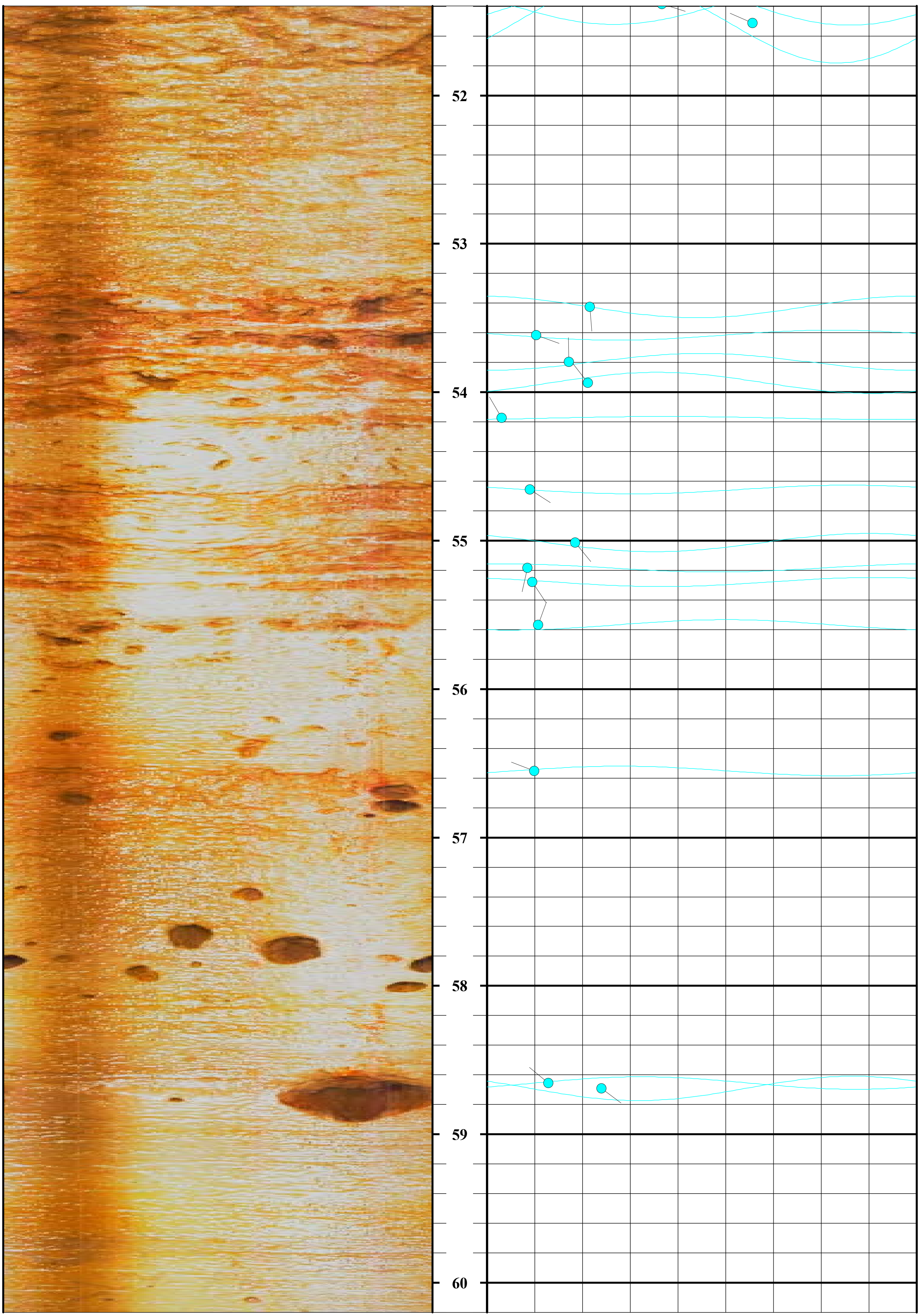
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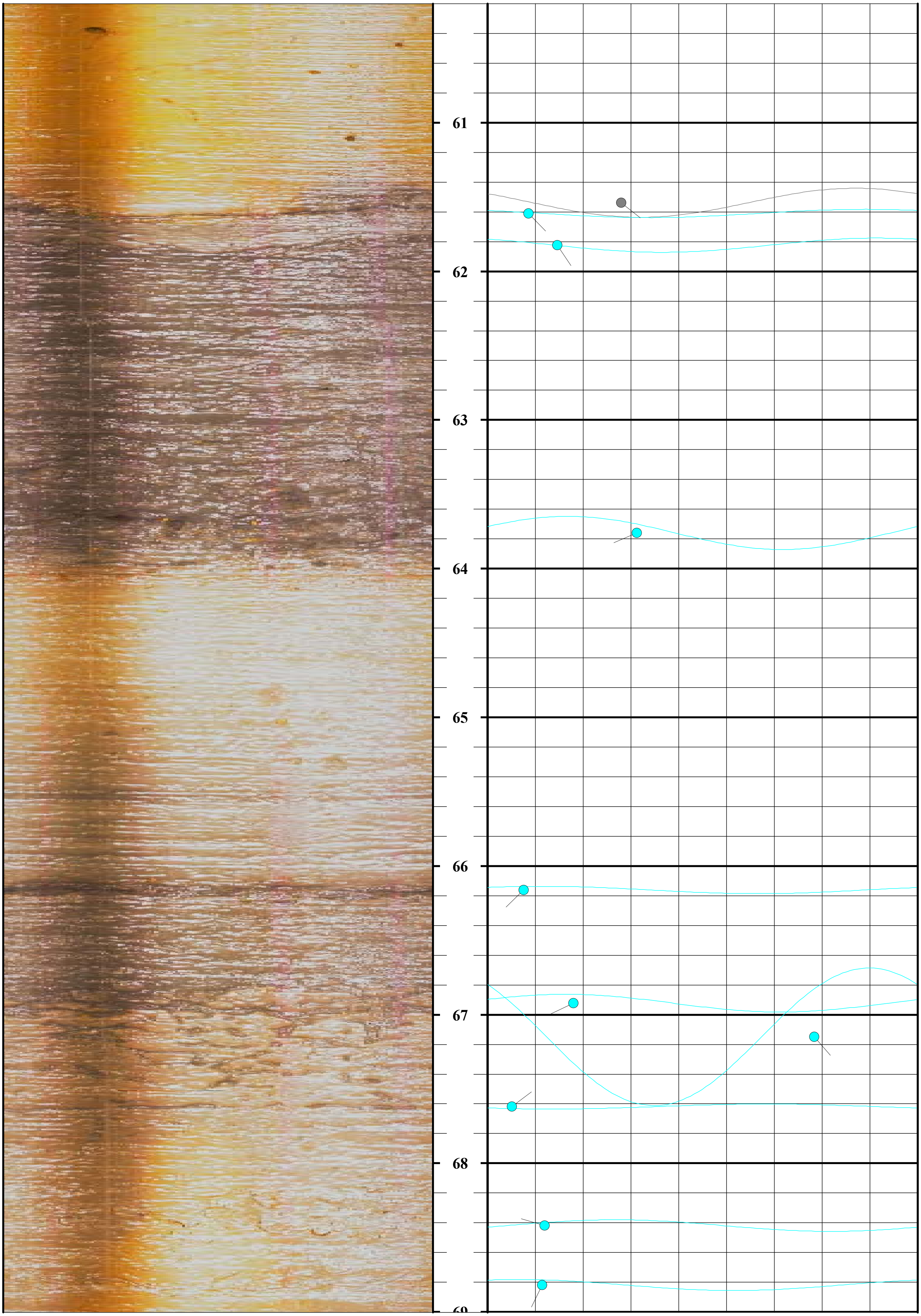
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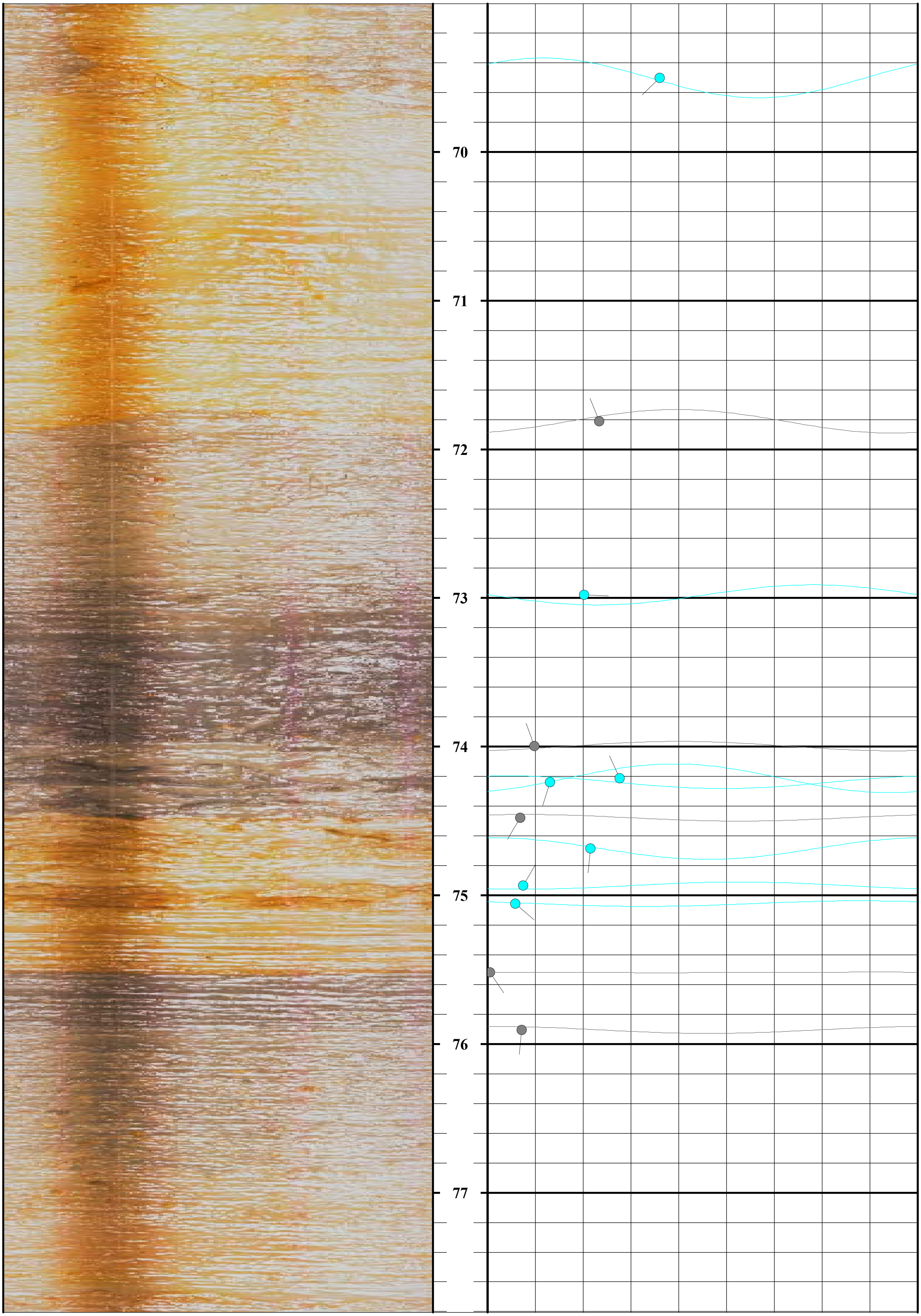
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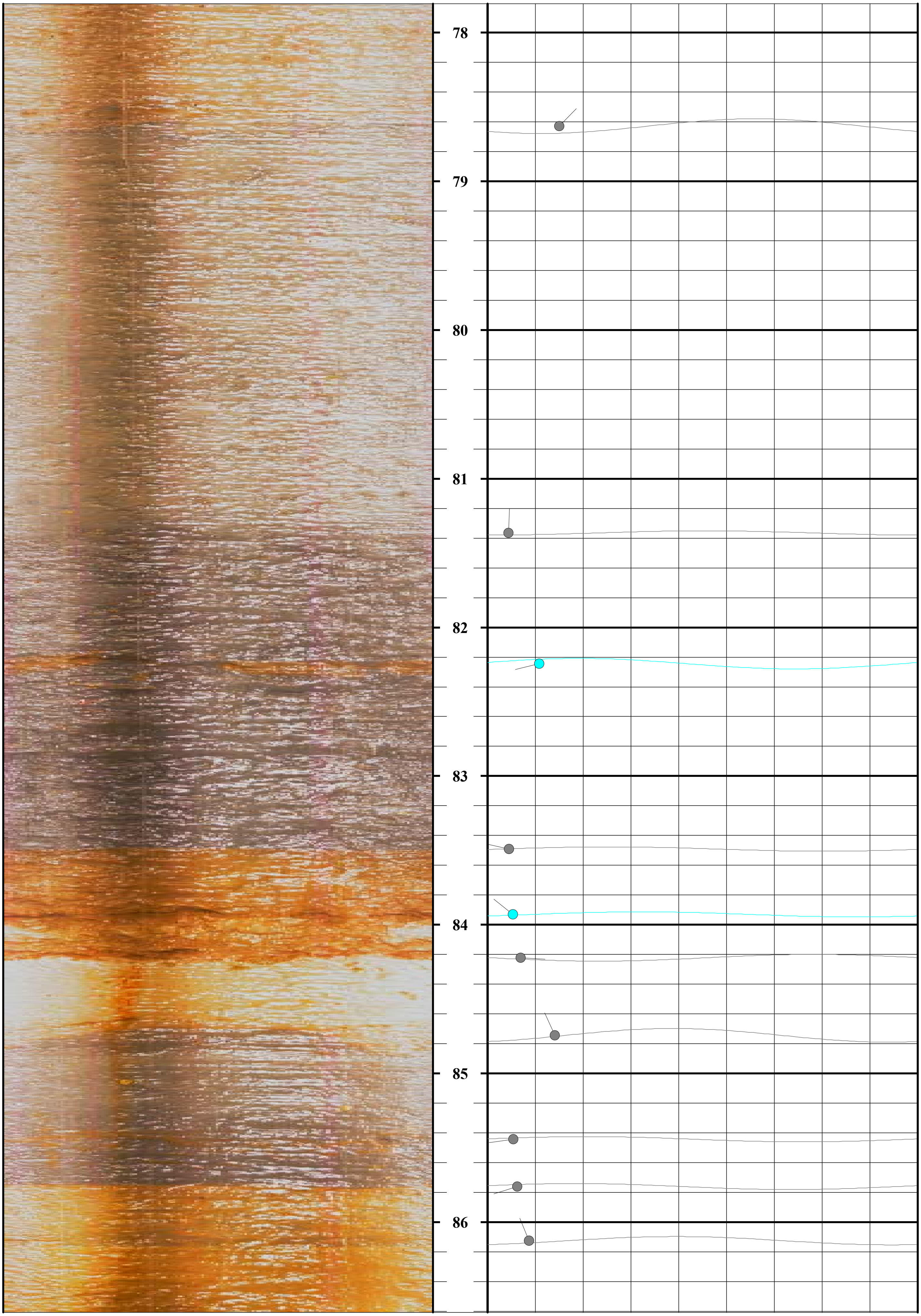
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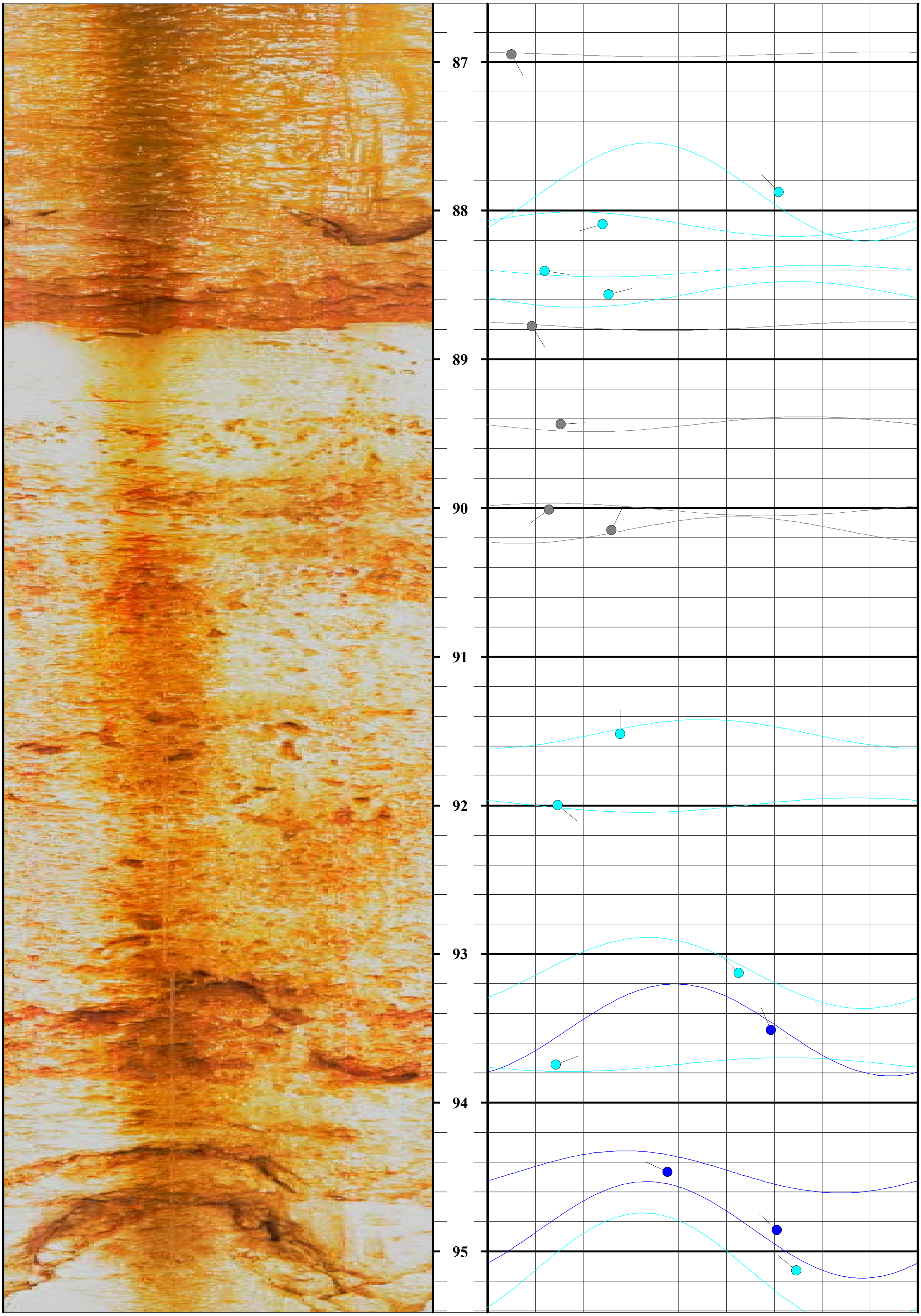
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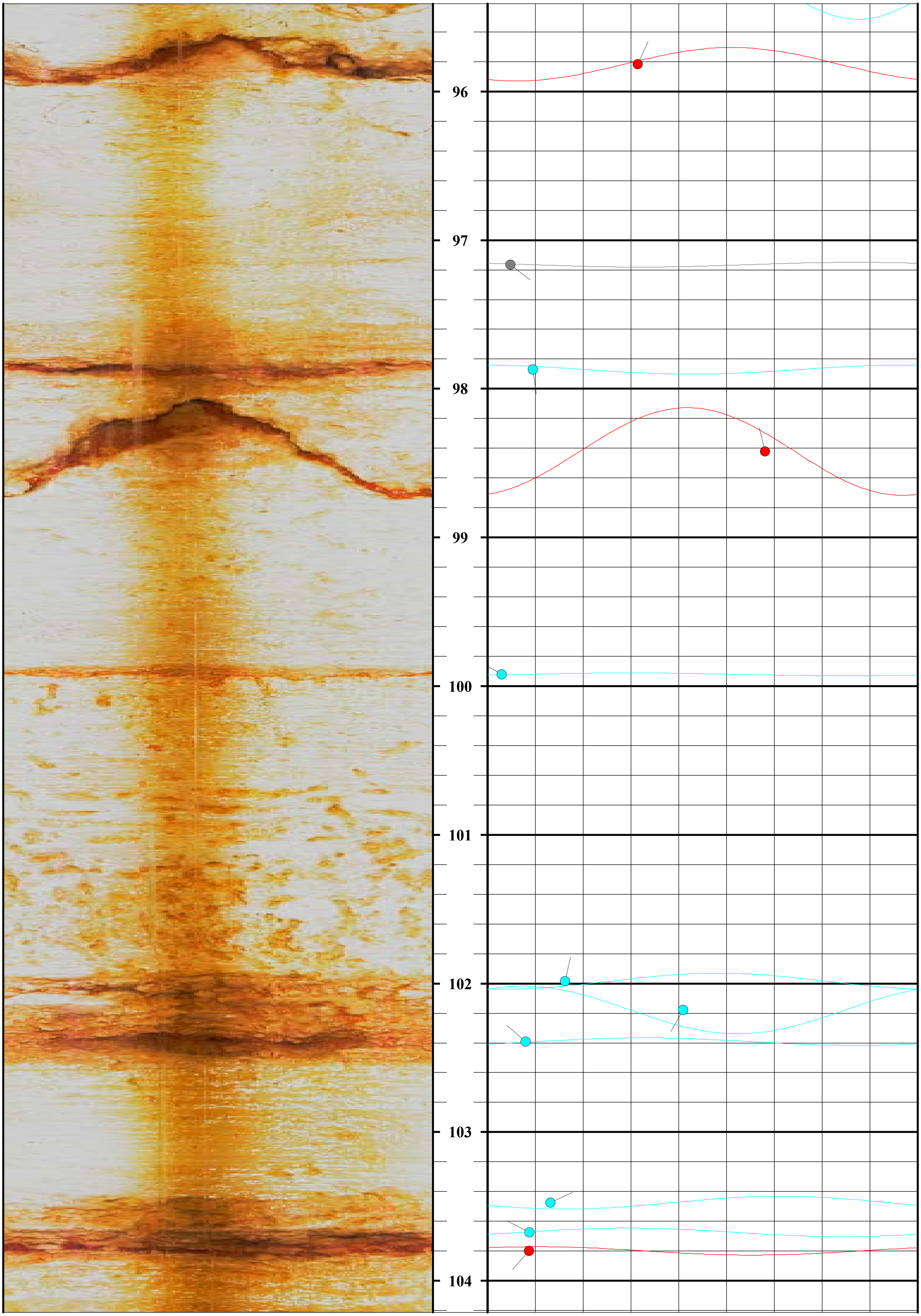
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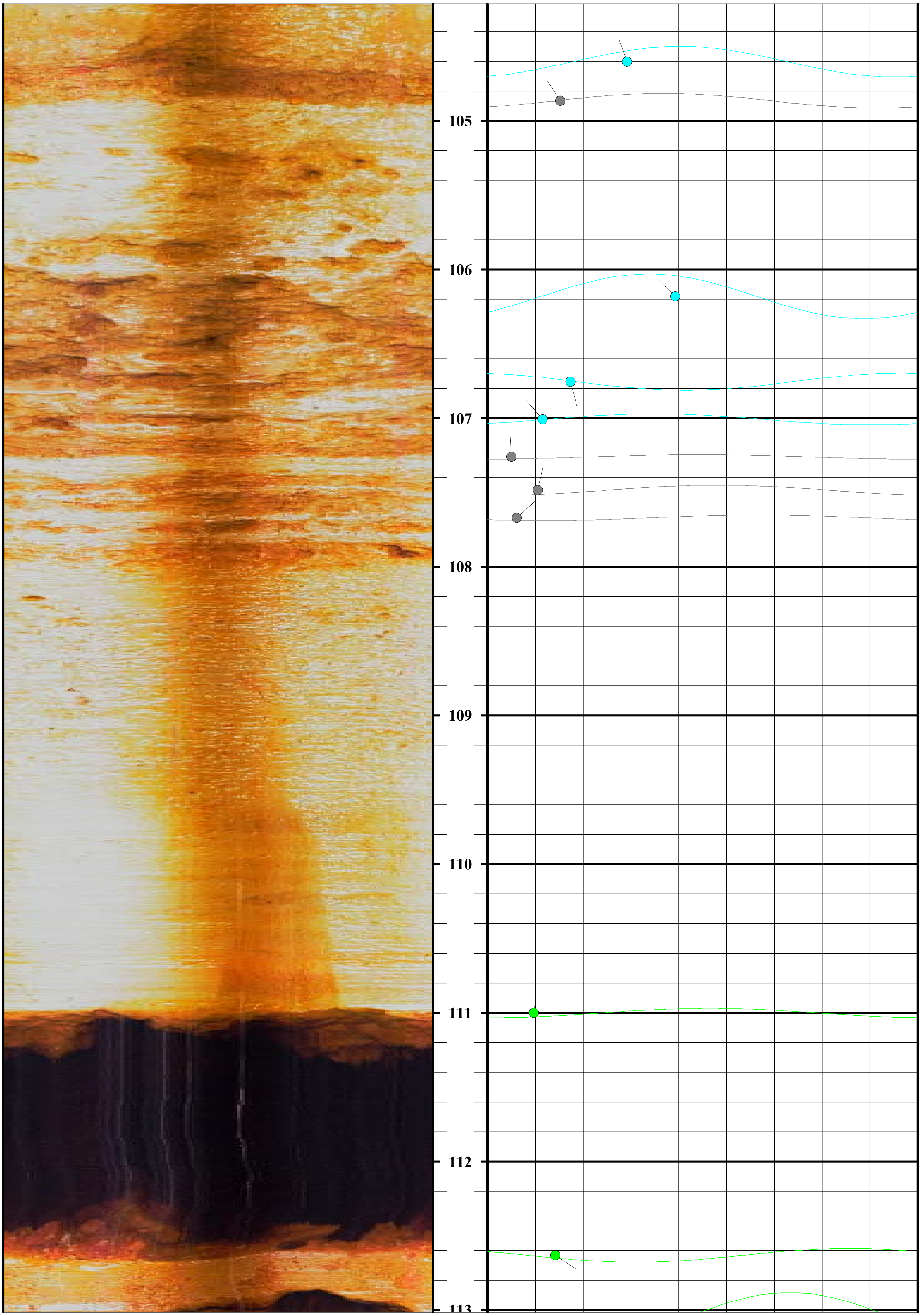
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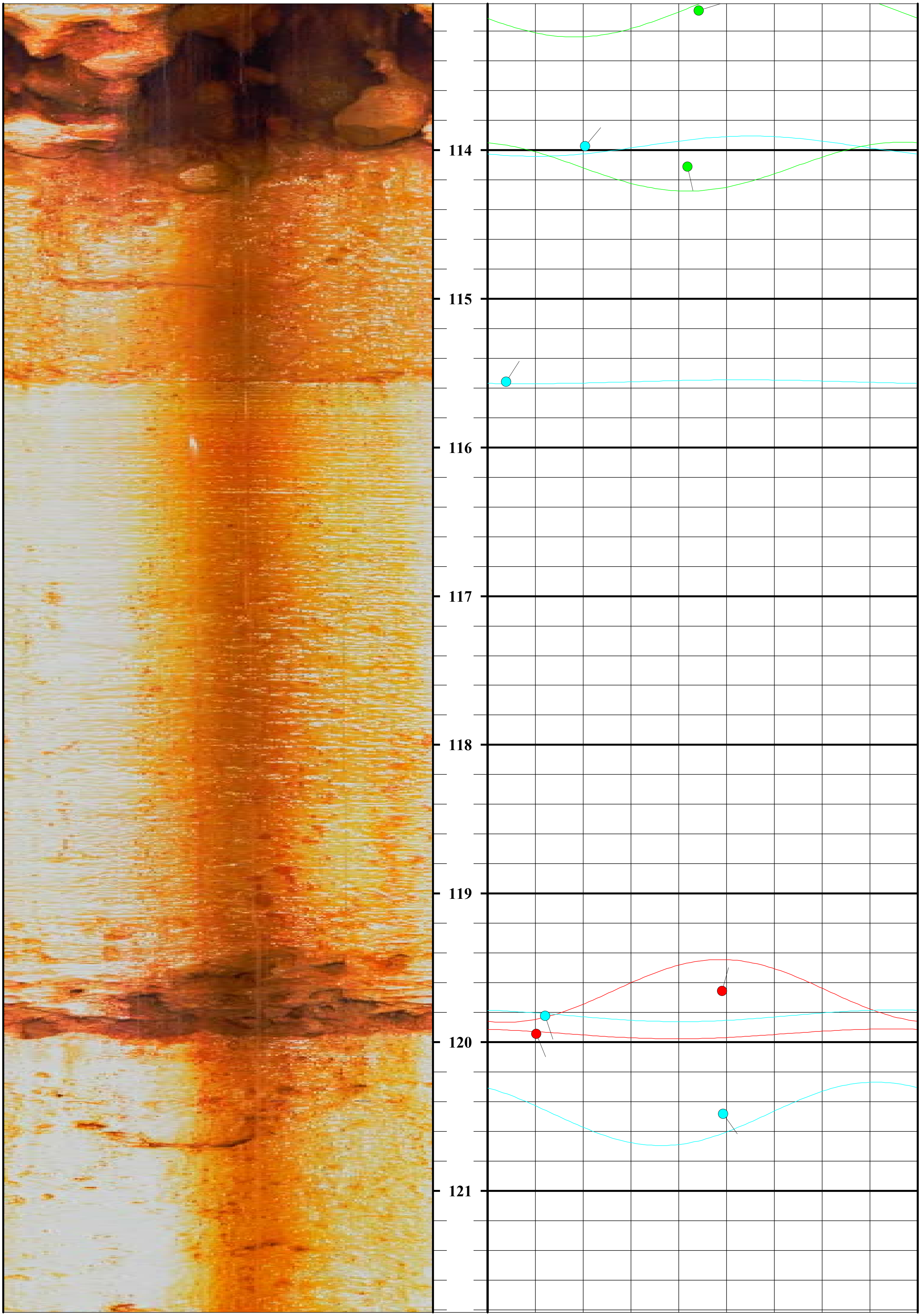
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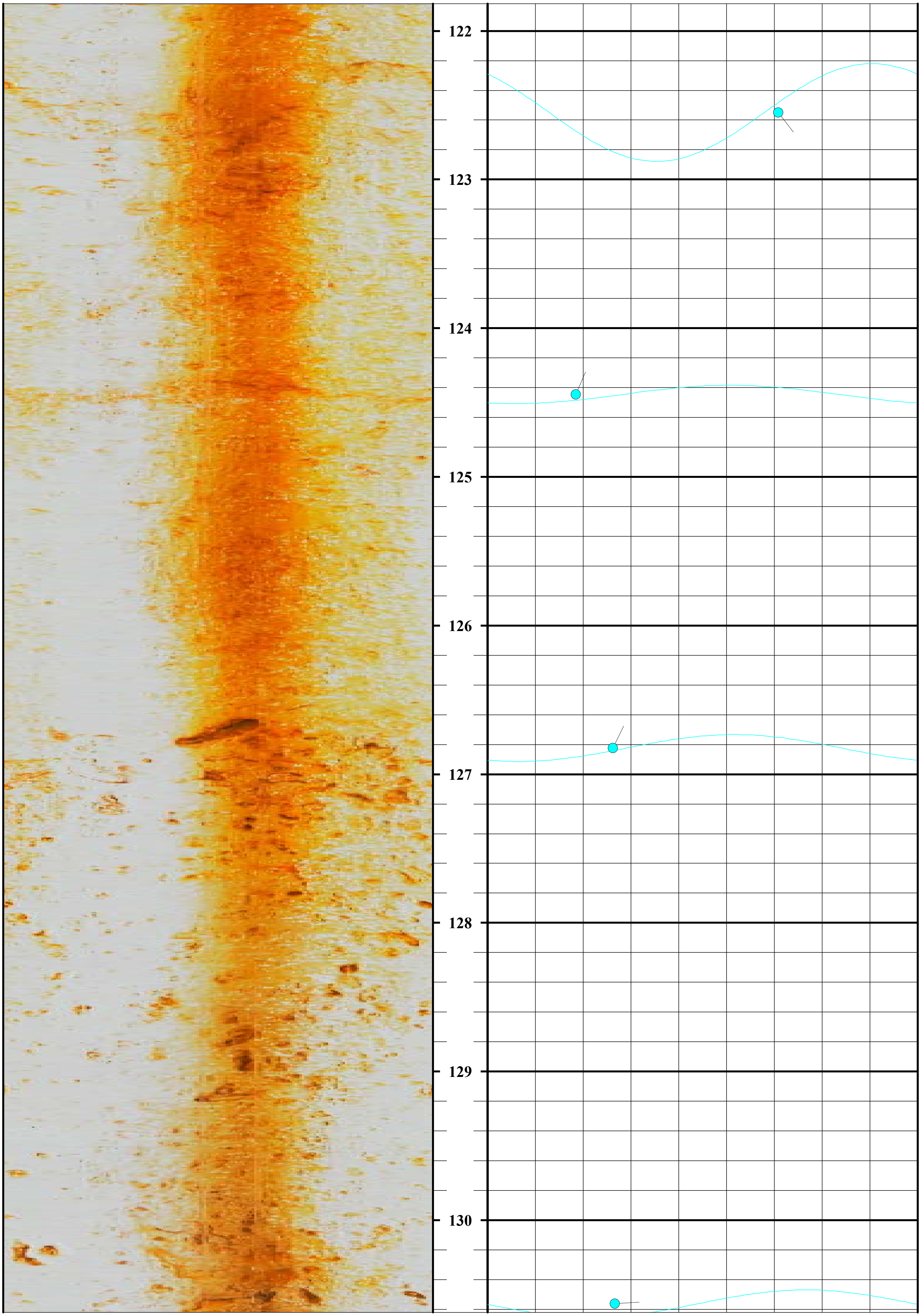
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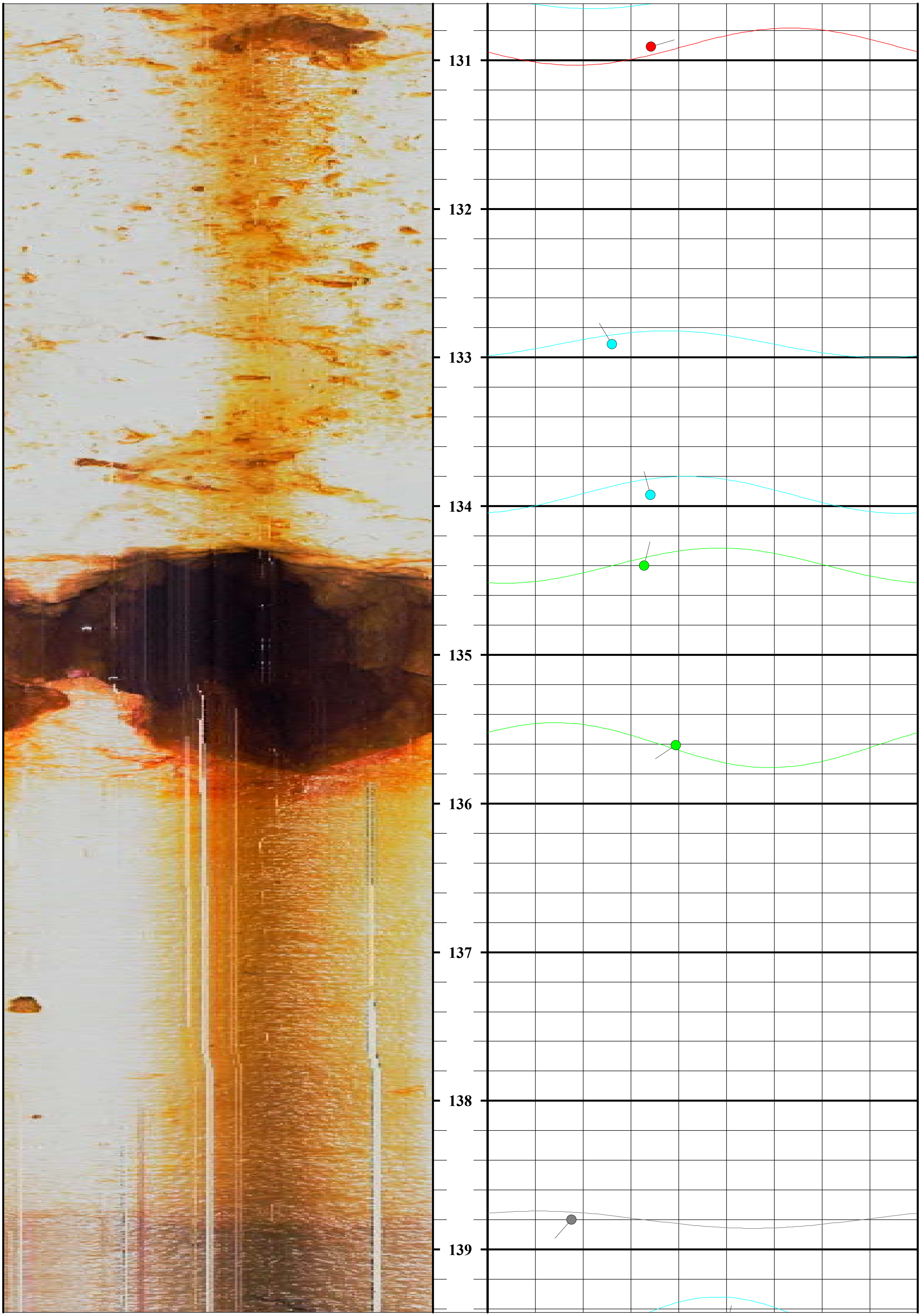
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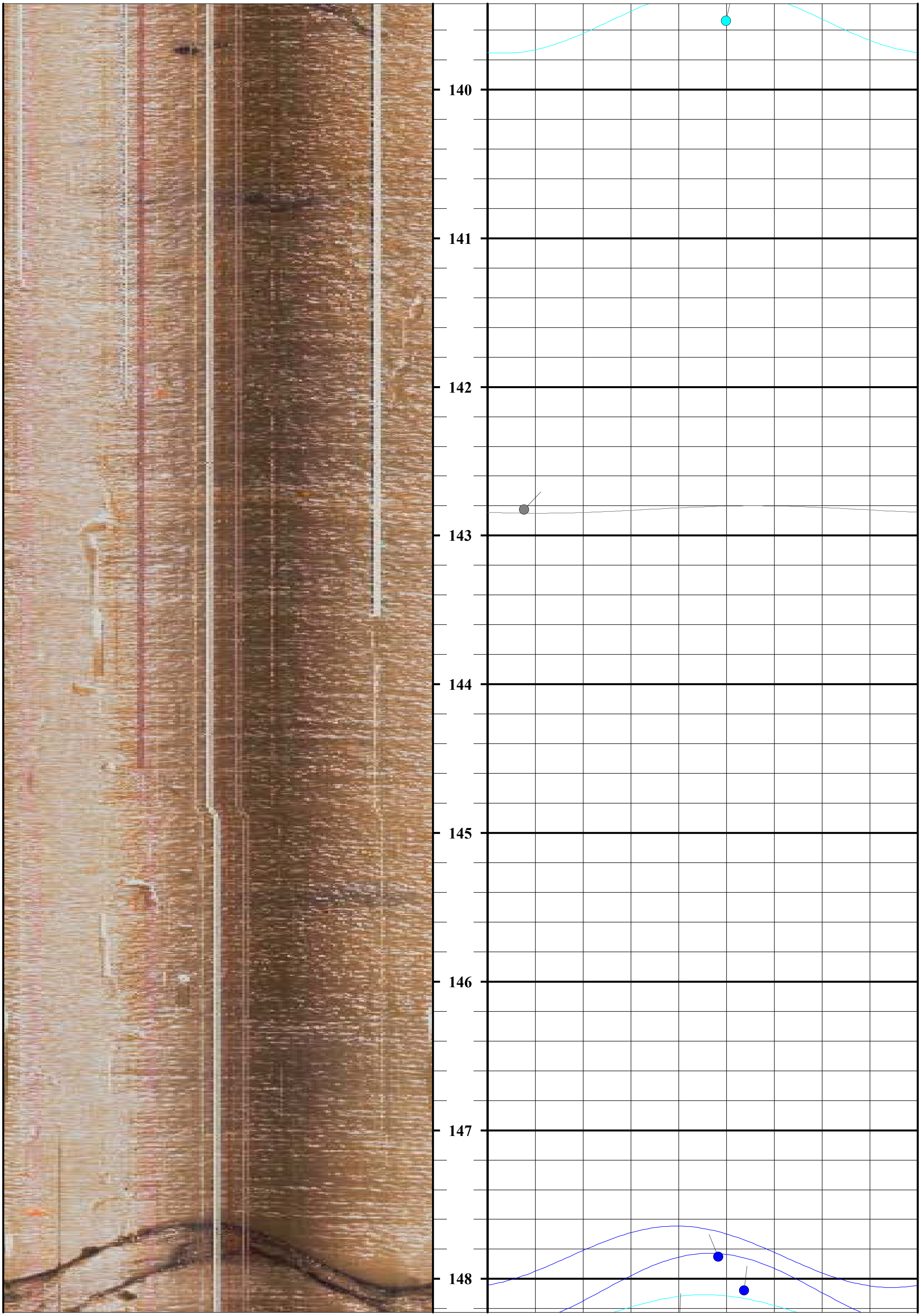
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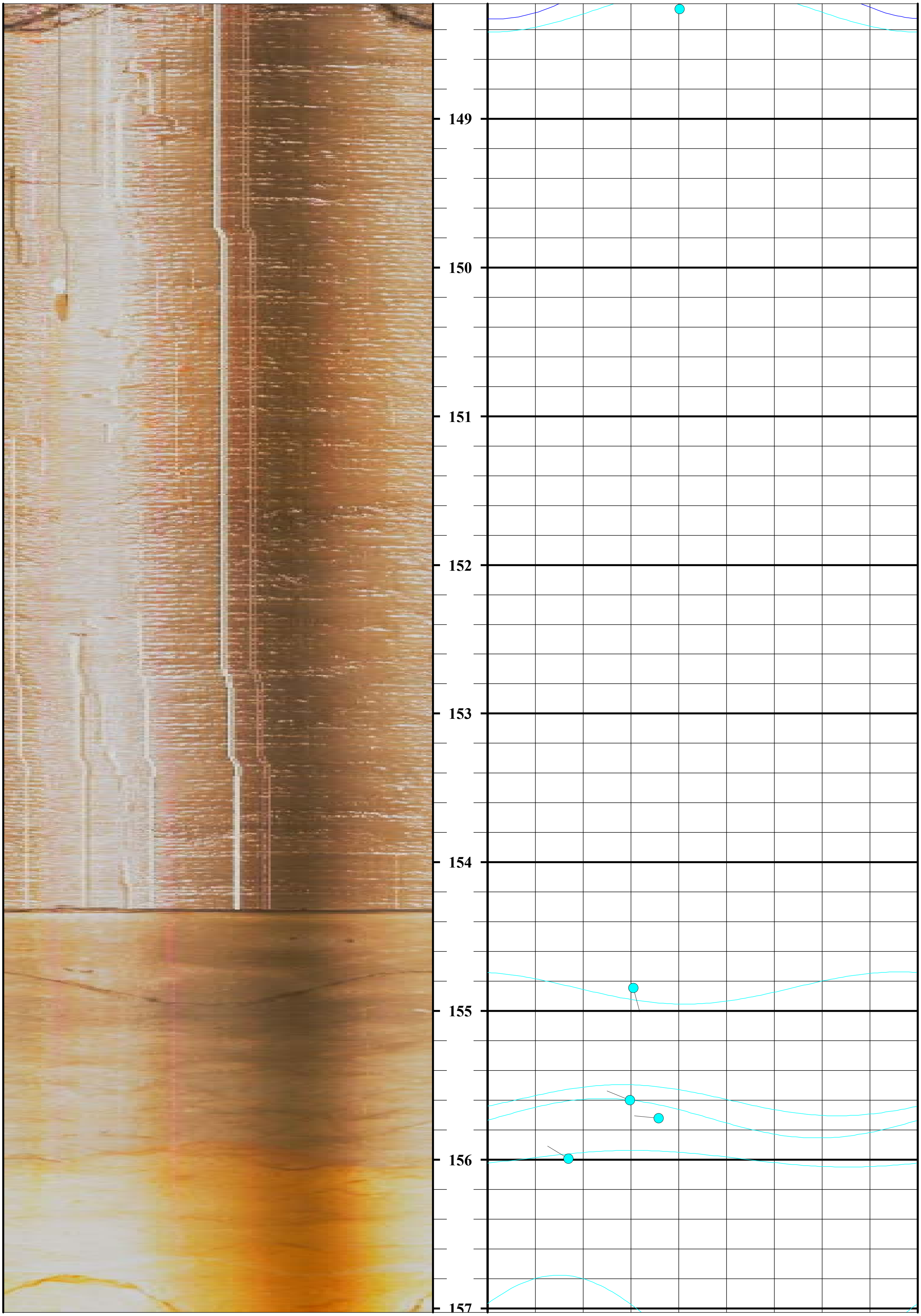
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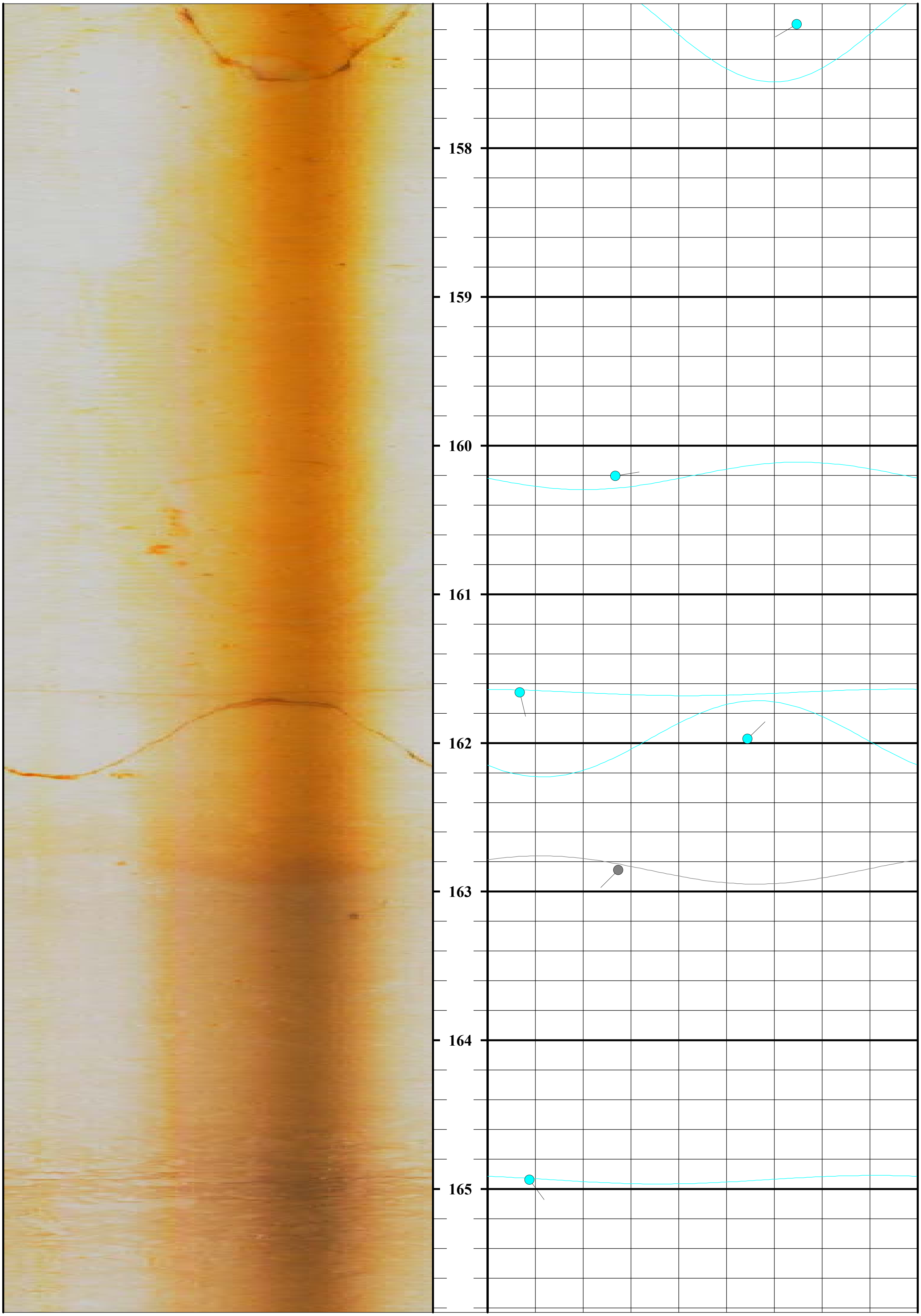
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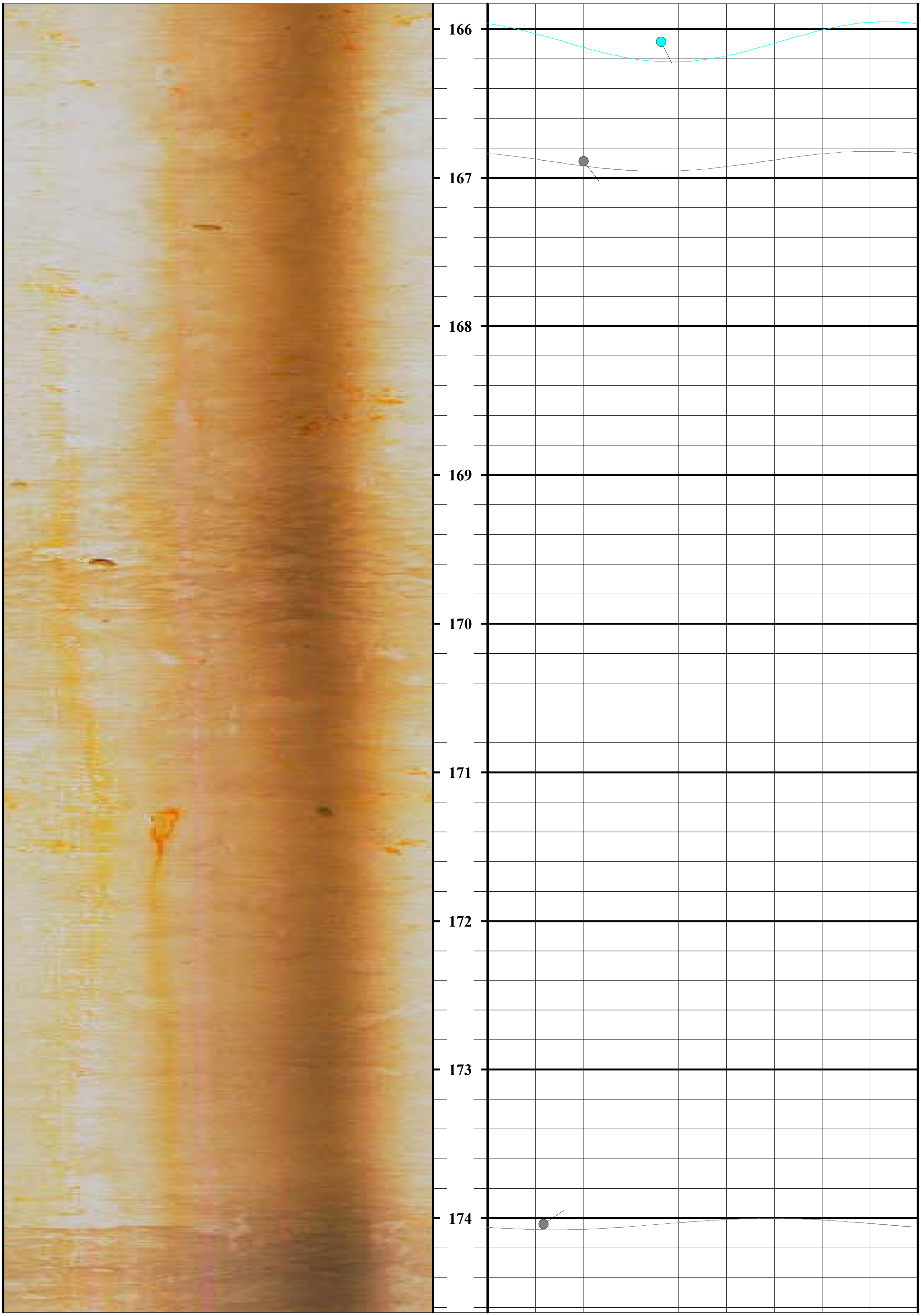
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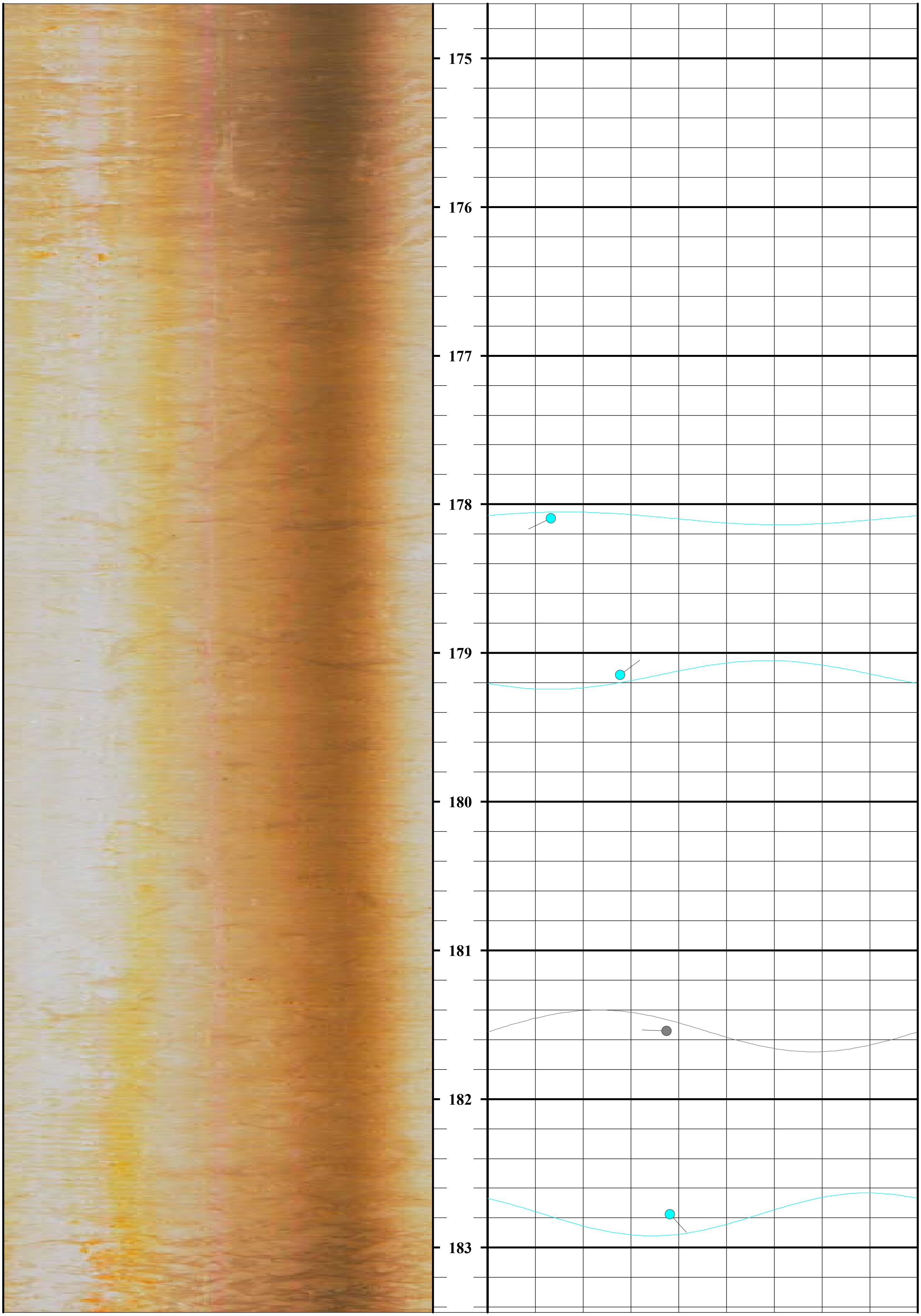
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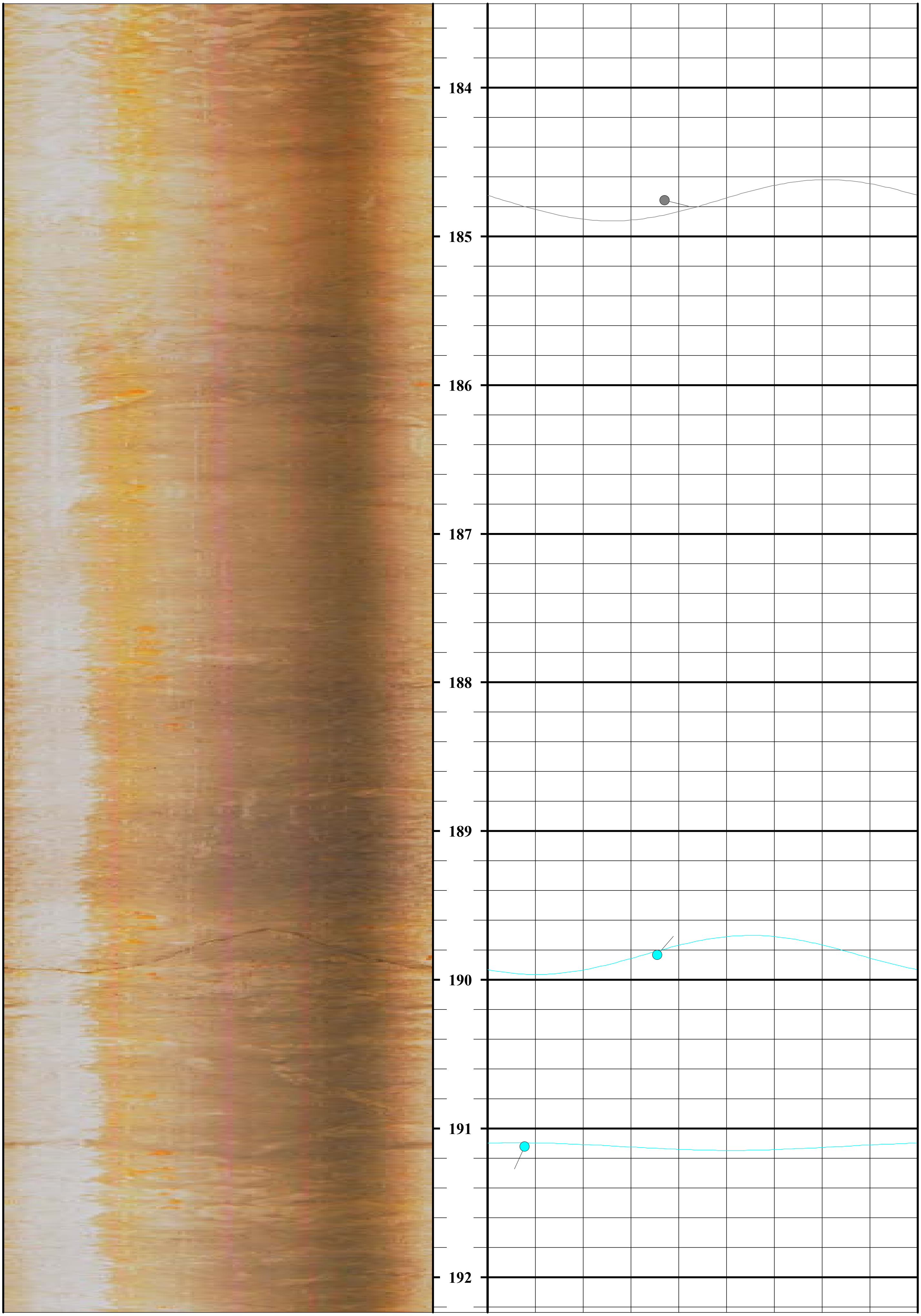
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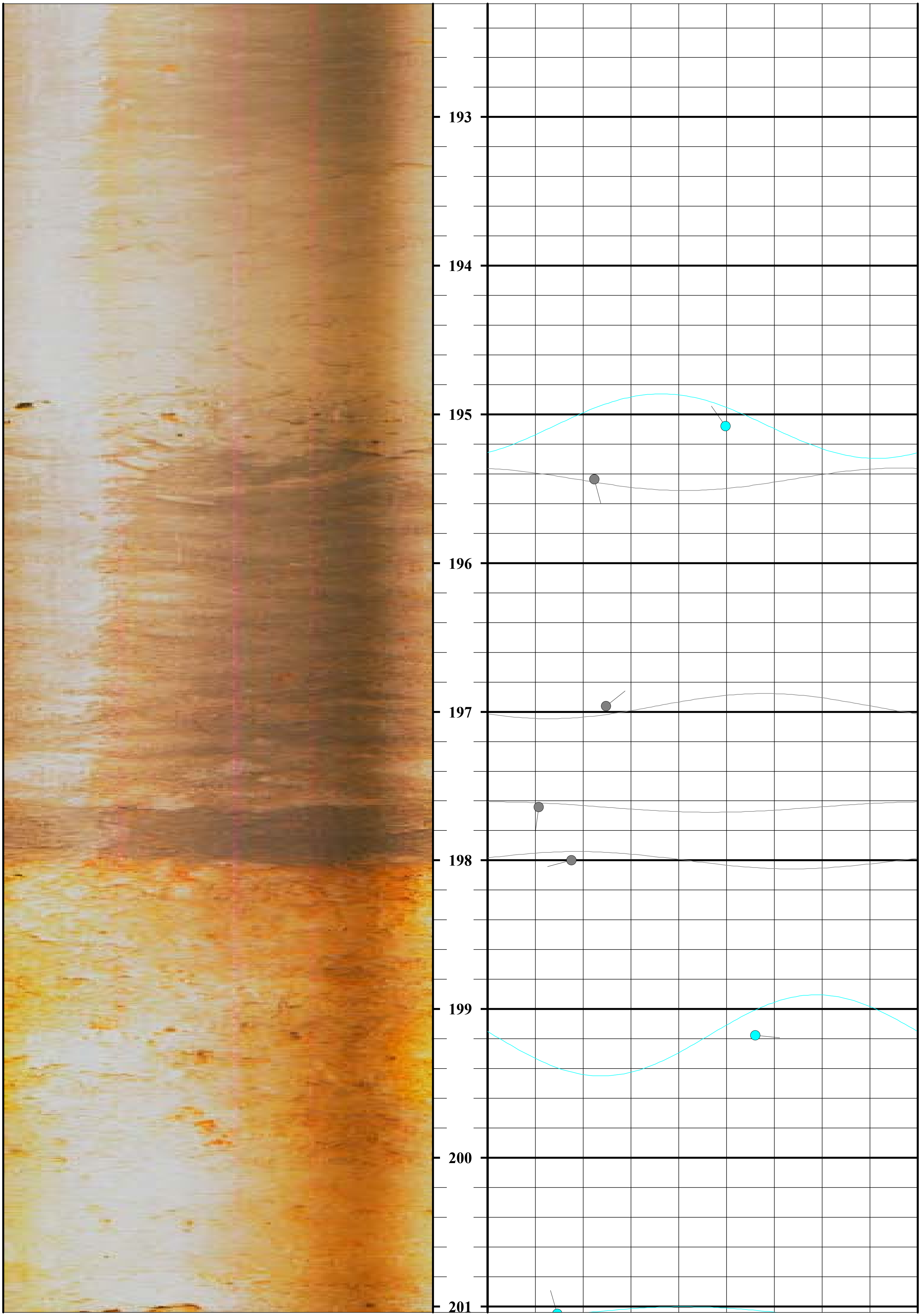
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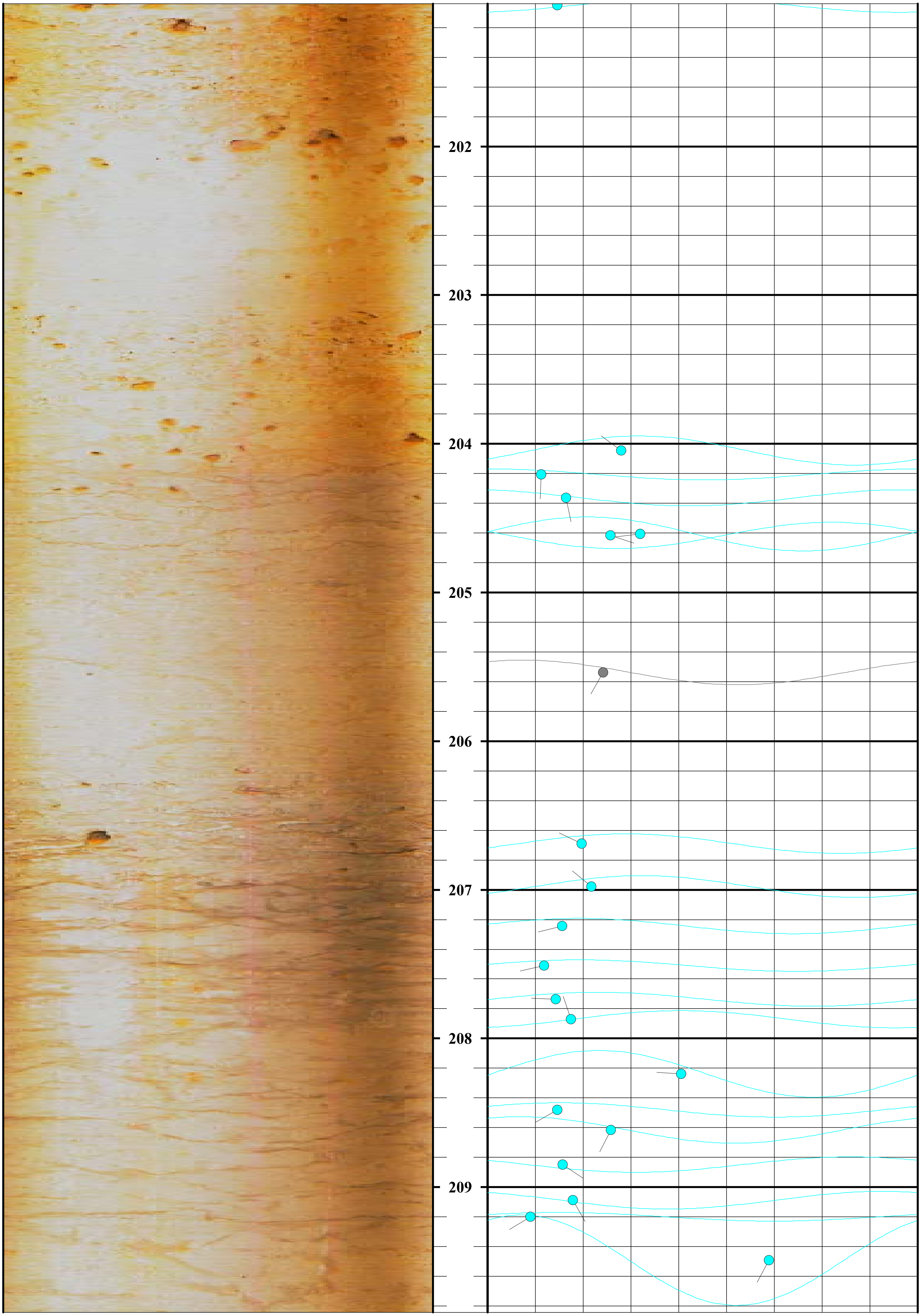
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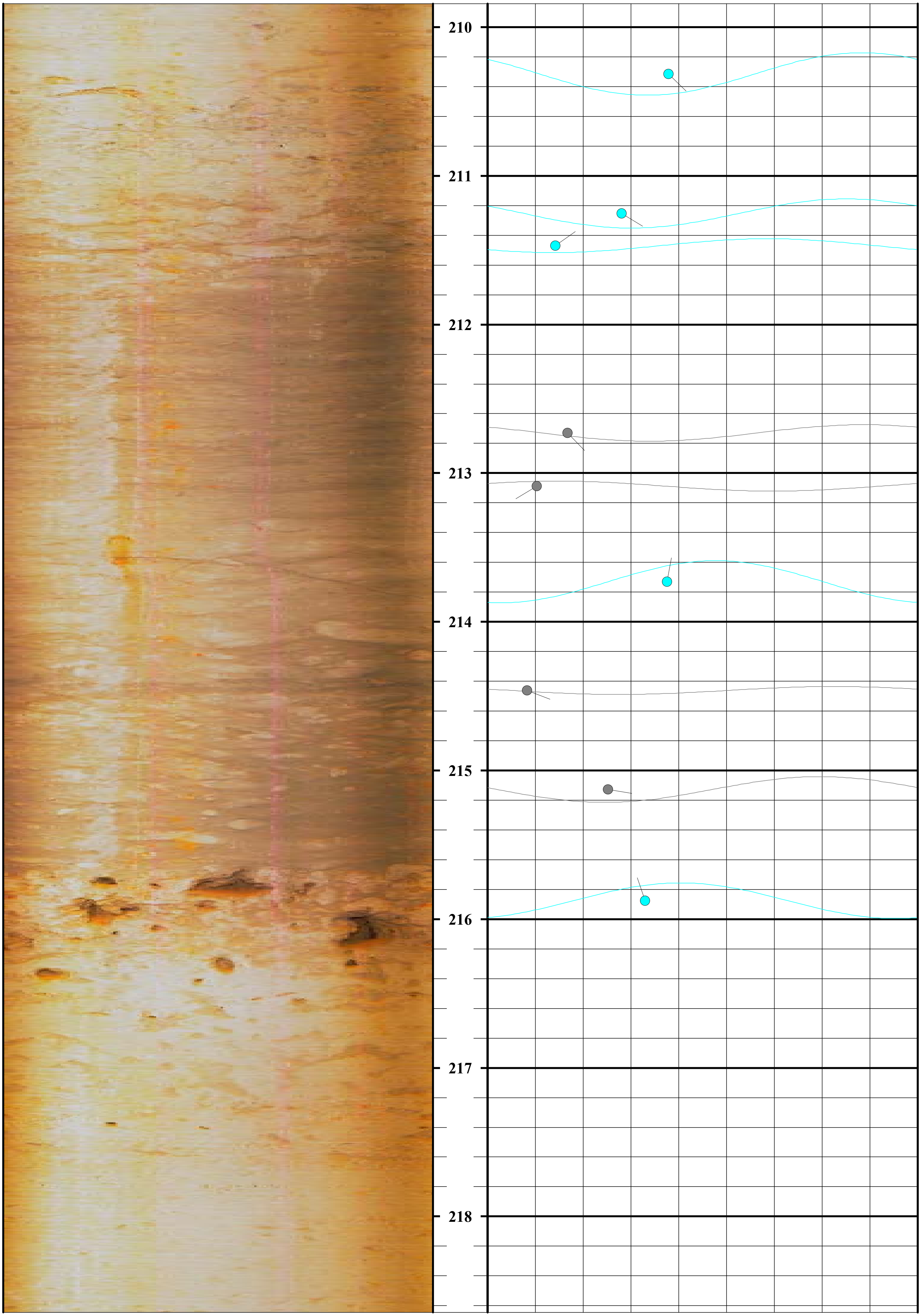
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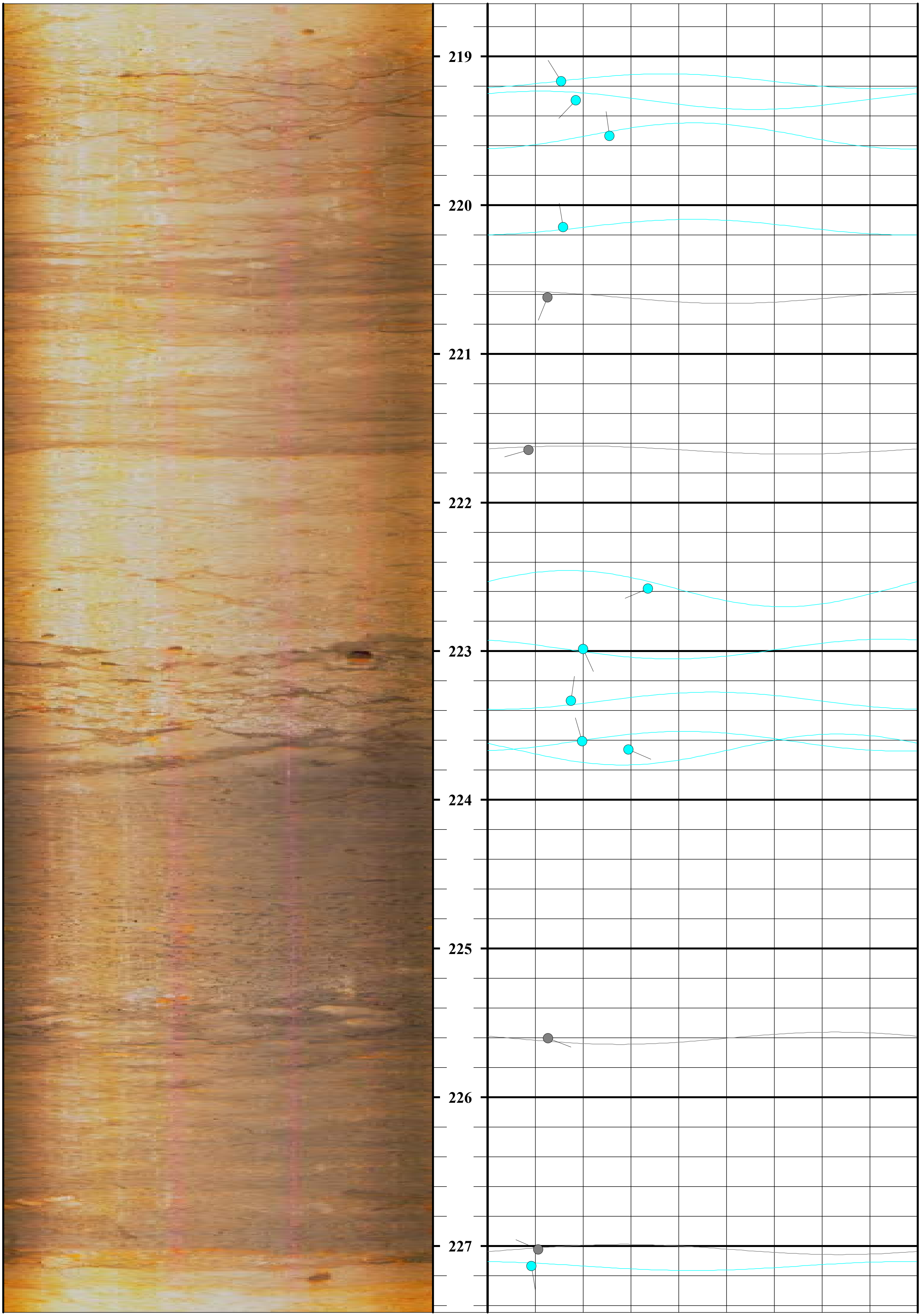
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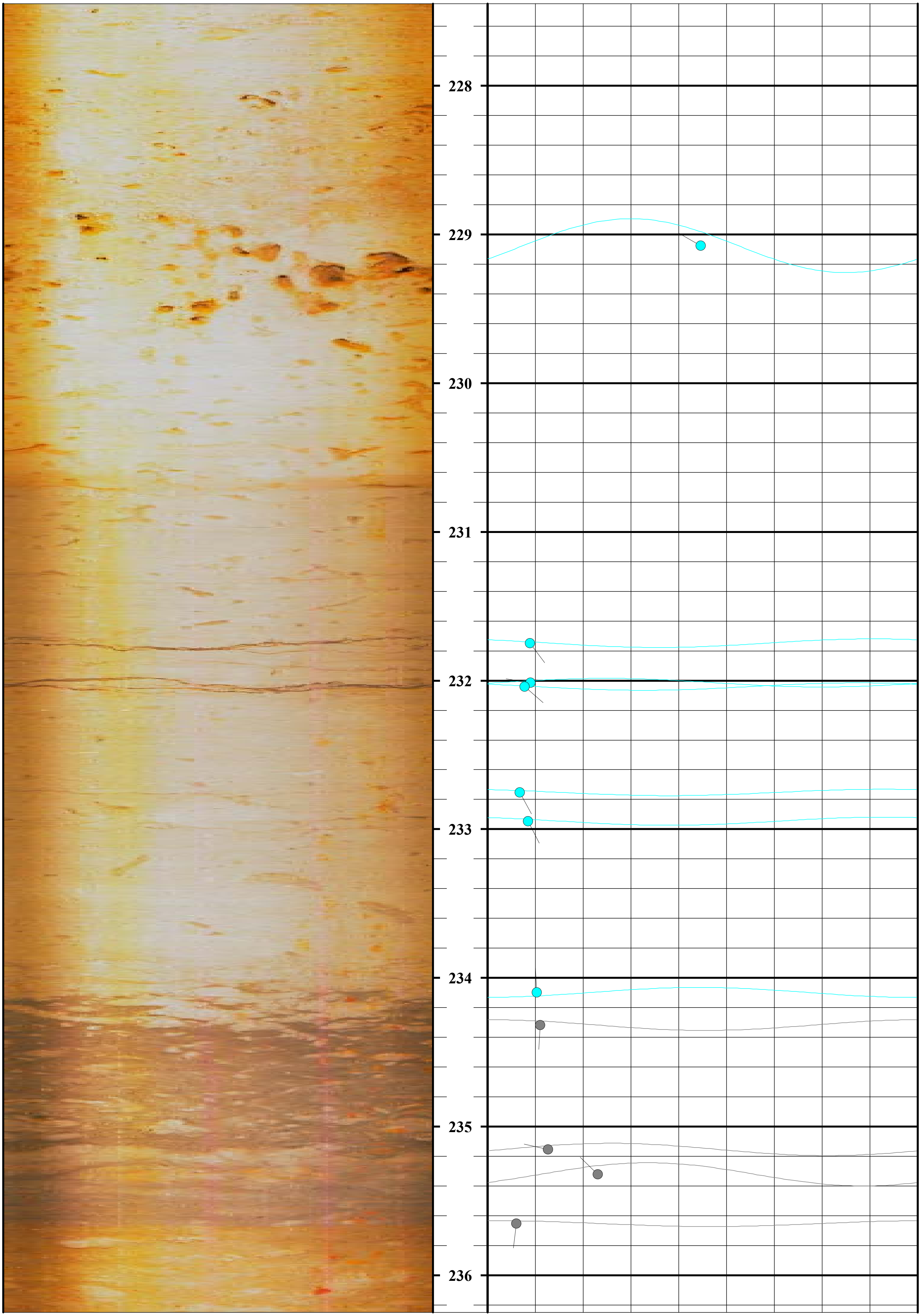
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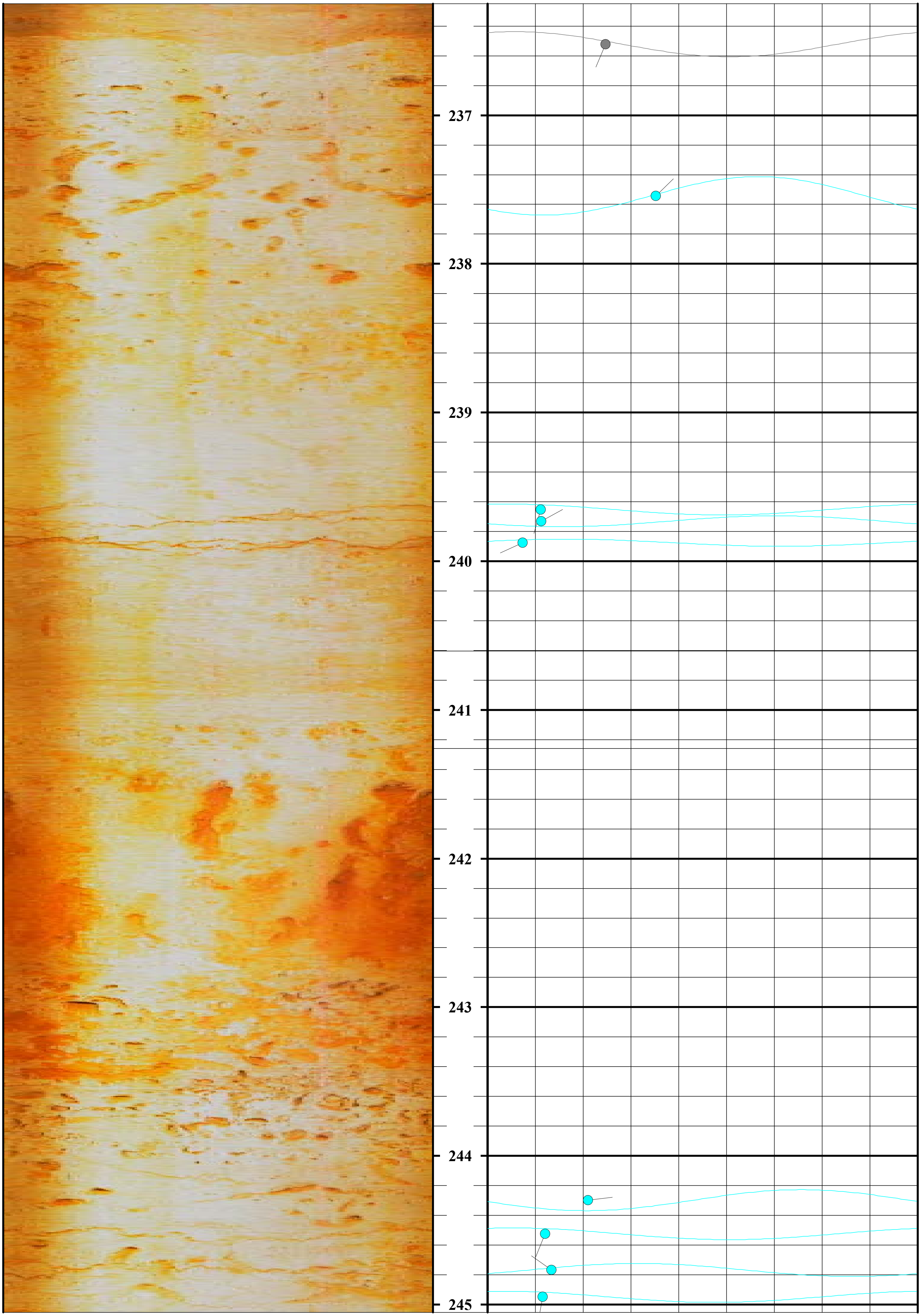
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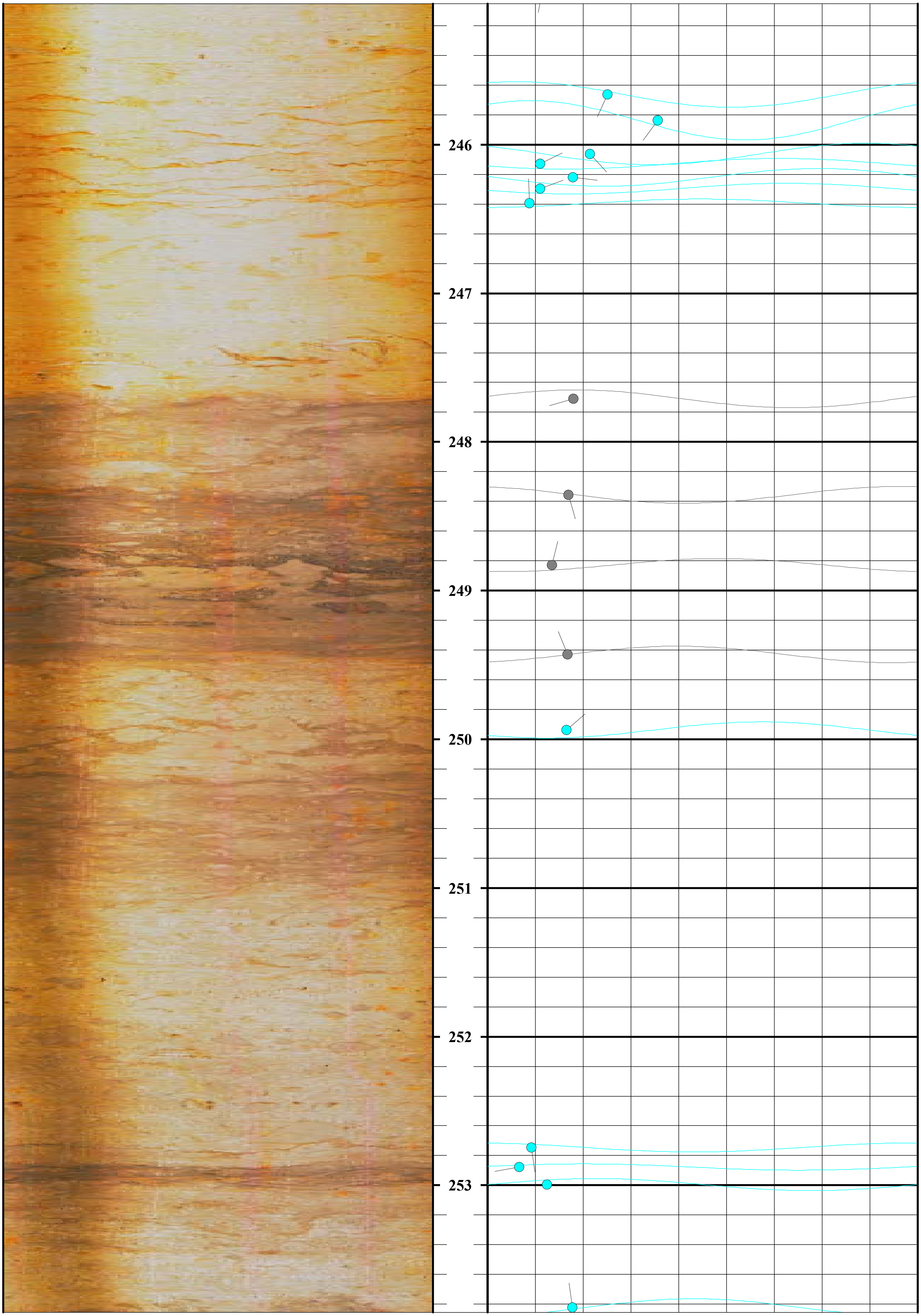
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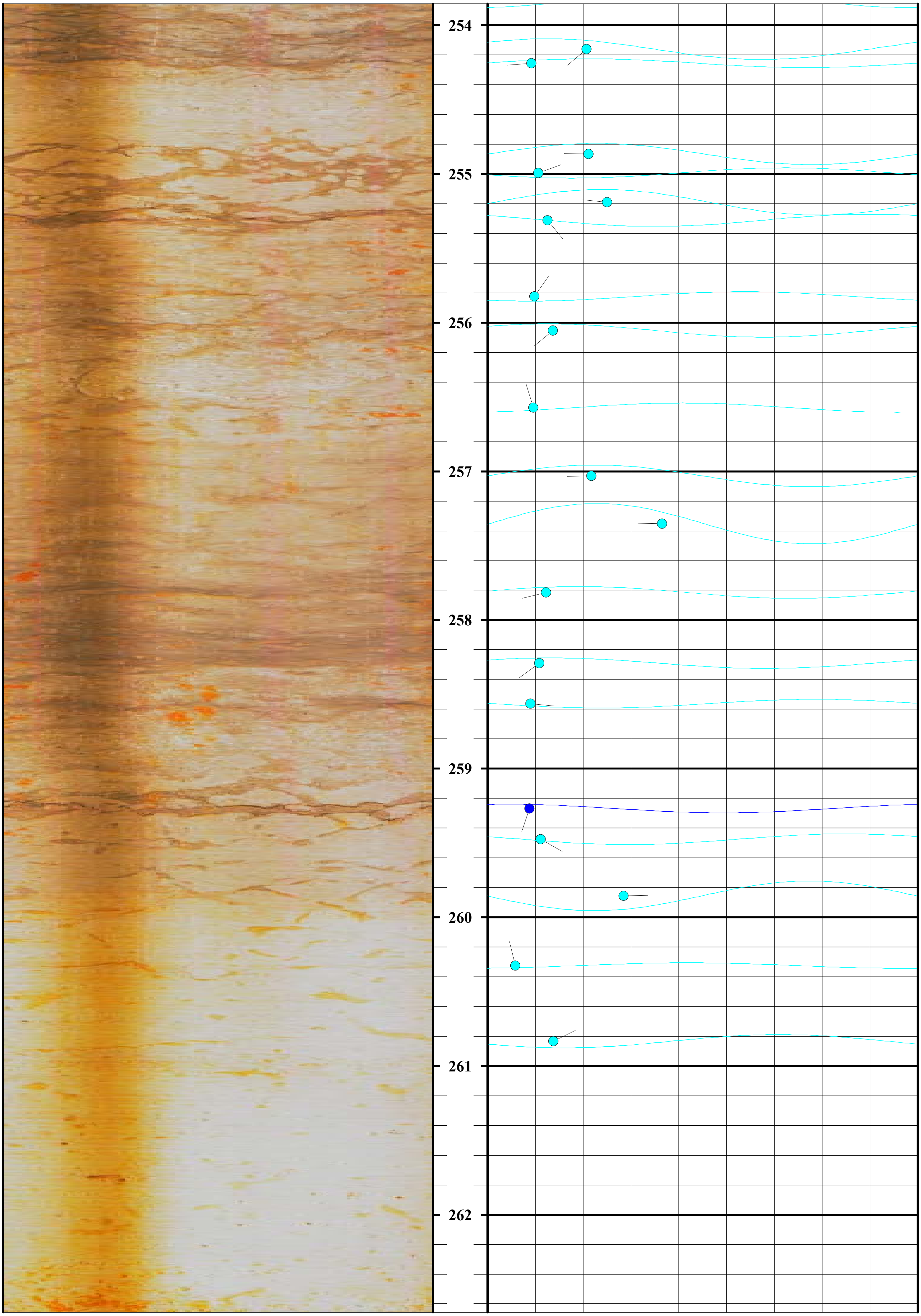
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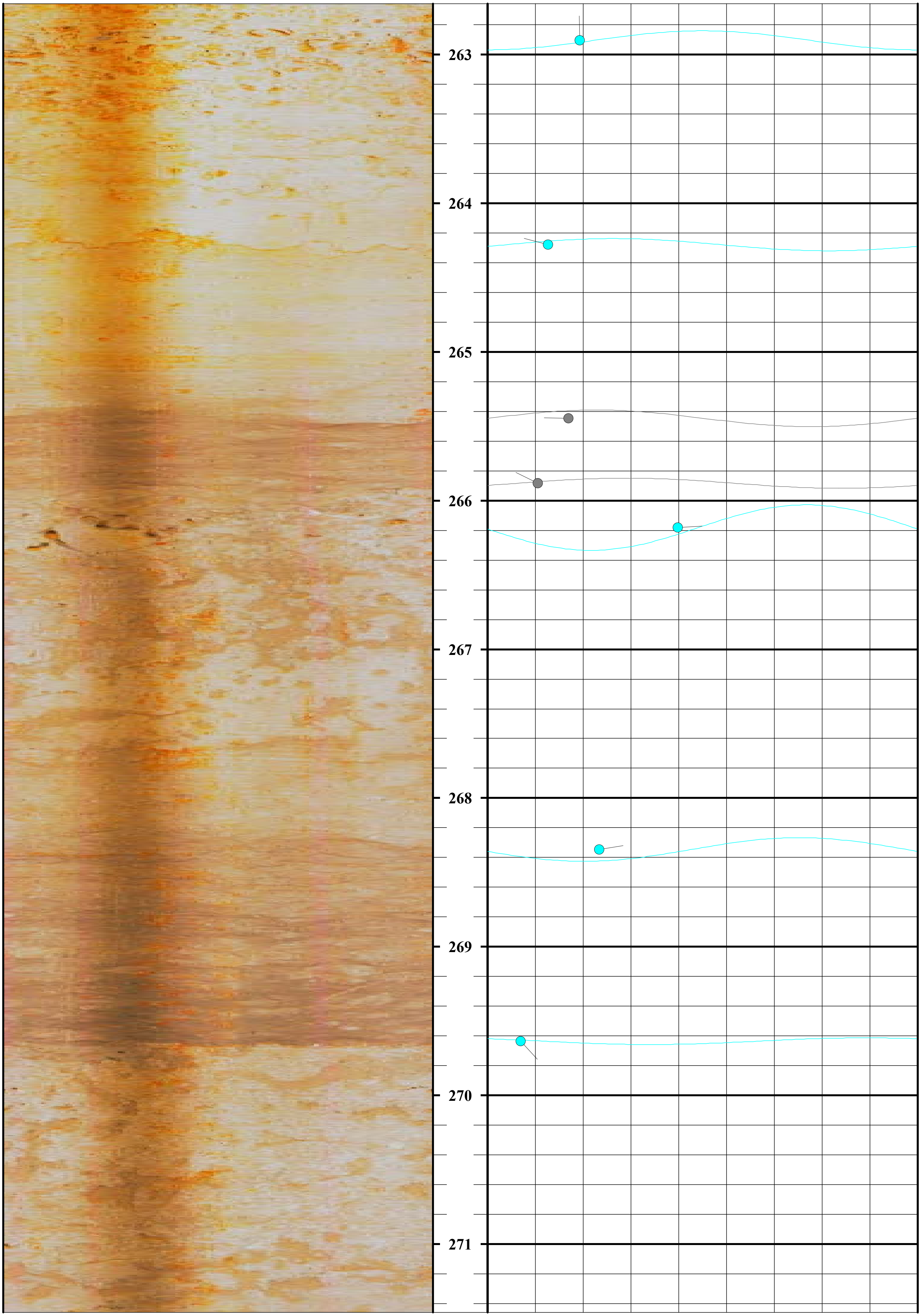
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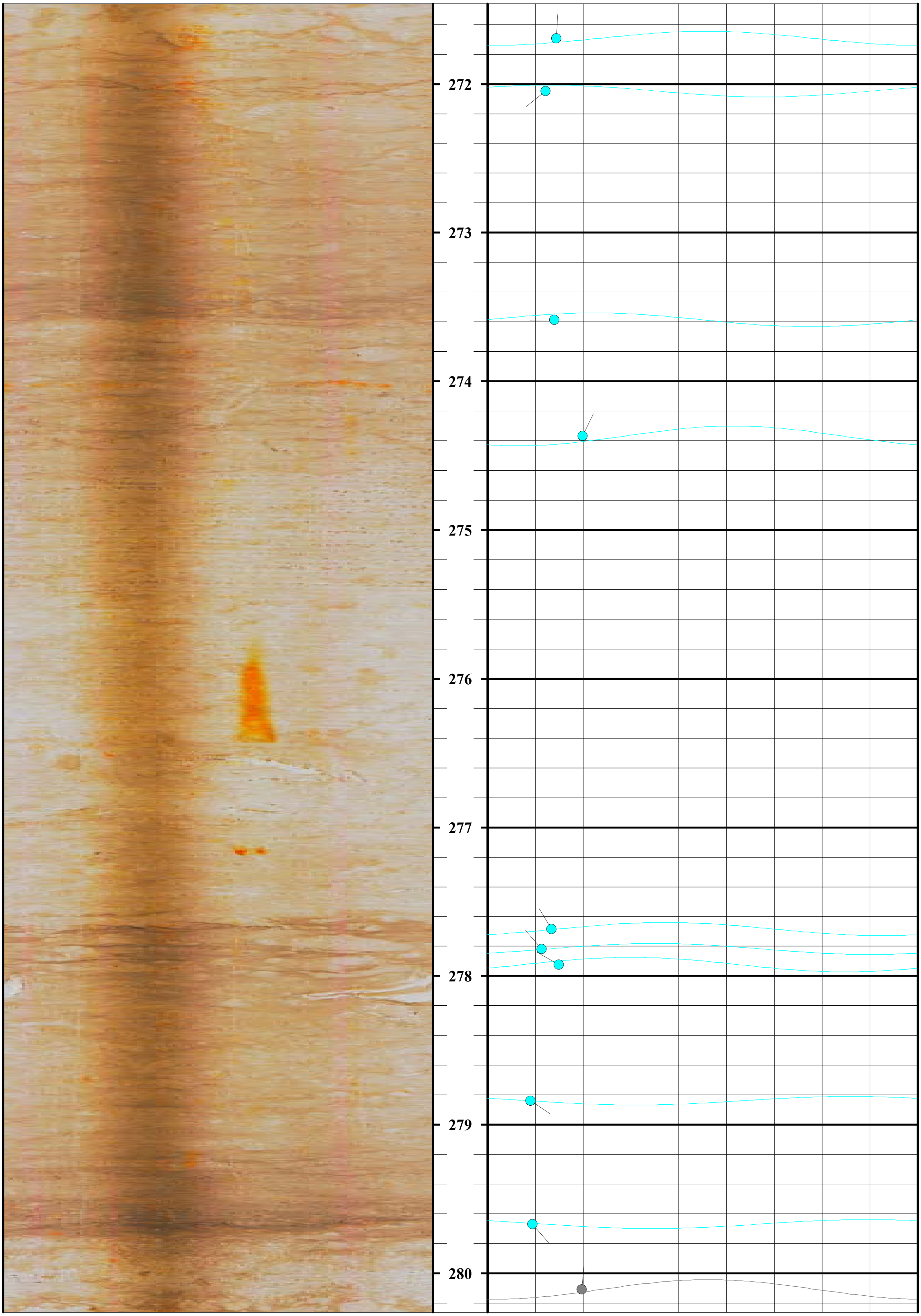
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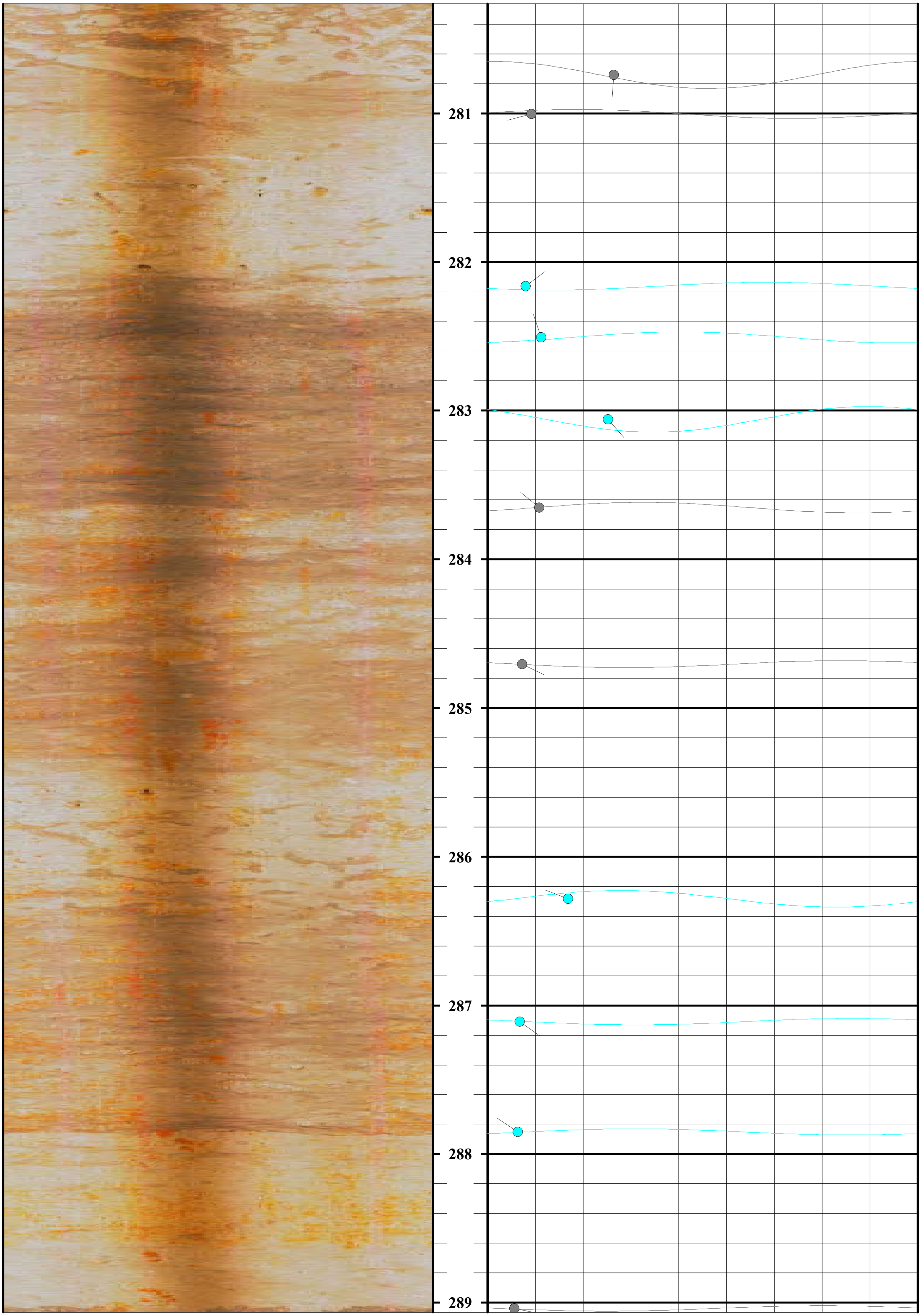
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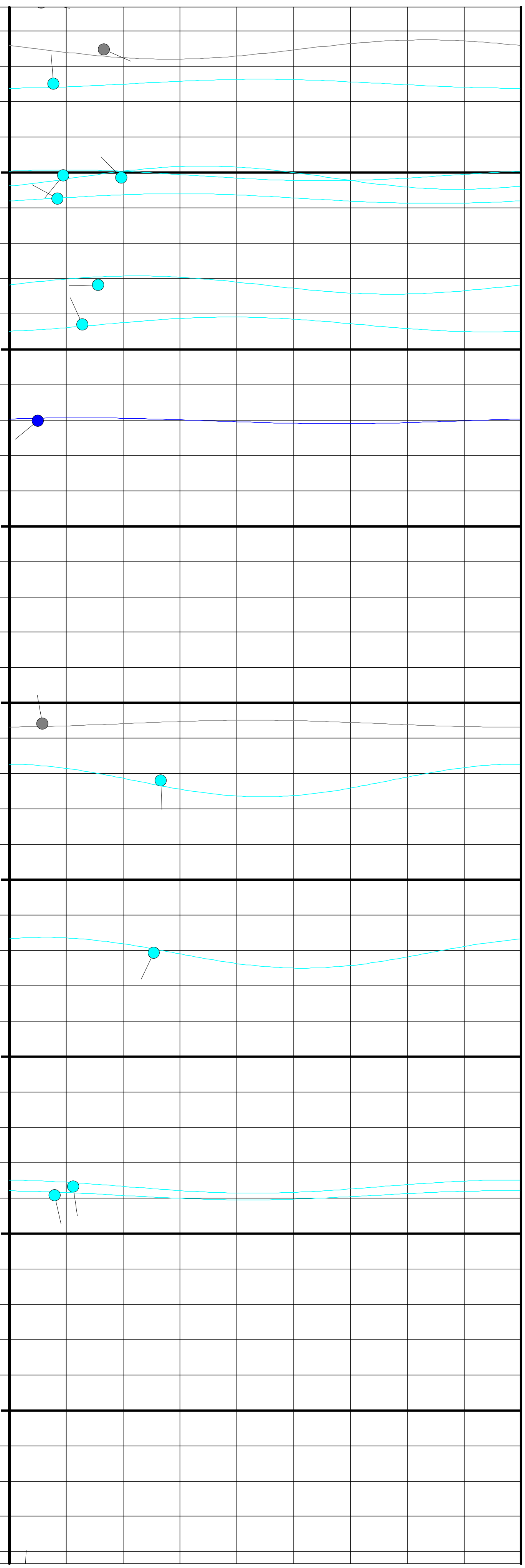

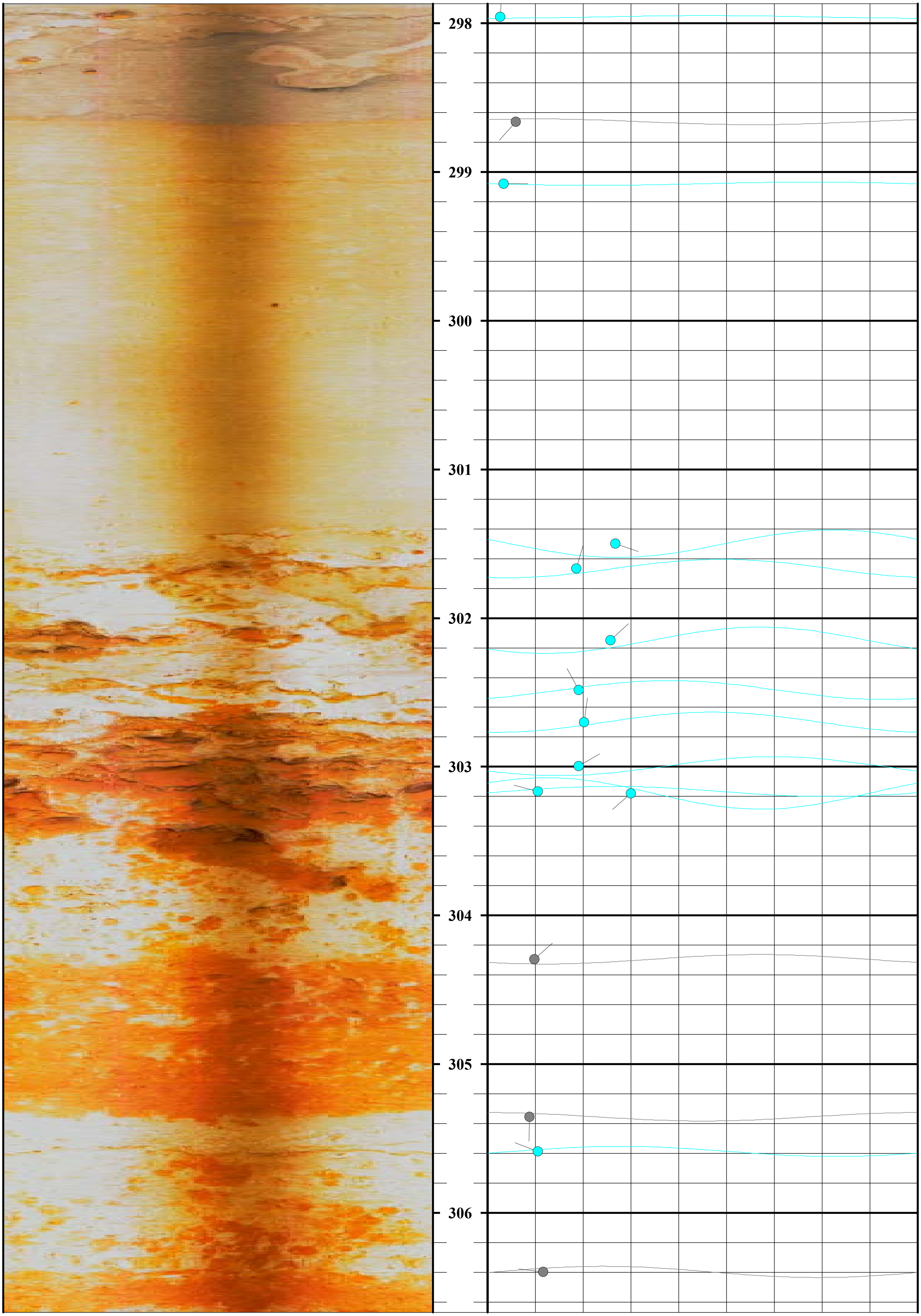
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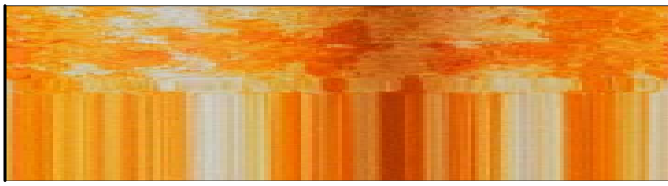

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Orientation Summary Table
Optical Image Features
Camp Stanley Storage Facility, Wellbore: WB-02
Parsons
July 20, 2003

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
1	8.45	27.7	275	11	5
2	8.54	28.0	341	9	1
3	8.61	28.3	218	8	1
4	8.64	28.4	192	8	4
5	8.70	28.6	171	5	4
6	8.72	28.6	349	11	1
7	8.80	28.9	178	7	1
8	8.85	29.0	222	4	1
9	8.90	29.2	217	4	1
10	8.96	29.4	220	3	1
11	9.03	29.6	231	8	0
12	9.12	29.9	273	5	0
13	9.27	30.4	221	3	0
14	9.34	30.6	212	5	0
15	9.43	30.9	219	5	0
16	9.72	31.9	124	9	0
17	10.18	33.4	317	50	1
18	10.29	33.8	259	48	1
19	10.43	34.2	328	16	1
20	10.64	34.9	284	14	1
21	10.70	35.1	283	7	1
22	10.78	35.4	202	10	1
23	10.87	35.7	55	5	1
24	10.93	35.9	335	8	1
25	10.96	36.0	291	11	4
26	11.09	36.4	339	13	4
27	11.21	36.8	1	8	1
28	11.37	37.3	161	1	0
29	11.45	37.6	343	7	0
30	11.63	38.2	120	24	3
31	12.18	40.0	282	9	1
32	12.20	40.0	216	6	1
33	12.25	40.2	201	5	1
34	12.27	40.3	163	5	0
35	12.36	40.5	170	6	0
36	12.42	40.8	168	5	0
37	12.63	41.4	189	2	0
38	12.66	41.5	193	8	0
39	12.72	41.7	141	4	0
40	12.75	41.8	137	4	0
41	13.16	43.2	220	16	1
42	13.55	44.5	197	14	1
43	13.68	44.9	198	7	0
44	13.73	45.0	136	3	0

All directions are with respect to magnetic north.

Orientation Summary Table
Optical Image Features
Camp Stanley Storage Facility, Wellbore: WB-02
Parsons
July 20, 2003

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
45	13.78	45.2	143	2	0
46	13.82	45.4	102	6	0
47	14.07	46.2	254	8	0
48	14.13	46.4	5	29	1
49	14.26	46.8	184	17	1
50	14.28	46.9	25	26	1
51	14.39	47.2	235	27	1
52	14.76	48.4	316	12	0
53	15.53	50.9	153	14	1
54	15.58	51.1	179	7	0
55	15.65	51.4	304	41	1
56	15.66	51.4	107	37	1
57	15.70	51.5	293	56	1
58	16.29	53.4	176	22	1
59	16.34	53.6	109	10	1
60	16.40	53.8	359	17	1
61	16.44	53.9	323	21	1
62	16.51	54.2	330	3	1
63	16.66	54.7	122	9	1
64	16.77	55.0	141	19	1
65	16.82	55.2	192	9	1
66	16.85	55.3	146	10	1
67	16.94	55.6	19	11	1
68	17.24	56.6	292	10	1
69	17.88	58.7	310	13	1
70	17.89	58.7	127	24	1
71	18.76	61.5	128	28	0
72	18.78	61.6	136	9	1
73	18.84	61.8	146	15	1
74	19.43	63.8	247	31	1
75	20.17	66.2	226	8	1
76	20.40	66.9	245	18	1
77	20.47	67.2	139	68	1
78	20.61	67.6	53	5	1
79	20.85	68.4	287	12	1
80	20.98	68.8	206	11	1
81	21.18	69.5	226	36	1
82	21.89	71.8	339	23	0
83	22.24	73.0	92	20	1
84	22.56	74.0	340	10	0
85	22.62	74.2	336	28	1
86	22.63	74.2	197	13	1
87	22.70	74.5	211	7	0
88	22.76	74.7	185	22	1

All directions are with respect to magnetic north.

Orientation Summary Table
Optical Image Features
Camp Stanley Storage Facility, Wellbore: WB-02
Parsons
July 20, 2003

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
89	22.84	74.9	30	8	1
90	22.88	75.1	131	6	1
91	23.02	75.5	146	1	0
92	23.13	75.9	185	7	0
93	23.97	78.6	44	15	0
94	24.80	81.4	2	4	0
95	25.07	82.2	257	11	1
96	25.45	83.5	282	5	0
97	25.58	83.9	309	5	1
98	25.67	84.2	93	7	0
99	25.83	84.7	336	14	0
100	26.04	85.4	263	5	0
101	26.14	85.8	254	6	0
102	26.25	86.1	338	9	0
103	26.50	87.0	151	5	0
104	26.78	87.9	316	61	1
105	26.85	88.1	254	24	1
106	26.95	88.4	98	12	1
107	26.99	88.6	76	25	1
108	27.06	88.8	149	9	0
109	27.26	89.4	86	15	0
110	27.44	90.0	235	13	0
111	27.48	90.2	26	26	0
112	27.90	91.5	1	28	1
113	28.04	92.0	128	15	1
114	28.39	93.1	314	53	1
115	28.50	93.5	337	59	2
116	28.57	93.7	68	14	1
117	28.79	94.5	295	38	2
118	28.91	94.9	313	61	2
119	29.00	95.1	310	65	1
120	29.21	95.8	24	31	3
121	29.62	97.2	127	5	0
122	29.83	97.9	172	10	1
123	30.00	98.4	347	58	3
124	30.46	99.9	300	3	1
125	31.09	102.0	13	16	1
126	31.14	102.2	209	41	1
127	31.21	102.4	311	8	1
128	31.54	103.5	65	13	1
129	31.60	103.7	297	9	1
130	31.64	103.8	222	9	3
131	31.88	104.6	341	29	1
132	31.96	104.9	327	15	0

All directions are with respect to magnetic north.

Orientation Summary Table
Optical Image Features
Camp Stanley Storage Facility, Wellbore: WB-02
Parsons
July 20, 2003

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
133	32.36	106.2	315	39	1
134	32.54	106.8	165	17	1
135	32.62	107.0	320	12	1
136	32.69	107.3	357	5	0
137	32.76	107.5	13	11	0
138	32.82	107.7	47	6	0
139	33.83	111.0	6	10	5
140	34.33	112.6	124	14	5
141	34.46	113.1	73	44	5
142	34.74	114.0	40	20	1
143	34.78	114.1	167	42	5
144	35.22	115.6	32	4	1
145	36.47	119.7	15	49	3
146	36.52	119.8	161	12	1
147	36.56	119.9	158	10	3
148	36.72	120.5	145	49	1
149	37.35	122.6	142	61	1
150	37.93	124.5	23	19	1
151	38.65	126.8	26	26	1
152	39.79	130.6	87	27	1
153	39.90	130.9	74	34	3
154	40.51	132.9	330	26	1
155	40.82	133.9	346	34	1
156	40.97	134.4	14	33	5
157	41.33	135.6	236	39	5
158	42.31	138.8	222	18	0
159	42.53	139.5	13	50	1
160	43.53	142.8	43	8	0
161	45.06	147.9	338	48	2
162	45.13	148.1	6	54	2
163	45.19	148.3	2	40	1
164	47.20	154.9	165	31	1
165	47.43	155.6	293	30	1
166	47.46	155.7	276	36	1
167	47.55	156.0	302	17	1
168	47.91	157.2	240	65	1
169	48.83	160.2	81	27	1
170	49.27	161.7	166	7	1
171	49.37	162.0	46	54	1
172	49.64	162.9	224	27	0
173	50.27	164.9	143	9	1
174	50.62	166.1	154	36	1
175	50.87	166.9	142	20	0
176	53.05	174.0	56	12	0

All directions are with respect to magnetic north.

Orientation Summary Table
Optical Image Features
Camp Stanley Storage Facility, Wellbore: WB-02
Parsons
July 20, 2003

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
177	54.28	178.1	245	13	1
178	54.60	179.2	54	28	1
179	55.33	181.5	273	38	0
180	55.71	182.8	138	38	1
181	56.31	184.8	104	37	0
182	57.86	189.8	41	36	1
183	58.25	191.1	204	8	1
184	59.46	195.1	325	50	1
185	59.57	195.4	165	22	0
186	60.03	197.0	51	25	0
187	60.24	197.6	187	11	0
188	60.35	198.0	255	18	0
189	60.71	199.2	95	56	1
190	61.28	201.1	344	15	1
191	62.19	204.1	307	28	1
192	62.24	204.2	182	11	1
193	62.29	204.4	168	16	1
194	62.37	204.6	263	32	1
195	62.37	204.6	108	26	1
196	62.65	205.5	209	24	0
197	63.00	206.7	296	20	1
198	63.09	207.0	310	22	1
199	63.17	207.2	256	16	1
200	63.25	207.5	258	12	1
201	63.32	207.7	272	14	1
202	63.36	207.9	342	18	1
203	63.47	208.2	273	41	1
204	63.54	208.5	240	15	1
205	63.58	208.6	207	26	1
206	63.66	208.9	124	16	1
207	63.73	209.1	151	18	1
208	63.76	209.2	239	9	1
209	63.85	209.5	208	59	1
210	64.10	210.3	134	38	1
211	64.39	211.3	120	28	1
212	64.46	211.5	55	14	1
213	64.84	212.7	135	17	0
214	64.95	213.1	239	10	0
215	65.14	213.7	11	38	1
216	65.37	214.5	110	8	0
217	65.57	215.1	98	25	0
218	65.80	215.9	342	33	1
219	66.80	219.2	329	15	1
220	66.84	219.3	224	19	1

All directions are with respect to magnetic north.

Orientation Summary Table
Optical Image Features
Camp Stanley Storage Facility, Wellbore: WB-02
Parsons
July 20, 2003

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
221	66.91	219.5	352	26	1
222	67.10	220.2	351	16	1
223	67.24	220.6	201	13	0
224	67.56	221.7	254	9	0
225	67.84	222.6	248	34	1
226	67.96	223.0	155	20	1
227	68.07	223.3	8	17	1
228	68.15	223.6	345	20	1
229	68.17	223.7	113	30	1
230	68.77	225.6	110	13	0
231	69.20	227.0	294	11	0
232	69.23	227.1	171	9	1
233	69.82	229.1	300	45	1
234	70.64	231.8	143	9	1
235	70.72	232.0	279	9	1
236	70.73	232.0	130	8	1
237	70.94	232.8	152	7	1
238	71.00	233.0	152	9	1
239	71.35	234.1	357	10	1
240	71.42	234.3	182	11	0
241	71.67	235.2	283	13	0
242	71.73	235.3	314	23	0
243	71.83	235.7	186	6	0
244	72.09	236.5	203	25	0
245	72.40	237.5	46	35	1
246	73.05	239.7	196	11	1
247	73.07	239.7	61	11	1
248	73.12	239.9	245	7	1
249	74.46	244.3	83	21	1
250	74.53	244.5	202	12	1
251	74.61	244.8	305	13	1
252	74.66	245.0	190	12	1
253	74.88	245.7	204	25	1
254	74.93	245.8	216	36	1
255	75.00	246.1	138	21	1
256	75.02	246.1	64	11	1
257	75.05	246.2	97	18	1
258	75.07	246.3	71	11	1
259	75.10	246.4	358	9	1
260	75.50	247.7	254	18	0
261	75.70	248.4	164	17	0
262	75.84	248.8	14	14	0
263	76.03	249.4	339	17	0
264	76.18	249.9	49	17	1

All directions are with respect to magnetic north.

Orientation Summary Table
Optical Image Features
Camp Stanley Storage Facility, Wellbore: WB-02
Parsons
July 20, 2003

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
265	77.04	252.7	172	9	1
266	77.08	252.9	260	7	1
267	77.11	253.0	270	12	1
268	77.36	253.8	353	18	1
269	77.47	254.2	229	21	1
270	77.50	254.3	266	9	1
271	77.68	254.9	271	21	1
272	77.72	255.0	70	11	1
273	77.78	255.2	276	25	1
274	77.82	255.3	140	13	1
275	77.97	255.8	35	10	1
276	78.04	256.1	231	14	1
277	78.20	256.6	343	10	1
278	78.34	257.0	270	22	1
279	78.44	257.4	271	37	1
280	78.58	257.8	257	12	1
281	78.73	258.3	233	11	1
282	78.81	258.6	95	9	1
283	79.03	259.3	197	9	2
284	79.09	259.5	119	11	1
285	79.21	259.9	89	29	1
286	79.35	260.3	347	6	1
287	79.50	260.8	65	14	1
288	80.13	262.9	360	19	1
289	80.55	264.3	285	13	1
290	80.91	265.4	271	17	0
291	81.04	265.9	296	11	0
292	81.13	266.2	86	40	1
293	81.79	268.4	81	23	1
294	82.19	269.6	137	7	1
295	82.81	271.7	3	14	1
296	82.92	272.1	231	12	1
297	83.39	273.6	270	14	1
298	83.63	274.4	26	20	1
299	84.64	277.7	329	13	1
300	84.68	277.8	320	11	1
301	84.71	277.9	300	15	1
302	84.99	278.8	124	9	1
303	85.24	279.7	138	9	1
304	85.38	280.1	5	20	0
305	85.57	280.7	184	26	0
306	85.65	281.0	255	9	0
307	86.00	282.2	54	8	1
308	86.11	282.5	342	11	1

All directions are with respect to magnetic north.

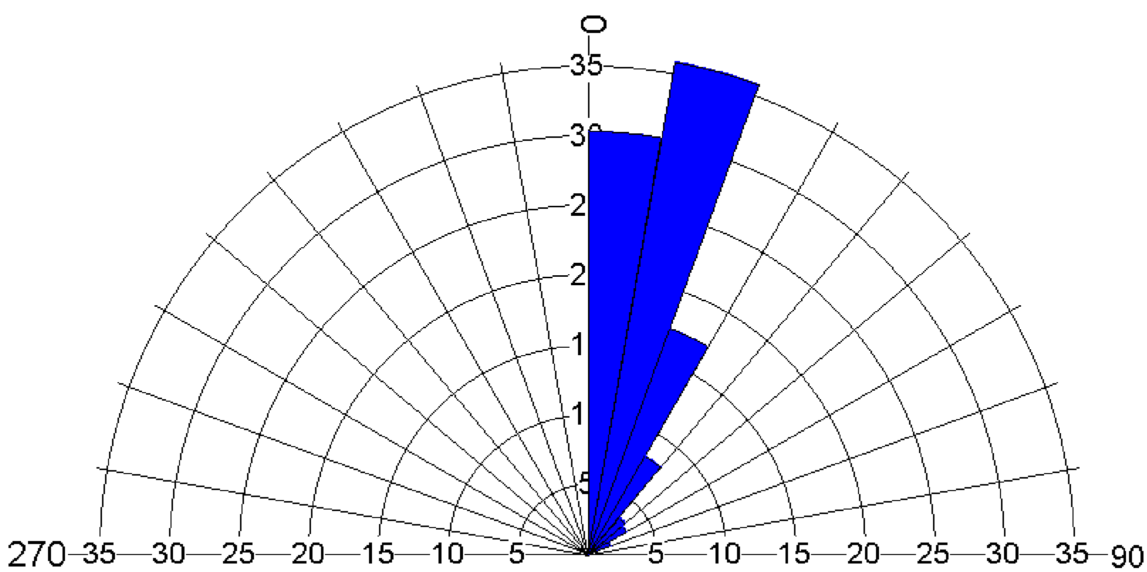
Orientation Summary Table
Optical Image Features
Camp Stanley Storage Facility, Wellbore: WB-02
Parsons
July 20, 2003

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
309	86.28	283.1	139	25	1
310	86.46	283.7	310	11	0
311	86.78	284.7	115	7	0
312	87.26	286.3	292	17	1
313	87.51	287.1	125	7	1
314	87.74	287.9	304	6	1
315	88.10	289.0	101	6	0
316	88.18	289.3	113	17	0
317	88.24	289.5	356	8	1
318	88.40	290.0	220	10	1
319	88.40	290.0	316	20	1
320	88.44	290.2	298	8	1
321	88.59	290.6	269	16	1
322	88.65	290.9	336	13	1
323	88.82	291.4	231	5	2
324	89.34	293.1	351	6	0
325	89.44	293.4	178	27	1
326	89.74	294.4	206	25	1
327	90.14	295.7	172	11	1
328	90.15	295.8	168	8	1
329	90.82	298.0	4	3	1
330	91.03	298.7	222	6	0
331	91.16	299.1	89	3	1
332	91.90	301.5	108	27	1
333	91.95	301.7	16	19	1
334	92.10	302.2	48	26	1
335	92.20	302.5	332	19	1
336	92.26	302.7	8	20	1
337	92.35	303.0	59	19	1
338	92.41	303.2	285	11	1
339	92.41	303.2	229	30	1
340	92.75	304.3	48	10	0
341	93.07	305.4	181	9	0
342	93.14	305.6	291	11	1
343	93.39	306.4	277	12	0

All directions are with respect to magnetic north.

Figure WB-02:5
Rose Diagram of Optical Televiewer Features
Parsons
Camp Stanley Storage Facility: Wellbore WB-02
July 20, 2003

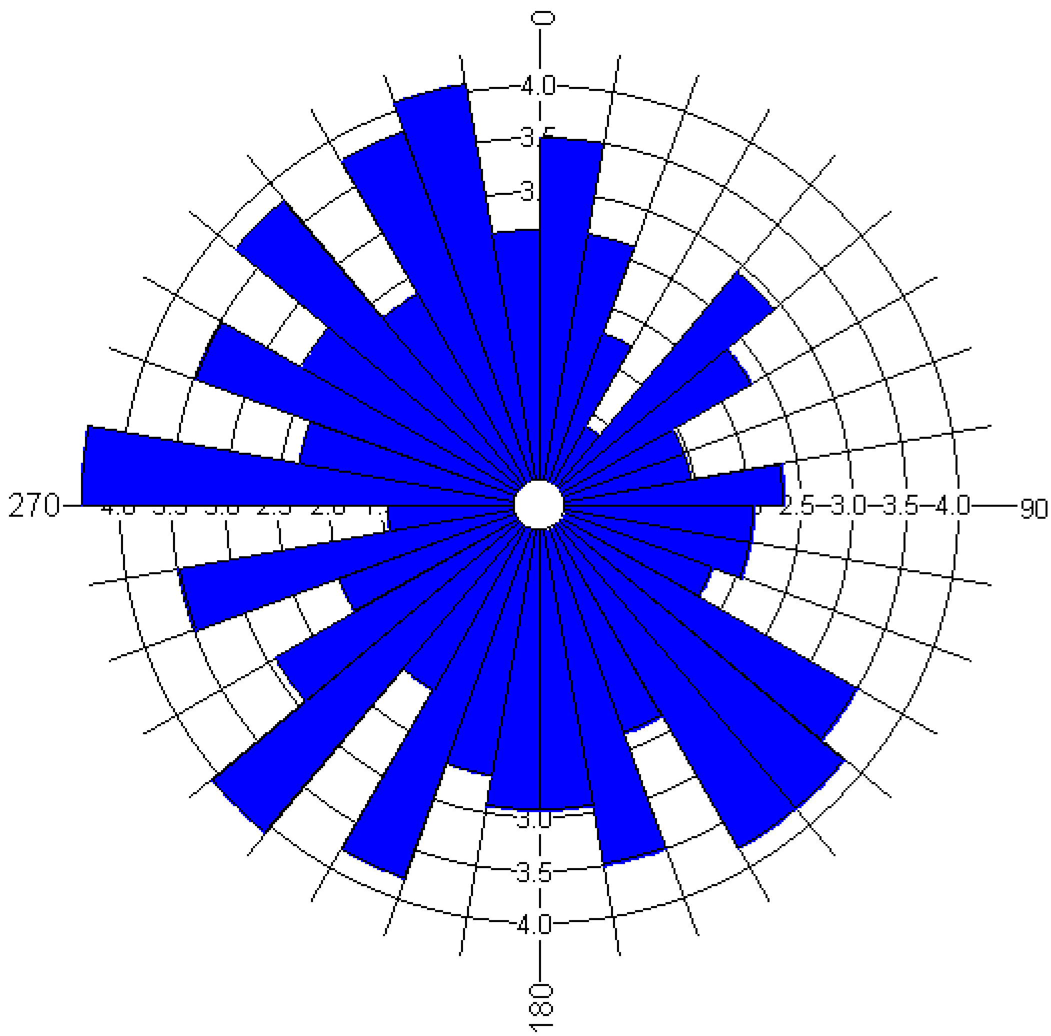
Dip Angles



Shown as *percent* of features with observed dip angle

Figure WB-02:6
Rose Diagram of Optical Televiewer Features
Parsons
Camp Stanley Storage Facility: Wellbore WB-02
July 20 , 2003

Dip Direction

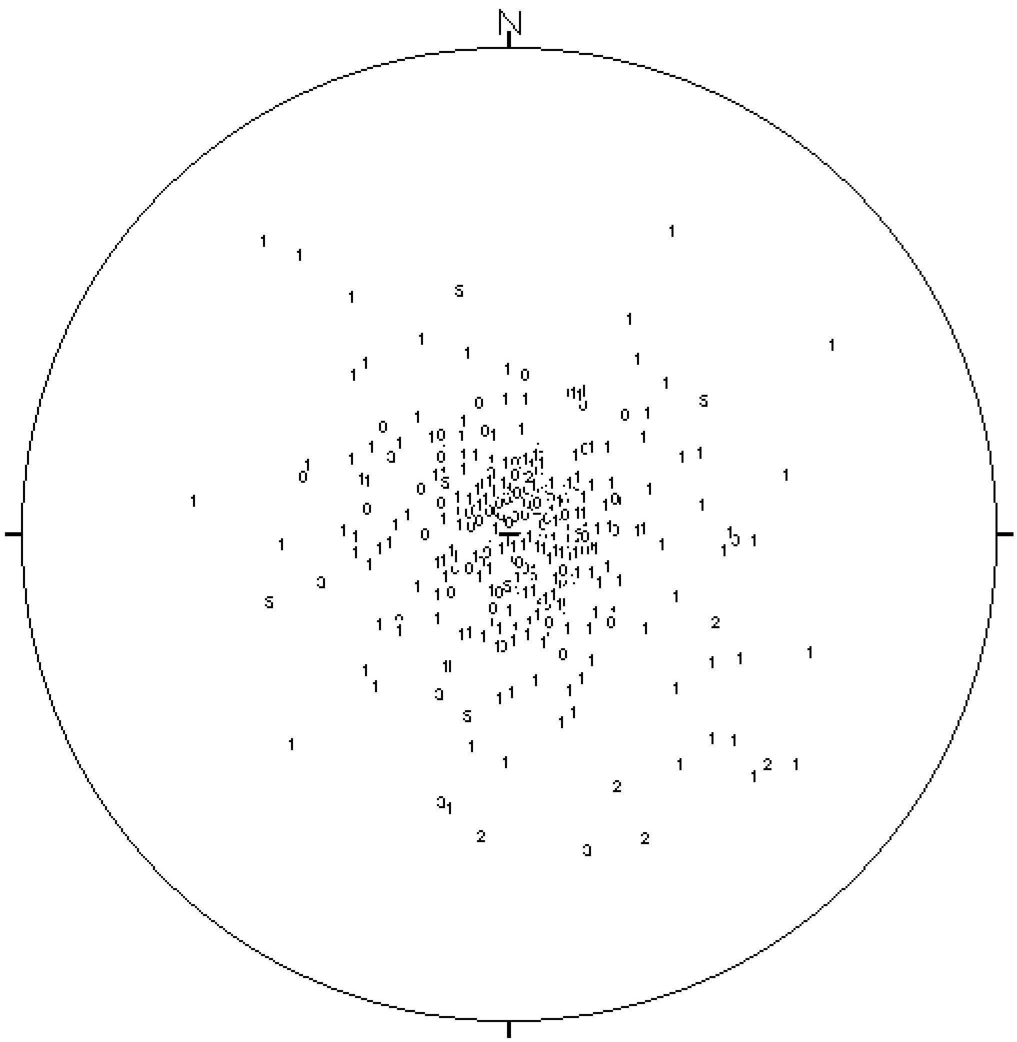


Shown as *percent* of features with observed dip direction

All directions are with respect to magnetic north.

Figure WB-02:7
Stereonet of Optical Televiewer Features
Parsons
Camp Stanley Storage Facility: Wellbore WB-02
July 20, 2003

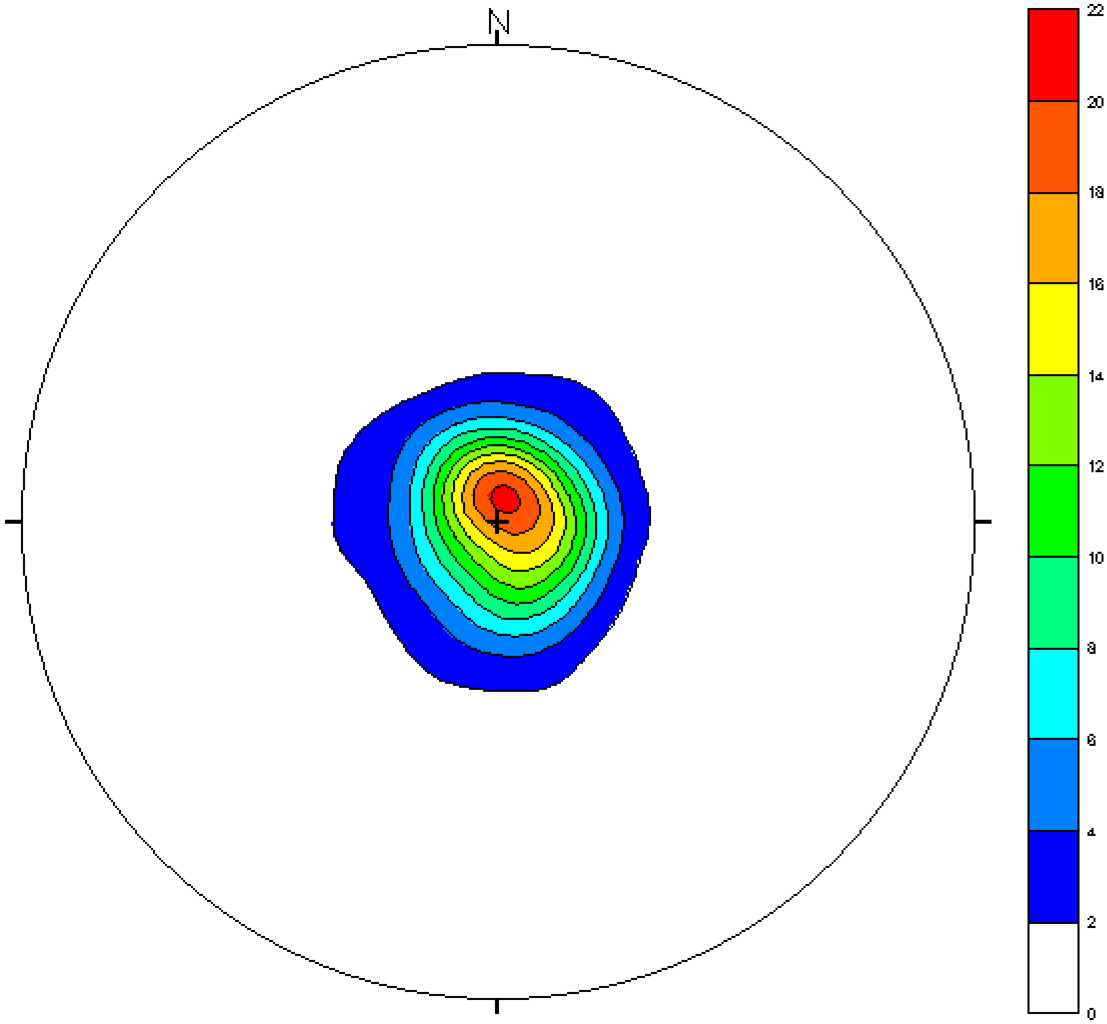
Schmidt Projection with Contours



All directions are with respect to magnetic north.

Figure WB-02:8
Stereonet of Optical Televiewer Features
Parsons
Camp Stanley Storage Facility: Wellbore WB-02
July 20, 2003

Schmidt Projection with Feature Ranks



All directions are with respect to magnetic north.

Geophysical Summary Plot

BOREHOLE GEOPHYSICS & HYDROPHYSICS
COLOG
A DIVISION OF LAYNE CHRISTENSEN COMPANY

COMPANY: Parsons	PROJECT: Camp Stanley
DATE LOGGED: 20 July 2003	WELL: WB-02

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17301 W.Colfax Ave, Ste 265, Golden, CO 80401
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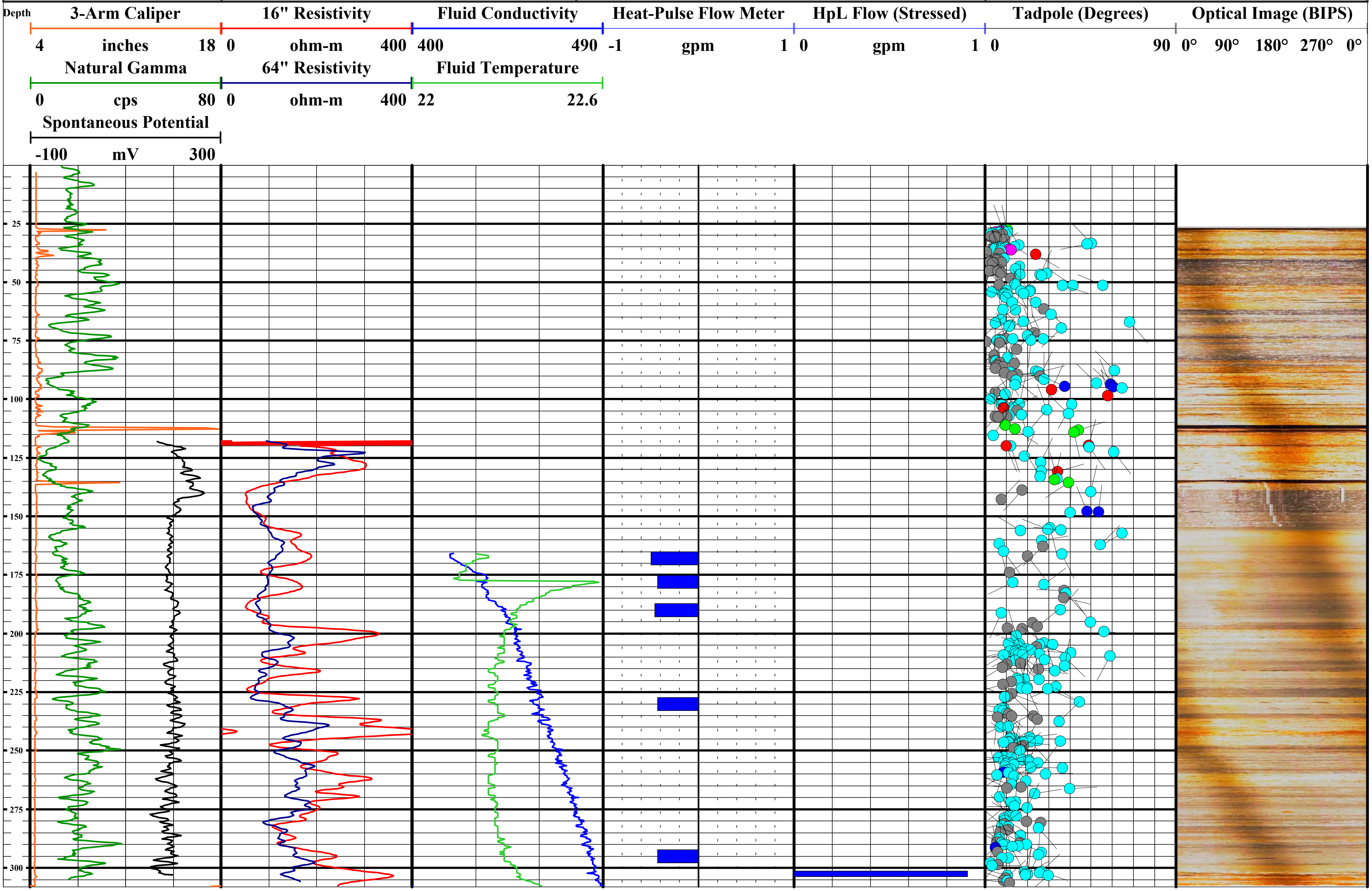


WB-03 Logging Results

1.0 HydroPhysical™ Logging

1.1 Ambient Fluid Electrical Conductivity and Temperature Log: WB-03

At 1012 hours on July 23, 2003, after a calibration check of the fluid electrical conductivity (FEC) and temperature logging tool, the fluid column was logged for FEC and temperature profiles with COLOG's 1.5-inch diameter HpL™ tool. These logs were performed prior to the installation of any pumping equipment. Please refer to Figure WB-03:1. The ambient FEC/temperature profiles indicate numerous changes in fluid FEC at depths of approximately 108, 124, 129, 134, 157, 159, 174, 186, 195, 214, 221, 225 and 232 feet suggesting a dynamic, or flowing condition in the borehole at these depths. Numerous changes in fluid temperature were also observed at depths of approximately 108, 115, 121, 124, 157, 159, 163, 169, 174, 183, 195, 205, 214, 221, 225, 232, 237 and 243 feet. Many of the observed inflections in fluid FEC and/or temperature correspond well with flow intervals observed by HpL testing. In vertically flowing conditions, where water enters the borehole, termed inflow, a change in either FEC and/or temperature is typically seen.

1.2 Ambient Flow Characterization: WB-03

On July 23, 2003, an ambient flow characterization was conducted in boring WB-03. For ambient flow assessment, the fluid column in the borehole was replaced with de-ionized water (DI) and the boring left in an undisturbed state to allow any natural flow to occur. The pump was removed from the boring to insure that water in the pump standpipe would not drain back into the boring. Prior to this period and throughout all HpL™ testing, water levels and flow rates were monitored and recorded digitally every ten seconds. Ambient flow evaluation is reported for the period after the water surface returned to near pre-DI water emplacement levels. A series of FEC and temperature logs were then conducted over the duration of testing to identify changes in the fluid column associated with ambient flow. Ambient flow characterization is conducted to evaluate the presence of both vertical and horizontal flow.

On July 23, 2003, at 1134 hours (t=0 minutes, elapsed time of test), dilution of the fluid column was complete. Minimal to no DI water was lost to the formation due to the slightly depressed head maintained during DI water emplacement procedures. During the 5.3 hours following the emplacement of DI water, multiple logs were conducted. Of these logs, seventeen are presented in Figure WB-03:2, with the first log (FEC1130) occurring during emplacement. The designation of each logging with the FEC tool is indicated in the figure legend by the time of logging (e.g., FEC1130 versus a subsequent logging at FEC1143), thus the progressing of curves to the right in this figure represents changes in FEC over the total logging period. The last four digits of each log ID corresponds to the time at which that particular log was started. Only logs acquired during logging in the downward direction are presented as the design of the FEC/temperature probe allows for the most accurate data to be collected in the downward direction. The logs acquired in the upward logging direction are not representative of downhole conditions and are therefore omitted. These logs illustrate changes in FEC at several intervals throughout the length of the borehole. These changes in the FEC profiles with respect to time are associated with ambient vertical flow occurring within these intervals.

Formation water migration caused by downward vertical flow within the fluid column is indicated by the increase in FEC over time in Figure WB-03:2. Ambient inflow enters the wellbore at 106.2 to 109.6, 112.0 to 112.8 and 133.5 to 137.2 feet, and the combined flow of these three intervals migrates down the borehole. Numeric modeling of the reported field data for these intervals suggest inflow is occurring at rates of 0.053, 0.437 and 0.53 gpm, respectively. The aggregate ambient downflow migrates down the borehole at a rate of 0.560 gpm. At a depth of 243.0 to 306.0 feet groundwater is observed to exit the wellbore. Numeric modeling of the reported field data for this interval suggests flow is exiting the wellbore at a rate of 0.560 gpm. All flow rates are based on the rate of increase of mass at their respective intervals. Please refer to Table WB-03:1 and SUMMARY:1 for a complete summary of the HydroPhysical™ logging results. Please refer to Appendix B for a discussion of the methodology and code used to calculate these values. The ambient depth to water at the time of testing was 106.05 ftbgs.

1.3 Flow Characterization During 7 GPM Production Test: WB-03

Pumping of borehole fluids and simultaneous DI injection was conducted at one pumping rate to establish the inflow locations and evaluate the interval-specific inflow rates during production testing. Development pumping at a given rate was conducted until reasonably constant drawdown and repeatable FEC logs downhole were observed. When these conditions were observed, DI injection was initiated at approximately 20% of the pumping rate while the extraction pumping rate was increased the same amount to maintain a constant total formation production rate (i.e. pumping rate prior to DI water injection). These procedures were conducted at a differential rate of 6.80 gpm.

On July 24, 2003 at 1004 hours (t = 0 minutes elapsed time of testing), development pumping was initiated at approximately 7 gpm. Prior to initiating pumping, the ambient depth to water was recorded at 106.01 ftbgs. All drawdown values are referenced to this ambient water level. Time dependent depth to water, totals and flow rate information were recorded digitally every ten seconds and are presented in Figure WB-03:3. Pumping was maintained at a time-averaged rate of 6.95 gpm until 1131 hours (t = 87 minutes, elapsed time of testing). During development pumping numerous FEC logs were acquired to monitor the development process and assist in identifying the depths of flow zones. Of these FEC logs, three (FEC1101, FEC1116 and FEC1126) are presented in Figure WB-03:4. The FEC logs acquired during development pumping illustrate a reasonably stable condition of the fluid column with local inflow locations identified by spikes or incremental increases or decreases in FEC. DI water injection from the bottom of the wellbore was initiated at 1131 hours at a time-averaged rate of 1.38 gpm while the total extraction rate was increased to a time-averaged rate of 8.18 gpm, resulting in a total borehole formation time-averaged production rate of 6.80 gpm. At 1208 hours a hose fitting on the extraction pump line failed, causing pumping to cease until 1212 hours where the pump was back on line. These flow conditions were maintained until 1500 hours (t = 296 minutes) during which time a relatively constant drawdown of approximately 19.41 feet was observed. The FEC logs acquired during dilution procedures illustrate a reasonably stable condition of the fluid column with local inflow locations identified by spikes or incremental increases in FEC. Thirteen inflow zones were identified from these logs with flow rates ranging from 0.022 to 0.335 gpm. The logs indicate the two intervals that generated the most inflow, 157.4 to 198.0 and 243.0 to 306.0 feet behaved more like a porous medium (primary porosity) than a fractured medium (secondary porosity). This conclusion is based on the continuous increase in FEC, i.e. continuous formation production, throughout the length of these two intervals. The extraction pump location (approximately 123 ftbgs) and pump diameter did not allow for testing of the two uppermost flow intervals identified during ambient testing. This is because the combined diameter of the submersible pump and HpL logging tool is greater than the diameter of the wellbore. However, the majority of inflow during development pumping can be assumed to originate from the two intervals at 106.2 to 109.6 and 112.0 to 112.8 feet, and any additional intervals between water level and the submersible pump. It is possible that intervals of inflow may be present during development that may not have produced any flow during ambient conditions, therefore, it cannot be assumed that all the unaccounted for flow originates from the uppermost two ambient flow intervals. Please refer to Tables WB-03:1 and ARNOLD:1 for a summary of HydroPhysical™ flow results and the depths of individual inflow zones.

1.4 Estimation of Interval Specific Transmissivity: WB-03

An estimation of transmissivity (T) can be made using an equation after Hvorslev (1951) assuming steady-state radial flow in an unconfined aquifer:

$$T = KL = \frac{q_i}{2\pi \Delta h_w} \ln\left(\frac{r_e}{r_w}\right)$$

where K is the hydraulic conductivity, q_i is the interval specific inflow rate calculated by HpL™ results, r_w is the borehole radius (0.17 ft), r_e is the effective pumping radius , Δh_w is the observed maximum drawdown (19.41 feet) and L is the thickness of the zone through which flow occurs. For our calculations, COLOG used r_e of 100 feet (assumed). By applying L and q_i from the HpL™ results under the two pressure conditions, the interval specific transmissivity can be calculated for each identified water-producing interval. These calculations were made at each identified interval and are presented in Table WB-03:1. In summary, the interval at 243.0 to 306.0 feet registered the highest transmissivity at 9.06 feet^2/day.

2.0 Geophysical Logging

On July 23 and 24, 2003, downhole geophysical investigations were performed in boring WB-03. The geophysical logs performed were: optical televiewer (BIPS) and heat-pulse flowmeter. The data for these logs is presented in the WB-03 Geophysical Summary Plot. A contractor other than COLOG conducted additional geophysical logging in wellbore WB-03. This data is presented in the WB-03 Geophysical Summary Plot.

3.0 Data Summary

Processing and interpretation of the geophysical and HydroPhysical™ logs in WB-03 suggest the presence of 13 identified producing intervals for this borehole. Numerical modeling of the reported HydroPhysical™ field data was performed using computer programs FLOWCALC and/or BOREII. These analyses were performed to estimate the rate of inflow for each identified hydraulically conductive borehole interval during DI injection procedures. The results of these analyses are presented in Table WB-03:1. The identified producing intervals correlate well with water-bearing zones identified during ambient testing. In summary, the interval at 243.0 to 306.0 feet dominated inflow during the production test, producing a total of 0.335 gpm or 5 percent, of the total flow during the production test.

During ambient testing, boring WB-03 exhibited downward vertical flow. Four water-bearing zones were identified under ambient conditions. A downward vertical pressure gradient was observed in the wellbore under ambient conditions.

Additionally, the wellbore was logged under ambient conditions with the heat-pulse flowmeter on July 24, 2003. The data acquired by the heat pulse flowmeter suggests the presence of a downward vertical gradient present in the wellbore at the time of testing. Ambient flow is observed to enter the wellbore above 114 feet at approximately 0.46 gpm and migrate downward. At 130 feet ambient downflow of 0.49 gpm was observed. At 150 feet ambient downflow of 0.56 gpm was observed. At 222 feet ambient downflow of 0.56 gpm was observed. At 297 feet 0.46 gpm of ambient downflow was observed. At 309 feet no ambient flow was observed.

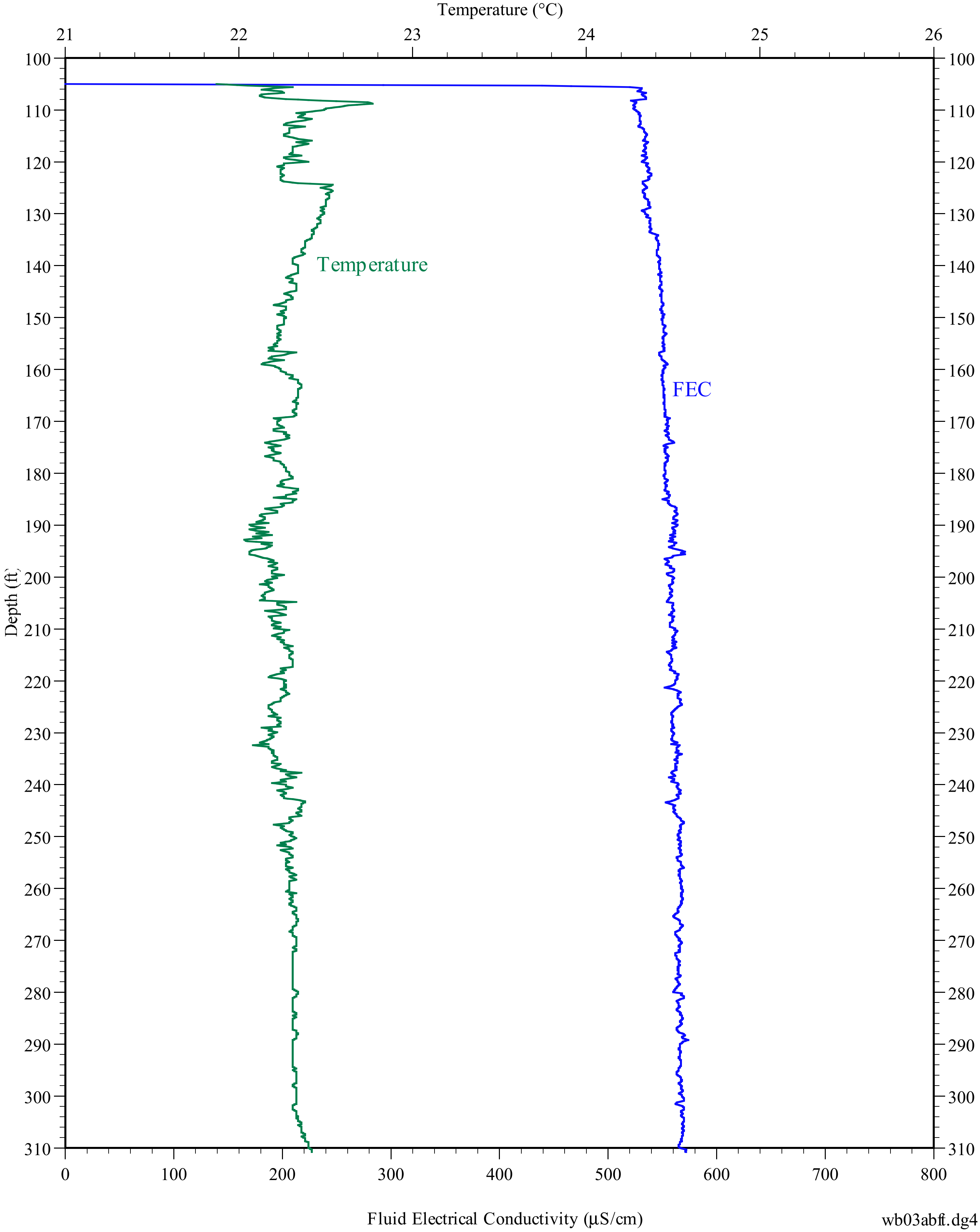
The optical televiewer identified features at depths correlating well with the HpL™ data. The features observed by the optical televiewer at water-bearing intervals identified from the HpL™ data had apparent aperture. Twenty-three high-angle features (features of dip angle greater than 45 degrees) were identified from the optical televiewer data. One of the features is qualitatively ranked greater than one, suggesting this feature has flow potential. This high-angle feature at 133.8 feet also corresponds well with a flow interval identified at 133.5 to 137.2 feet.

The thirteen interval-specific estimated transmissivities in WB-03 ranged from 0.704 to 9.06 square feet per day with the interval of 243.0 to 306.0 feet registering the highest transmissivity. The thirteen interval-specific transmissivity estimates do not differ significantly with respect to each other.

Fracture inter-connectiveness in the immediate vicinity of a wellbore can be inferred by the similarity, or lack there of, of parameters such as interval-specific transmissivity estimates and interval-specific FEC, along with the presence of high-angle fractures and pressure differentials within the borehole. Similar transmissivity and FEC estimates would suggest an inter-connected network of fractures or aquifers in the immediate vicinity of the wellbore. A pressure differential present in the wellbore would suggest the driving force for vertical communication is present and high-angle fractures with aperture may provide the conduit for vertical communication.

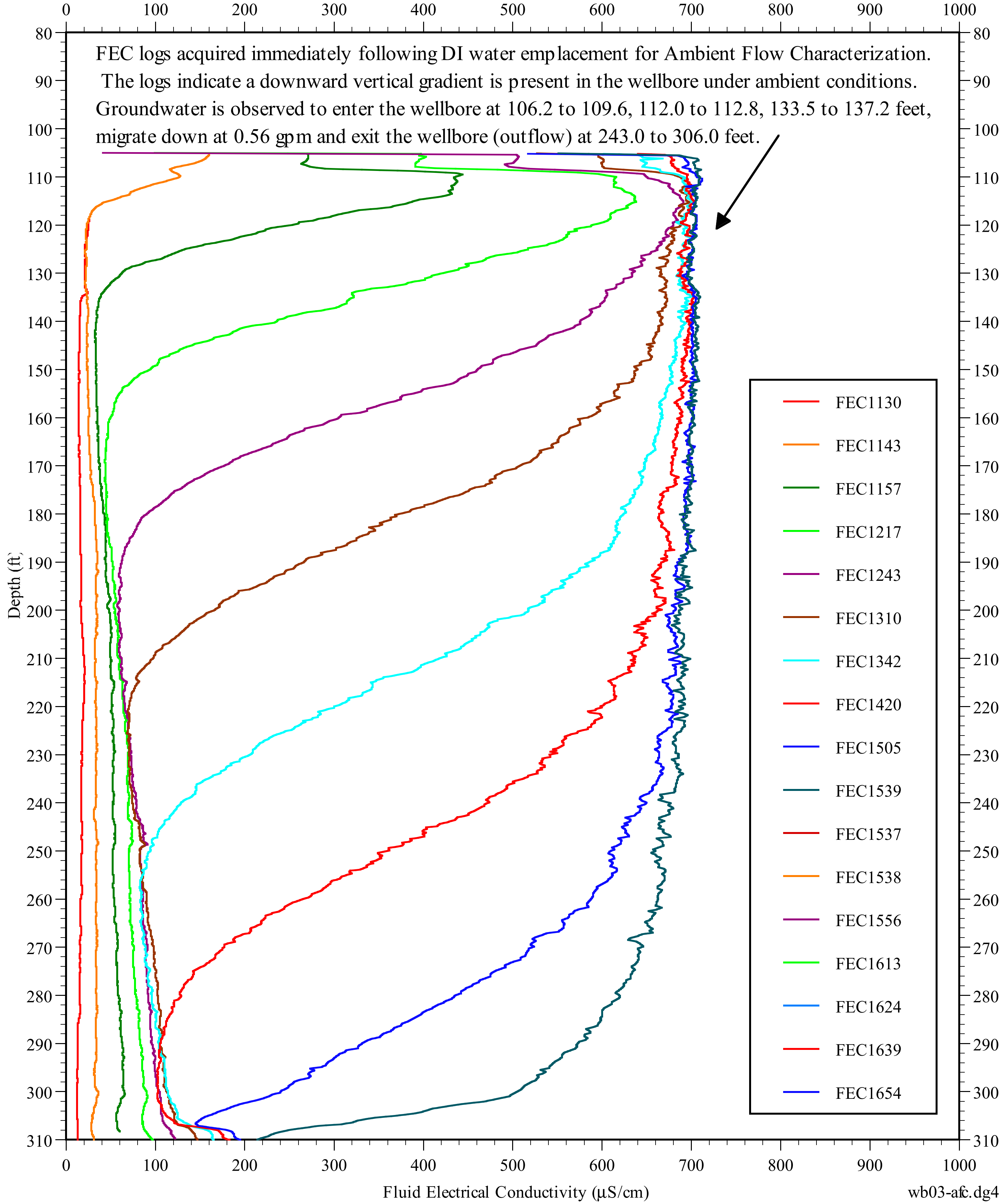
The data acquired in WB-03 exhibited similar interval-specific transmissivity and similar FEC estimates. A downward vertical gradient is observed in the wellbore. Major high angle features were identified in the wellbore to provide a conduit for vertical communication. The low flow rates identified in this wellbore under pumping and ambient conditions may contribute to the similar transmissivity estimates. The data suggest the fractures intersecting the wellbore are possibly interconnected in the immediate vicinity of the wellbore. Please see Tables WB-03:1 and SUMMARY:1 for a summary that includes the locations, flow rates and hydraulic conductivity estimates assessed by COLOG.

FIGURE WB-03:1. AMBIENT TEMPERATURE AND FLUID ELECTRICAL CONDUCTIVITY; PARSONS; CAMP STANLEY STORAGE FACILITY; SAN ANTONIO; TX; WELLBORE: WB-03.



wb03abft.dg4

FIGURE WB-03:2 SUMMARY OF HYDROPHYSICAL LOGS DURING AMBIENT FLOW CHARACTERIZATION; PARSONS; CAMP STANLEY STORAGE FACILITY; SAN ANTONIO, TX; WELLBORE: WB-03.



wb03-afc.dg4

FIGURE WB-03:3. PUMPING AND DRAWDOWN DATA DURING 7 GPM PRODUCTION TEST; PARSONS; CAMP STANELY STORAGE FACILITY; SAN ANTONIO, TX; BOREHOLE: WB-03.

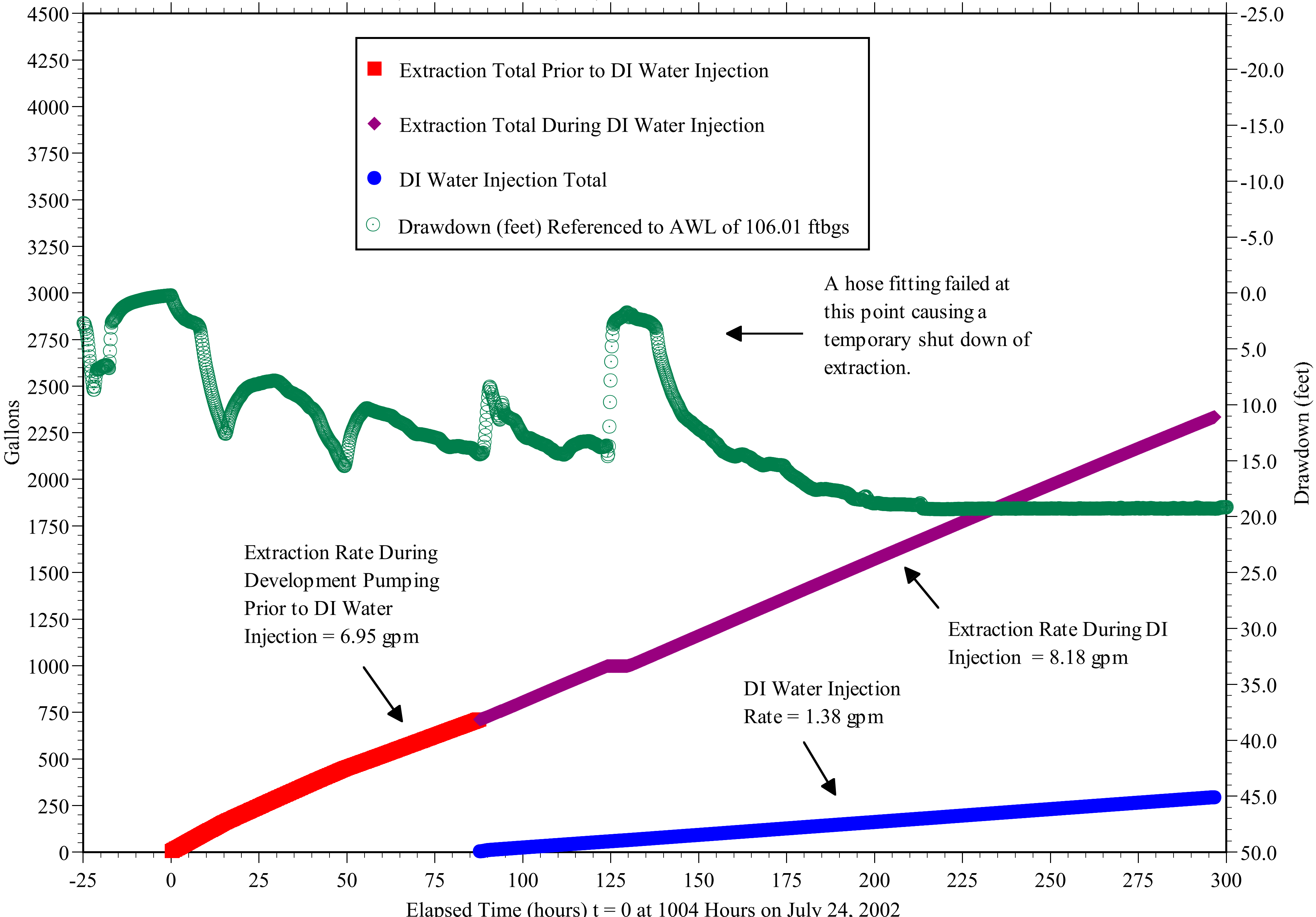


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FIGURE WB-03:4. SUMMARY OF HYDROPHYSICAL LOGS DURING 7 GPM PRODUCTION TEST; PARSONS; CAMP STANLEY STORAGE FACILITY; SAN ANTONIO, TX; WELL: WB-03.

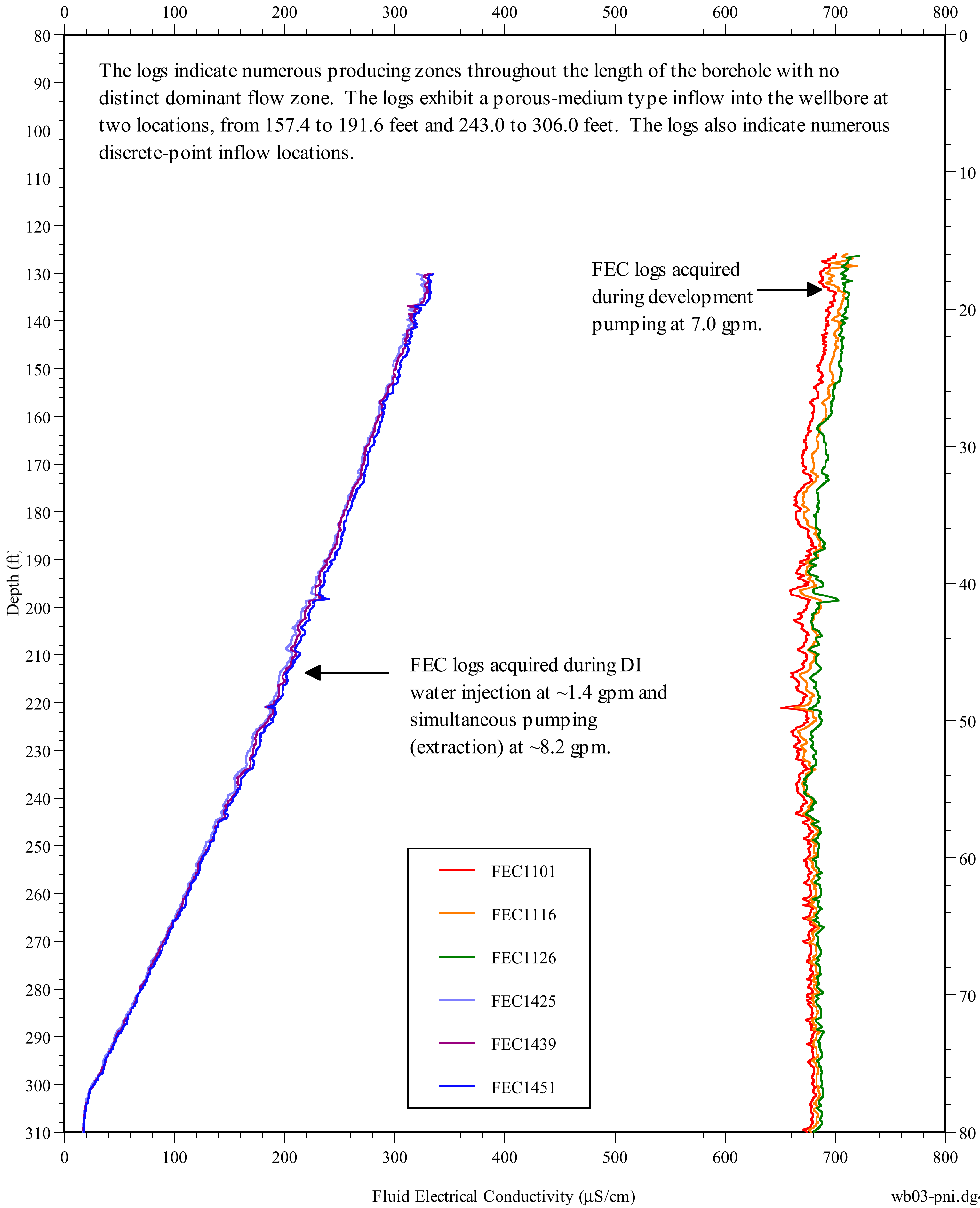

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TABLE WB-03:1. SUMMARY OF HYDROPHYSICAL™ LOGGING RESULTS WITH HYDRAULIC CONDUCTIVITY AND TRANSMISSIVITY ESTIMATIONS; PARSONS; CAMP STANLEY STORAGE FACILITY; WELL: WB-03.

Well name	WB-03
Ambient Depth to water (ft)	106.01
Diameter of Borehole (ft)	0.33
Maximum Drawdown (ft)	19.41
Effective Radius (ft)	100

Interval No.	Top of Interval (ft)	Bottom of Interval (ft)	Length of Interval (ft)	Ambient Flow[1] (gpm)	Darcy Velocity in Aquifer[2] (Specific Discharge) (ft/day)	Interval Specific Flow Rate (gpm)	Delta Flow[3] (gpm)	Delta Flow (ft^3/min.)	Interval Specific Hydraulic Conductivity[4] (ft/day)	Transmissivity (ft2/day)	Interval Specific Fluid Electrical Conductivity (microS/cm)
1	106.2	109.6	3.4	0.053	NA	NA	NA	NA	NA	NA	705
2	112.0	112.8	0.8	0.437	NA	NA	NA	NA	NA	NA	713
3	133.5	137.2	3.7	0.053	NA	0.076	0.023	0.00307	6.29E-02	2.33E-01	684
4	145.9	146.5	0.6	0.000	NA	0.079	0.079	0.01056	1.33E+00	7.99E-01	602
5	152.6	153.9	1.3	0.000	NA	0.053	0.053	0.00709	4.13E-01	5.36E-01	754
6	157.4	191.6	34.2	0.000	NA	0.264	0.264	0.03529	7.81E-02	2.67E+00	661
7	196.6	198.0	1.4	0.000	NA	0.062	0.062	0.00829	4.48E-01	6.27E-01	709
8	204.4	207.0	2.6	0.000	NA	0.033	0.033	0.00441	1.28E-01	3.34E-01	622
9	209.2	210.0	0.8	0.000	NA	0.031	0.031	0.00414	3.92E-01	3.14E-01	769
10	212.7	214.7	2.0	0.000	NA	0.044	0.044	0.00588	2.23E-01	4.45E-01	630
11	220.3	221.6	1.3	0.000	NA	0.049	0.049	0.00655	3.81E-01	4.96E-01	711
12	230.9	231.4	0.5	0.000	NA	0.022	0.022	0.00294	4.45E-01	2.23E-01	738
13	234.2	234.8	0.6	0.000	NA	0.036	0.036	0.00481	6.07E-01	3.64E-01	829
14	239.0	239.7	0.7	0.000	NA	0.047	0.047	0.00628	6.79E-01	4.76E-01	706
15	243.0	306.0	63.0	-0.560	NA	0.335	0.895	0.11965	1.44E-01	9.06E+00	810

[1] All ambient flow identified for this wellbore is downward flow.

[2] Darcy Velocity is calculated using the observed volumetric flow rate, the cross-sectional area of the flow interval in the wellbore and a wellbore convergence factor of 2.5 (Drost, 1968). The Darcy Velocity is only applicable to ambient horizontal flow.

[3] Delta Flow is the difference between Interval-Specific Flow Rate (during pumping) and Ambient Flow Rate.

[4] Hydraulic conductivity and transmissivity estimates are based on single well drawdown data, a porus-medium equivilent model and Hvorslev's 1951 porosity equation.

Optical Borehole Image Plot

COMPANY: Parsons	PROJECT: Camp Stanley
DATE LOGGED: 23 July 2003	WELL: WB-03

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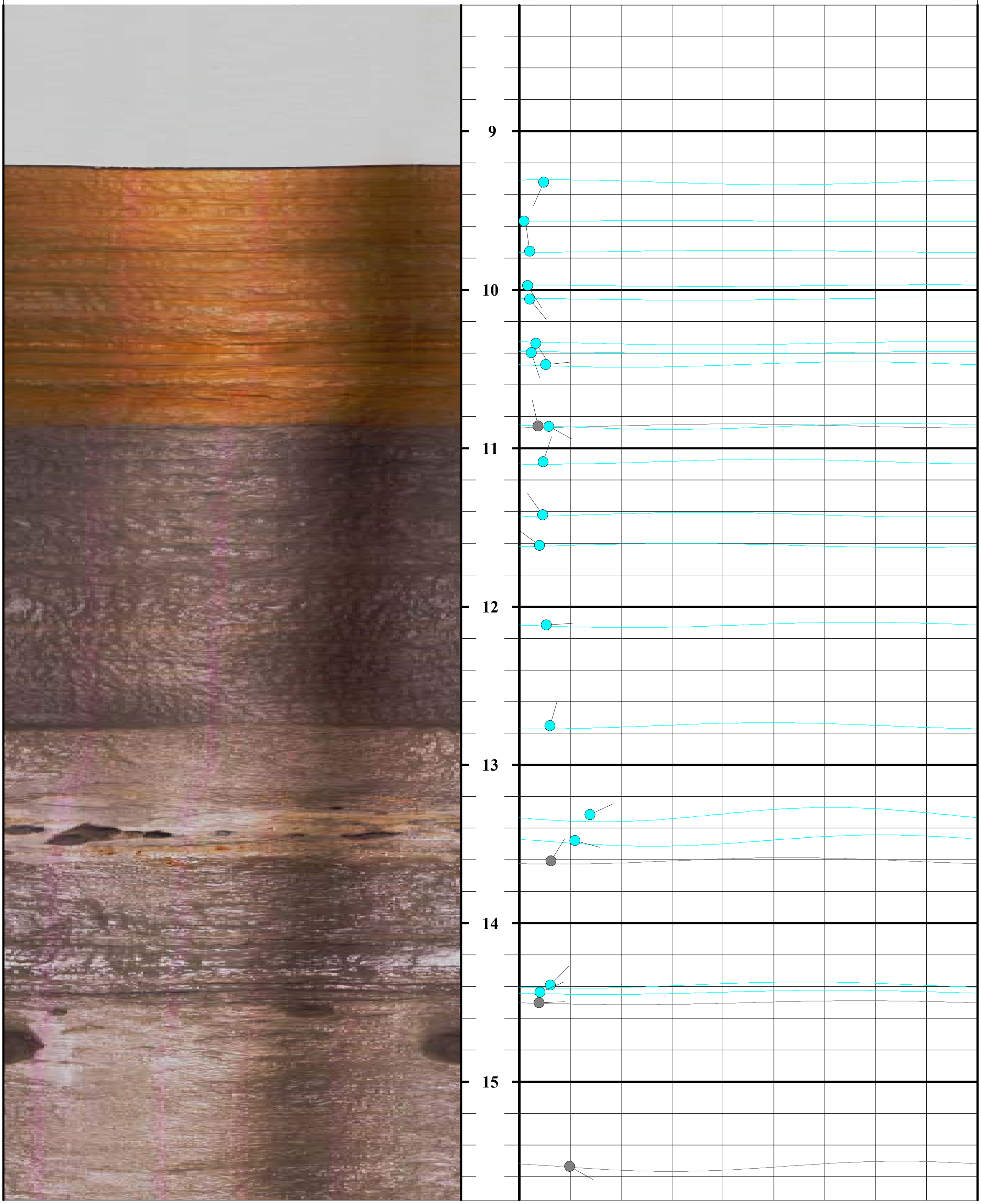
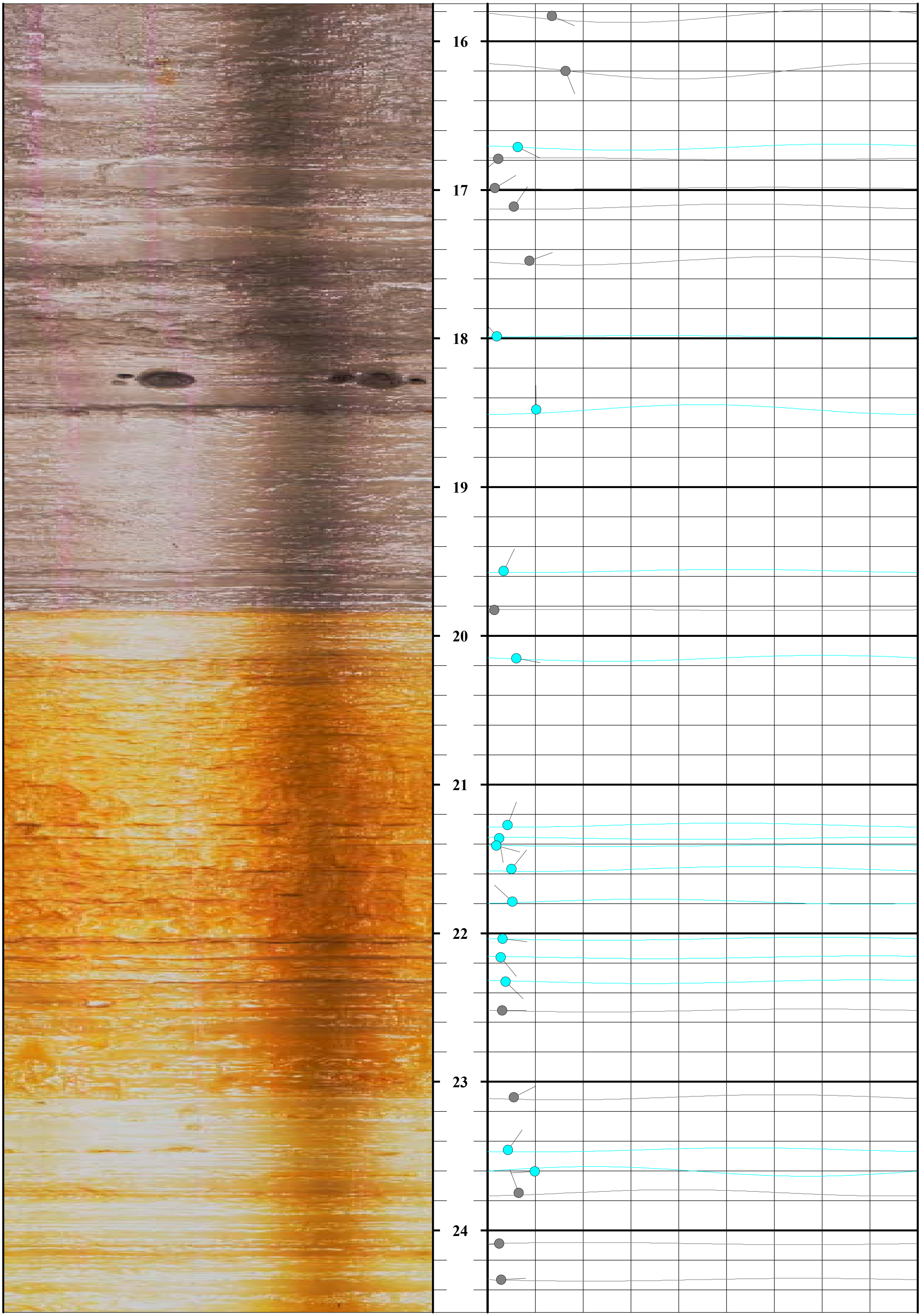
Optical Televiewer (BIPS)	Depth	Projection
0° 90° 180° 270° 0°		0° 90° 180° 270° 0°
		Tadpole (Degrees)
		0 90

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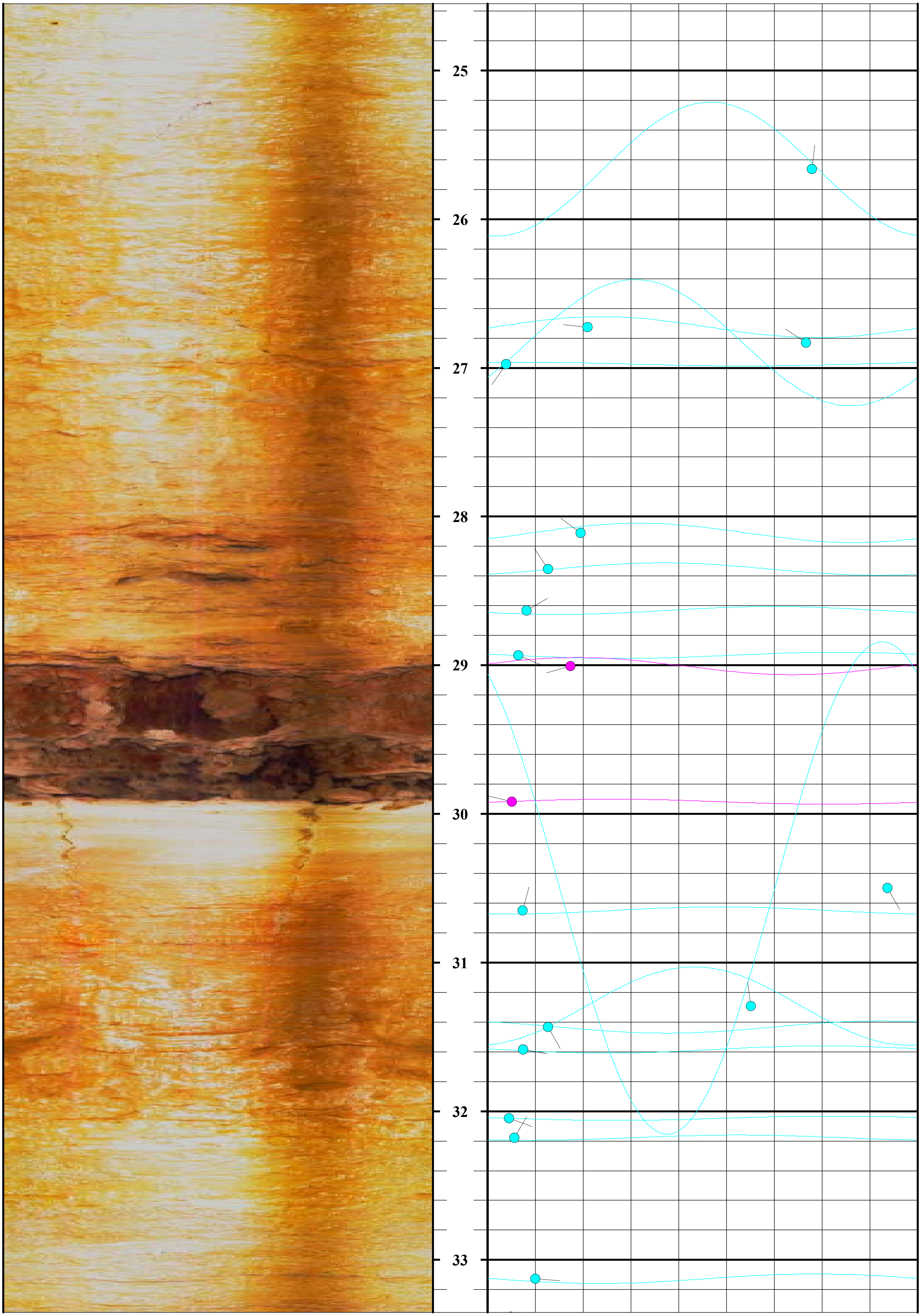
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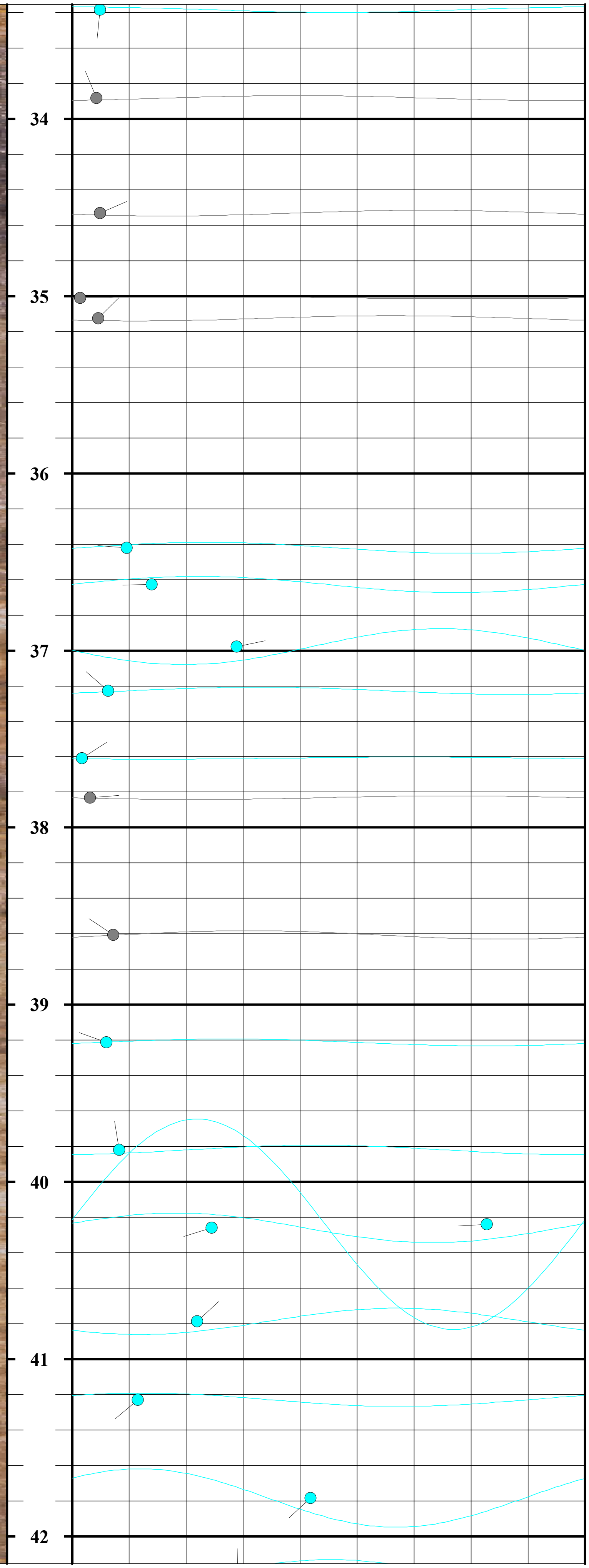
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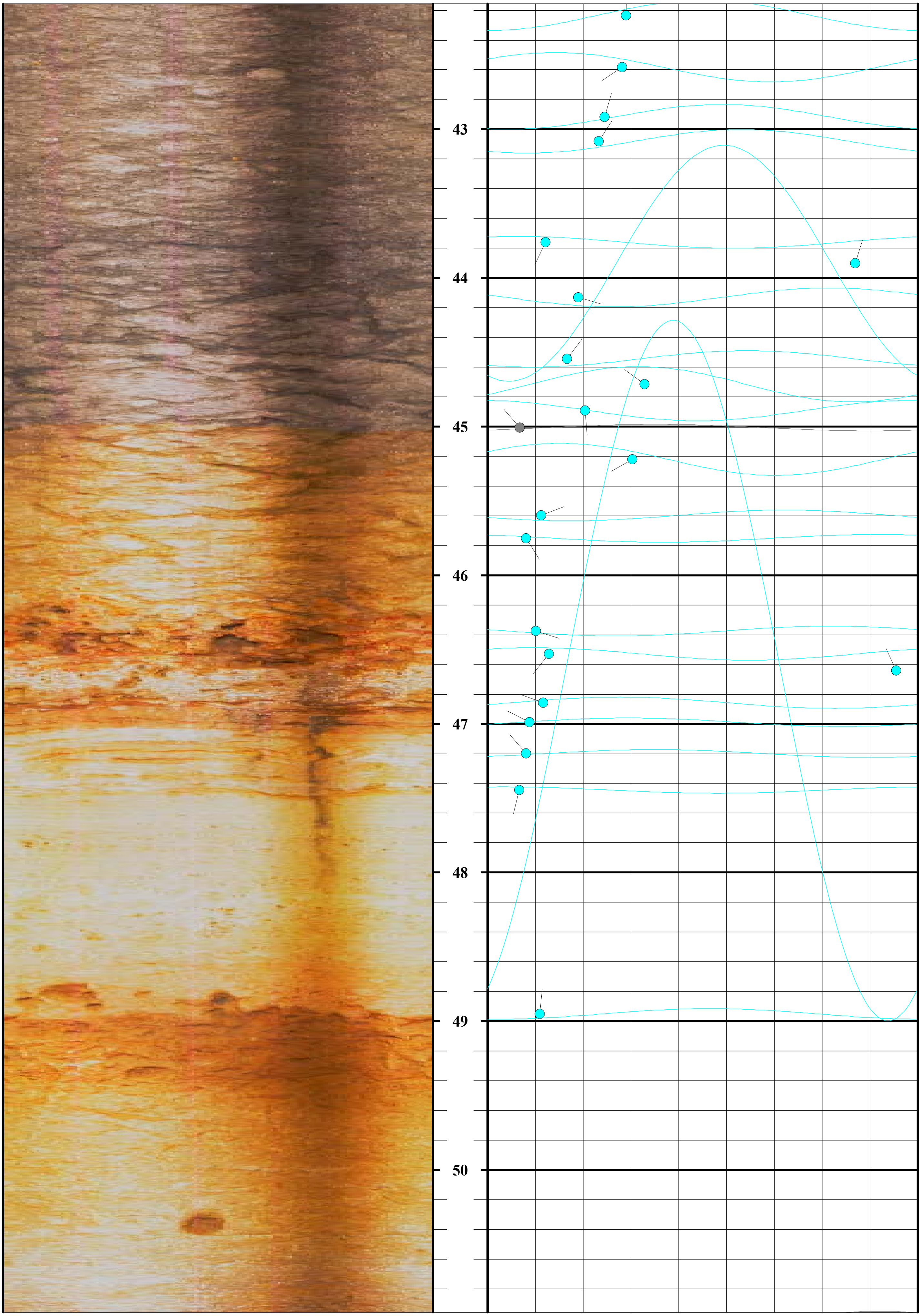
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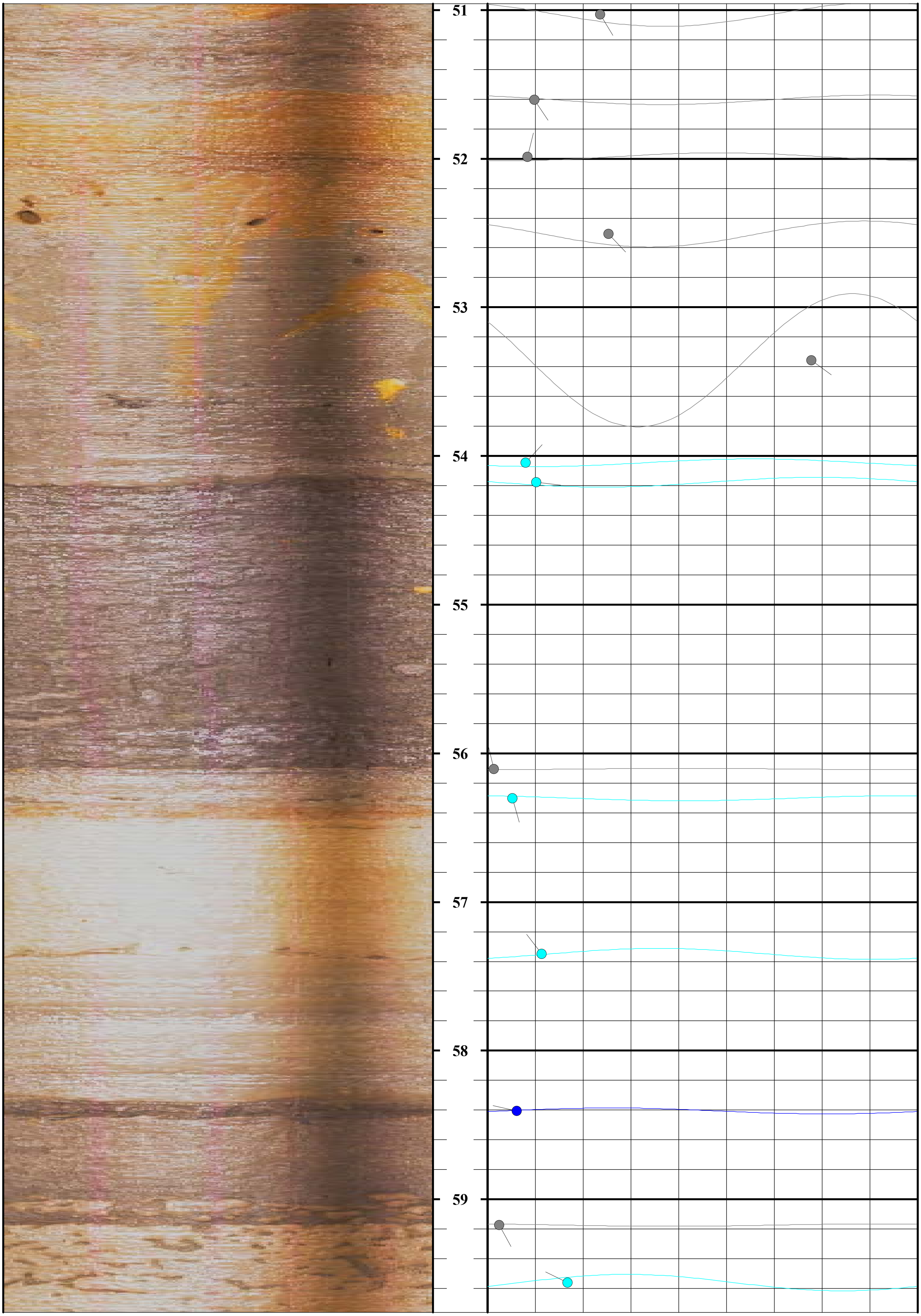
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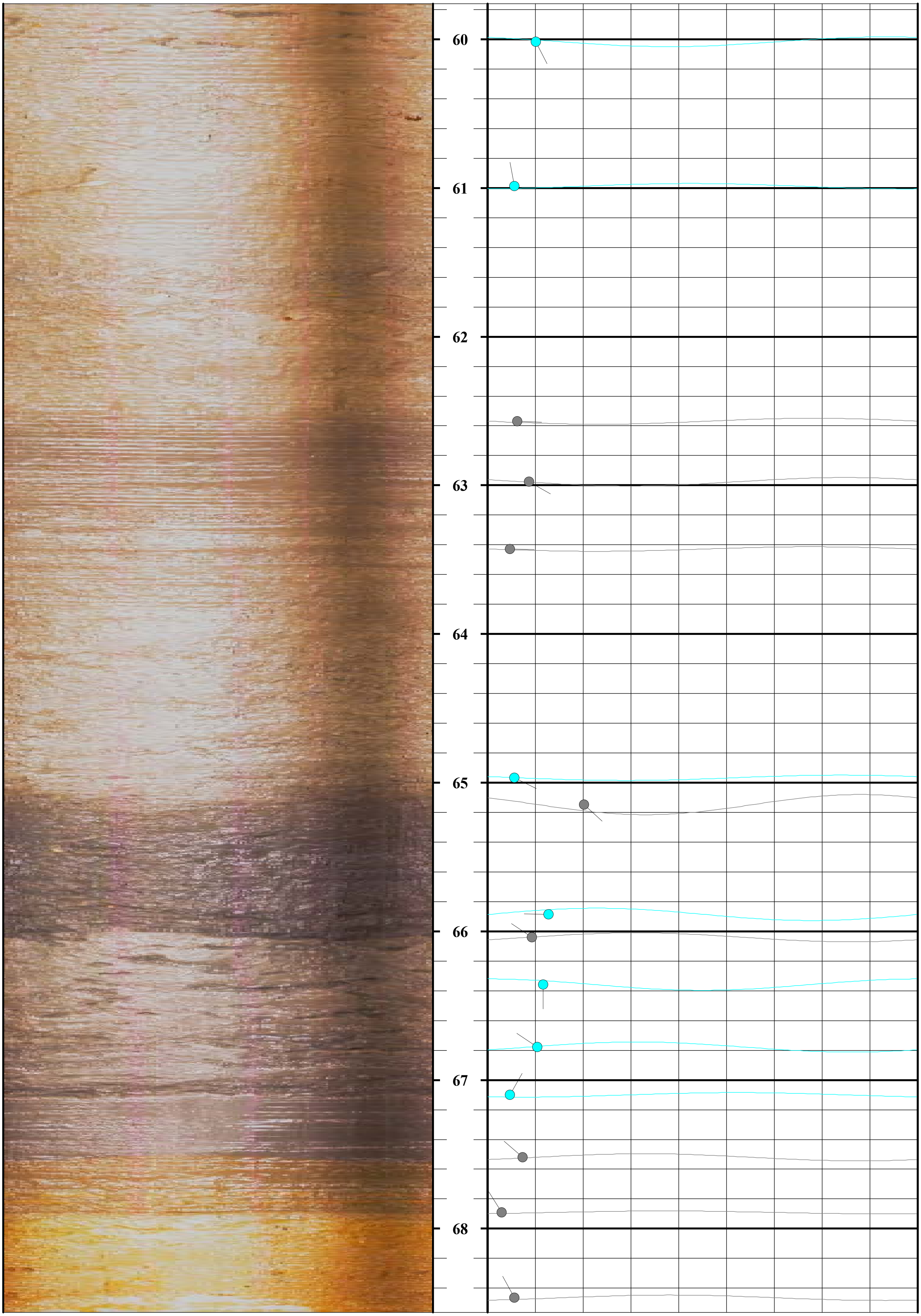
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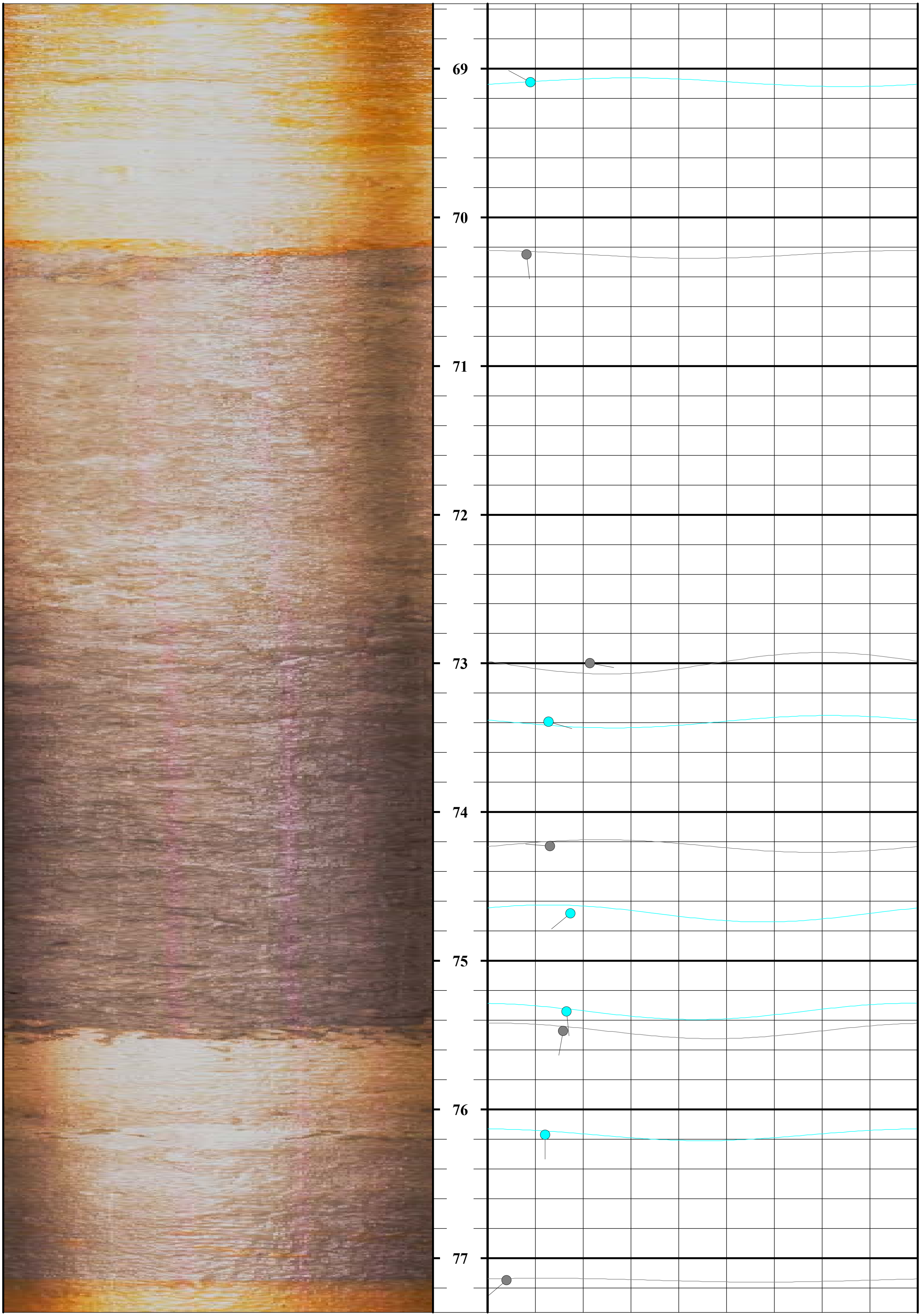
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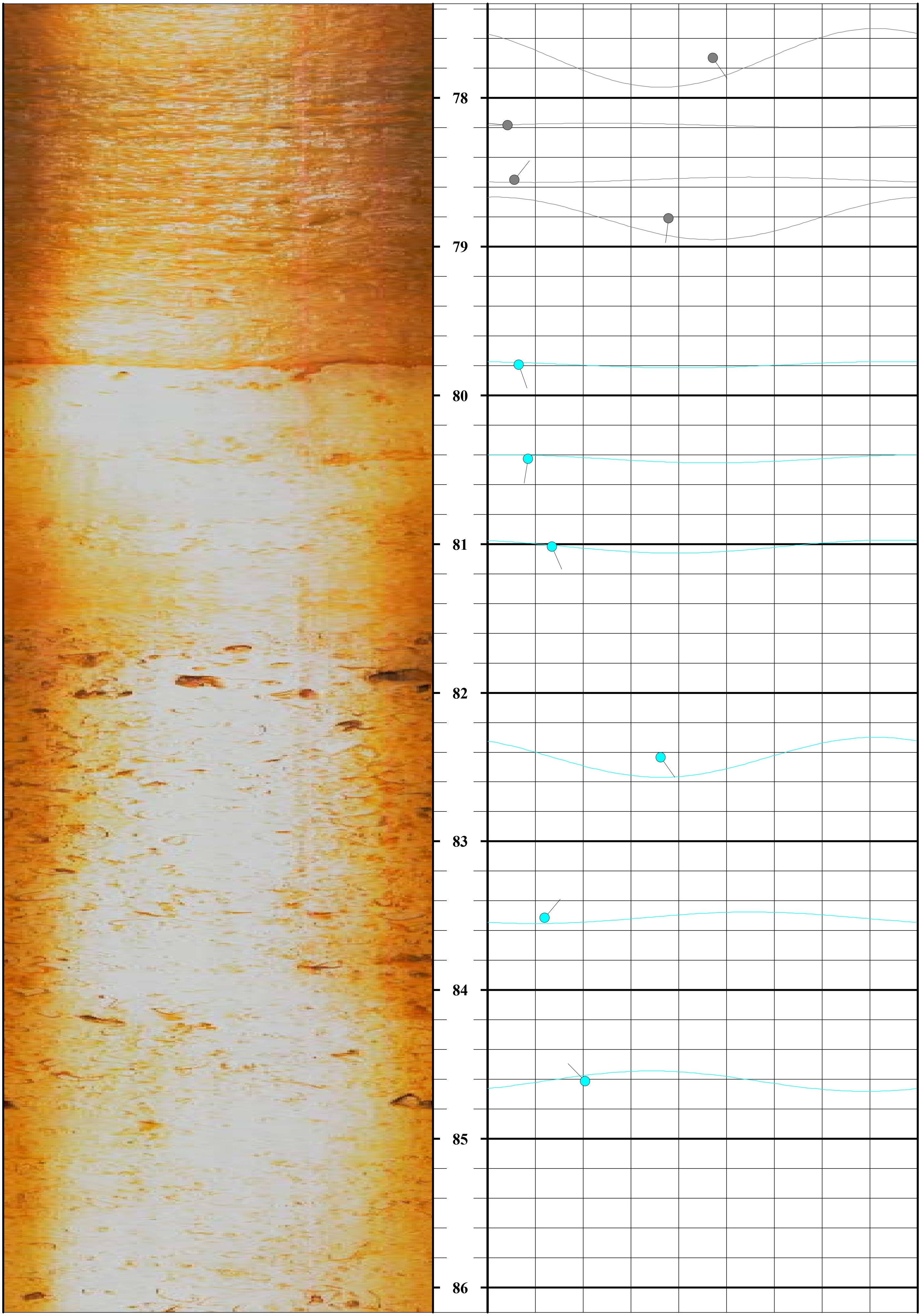
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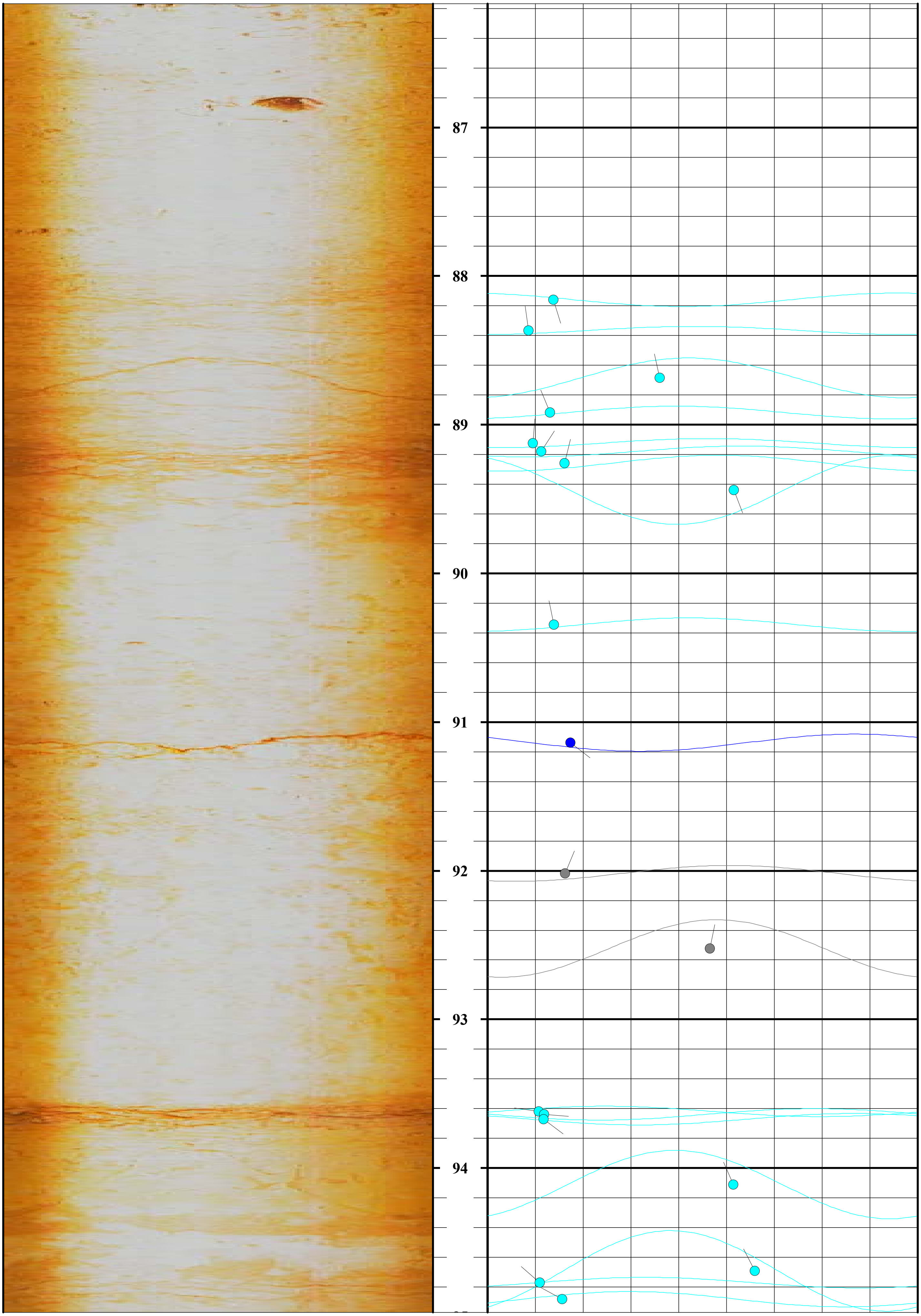
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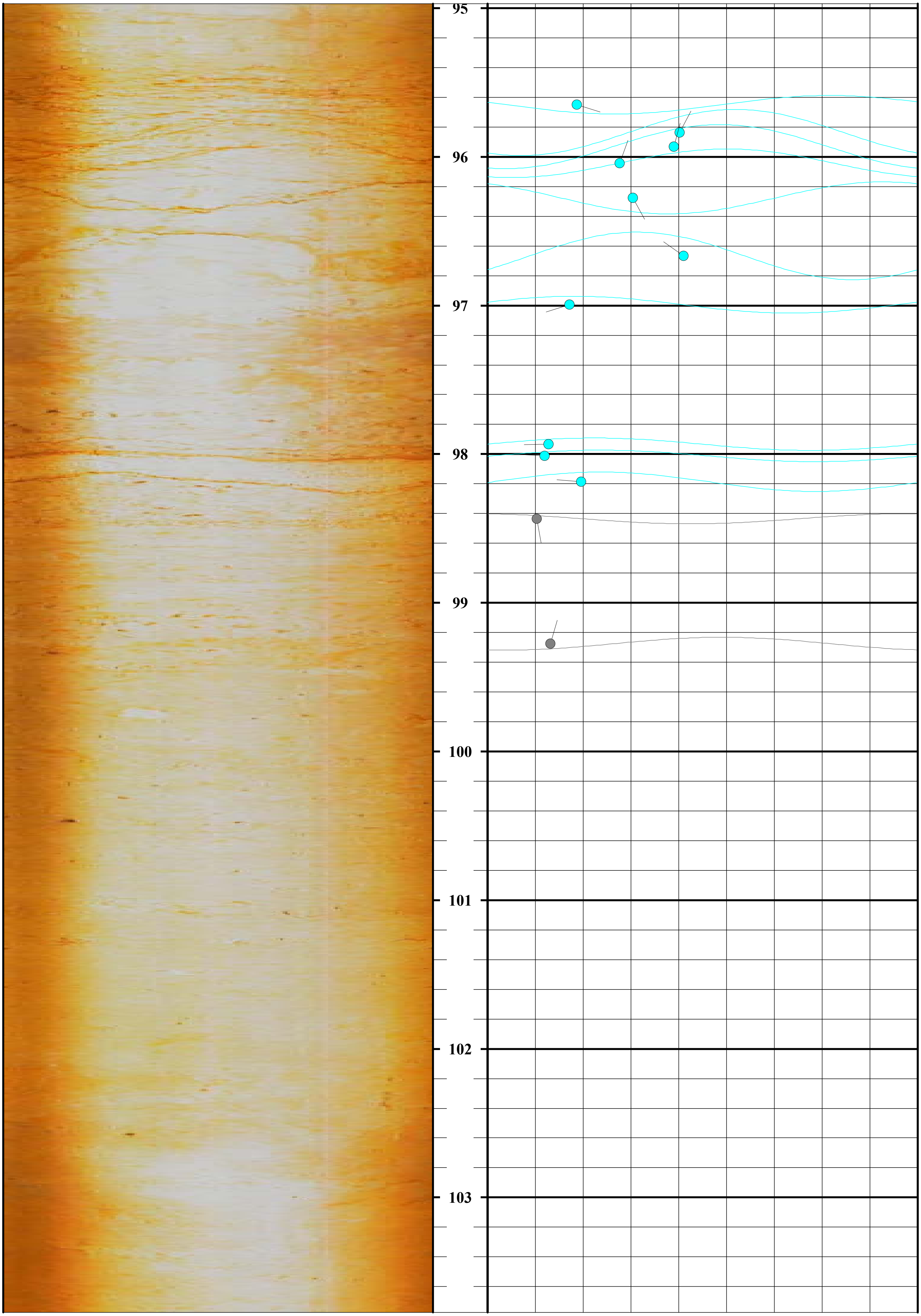
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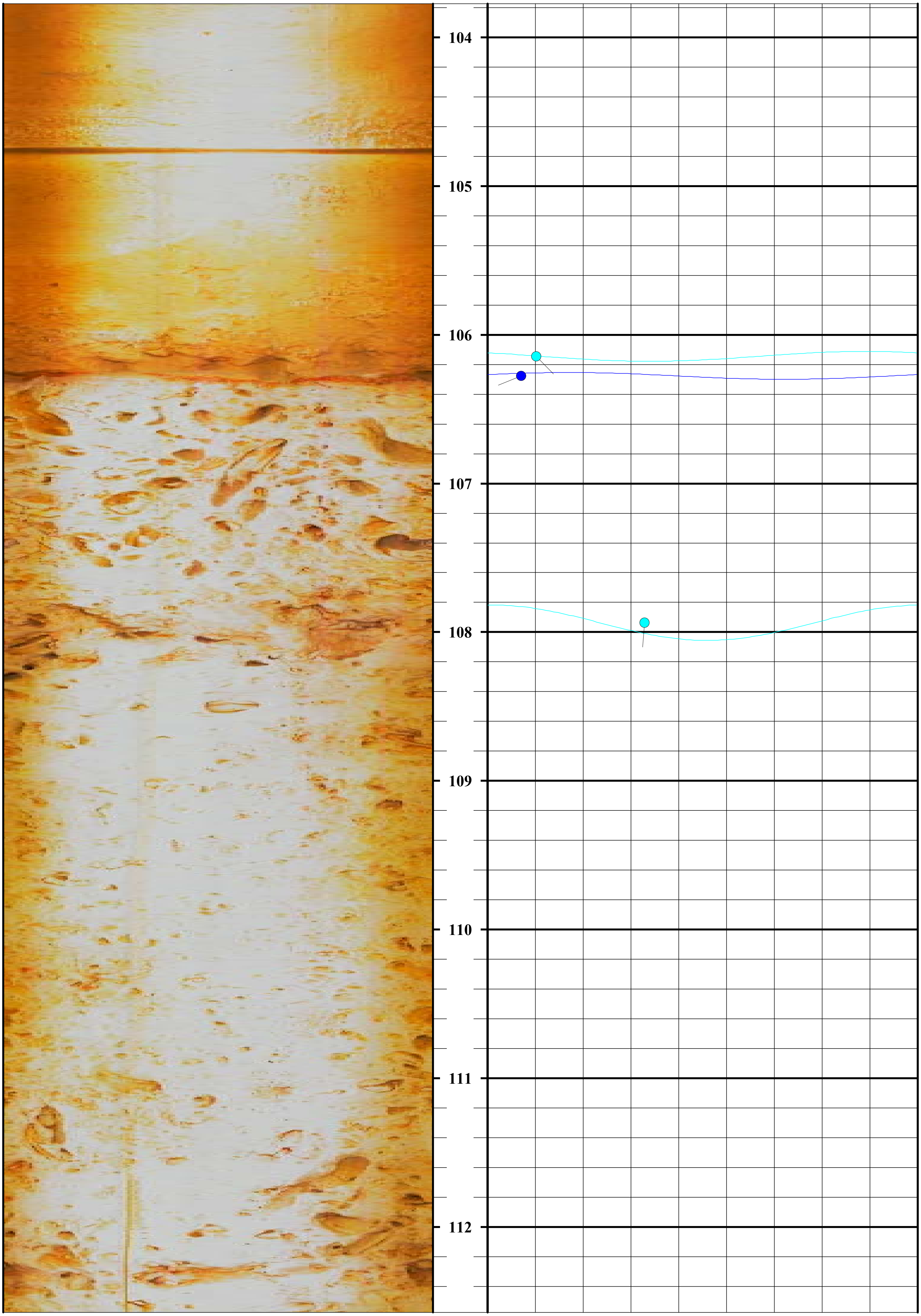
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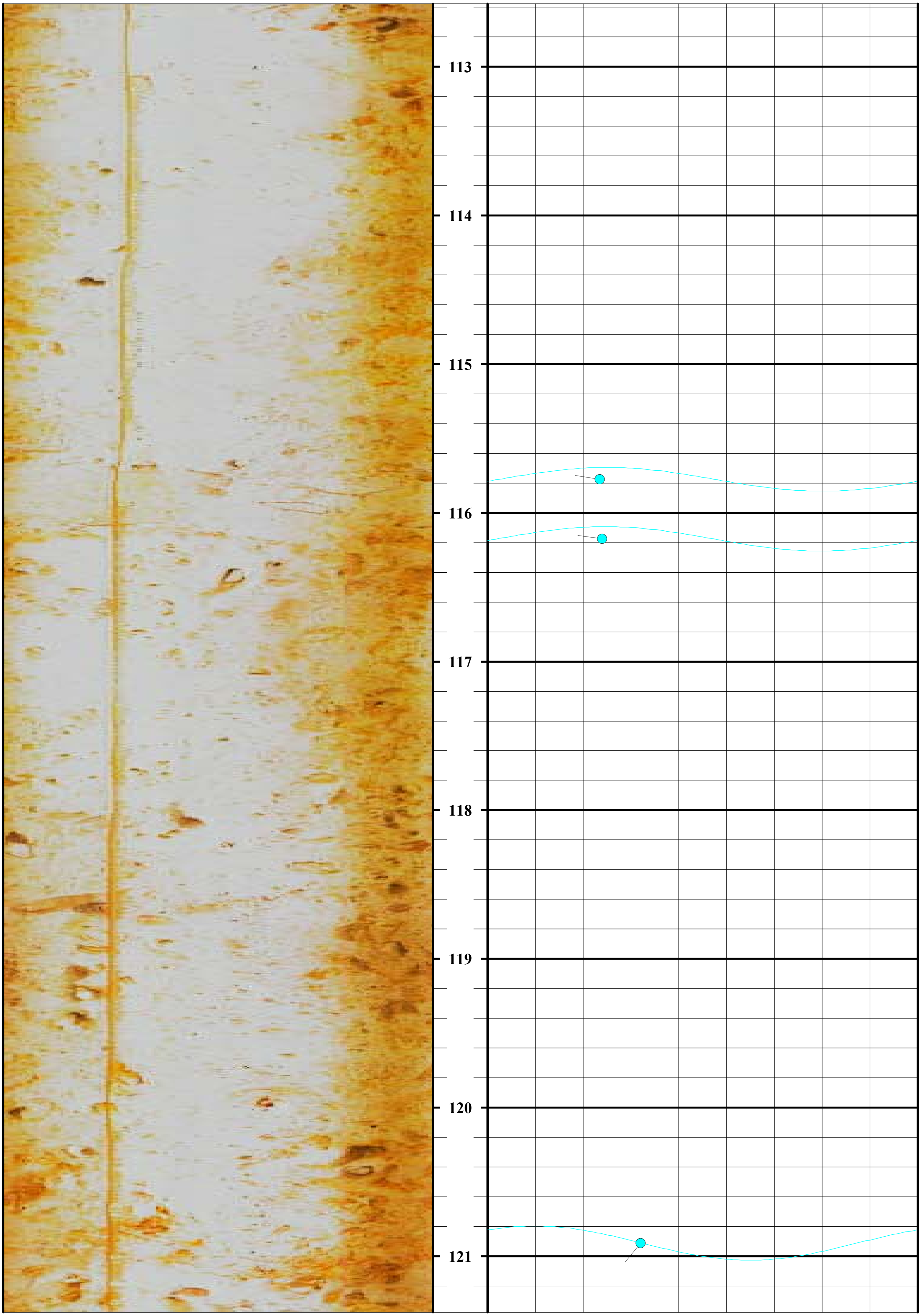
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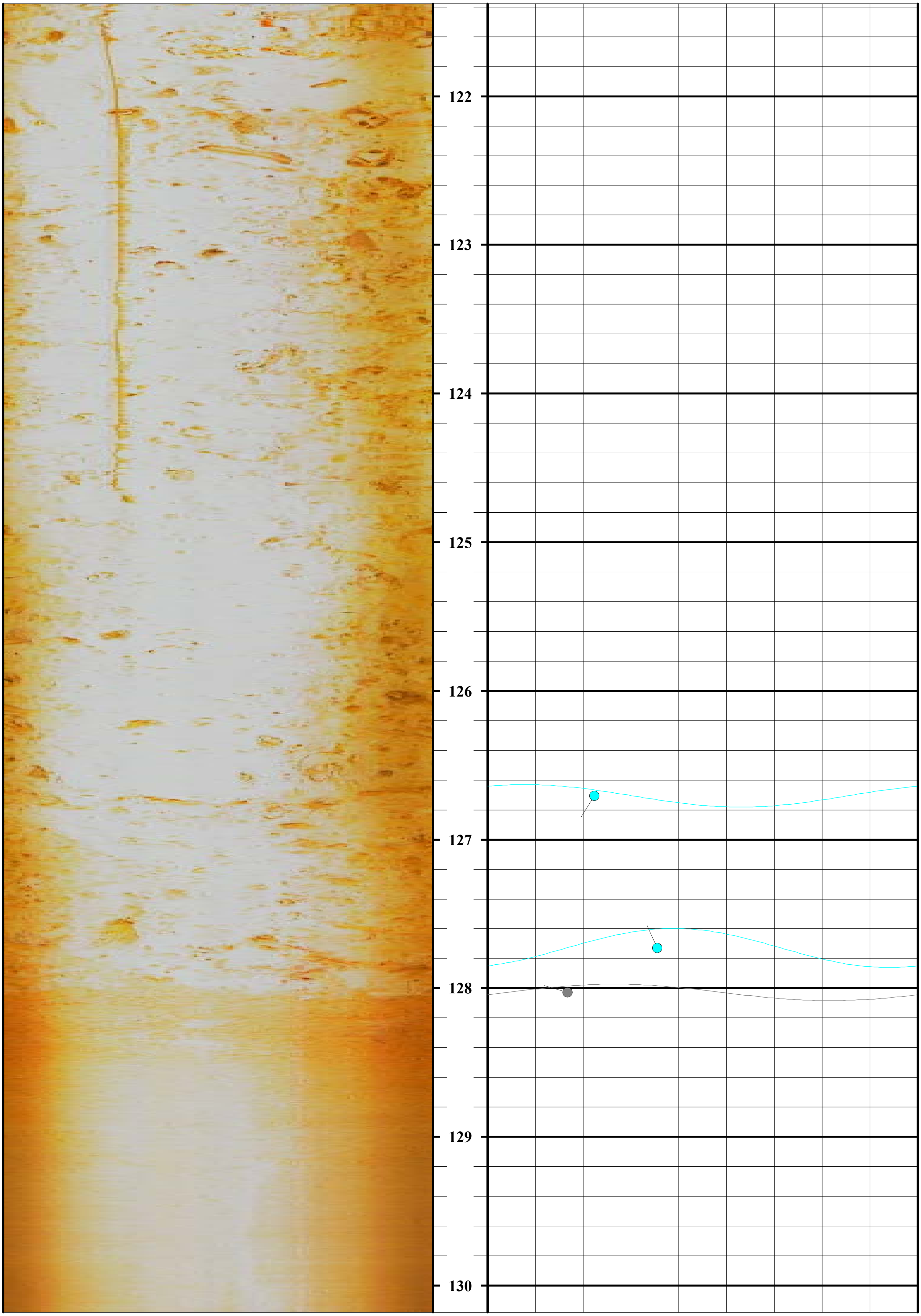

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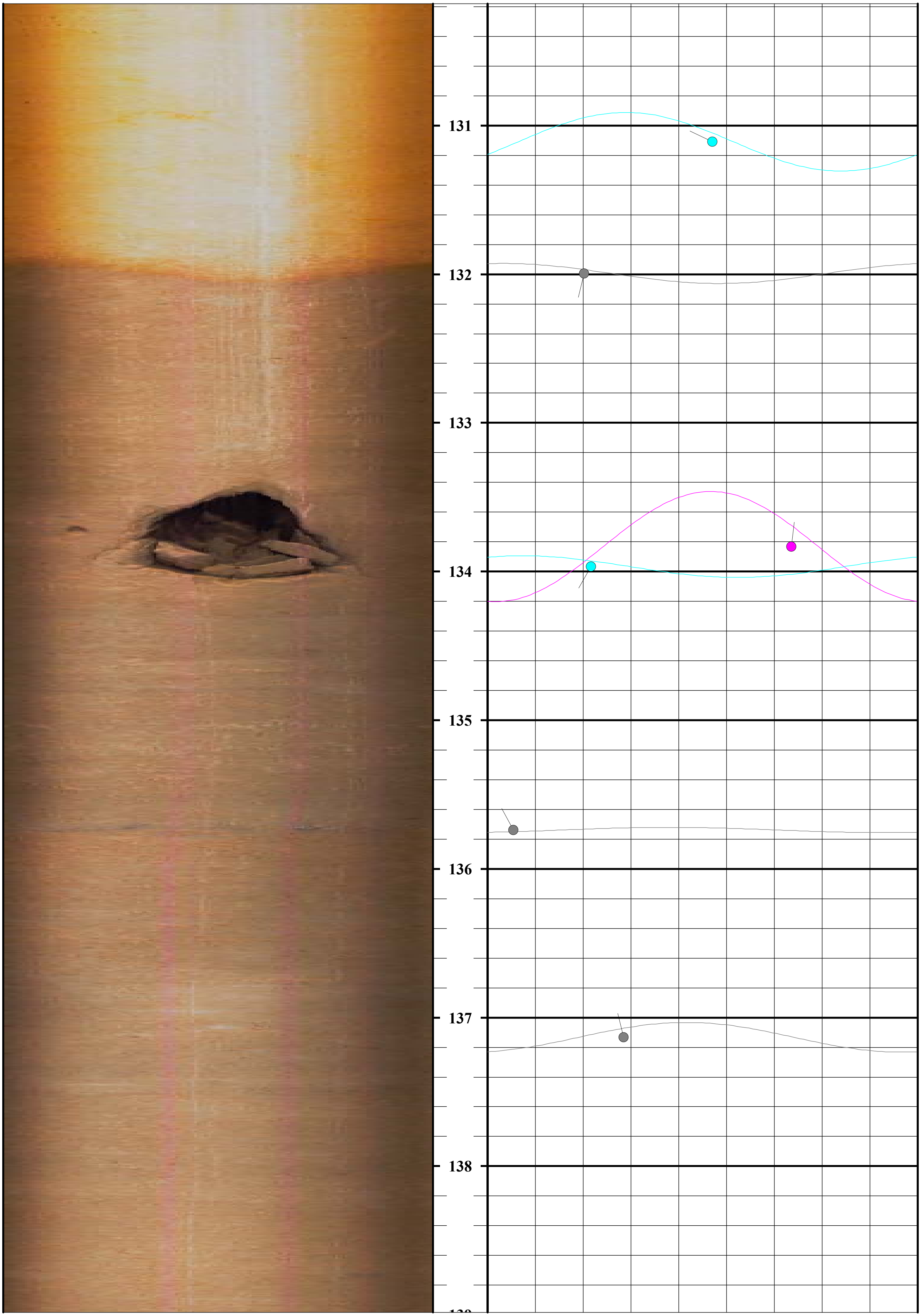
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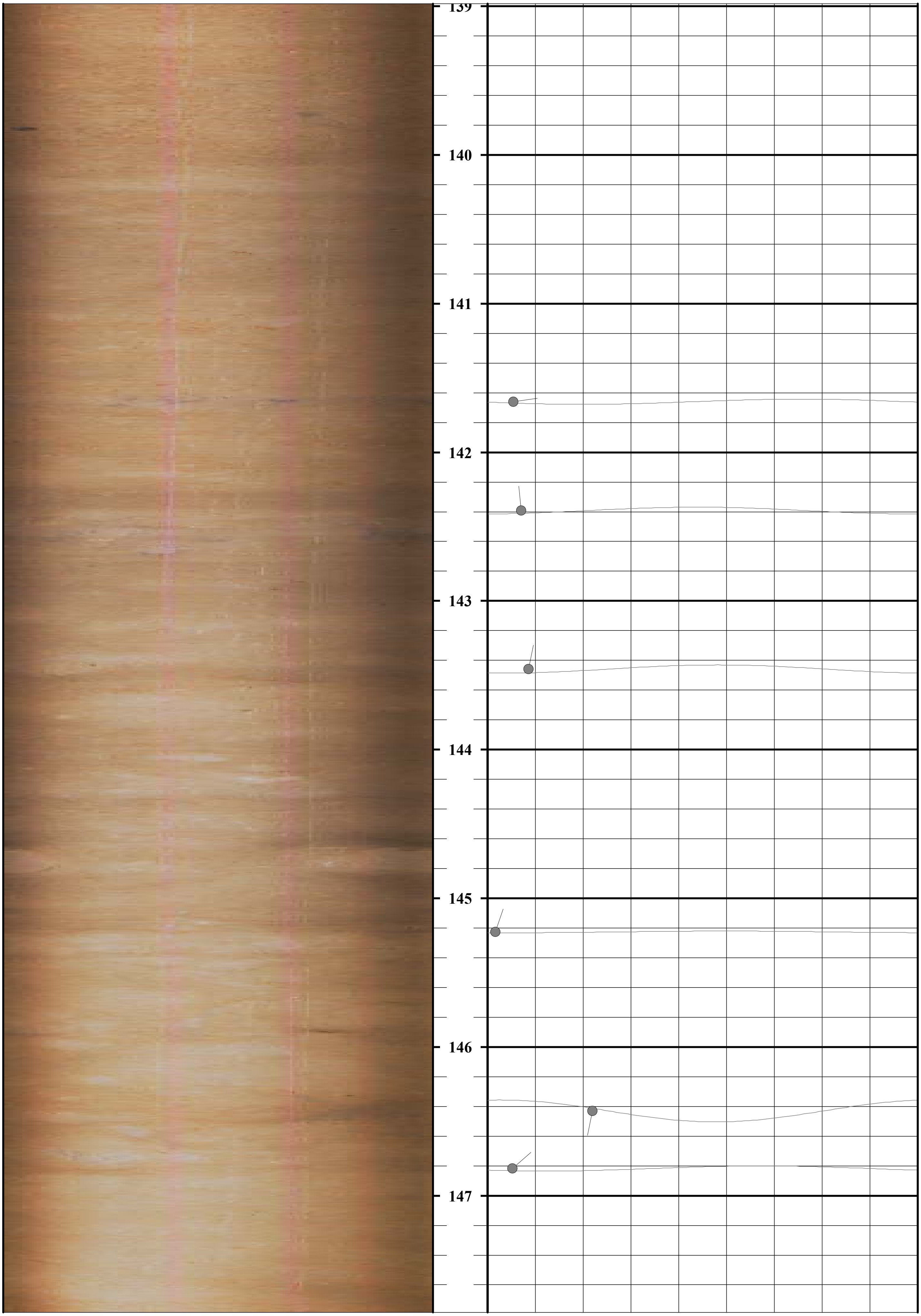
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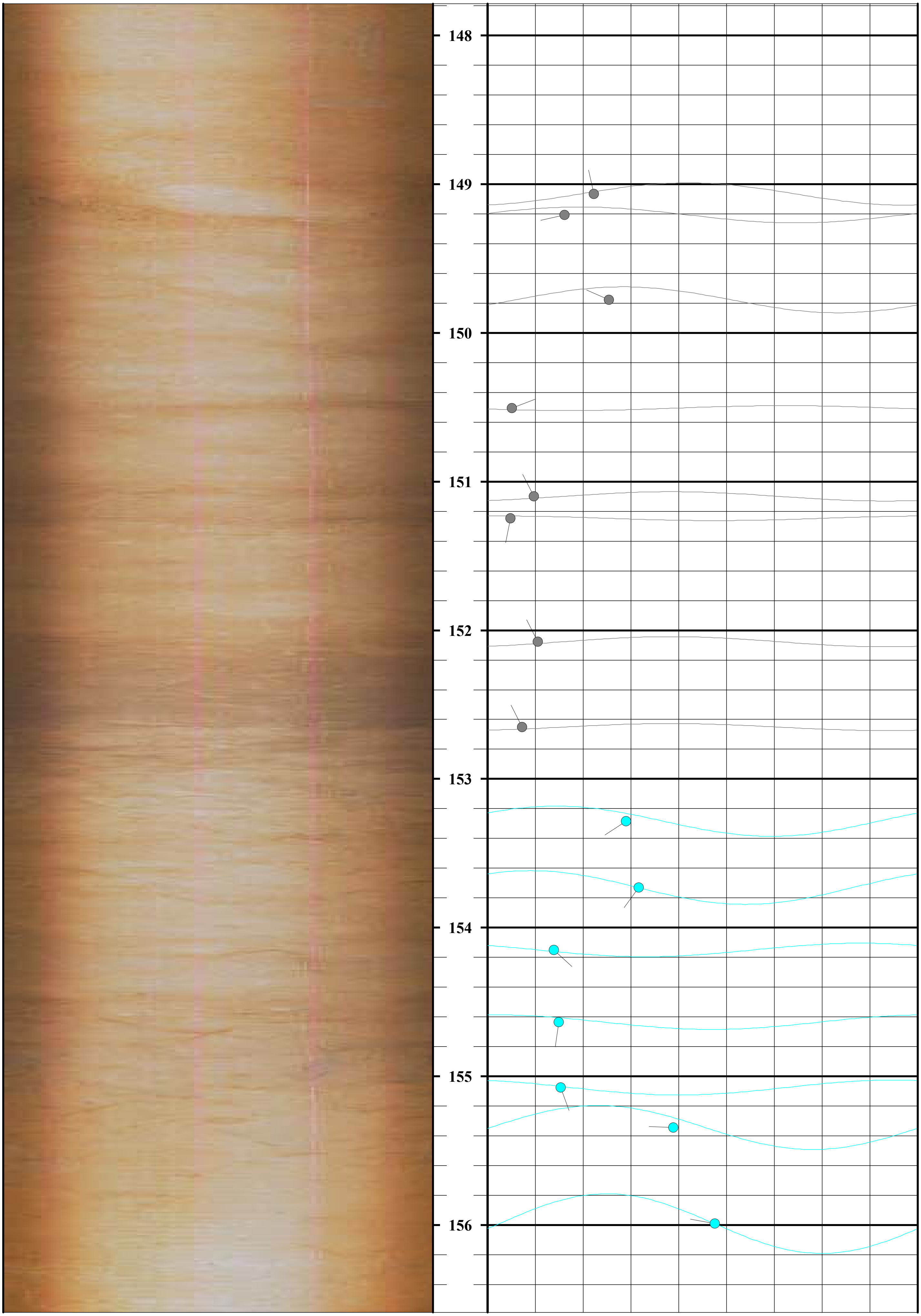
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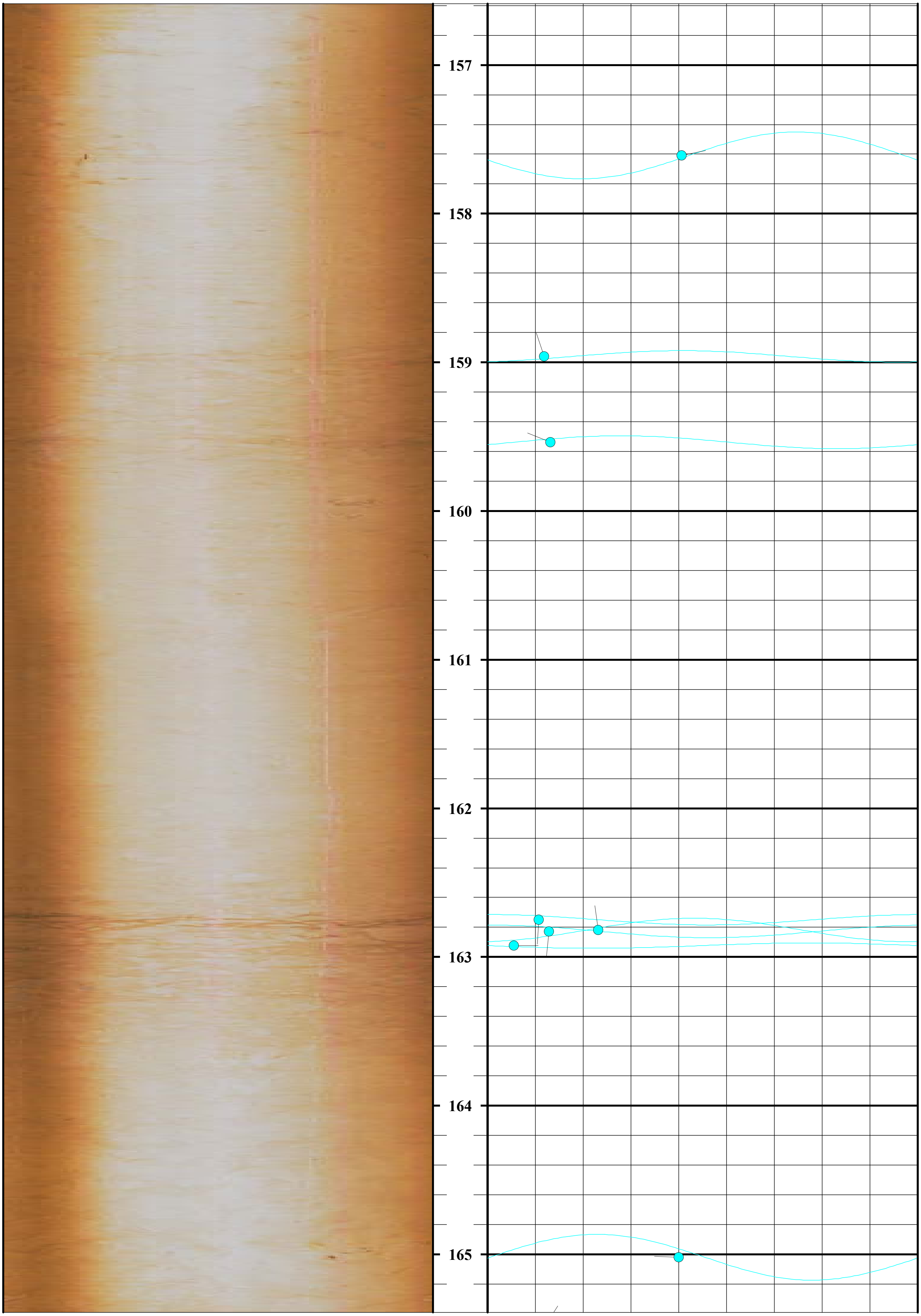
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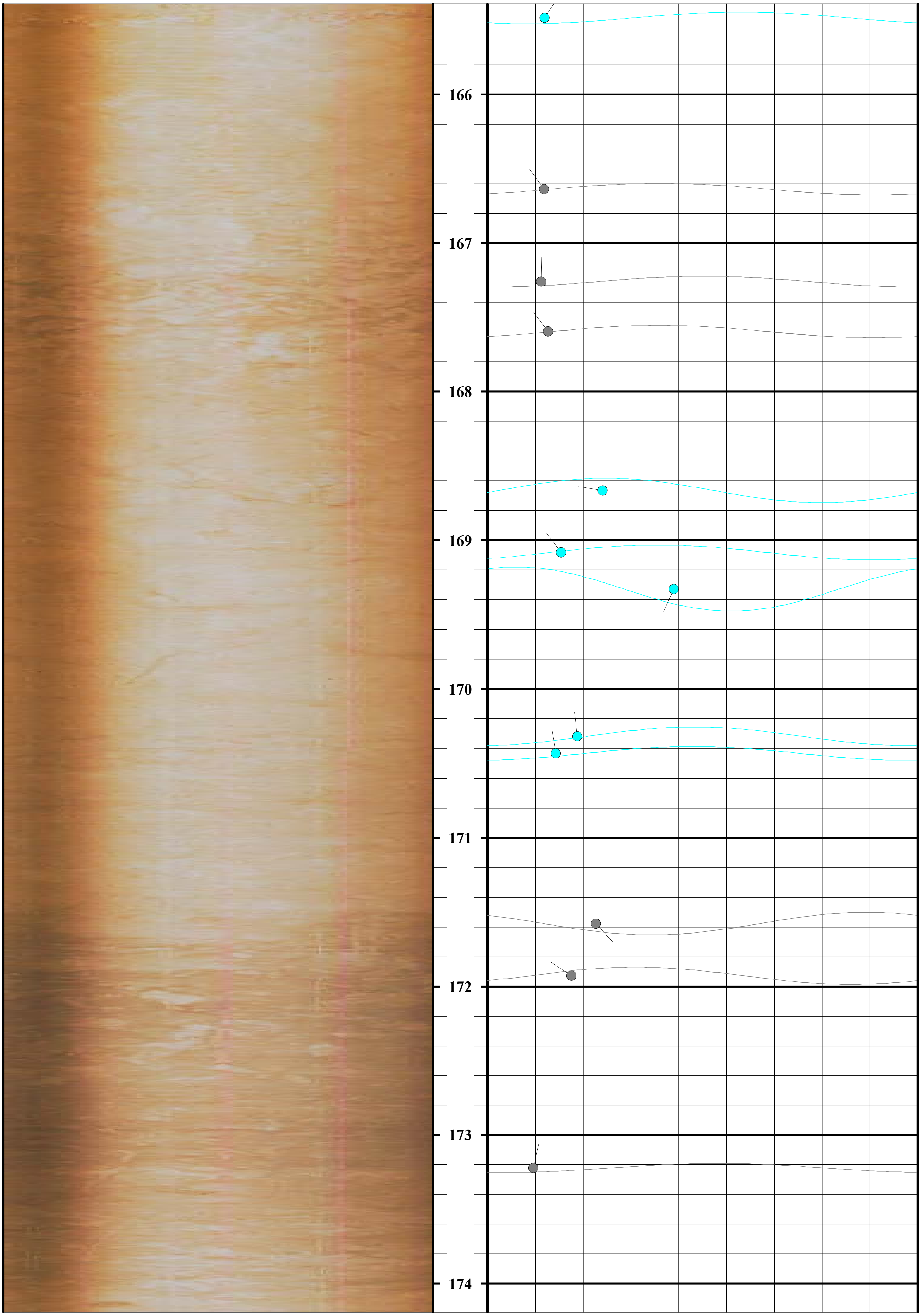
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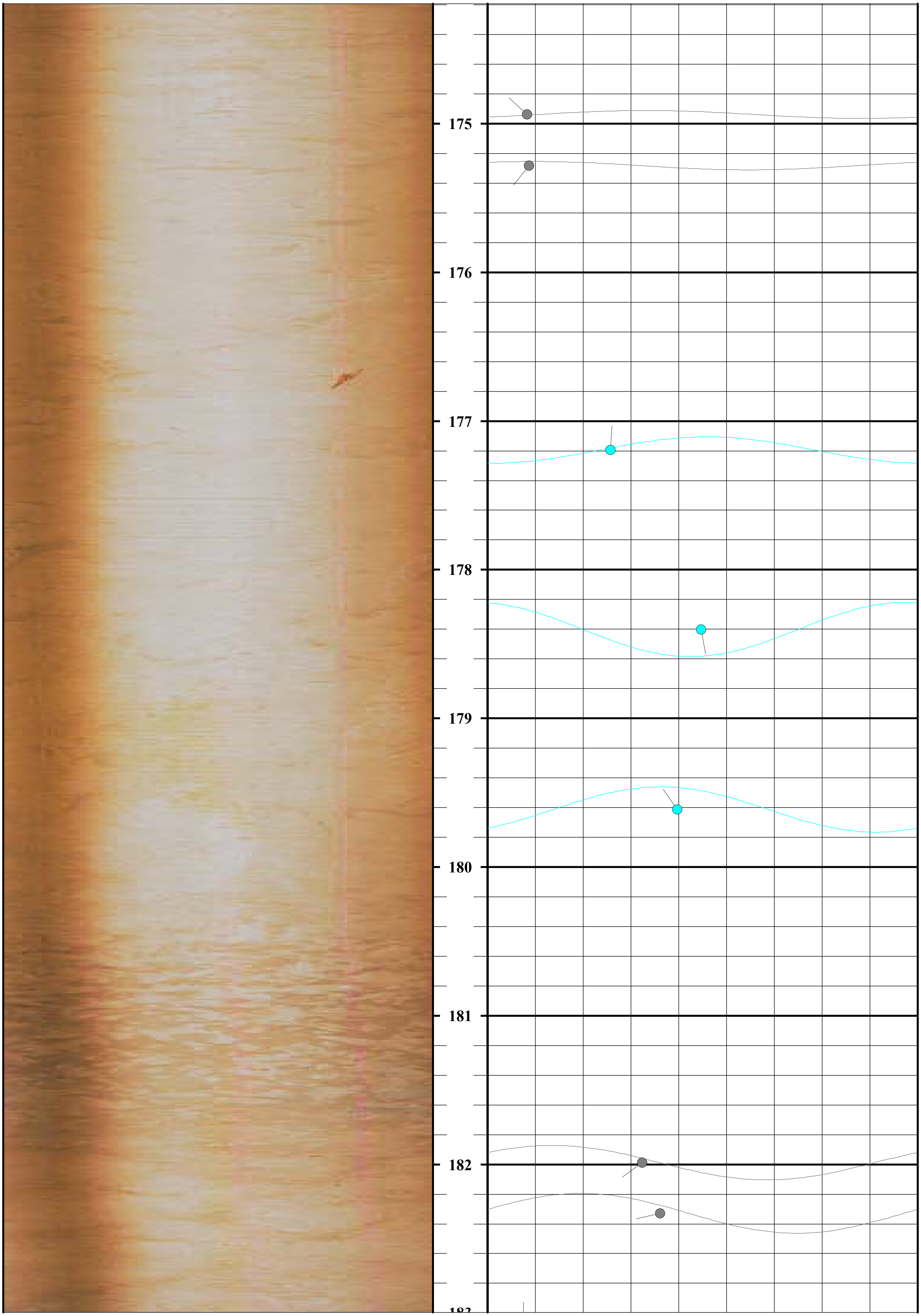
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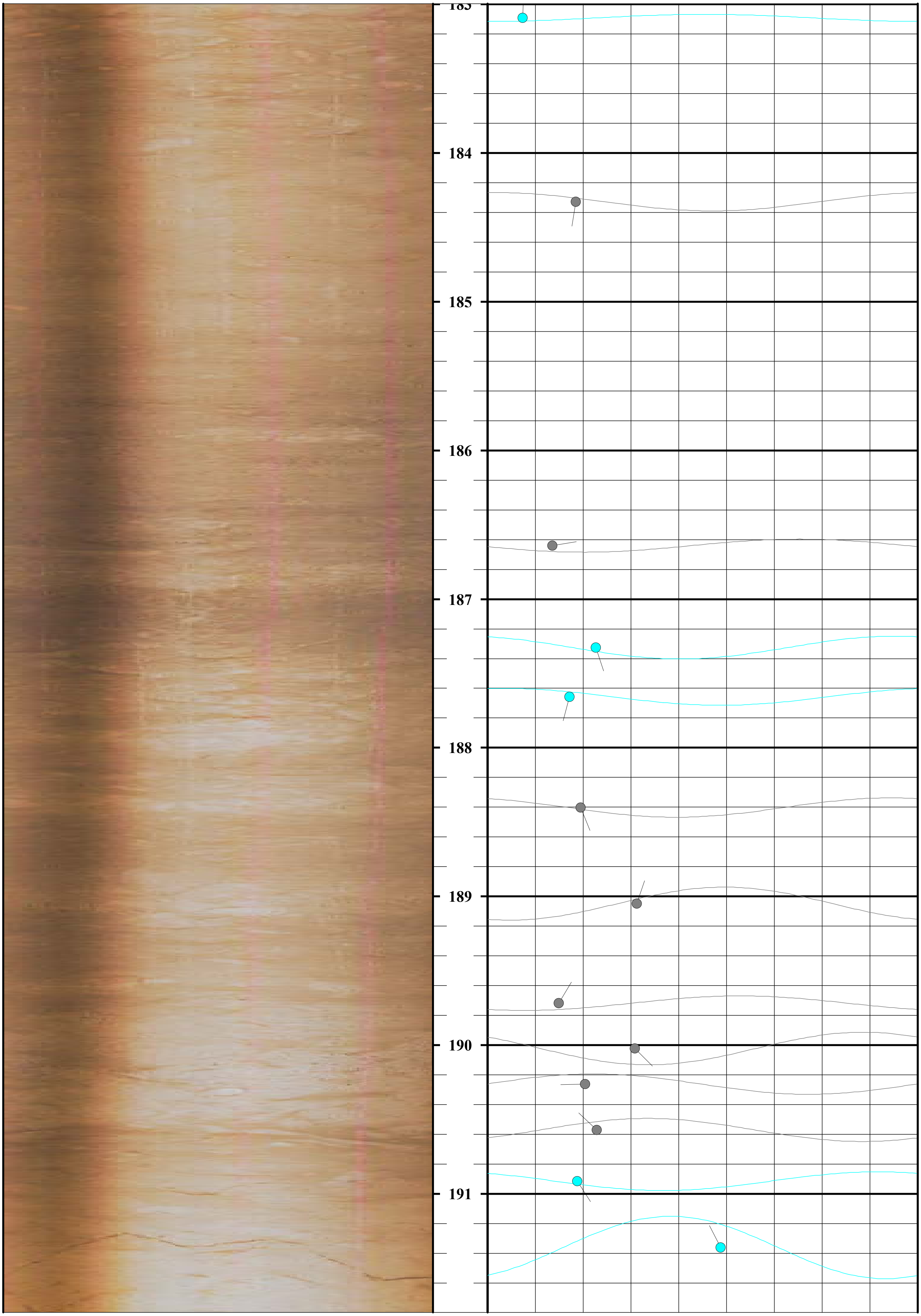
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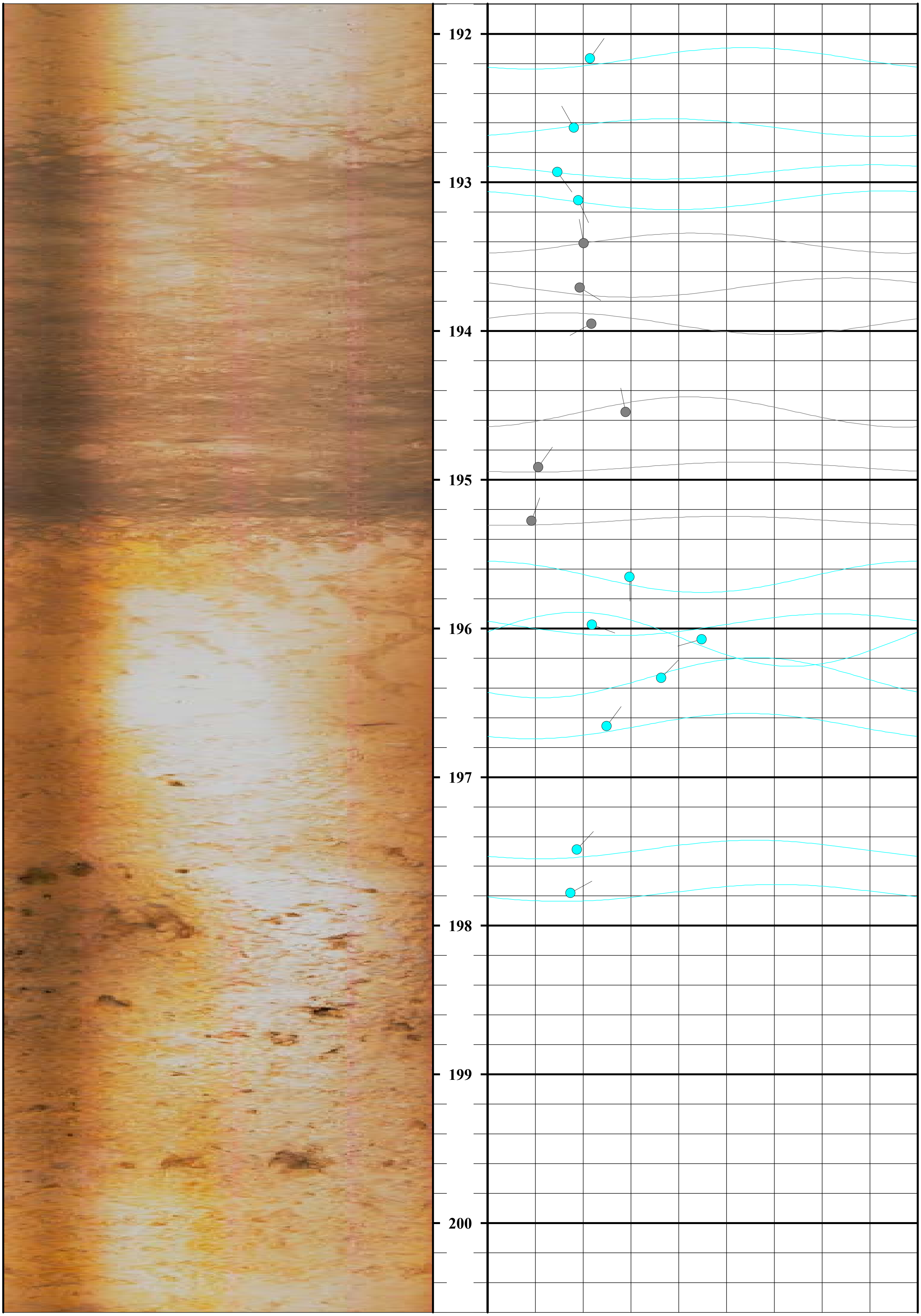
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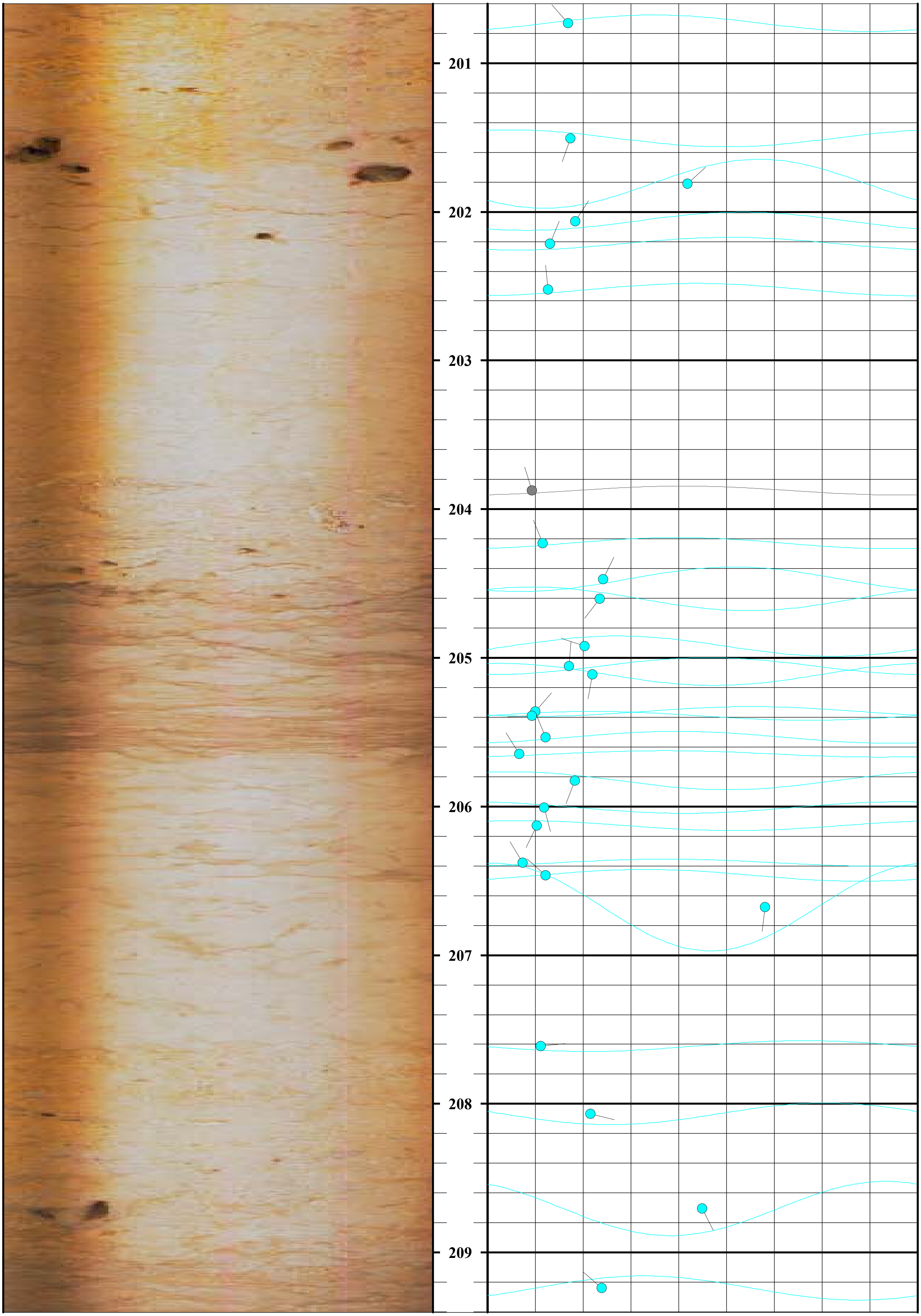

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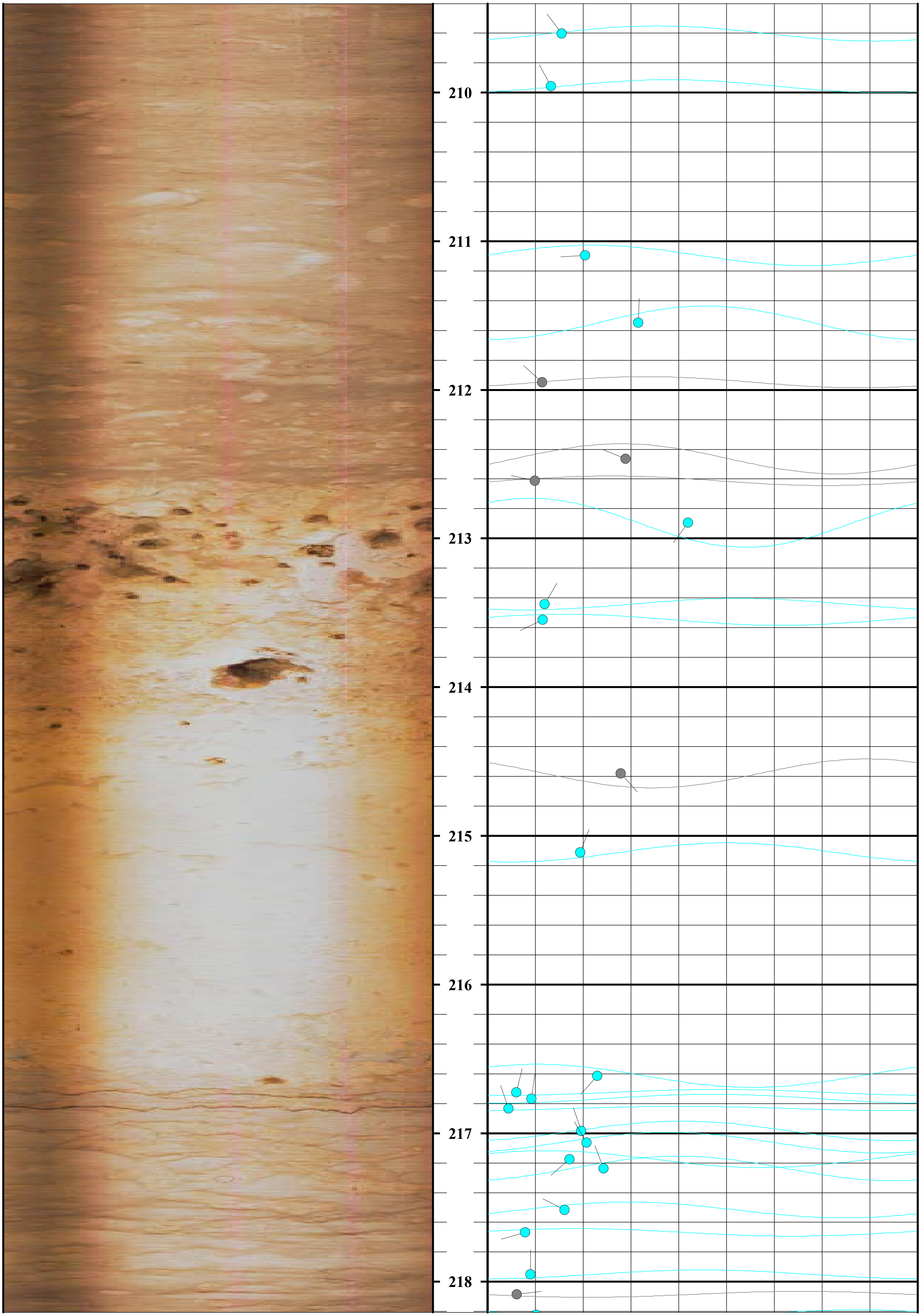
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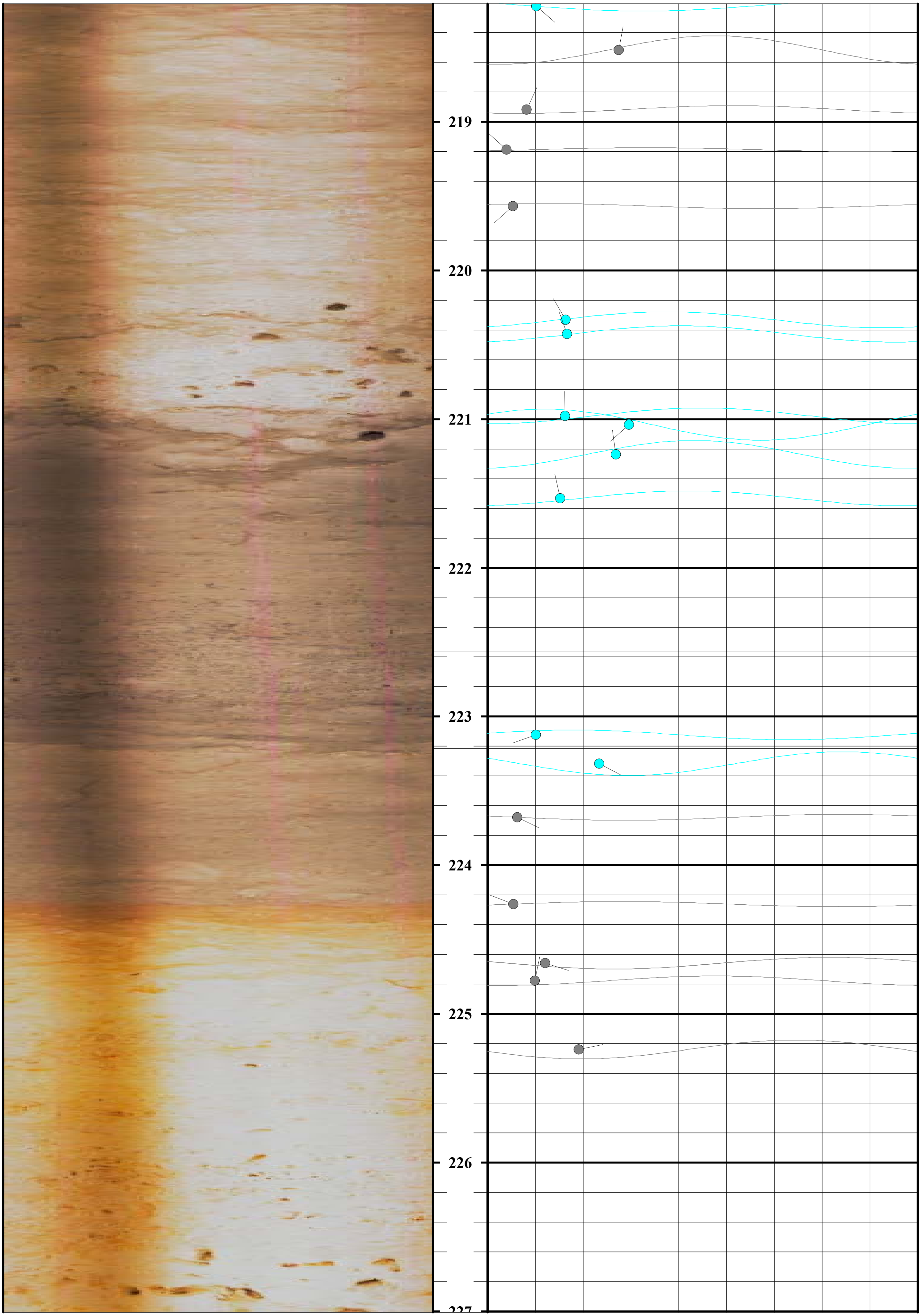
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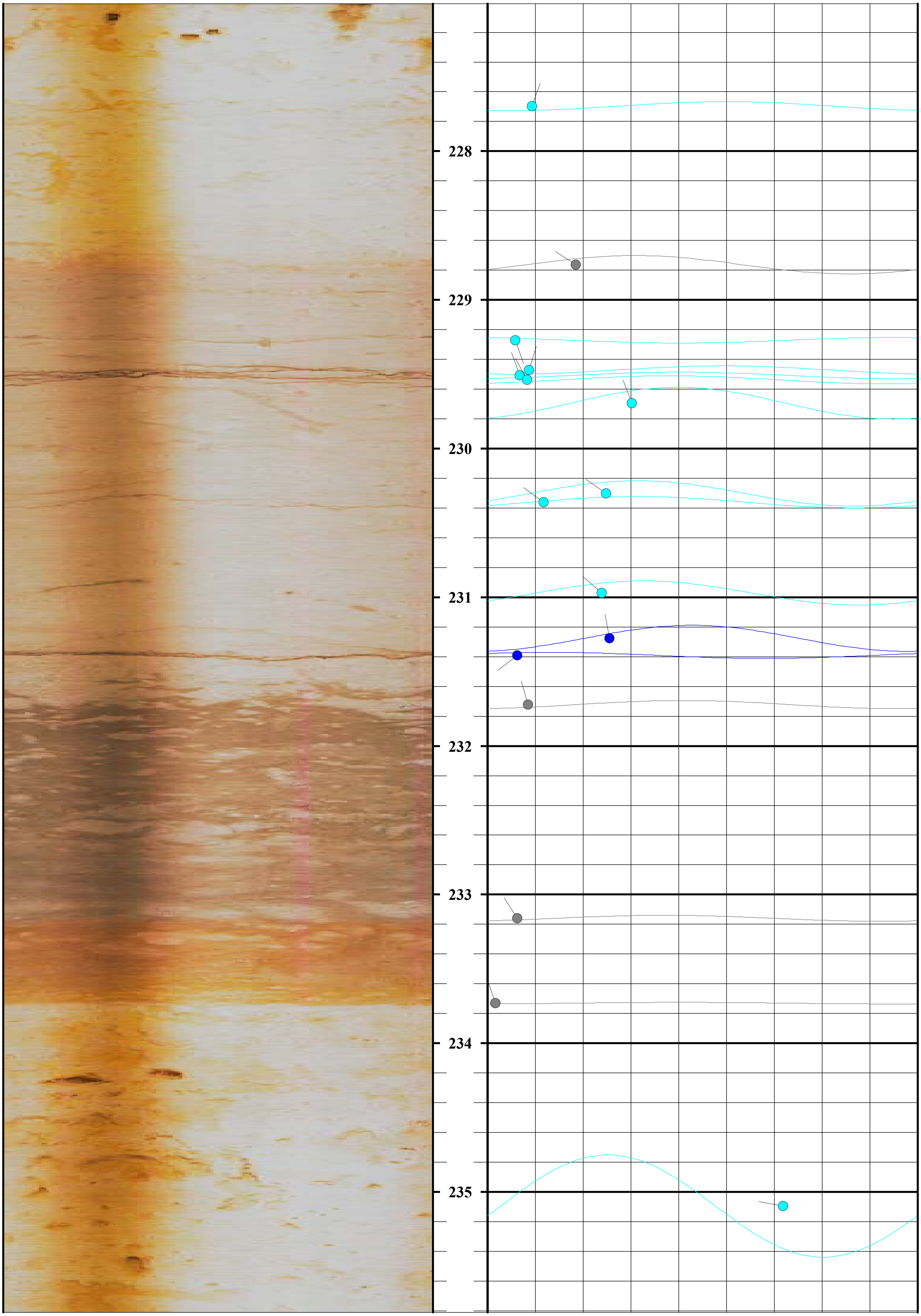
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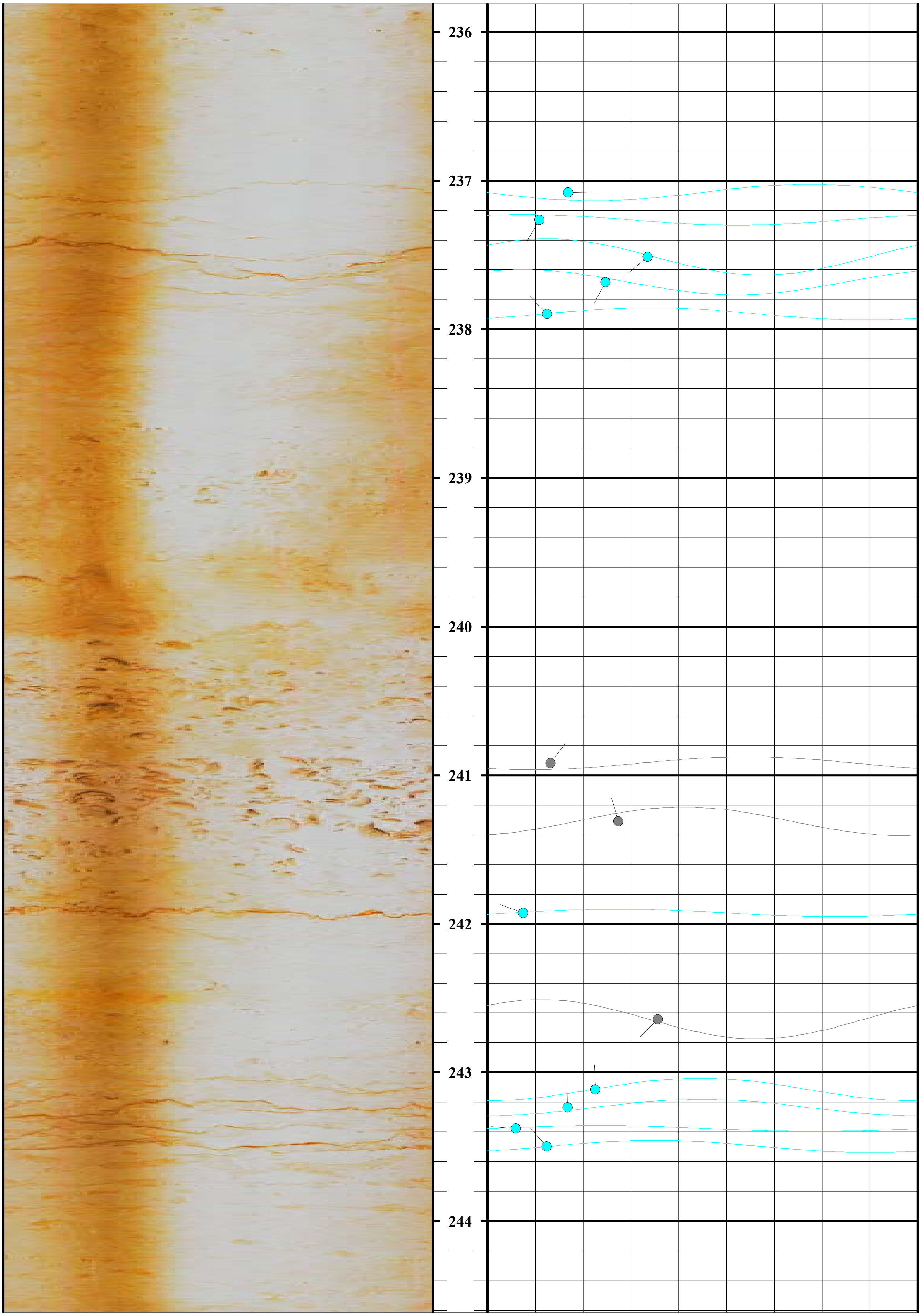
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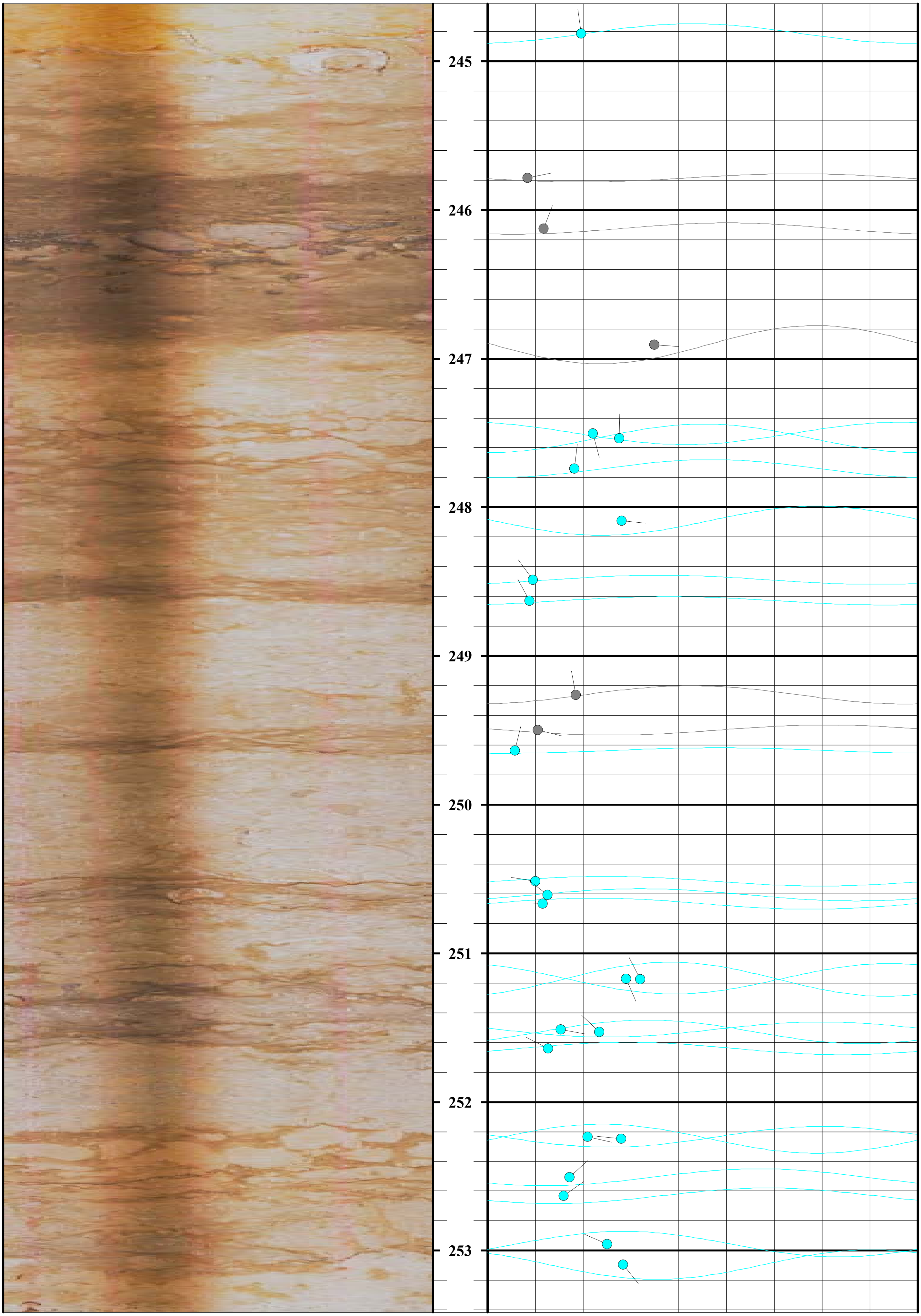
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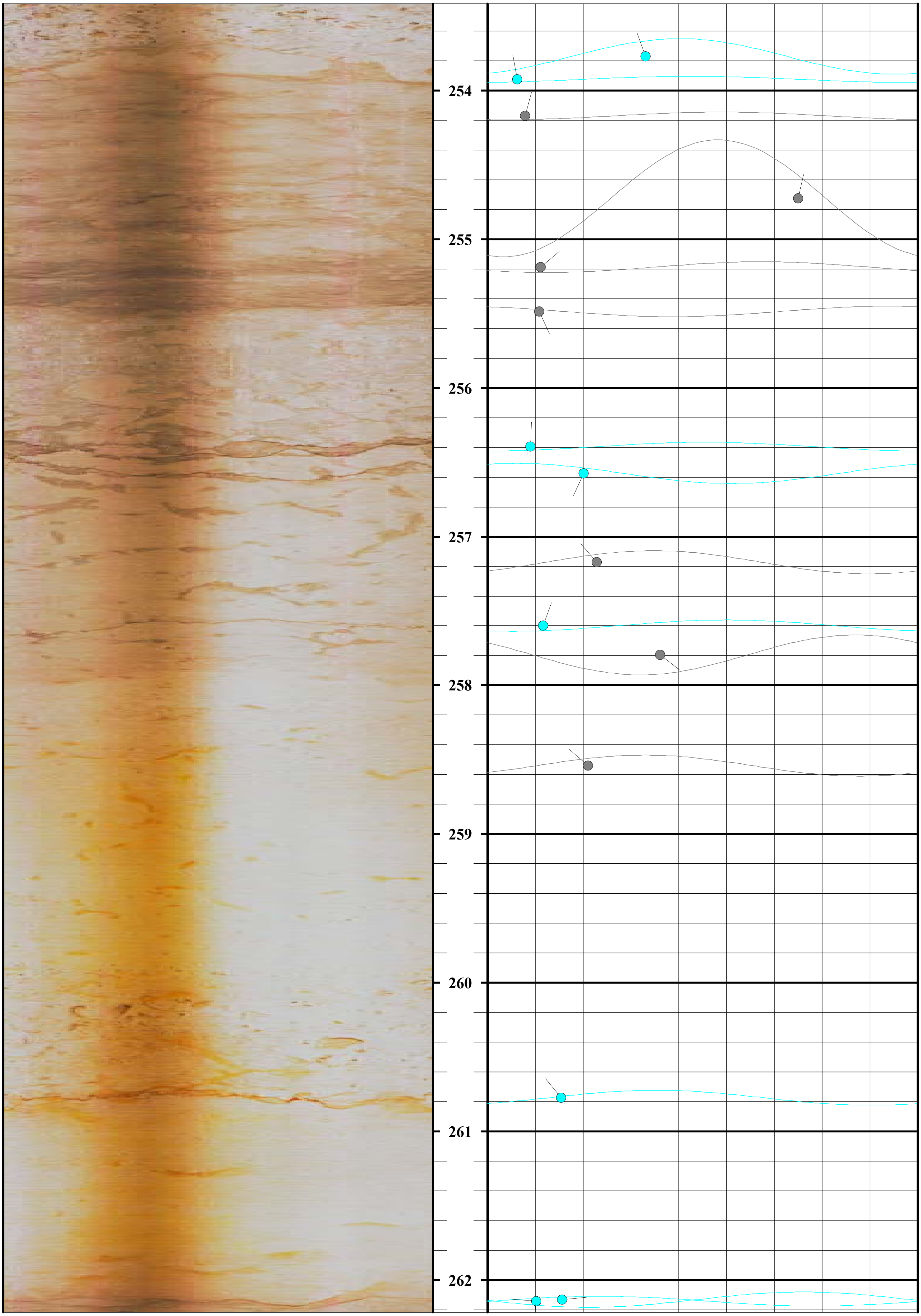
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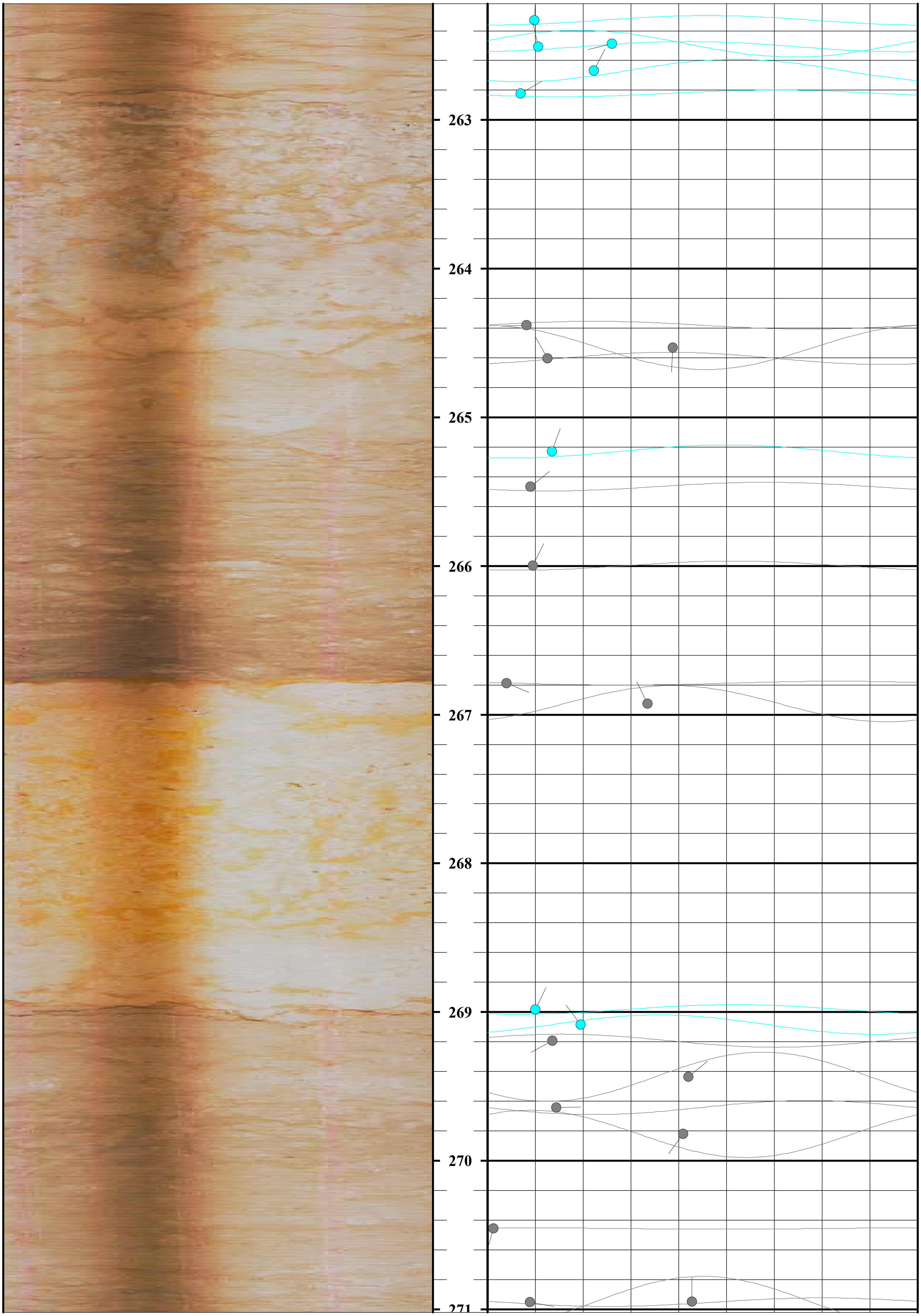
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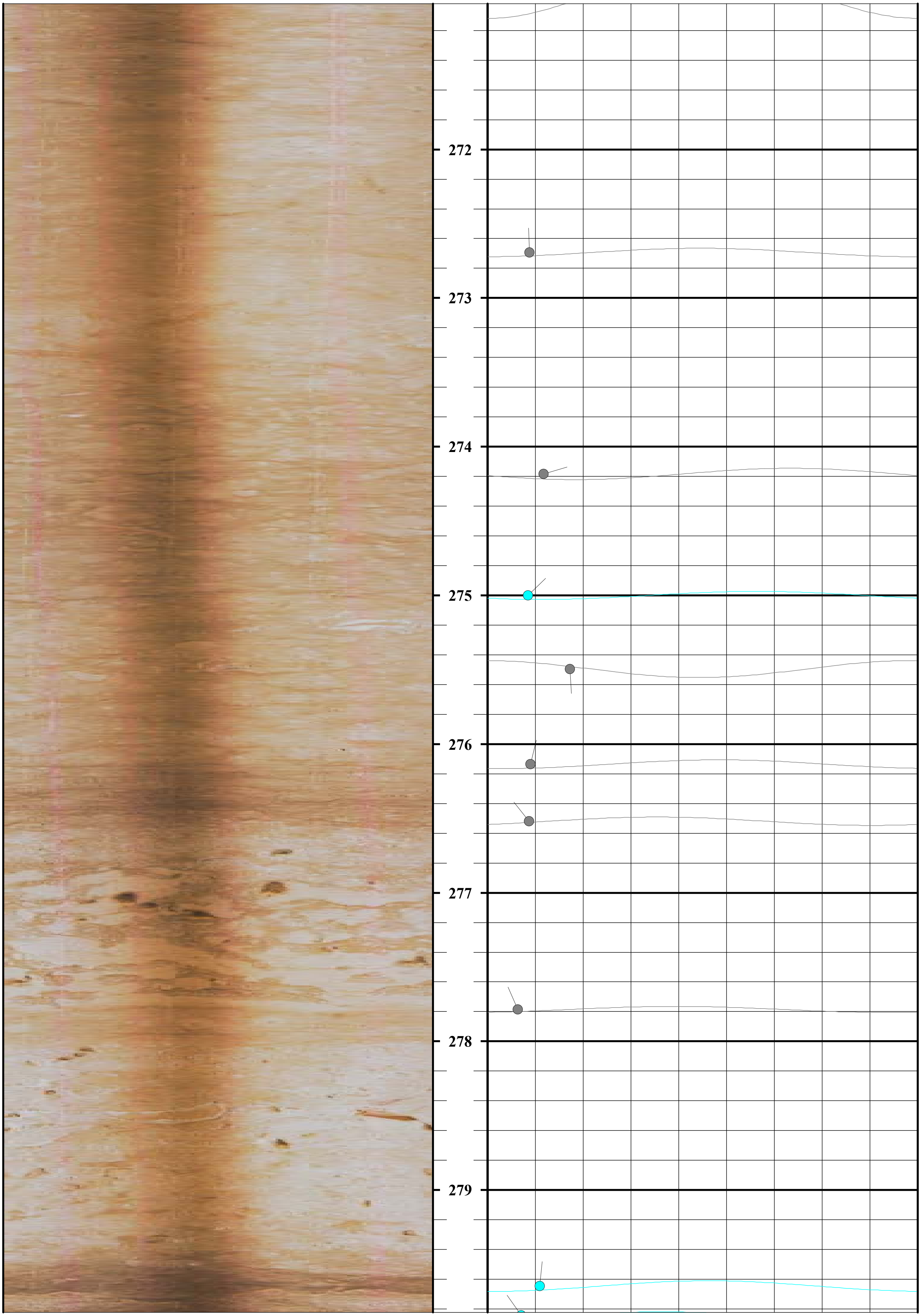
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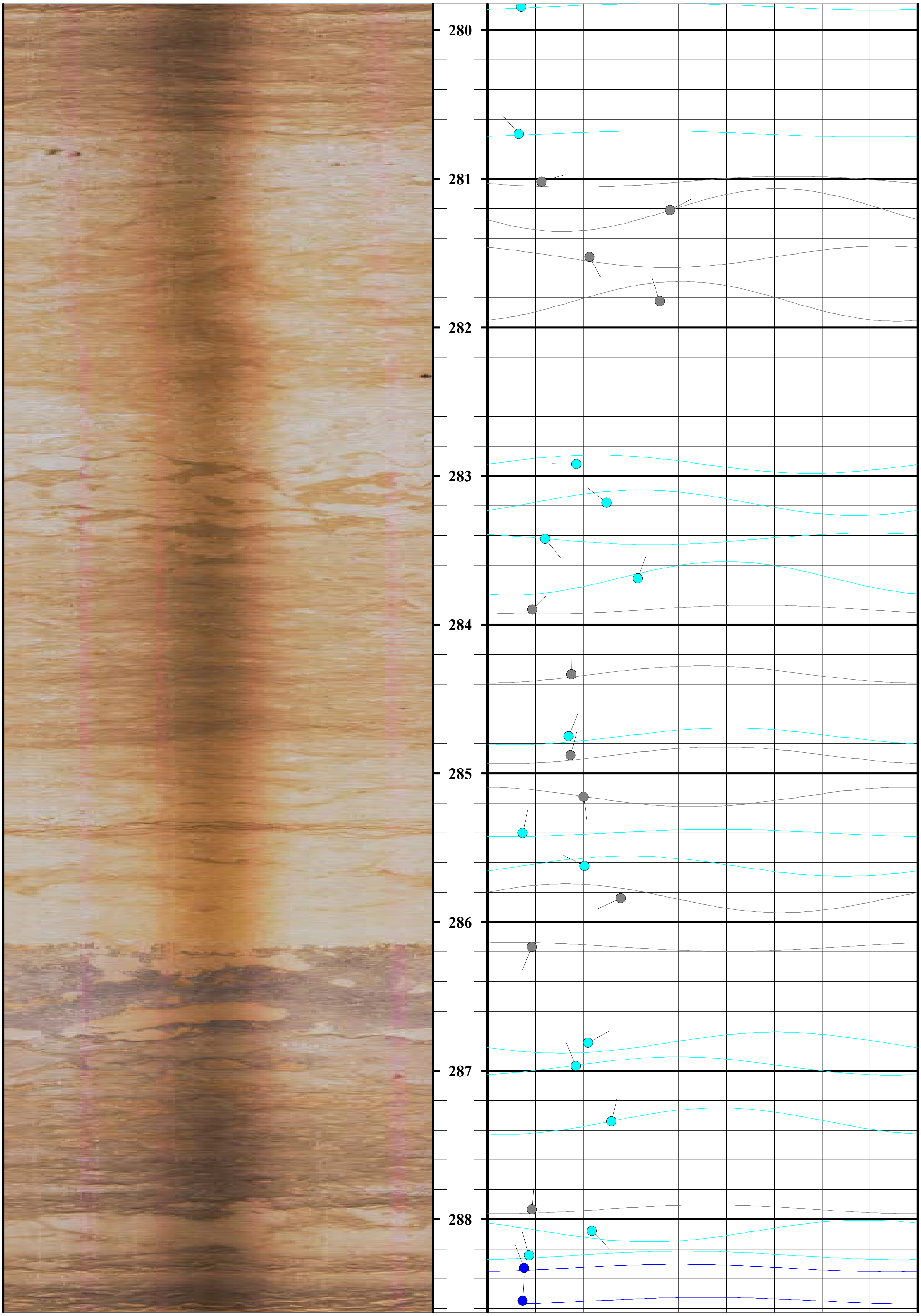
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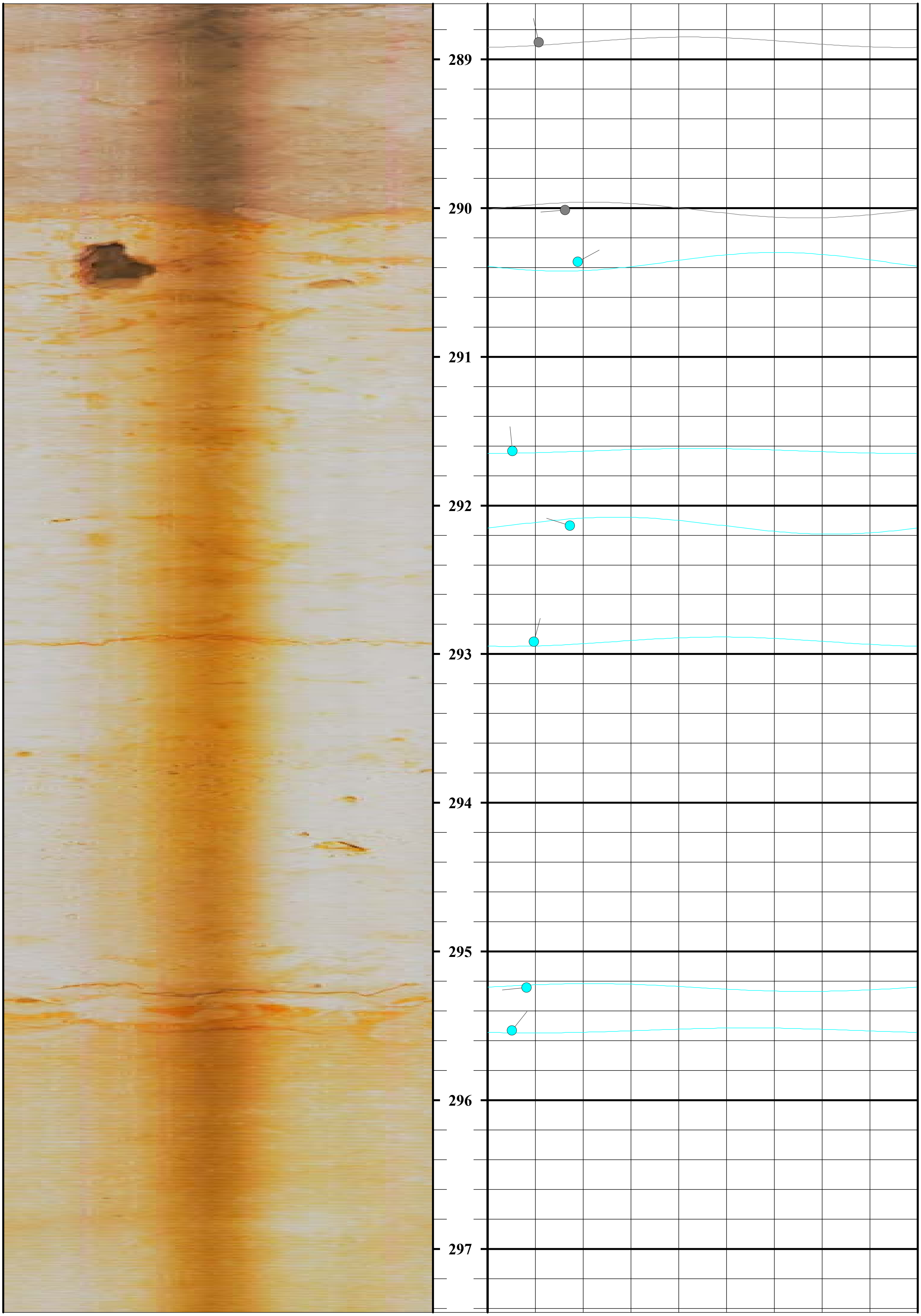
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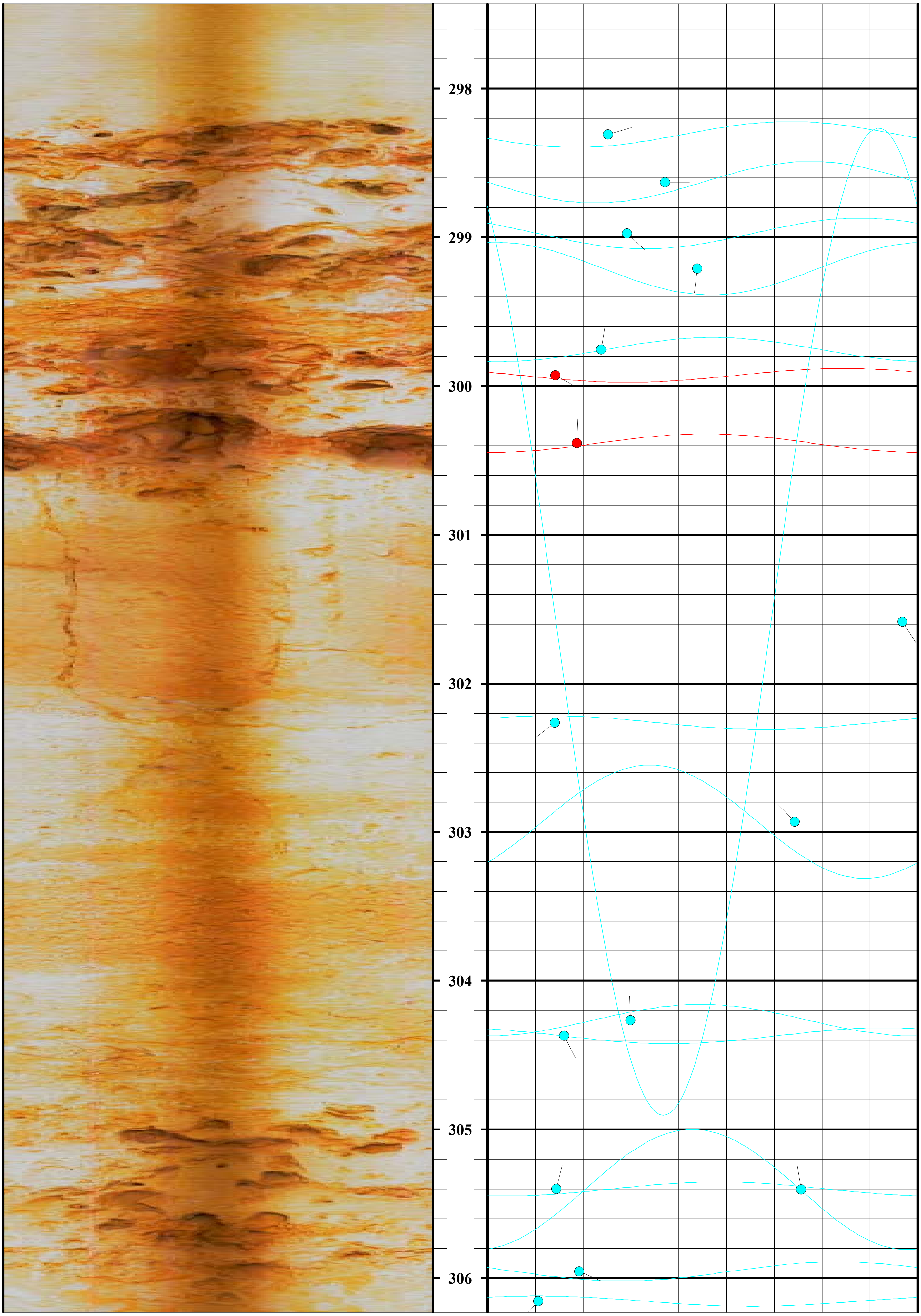
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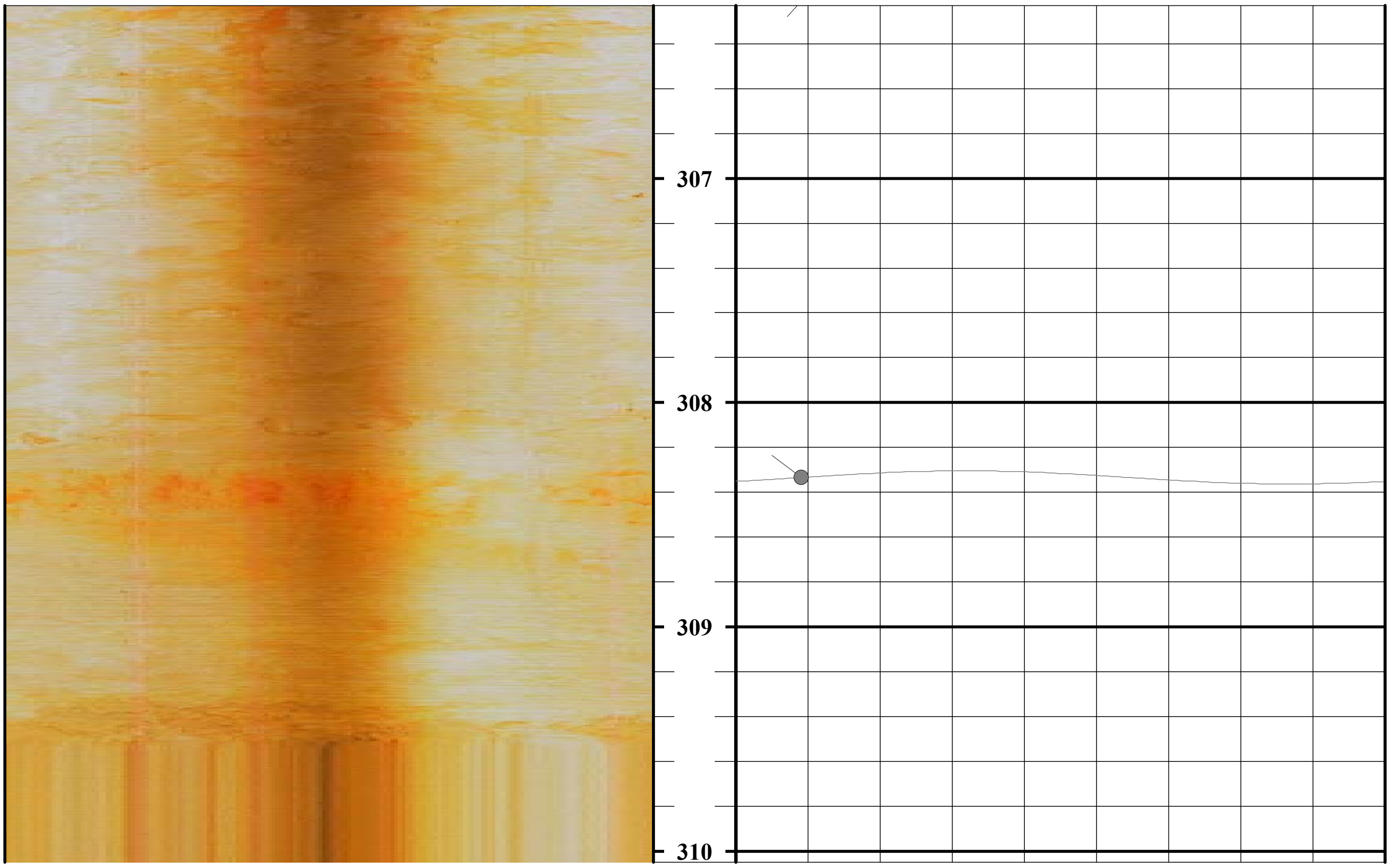
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Orientation Summary Table
Optical Image Features
Camp Stanley Storage Facility, Wellbore: WB-03
Parsons
July 23, 2003

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
1	2.84	9.3	203	5	1
2	2.92	9.6	304	1	1
3	2.97	9.8	353	2	1
4	3.04	10.0	147	2	1
5	3.07	10.1	140	2	1
6	3.15	10.3	147	3	1
7	3.17	10.4	162	2	1
8	3.19	10.5	84	5	1
9	3.31	10.9	348	4	0
10	3.31	10.9	118	6	1
11	3.38	11.1	18	5	1
12	3.48	11.4	325	5	1
13	3.54	11.6	307	4	1
14	3.69	12.1	86	5	1
15	3.89	12.8	16	6	1
16	4.06	13.3	65	14	1
17	4.11	13.5	104	11	1
18	4.15	13.6	32	6	0
19	4.39	14.4	44	6	1
20	4.40	14.4	66	4	1
21	4.42	14.5	88	4	0
22	4.73	15.5	119	10	0
23	4.82	15.8	113	14	0
24	4.94	16.2	158	16	0
25	5.09	16.7	115	6	1
26	5.12	16.8	231	2	0
27	5.18	17.0	59	2	0
28	5.22	17.1	34	6	0
29	5.33	17.5	70	9	0
30	5.48	18.0	319	2	1
31	5.63	18.5	360	10	1
32	5.96	19.6	26	3	1
33	6.04	19.8	248	2	0
34	6.14	20.2	100	6	1
35	6.48	21.3	21	4	1
36	6.51	21.4	170	2	1
37	6.53	21.4	104	2	1
38	6.57	21.6	39	5	1
39	6.64	21.8	313	5	1
40	6.72	22.0	97	3	1
41	6.75	22.2	140	3	1
42	6.81	22.3	134	4	1
43	6.86	22.5	90	3	0
44	7.04	23.1	63	6	0

All directions are with respect to magnetic north.

Orientation Summary Table
Optical Image Features
Camp Stanley Storage Facility, Wellbore: WB-03
Parsons
July 23, 2003

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
45	7.15	23.5	36	4	1
46	7.19	23.6	268	10	1
47	7.24	23.8	339	7	0
48	7.34	24.1	265	2	0
49	7.42	24.3	86	3	0
50	7.82	25.7	7	68	1
51	8.15	26.7	275	21	1
52	8.18	26.8	303	67	1
53	8.22	27.0	215	4	1
54	8.57	28.1	306	20	1
55	8.64	28.4	327	13	1
56	8.73	28.6	60	8	1
57	8.82	28.9	112	6	1
58	8.84	29.0	255	17	4
59	9.12	29.9	284	5	4
60	9.30	30.5	150	84	1
61	9.34	30.7	15	7	1
62	9.54	31.3	353	55	1
63	9.58	31.4	149	13	1
64	9.63	31.6	100	7	1
65	9.77	32.1	109	5	1
66	9.81	32.2	30	6	1
67	10.10	33.1	94	10	1
68	10.17	33.4	185	5	1
69	10.33	33.9	338	4	0
70	10.52	34.5	67	5	0
71	10.67	35.0	278	1	0
72	10.70	35.1	45	5	0
73	11.10	36.4	275	10	1
74	11.16	36.6	269	14	1
75	11.27	37.0	78	29	1
76	11.35	37.2	311	6	1
77	11.46	37.6	57	2	1
78	11.53	37.8	86	3	0
79	11.77	38.6	304	7	0
80	11.95	39.2	290	6	1
81	12.14	39.8	351	8	1
82	12.27	40.2	268	73	1
83	12.27	40.3	253	25	1
84	12.43	40.8	48	22	1
85	12.57	41.2	230	12	1
86	12.74	41.8	227	42	1
87	12.87	42.2	1	29	1
88	12.98	42.6	237	28	1

All directions are with respect to magnetic north.

Orientation Summary Table
Optical Image Features
Camp Stanley Storage Facility, Wellbore: WB-03
Parsons
July 23, 2003

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
89	13.08	42.9	16	25	1
90	13.13	43.1	33	23	1
91	13.34	43.8	205	12	1
92	13.38	43.9	18	77	1
93	13.45	44.1	106	19	1
94	13.58	44.6	38	17	1
95	13.63	44.7	306	33	1
96	13.68	44.9	175	21	1
97	13.72	45.0	320	7	0
98	13.78	45.2	241	30	1
99	13.90	45.6	69	11	1
100	13.94	45.8	147	8	1
101	14.13	46.4	107	10	1
102	14.18	46.5	219	13	1
103	14.22	46.6	335	86	1
104	14.28	46.9	290	12	1
105	14.32	47.0	298	9	1
106	14.39	47.2	320	8	1
107	14.46	47.4	193	7	1
108	14.92	49.0	6	11	1
109	15.55	51.0	148	24	0
110	15.73	51.6	146	10	0
111	15.85	52.0	14	8	0
112	16.01	52.5	136	25	0
113	16.26	53.4	126	68	0
114	16.47	54.0	43	8	1
115	16.51	54.2	96	10	1
116	17.10	56.1	347	1	0
117	17.16	56.3	164	5	1
118	17.48	57.4	323	11	1
119	17.80	58.4	283	6	2
120	18.04	59.2	151	2	0
121	18.15	59.6	297	17	1
122	18.29	60.0	152	10	1
123	18.59	61.0	350	6	1
124	19.07	62.6	92	6	0
125	19.19	63.0	119	9	0
126	19.33	63.4	91	5	0
127	19.80	65.0	116	6	1
128	19.86	65.2	132	20	0
129	20.08	65.9	271	13	1
130	20.13	66.0	304	9	0
131	20.23	66.4	180	12	1
132	20.35	66.8	305	10	1

All directions are with respect to magnetic north.

Orientation Summary Table
Optical Image Features
Camp Stanley Storage Facility, Wellbore: WB-03
Parsons
July 23, 2003

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
133	20.45	67.1	29	5	1
134	20.58	67.5	311	7	0
135	20.69	67.9	328	3	0
136	20.87	68.5	332	6	0
137	21.06	69.1	298	9	1
138	21.41	70.3	173	8	0
139	22.25	73.0	100	21	0
140	22.37	73.4	106	13	1
141	22.63	74.2	275	13	0
142	22.76	74.7	231	17	1
143	22.96	75.3	174	17	1
144	23.00	75.5	189	16	0
145	23.22	76.2	180	12	1
146	23.52	77.2	230	4	0
147	23.69	77.7	145	47	0
148	23.83	78.2	276	4	0
149	23.94	78.6	39	6	0
150	24.02	78.8	187	38	0
151	24.32	79.8	161	7	1
152	24.52	80.4	188	9	1
153	24.69	81.0	156	14	1
154	25.12	82.4	145	36	1
155	25.45	83.5	40	12	1
156	25.79	84.6	317	20	1
157	26.87	88.2	163	14	1
158	26.94	88.4	353	9	1
159	27.03	88.7	348	36	1
160	27.10	88.9	338	13	1
161	27.16	89.1	5	10	1
162	27.18	89.2	33	11	1
163	27.21	89.3	13	16	1
164	27.26	89.4	158	52	1
165	27.54	90.3	349	14	1
166	27.78	91.1	127	17	2
167	28.05	92.0	23	16	0
168	28.20	92.5	12	47	0
169	28.54	93.6	278	11	1
170	28.54	93.6	94	12	1
171	28.55	93.7	127	12	1
172	28.68	94.1	337	51	1
173	28.86	94.7	333	56	1
174	28.89	94.8	312	11	1
175	28.92	94.9	299	16	1
176	29.15	95.7	106	19	1

All directions are with respect to magnetic north.

Orientation Summary Table
Optical Image Features
Camp Stanley Storage Facility, Wellbore: WB-03
Parsons
July 23, 2003

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
177	29.21	95.8	28	40	1
178	29.24	95.9	15	39	1
179	29.27	96.0	20	28	1
180	29.35	96.3	151	30	1
181	29.47	96.7	305	41	1
182	29.56	97.0	253	17	1
183	29.85	97.9	269	13	1
184	29.87	98.0	274	12	1
185	29.93	98.2	275	20	1
186	30.00	98.4	170	10	0
187	30.26	99.3	16	13	0
188	32.35	106.2	136	10	1
189	32.39	106.3	248	7	2
190	32.90	107.9	184	33	1
191	35.29	115.8	280	24	1
192	35.41	116.2	278	24	1
193	36.85	120.9	219	32	1
194	38.62	126.7	211	22	1
195	38.93	127.7	336	36	1
196	39.02	128.0	286	17	0
197	39.96	131.1	296	47	1
198	40.23	132.0	194	20	0
199	40.79	133.8	7	64	4
200	40.83	134.0	209	22	1
201	41.37	135.7	333	5	0
202	41.80	137.1	346	29	0
203	43.18	141.7	81	5	0
204	43.40	142.4	355	7	0
205	43.73	143.5	12	9	0
206	44.27	145.2	19	2	0
207	44.63	146.4	191	22	0
208	44.75	146.8	49	5	0
209	45.44	149.1	348	22	0
210	45.48	149.2	258	16	0
211	45.65	149.8	294	25	0
212	45.88	150.5	69	5	0
213	46.06	151.1	334	10	0
214	46.10	151.3	190	5	0
215	46.35	152.1	334	11	0
216	46.53	152.7	333	7	0
217	46.72	153.3	237	29	1
218	46.86	153.7	216	32	1
219	46.98	154.2	132	14	1
220	47.13	154.6	188	15	1

All directions are with respect to magnetic north.

Orientation Summary Table
Optical Image Features
Camp Stanley Storage Facility, Wellbore: WB-03
Parsons
July 23, 2003

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
221	47.27	155.1	160	15	1
222	47.35	155.4	272	39	1
223	47.55	156.0	280	48	1
224	48.04	157.6	79	41	1
225	48.45	159.0	342	12	1
226	48.63	159.5	292	13	1
227	49.61	162.8	183	11	1
228	49.63	162.8	353	23	1
229	49.63	162.8	186	13	1
230	49.66	162.9	90	6	1
231	50.30	165.0	272	40	1
232	50.44	165.5	32	12	1
233	50.79	166.6	324	12	0
234	50.98	167.3	1	11	0
235	51.08	167.6	324	13	0
236	51.41	168.7	279	24	1
237	51.54	169.1	323	15	1
238	51.61	169.3	204	39	1
239	51.91	170.3	353	19	1
240	51.95	170.4	352	14	1
241	52.30	171.6	137	23	0
242	52.40	171.9	304	18	0
243	52.80	173.2	13	10	0
244	53.32	174.9	313	8	0
245	53.43	175.3	219	9	0
246	54.01	177.2	4	26	1
247	54.38	178.4	170	45	1
248	54.75	179.6	325	40	1
249	55.47	182.0	234	32	0
250	55.57	182.3	258	36	0
251	55.81	183.1	2	7	1
252	56.18	184.3	188	19	0
253	56.89	186.6	81	14	0
254	57.10	187.3	161	23	1
255	57.20	187.7	195	17	1
256	57.42	188.4	158	20	0
257	57.62	189.1	19	31	0
258	57.83	189.7	31	15	0
259	57.92	190.0	134	31	0
260	57.99	190.3	269	21	0
261	58.09	190.6	314	23	0
262	58.19	190.9	147	19	1
263	58.33	191.4	333	49	1
264	58.57	192.2	35	21	1

All directions are with respect to magnetic north.

Orientation Summary Table
Optical Image Features
Camp Stanley Storage Facility, Wellbore: WB-03
Parsons
July 23, 2003

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
265	58.71	192.6	331	18	1
266	58.81	192.9	144	15	1
267	58.86	193.1	156	19	1
268	58.95	193.4	350	20	0
269	59.04	193.7	120	19	0
270	59.12	194.0	241	22	0
271	59.30	194.5	349	29	0
272	59.41	194.9	36	11	0
273	59.52	195.3	19	9	0
274	59.63	195.7	179	30	1
275	59.73	196.0	109	22	1
276	59.76	196.1	255	45	1
277	59.84	196.3	44	36	1
278	59.94	196.7	36	25	1
279	60.19	197.5	43	19	1
280	60.28	197.8	62	17	1
281	61.18	200.7	319	17	1
282	61.42	201.5	199	17	1
283	61.51	201.8	47	42	1
284	61.59	202.1	33	18	1
285	61.63	202.2	23	13	1
286	61.73	202.5	355	13	1
287	62.14	203.9	343	9	0
288	62.25	204.2	339	12	1
289	62.32	204.5	26	24	1
290	62.36	204.6	218	23	1
291	62.46	204.9	289	20	1
292	62.50	205.1	4	17	1
293	62.52	205.1	190	22	1
294	62.59	205.4	41	10	1
295	62.60	205.4	268	9	1
296	62.65	205.5	338	12	1
297	62.68	205.6	328	7	1
298	62.74	205.8	200	18	1
299	62.79	206.0	165	12	1
300	62.83	206.1	206	10	1
301	62.90	206.4	330	7	1
302	62.93	206.5	312	12	1
303	63.00	206.7	186	58	1
304	63.28	207.6	84	11	1
305	63.42	208.1	103	22	1
306	63.61	208.7	153	45	1
307	63.78	209.2	311	24	1
308	63.89	209.6	323	16	1

All directions are with respect to magnetic north.

Orientation Summary Table
Optical Image Features
Camp Stanley Storage Facility, Wellbore: WB-03
Parsons
July 23, 2003

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
309	64.00	210.0	332	13	1
310	64.34	211.1	267	20	1
311	64.48	211.6	3	32	1
312	64.60	212.0	312	11	0
313	64.76	212.5	292	29	0
314	64.80	212.6	283	10	0
315	64.89	212.9	216	42	1
316	65.06	213.4	30	12	1
317	65.09	213.6	245	12	1
318	65.40	214.6	138	28	0
319	65.57	215.1	21	19	1
320	66.03	216.6	222	23	1
321	66.06	216.7	14	6	1
322	66.07	216.8	8	9	1
323	66.09	216.8	342	4	1
324	66.14	217.0	343	20	1
325	66.16	217.1	330	21	1
326	66.19	217.2	229	17	1
327	66.21	217.2	340	24	1
328	66.30	217.5	298	16	1
329	66.35	217.7	254	8	1
330	66.43	218.0	0	9	1
331	66.47	218.1	83	6	0
332	66.51	218.2	130	10	1
333	66.60	218.5	11	28	0
334	66.73	218.9	25	8	0
335	66.81	219.2	312	4	0
336	66.92	219.6	229	5	0
337	67.16	220.3	330	16	1
338	67.19	220.4	341	17	1
339	67.35	221.0	359	16	1
340	67.37	221.0	228	30	1
341	67.43	221.2	353	27	1
342	67.52	221.5	348	15	1
343	68.01	223.1	251	10	1
344	68.07	223.3	117	23	1
345	68.18	223.7	115	6	0
346	68.35	224.3	292	6	0
347	68.48	224.7	106	12	0
348	68.51	224.8	11	10	0
349	68.65	225.2	78	19	0
350	69.40	227.7	20	9	1
351	69.73	228.8	303	19	0
352	69.88	229.3	160	6	1

All directions are with respect to magnetic north.

Orientation Summary Table
Optical Image Features
Camp Stanley Storage Facility, Wellbore: WB-03
Parsons
July 23, 2003

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
353	69.94	229.5	18	9	1
354	69.95	229.5	341	7	1
355	69.96	229.5	332	8	1
356	70.01	229.7	339	30	1
357	70.20	230.3	305	25	1
358	70.21	230.4	306	12	1
359	70.40	231.0	311	24	1
360	70.49	231.3	351	26	2
361	70.53	231.4	232	6	2
362	70.63	231.7	344	9	0
363	71.07	233.2	327	6	0
364	71.24	233.7	342	2	0
365	71.66	235.1	281	62	1
366	72.26	237.1	89	17	1
367	72.32	237.3	209	11	1
368	72.39	237.5	230	34	1
369	72.45	237.7	208	25	1
370	72.51	237.9	317	13	1
371	73.43	240.9	37	13	0
372	73.55	241.3	344	27	0
373	73.74	241.9	290	8	1
374	73.96	242.6	225	36	0
375	74.10	243.1	358	23	1
376	74.14	243.2	359	17	1
377	74.18	243.4	274	6	1
378	74.22	243.5	320	12	1
379	74.62	244.8	352	20	1
380	74.91	245.8	79	8	0
381	75.02	246.1	21	12	0
382	75.26	246.9	95	35	0
383	75.44	247.5	165	22	1
384	75.45	247.5	1	28	1
385	75.51	247.7	7	18	1
386	75.62	248.1	96	28	1
387	75.74	248.5	324	10	1
388	75.78	248.6	332	9	1
389	75.97	249.3	350	18	0
390	76.05	249.5	104	11	0
391	76.09	249.6	14	6	1
392	76.36	250.5	279	10	1
393	76.39	250.6	308	13	1
394	76.40	250.7	270	12	1
395	76.56	251.2	156	29	1
396	76.56	251.2	333	32	1

All directions are with respect to magnetic north.

Orientation Summary Table
Optical Image Features
Camp Stanley Storage Facility, Wellbore: WB-03
Parsons
July 23, 2003

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
397	76.66	251.5	100	15	1
398	76.67	251.5	314	23	1
399	76.70	251.6	297	13	1
400	76.88	252.2	102	21	1
401	76.89	252.3	276	28	1
402	76.97	252.5	48	17	1
403	77.00	252.6	55	16	1
404	77.10	253.0	294	25	1
405	77.14	253.1	141	28	1
406	77.35	253.8	341	33	1
407	77.39	253.9	350	6	1
408	77.47	254.2	15	8	0
409	77.64	254.7	13	65	0
410	77.78	255.2	50	11	0
411	77.87	255.5	155	11	0
412	78.15	256.4	2	9	1
413	78.20	256.6	204	20	1
414	78.39	257.2	319	23	0
415	78.52	257.6	20	12	1
416	78.57	257.8	128	36	0
417	78.80	258.5	312	21	0
418	79.49	260.8	321	15	1
419	79.90	262.1	85	16	1
420	79.90	262.1	274	10	1
421	79.96	262.3	4	10	1
422	80.01	262.5	257	26	1
423	80.01	262.5	348	11	1
424	80.06	262.7	27	22	1
425	80.11	262.8	60	7	1
426	80.58	264.4	268	8	0
427	80.63	264.5	183	39	0
428	80.65	264.6	331	13	0
429	80.84	265.2	20	14	1
430	80.91	265.5	52	9	0
431	81.08	266.0	26	10	0
432	81.32	266.8	112	4	0
433	81.36	266.9	334	34	0
434	81.99	269.0	26	10	1
435	82.02	269.1	324	20	1
436	82.05	269.2	242	14	0
437	82.13	269.4	50	42	0
438	82.19	269.6	89	14	0
439	82.24	269.8	216	41	0
440	82.44	270.5	196	1	0

All directions are with respect to magnetic north.

Orientation Summary Table
Optical Image Features
Camp Stanley Storage Facility, Wellbore: WB-03
Parsons
July 23, 2003

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
441	82.59	271.0	0	43	0
442	82.59	271.0	100	9	0
443	83.12	272.7	358	9	0
444	83.57	274.2	74	12	0
445	83.82	275.0	45	8	1
446	83.97	275.5	177	17	0
447	84.17	276.1	13	9	0
448	84.28	276.5	322	9	0
449	84.67	277.8	337	6	0
450	85.23	279.6	5	11	1
451	85.30	279.8	326	7	1
452	85.56	280.7	319	7	1
453	85.65	281.0	73	11	0
454	85.71	281.2	63	38	0
455	85.81	281.5	151	21	0
456	85.90	281.8	342	36	0
457	86.23	282.9	271	19	1
458	86.31	283.2	308	25	1
459	86.39	283.4	140	12	1
460	86.47	283.7	20	32	1
461	86.53	283.9	44	9	0
462	86.66	284.3	359	18	0
463	86.79	284.8	22	17	1
464	86.83	284.9	15	17	0
465	86.92	285.2	173	20	0
466	86.99	285.4	13	7	1
467	87.06	285.6	298	20	1
468	87.12	285.8	246	28	0
469	87.22	286.2	202	9	0
470	87.42	286.8	62	21	1
471	87.47	287.0	339	19	1
472	87.58	287.3	14	26	1
473	87.76	287.9	5	9	0
474	87.81	288.1	135	22	1
475	87.86	288.2	344	9	1
476	87.88	288.3	339	8	2
477	87.95	288.6	3	7	2
478	88.05	288.9	348	11	0
479	88.40	290.0	266	16	0
480	88.50	290.4	62	19	1
481	88.89	291.6	354	5	1
482	89.04	292.1	288	17	1
483	89.28	292.9	15	10	1
484	89.99	295.2	265	8	1

All directions are with respect to magnetic north.

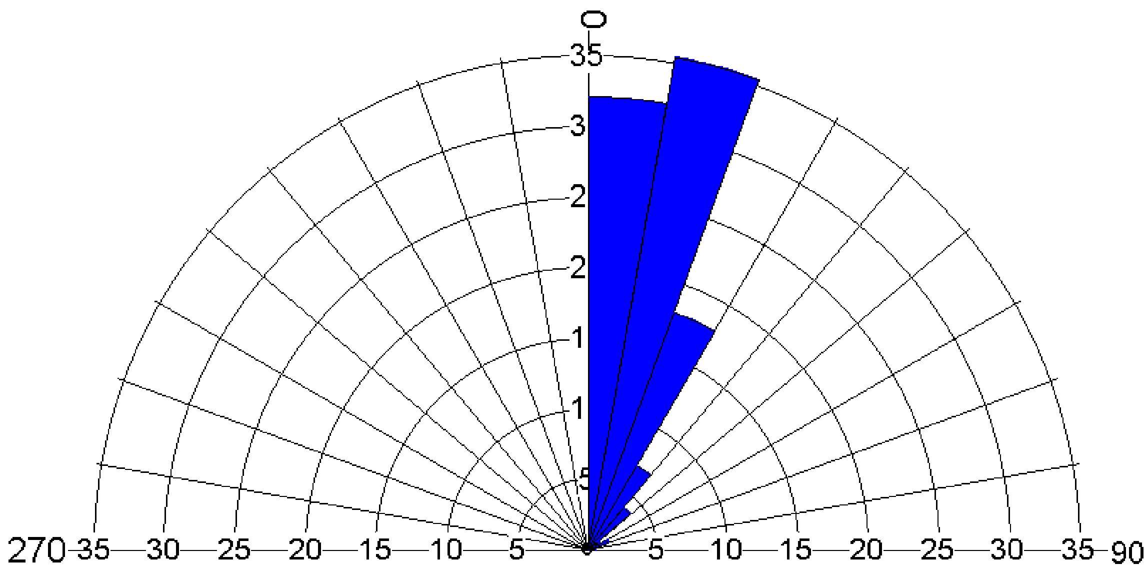
Orientation Summary Table
Optical Image Features
Camp Stanley Storage Facility, Wellbore: WB-03
Parsons
July 23, 2003

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
485	90.08	295.5	38	5	1
486	90.92	298.3	73	25	1
487	91.02	298.6	90	37	1
488	91.13	299.0	132	29	1
489	91.20	299.2	187	44	1
490	91.36	299.8	9	24	1
491	91.42	299.9	118	14	3
492	91.56	300.4	2	19	3
493	91.92	301.6	147	87	1
494	92.13	302.3	232	14	1
495	92.33	302.9	316	64	1
496	92.74	304.3	358	30	1
497	92.77	304.4	152	16	1
498	93.09	305.4	14	14	1
499	93.09	305.4	352	66	1
500	93.26	306.0	113	19	1
501	93.31	306.2	221	11	1
502	93.98	308.3	307	9	0

All directions are with respect to magnetic north.

Figure WB-03:5
Rose Diagram of Optical Televiewer Features
Parsons
Camp Stanley Storage Facility: Wellbore WB-03
July 23, 2003

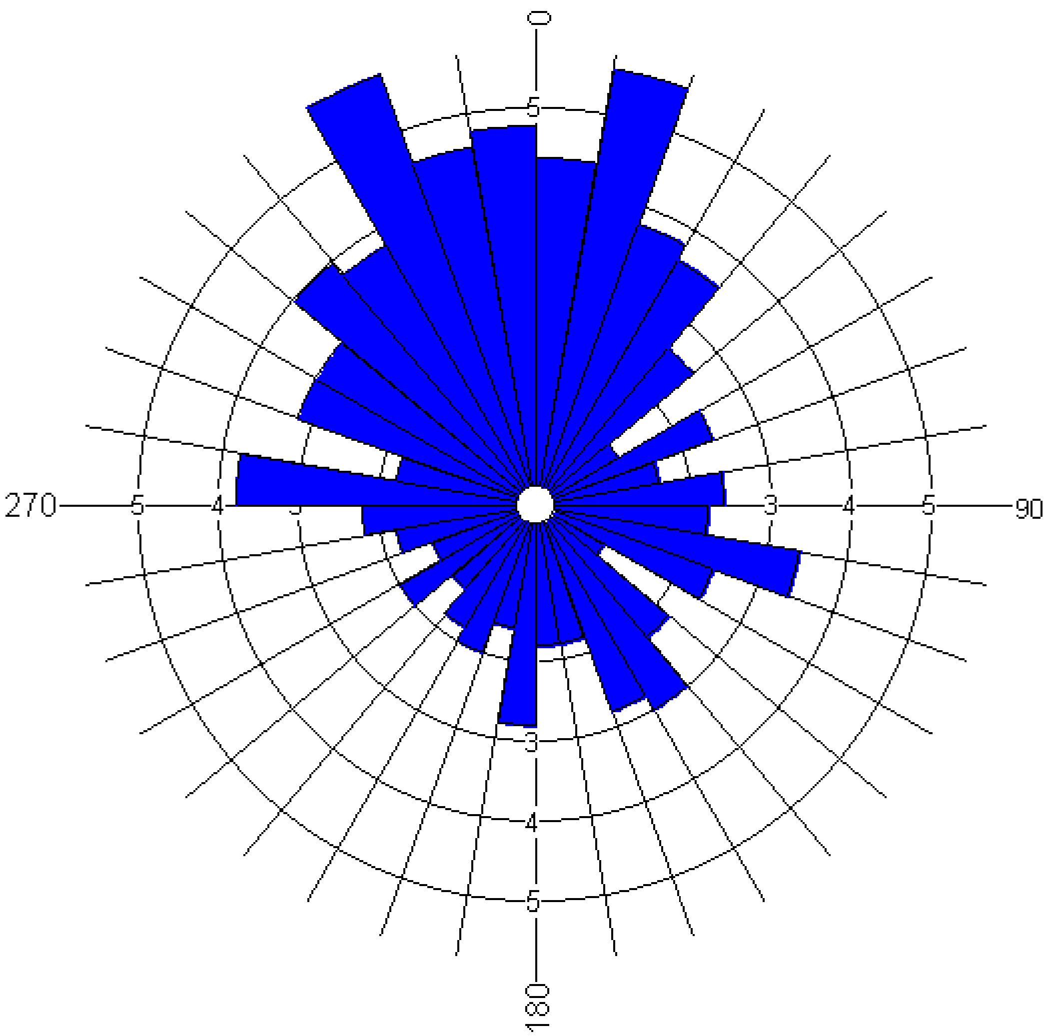
Dip Angles



Shown as *percent* of features with observed dip angle

Figure WB-03:6
Rose Diagram of Optical Televiewer Features
Parsons
Camp Stanley Storage Facility: Wellbore WB-03
July 23, 2003

Dip Direction

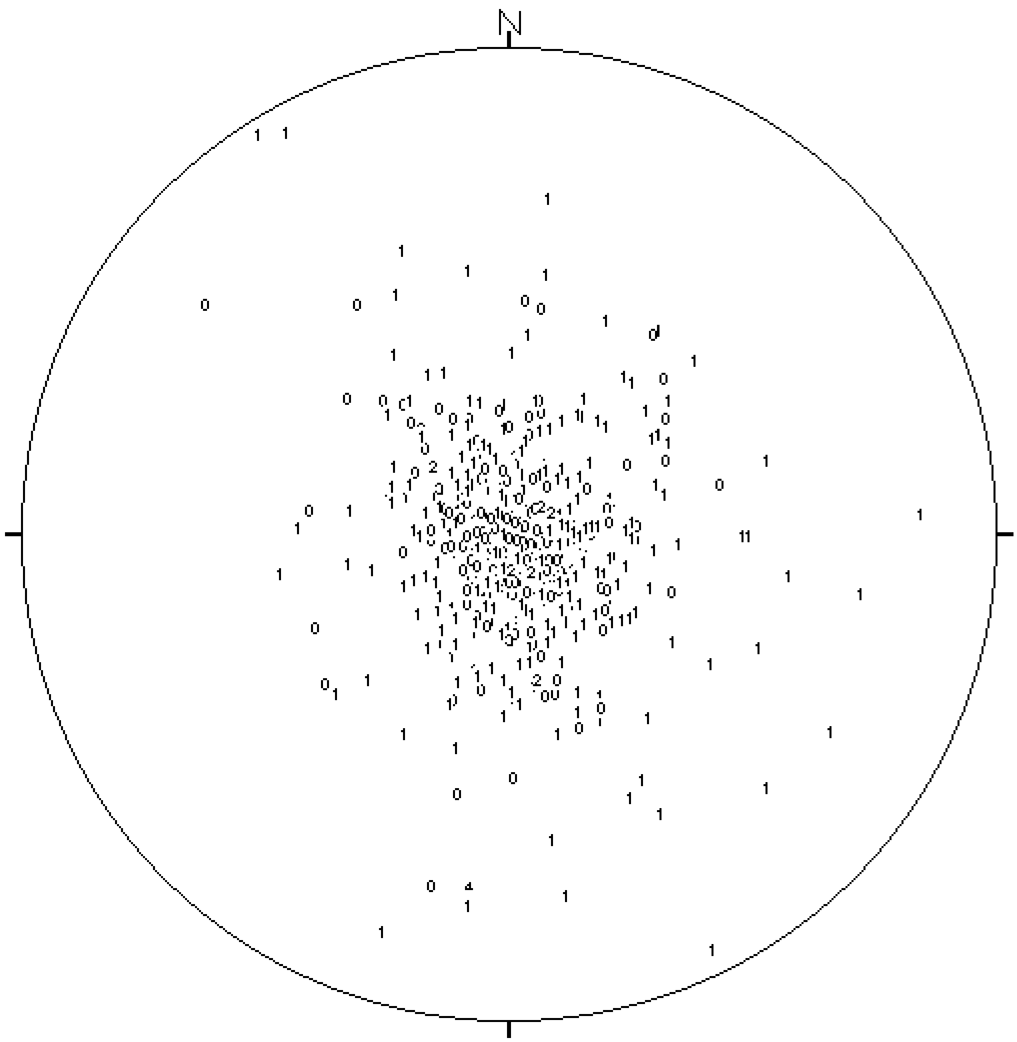


Shown as *percent* of features with observed dip direction

All directions are with respect to magnetic north.

Figure WB-03:7
Stereonet of Optical Televiewer Features
Parsons
Camp Stanley Storage Facility: Wellbore WB-03
July , 2003

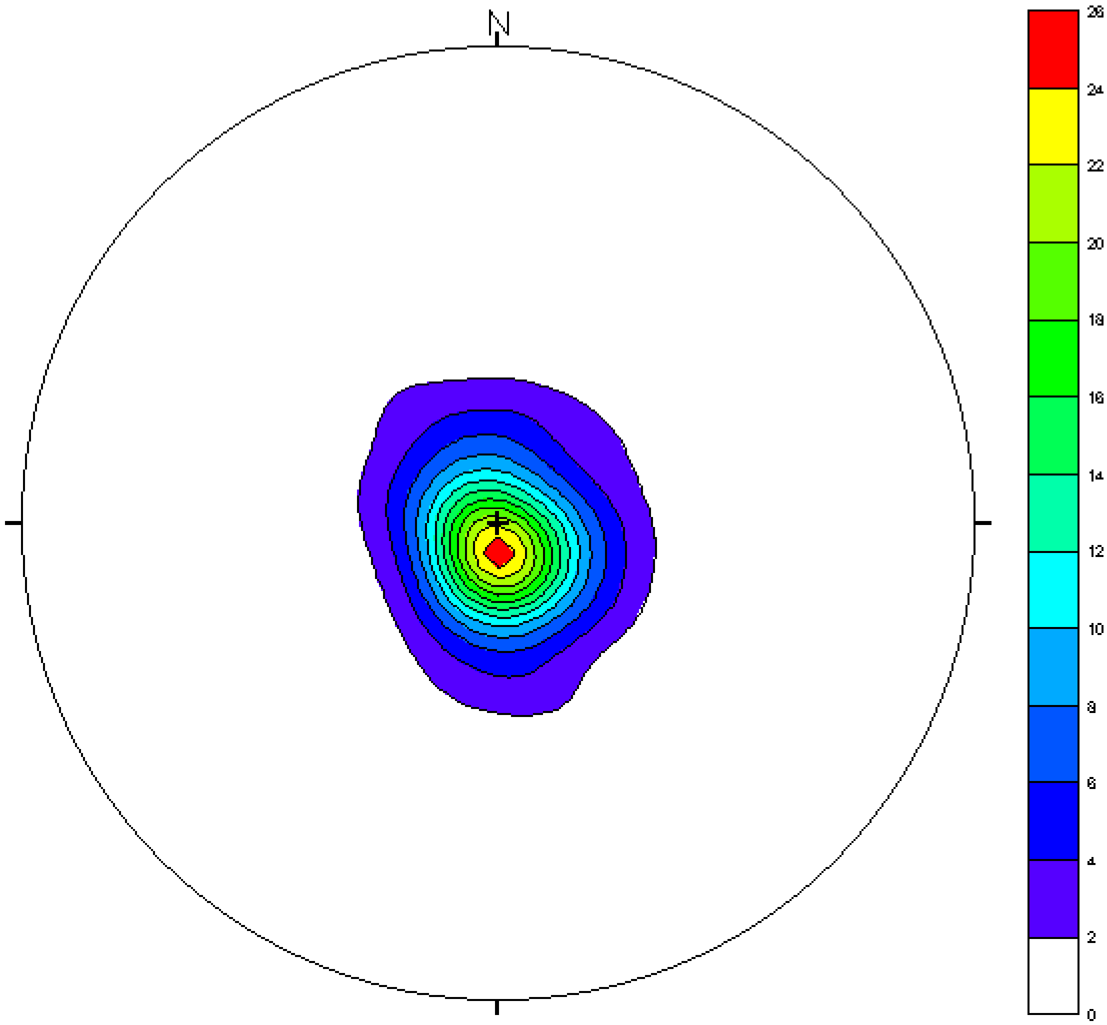
Schmidt Projection with Feature Ranks



All directions are with respect to magnetic north.

Figure WB-03:8
Stereonet of Optical Televiewer Features
Parsons
Camp Stanley Storage Facility: Wellbore WB-03
July 23, 2003

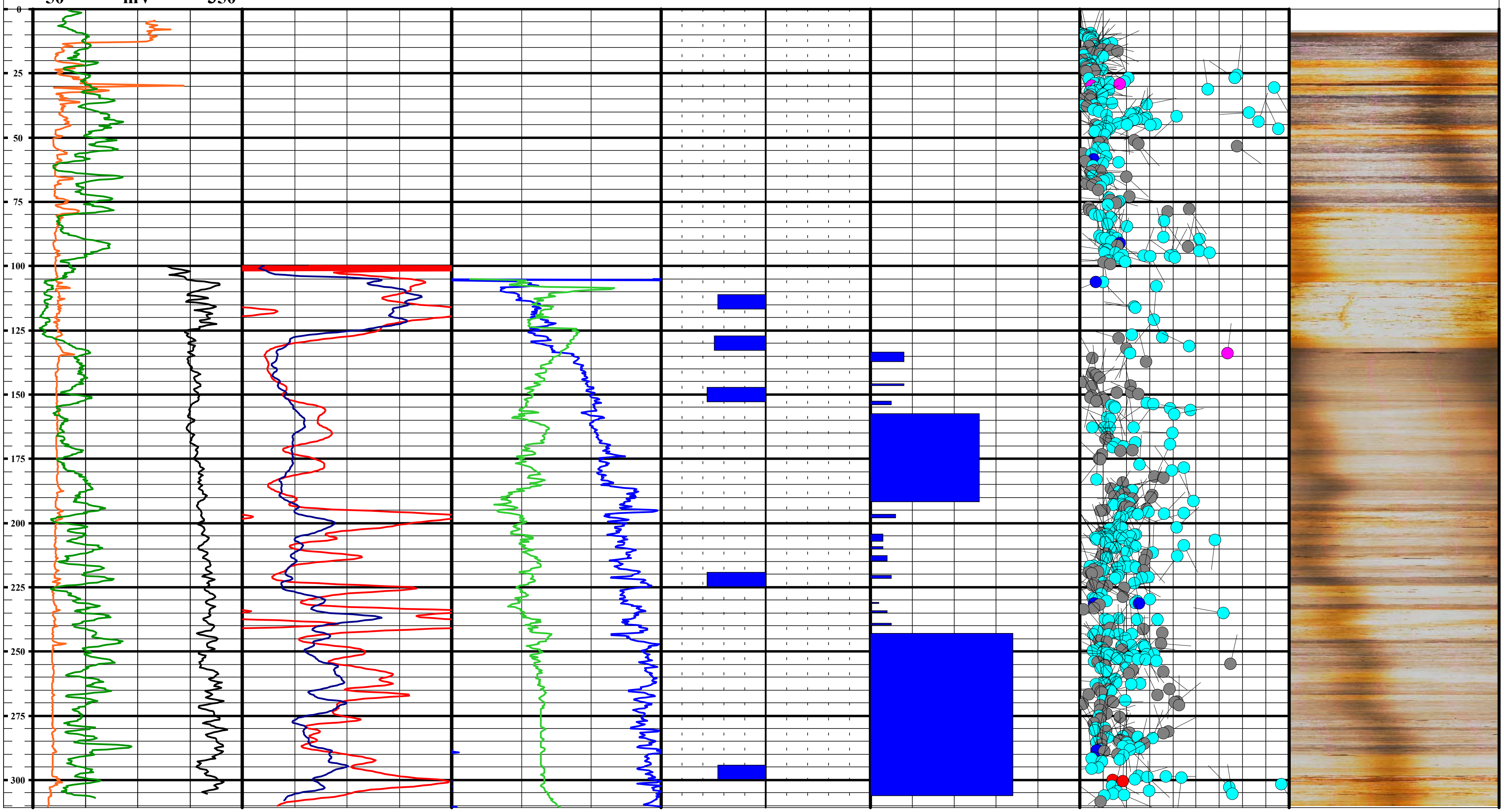
Schmidt Projection with Feature Ranks



All directions are with respect to magnetic north.

COLOG (A Division of Layne Christensen Company)	**Geophysical Summary Plot**	COLOG Main Office
	COMPANY: Parsons / PROJECT: Camp Stanley	17301 W.Colfax Ave, Ste 265, Golden, CO 80401
	DATE LOGGED: 23 July 2003 / WELL: WB-03	Phone: (303) 279-0171, Fax: (303) 278-0135
		E-mail: colog@colog.com

Depth	3-Arm Caliper (4 – 8 inches) / Natural Gamma (0 – 80 cps) / Spontaneous Potential (-50 – 350 mV)	16" Resistivity (0 – 400 ohm-m) / 64" Resistivity (0 – 400 ohm-m)	Fluid Conductivity (510 – 570) / Fluid Temperature (21.8 – 23)	Heat-Pulse Flow Meter (-1 – 1 gpm)	HpL Flow (Stressed) (0 – 0.5 gpm)	Tadpole (Degrees) (0 – 90)	Optical Image (BIPS) (0° 90° 180° 270° 0°)



WB-04 Logging Results

1.0 HydroPhysical™ Logging

1.1 Ambient Fluid Electrical Conductivity and Temperature Log: WB-04

At 1203 hours on July 18, 2003, after a calibration check of the fluid electrical conductivity (FEC) and temperature logging tool, the fluid column was logged for FEC and temperature profiles with COLOG's 1.5-inch diameter HpL™ tool. These logs were performed prior to the installation of any pumping equipment. Please refer to Figure WB-04:1. The ambient FEC/temperature profiles indicate numerous changes in fluid FEC at depths of approximately 166, 168, 179, 182, 198, 207, 236, 375, 426, 441, 466 and 482 feet suggesting a dynamic, or flowing condition in the borehole at these depths. Numerous changes in fluid temperature were also observed at depths of approximately 166, 168, 179, 182, 207, 236, 375, 426, 441, 466 and 482 feet. Many of the observed inflections in fluid FEC and/or temperature correspond well with flow intervals observed by HpL testing. In vertically flowing conditions, where water enters the borehole, termed inflow, a change in either FEC and/or temperature is typically seen.

1.2 Ambient Flow Characterization: WB-04

On July 18, 2003, an ambient flow characterization was conducted in boring WB-04. For ambient flow assessment, the fluid column in the borehole was replaced with de-ionized water (DI) and the boring left in an undisturbed state to allow any natural flow to occur. The pump was removed from the boring to insure that water in the pump standpipe would not drain back into the boring. Prior to this period and throughout all HpL™ testing, water levels and flow rates were monitored and recorded digitally every ten seconds. Ambient flow evaluation is reported for the period after the water surface returned to near pre-DI water emplacement levels. A series of FEC and temperature logs were then conducted over the duration of testing to identify changes in the fluid column associated with ambient flow. Ambient flow characterization is conducted to evaluate the presence of both vertical and horizontal flow.

On July 18, 2003, at 1402 hours (t=0 minutes, elapsed time of test), dilution of the fluid column was complete. Minimal to no DI water was lost to the formation due to the slightly depressed head maintained during DI water emplacement procedures. During the 2.7 hours following the emplacement of DI water, multiple logs were conducted. Of these logs, nine are presented in Figure WB-04:2, with the first log (FEC1356) occurring during emplacement. The designation of each logging with the FEC tool is indicated in the figure legend by the time of logging (e.g., FEC1356 versus a subsequent logging at FEC1413), thus the progressing of curves to the right in this figure represents changes in FEC over the total logging period. The last four digits of each log ID corresponds to the time at which that particular log was started. Only logs acquired during logging in the downward direction are presented as the design of the FEC/temperature probe allows for the most accurate data to be collected in the downward direction. The logs acquired in the upward logging direction are not representative of downhole conditions and are therefore omitted. These logs illustrate changes in FEC at several intervals throughout the length of the borehole. These changes in the FEC profiles with respect to time are associated with ambient vertical flow occurring within these intervals.

Formation water migration caused by downward vertical flow within the fluid column is indicated by the increase in FEC over time in Figure WB-04:2. Ambient inflow enters the wellbore at 177.6 to 179.5, 208.2 to 210.8, 227.9 to 229.0, 253.6 to 254.3, 309.2 to 310.7, 332.2 to 335.3, 360.0 to 362.6, 370.5 to 371.8 and 375.6 to 376.7 feet, and the combined flow of these nine intervals migrates down the borehole. Numeric modeling of the reported field data for these intervals suggest inflow is occurring at rates of 0.024, 0.030, 0.009, 0.039, 0.074, 0.238, 0.005, 0.018 and 0.159 gpm, respectively. The aggregate ambient downflow migrates down the borehole at a rate of 0.597 gpm. At a depth of 464.2 to 466.9 feet groundwater is observed to exit the wellbore. Numeric modeling of the reported field data for this interval suggests flow is exiting the wellbore at a rate of 0.597 gpm. All flow rates are based on the rate of increase of mass at their respective intervals. Please refer to Table WB-04:1 and SUMMARY:1 for a complete summary of the HydroPhysical™ logging results. Please refer to Appendix B for a discussion of the methodology and code used to calculate these values. During ambient testing in wellbore WB-04, a residential water pump would periodically turn on and off. This pump is believed to have been drawing groundwater from the same aquifers that the Ambient Flow Characterization test was being conducted on. This pump may have created an artificial pressure differential in wellbore WB-04. The ambient depth to water at the time of testing was 161.43 ftbgs.

1.3 Flow Characterization During 6 GPM Production Test: WB-04

Pumping of borehole fluids and simultaneous DI injection was conducted at one pumping rate to establish the inflow locations and evaluate the interval-specific inflow rates during production testing. Development pumping at a given rate was conducted until reasonably constant drawdown and repeatable FEC logs downhole were observed. When these conditions were observed, DI injection was initiated at approximately 20% of the pumping rate while the extraction pumping rate was increased the same amount to maintain a constant total formation production rate (i.e. pumping rate prior to DI water injection). These procedures were conducted at a differential rate of 5.88 gpm.

On July 19, 2003 at 1154 hours (t = 0 minutes elapsed time of testing), development pumping was initiated at approximately 6 gpm. Prior to initiating pumping, the ambient depth to water was recorded at 159.20 ftbgs. All drawdown values are referenced to this ambient water level. Time dependent depth to water, totals and flow rate information were recorded digitally every ten seconds and are presented in Figure WB-04:3. At 1209 hours a generator on the truck quit, causing pumping to cease and a gap in the data until 1224 hours where the generator was back on line. Pumping was maintained at a time-averaged rate of 6.08 gpm until 1659 hours (t = 305 minutes, elapsed time of testing). During development pumping numerous FEC logs were acquired to monitor the development process and assist in identifying the depths of flow zones. Of these FEC logs, three (FEC1618, FEC1636 and FEC1651) are presented in Figure WB-04:4. The FEC logs acquired during development pumping illustrate a reasonably stable condition of the fluid column with local inflow locations identified by spikes or incremental step increases or decreases in FEC. DI water injection from the bottom of the wellbore was initiated at 1659 hours at a time-averaged rate of 1.31 gpm while the total extraction rate was increased to a time-averaged rate of 7.19 gpm, resulting in a total borehole formation time-averaged production rate of 5.88 gpm. These flow conditions were maintained until 1919 hours (t = 445 minutes) during which time a relatively constant drawdown of approximately 12.20 feet was observed. The FEC logs acquired during dilution procedures illustrate a reasonably stable condition of the fluid column with local inflow locations identified by spikes or incremental step increases in FEC. Twelve inflow intervals were identified from these logs with flow rates ranging from 0.012 to

2.73 gpm. The logs indicate the interval 332.2 to 335.3 feet dominated flow during pumping, producing 2.73 gpm or 46 percent of the total flow. The extraction pump location (approximately 190 ftbgs) and pump diameter did not allow for testing of the single uppermost flow interval identified during ambient testing. This is because the combined diameter of the submersible pump and HpL logging tool is greater than the diameter of the wellbore. Additionally, to assume that the 0.032 gpm of flow that is unaccounted for when the inflow from the 12 tested intervals is summed may originate from the interval at 177.6 to 179.5 feet may be incorrect. This 0.032 gpm of flow may be inflowing from this interval, and others that did not yield any flow during ambient conditions. Please refer to Tables WB-04:1 and ARNOLD:1 for a summary of HydroPhysical™ flow results and the depths of individual inflow zones.

1.4 Estimation of Interval Specific Transmissivity: WB-04

An estimation of transmissivity (T) can be made using an equation after Hvorslev (1951) assuming steady-state radial flow in an unconfined aquifer:

$$T = KL = \frac{q_i}{2\pi\Delta h_w} \ln\left(\frac{r_e}{r_w}\right)$$

where K is the hydraulic conductivity, q_i is the interval specific inflow rate calculated by HpL™ results, r_w is the borehole radius (0.17 ft), r_e is the effective pumping radius , Δh_w is the observed maximum drawdown (12.20 feet) and L is the thickness of the zone through which flow occurs. For our calculations, COLOG used r_e of 100 feet (assumed). By applying L and q_i from the HpL™ results under the two pressure conditions, the interval specific hydraulic conductivity can be calculated for each identified water producing interval. These calculations were made at each identified interval and are presented in Table WB-04:1. In summary, the interval at 332.2 to 335.3 feet registered the highest transmissivity at 40.0 feet^2/day.

2.0 Geophysical Logging

On July 18 and 19, 2003, downhole geophysical investigations were performed in boring WB-04. The geophysical logs performed were: optical televiewer (BIPS) and heat pulse flowmeter. The data for these logs is presented in the WB-04 Geophysical Summary Plot. A contractor other than COLOG conducted additional geophysical logging in wellbore WB-04. This data is presented in the WB-04 Geophysical Summary Plot.

3.0 Data Summary

Processing and interpretation of the geophysical and HydroPhysical™ logs in WB-04 suggest the presence of 12 identified producing intervals for this borehole. Numerical modeling of the reported HydroPhysical™ field data was performed using computer programs FLOWCALC and/or BOREII. These analyses were performed to estimate the rate of inflow for each identified hydraulically conductive borehole interval during DI injection procedures. The results of these analyses are presented in Table WB-04:1. The identified producing intervals correlate well with water-bearing zones identified during ambient testing. In summary, the interval at 332.2 to 335.3

feet dominated inflow during the production test, producing a total of 2.73 gpm or 46 percent, of the total flow during the production test.

During ambient testing, boring WB-04 exhibited downward vertical flow. Ten water-bearing zones were identified under ambient conditions. A downward vertical pressure gradient was observed in the wellbore under ambient conditions.

Additionally, the wellbore was logged under ambient conditions with the heat pulse flowmeter on July 19, 2003. The heat pulse flow meter logging took place on the day following the HpL Ambient Flow Characterization Test. The ambient water level in wellbore WB-04 was approximately two feet higher on the 19th than on the 18th. This difference in water level may be due to a residential water pump that was approximately 100 feet from wellbore WB-04. On July 18th the pump was noted to be turning on periodically, and on the morning of July 19th, the pump was off. Therefore different downhole conditions most likely existed in wellbore WB-04 on these two days. The data acquired by the heat pulse flowmeter suggests the presence of a downward vertical gradient present in the wellbore at the time of testing. Ambient flow is observed to enter the wellbore above 195 feet at approximately 0.02 gpm and migrate downward. At 221 feet ambient downflow of 0.04 gpm was observed. At 247 feet ambient downflow of 0.08 gpm was observed. At 270 feet ambient downflow of 0.07 gpm was observed. At 325 feet 0.09 gpm of ambient downflow was observed. At 352 feet ambient downflow of 0.07 gpm was observed. At 450 feet 0.06 gpm of ambient downflow was observed. At 490 feet no ambient flow was observed.

The optical televiewer identified features at depths correlating well with the HpL™ data. The features observed by the optical televiewer at water-bearing intervals identified from the HpL™ data had apparent aperture. Fifty-two high-angle features (features of dip angle greater than 45 degrees) were identified from the optical televiewer data. Six of the features are qualitatively ranked greater than one, suggesting these features have flow potential. Two if these high-angle features correspond well with identified flow intervals at 177.7 to 179.5 and 227.9 to 229.0 feet.

The twelve interval-specific estimated transmissivities in WB-04 ranged from 0.019 to 40.0 square feet per day with the interval of 332.2 to 335.3 feet registering the highest transmissivity. With the exception of the interval from 208.2 to 210.8 feet the interval-specific transmissivity estimates do not differ significantly with respect to each other, and this exception is most likely due to the size and low flow of this interval.

Fracture inter-connectiveness in the immediate vicinity of a wellbore can be inferred by the similarity, or lack there of, of parameters such as interval-specific transmissivity estimates and interval-specific FEC, along with the presence of high-angle fractures and pressure differentials within the borehole. Similar transmissivity and FEC estimates would suggest an inter-connected network of fractures or aquifers in the immediate vicinity of the wellbore. A pressure differential present in the wellbore would suggest the driving force for vertical communication is present and high-angle fractures with aperture may provide the conduit for vertical communication.

The data acquired in WB-04 exhibited similar interval-specific transmissivity and similar FEC estimates. A downward vertical gradient is observed in the wellbore. Major high angle features were identified in the wellbore to provide a conduit for vertical communication. The data suggest the fractures intersecting the wellbore may be interconnected in the immediate vicinity of the wellbore. Please see Tables WB-04:1 and SUMMARY:1 for a summary that includes the locations, flow rates and hydraulic conductivity estimates assessed by COLOG.

FIGURE WB-04:1. AMBIENT TEMPERATURE AND FLUID ELECTRICAL CONDUCTIVITY; PARSONS; CAMP STANLEY STORAGE FACILITY; SAN ANTONIO, TX; WELLBORE WB-04.

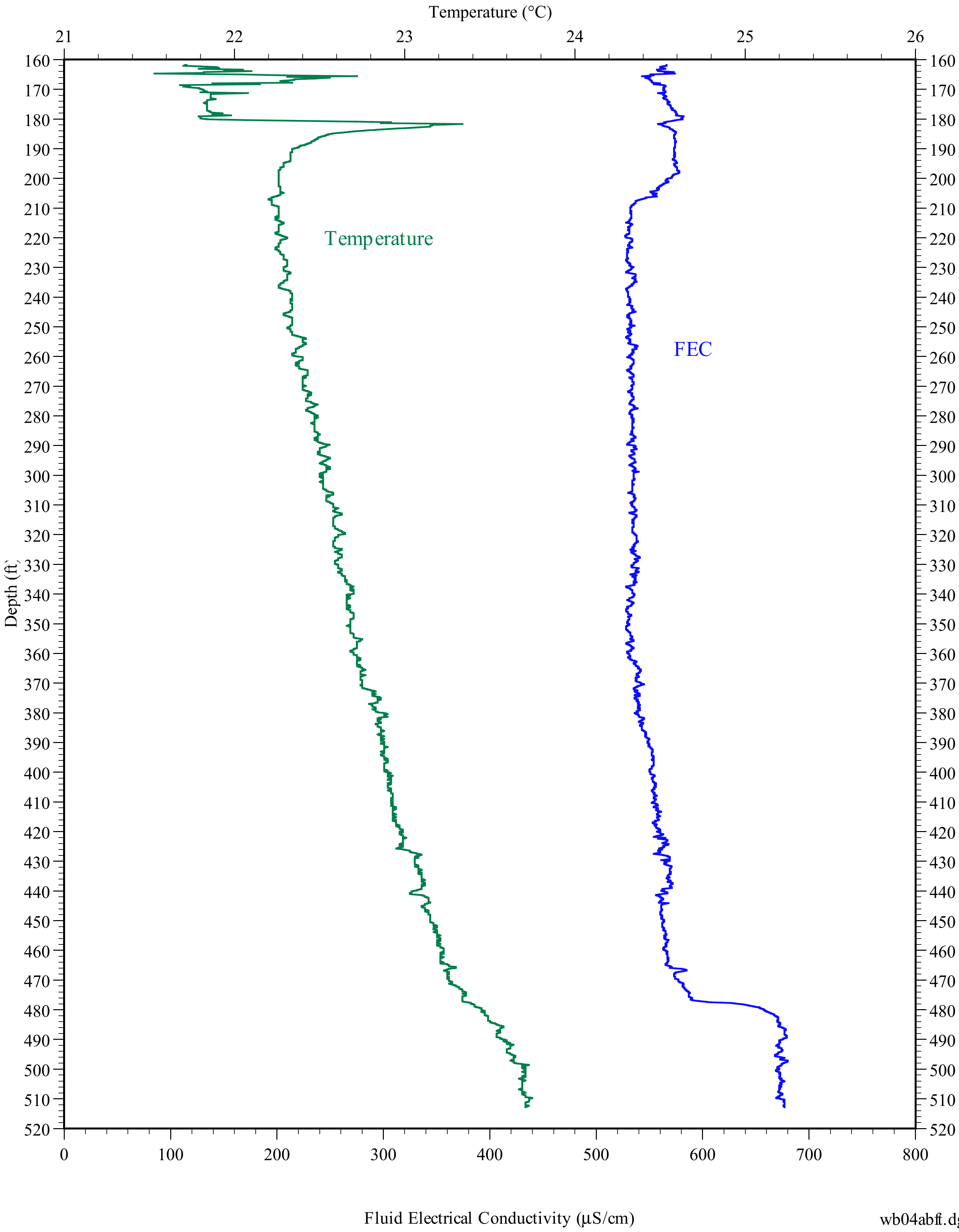


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FIGURE WB-04:2 SUMMARY OF HYDROPHYSICAL LOGS DURING AMBIENT FLOW CHARACTERIZATION; PARSONS; CAMP STANLEY STORAGE FACILITY; SAN ANTONIO, TX; WELLBORE: WB-04.

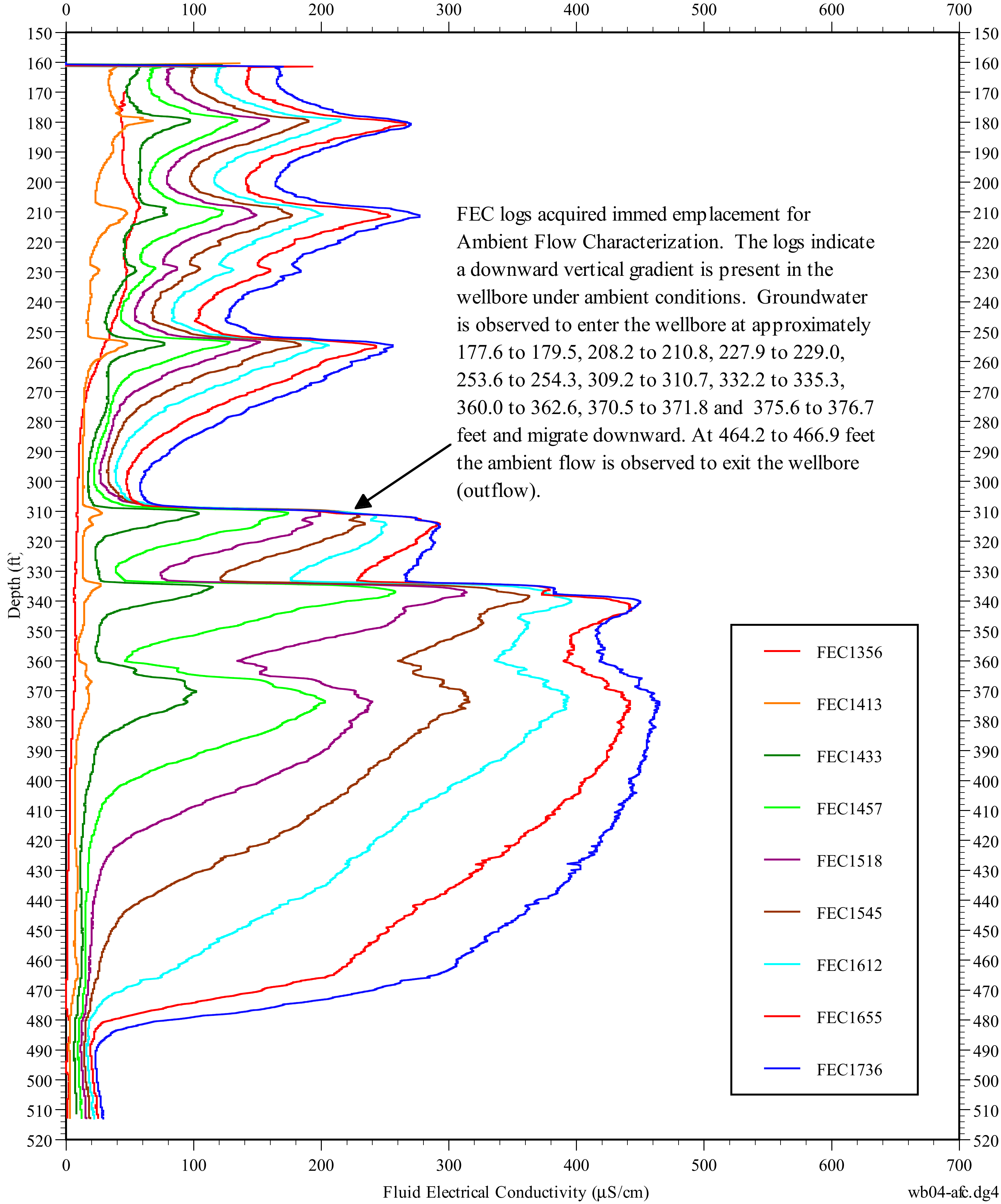

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FIGURE WB-04:3. PUMPING AND DRAWDOWN DATA DURING 6 GPM PRODUCTION TEST; PARSONS; CAMP STANLEY STORAGE FACILITY; SAN ANTONIO, TX; BOREHOLE: WB-04.

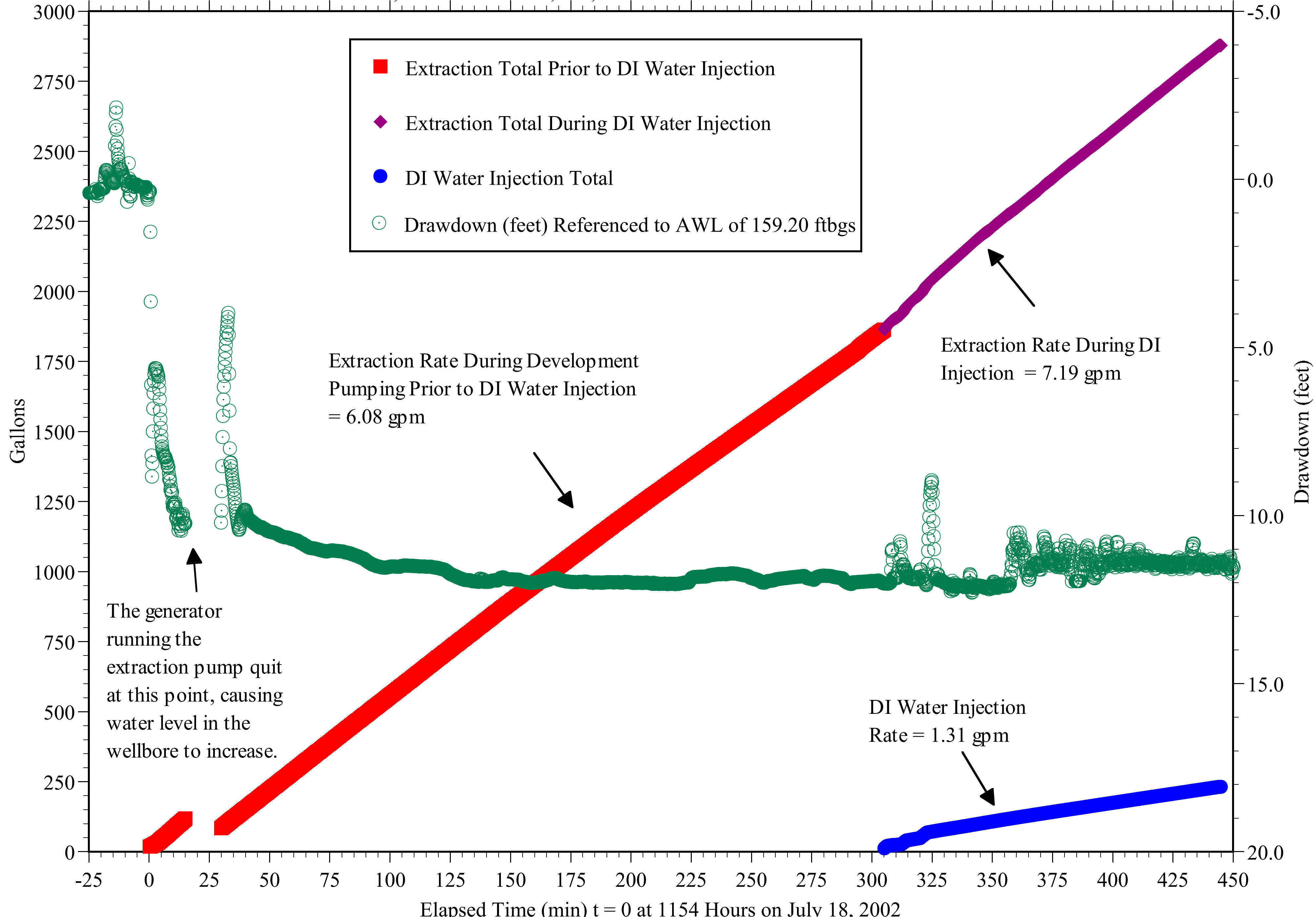

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FIGURE WB-04:4. SUMMARY OF HYDROPHYSICAL LOGS DURING 6 GPM PRODUCTION TEST; PARSONS; CAMP STANLEY STORAGE FACILITY; SAN ANTONIO, TX; WELL: WB-04.

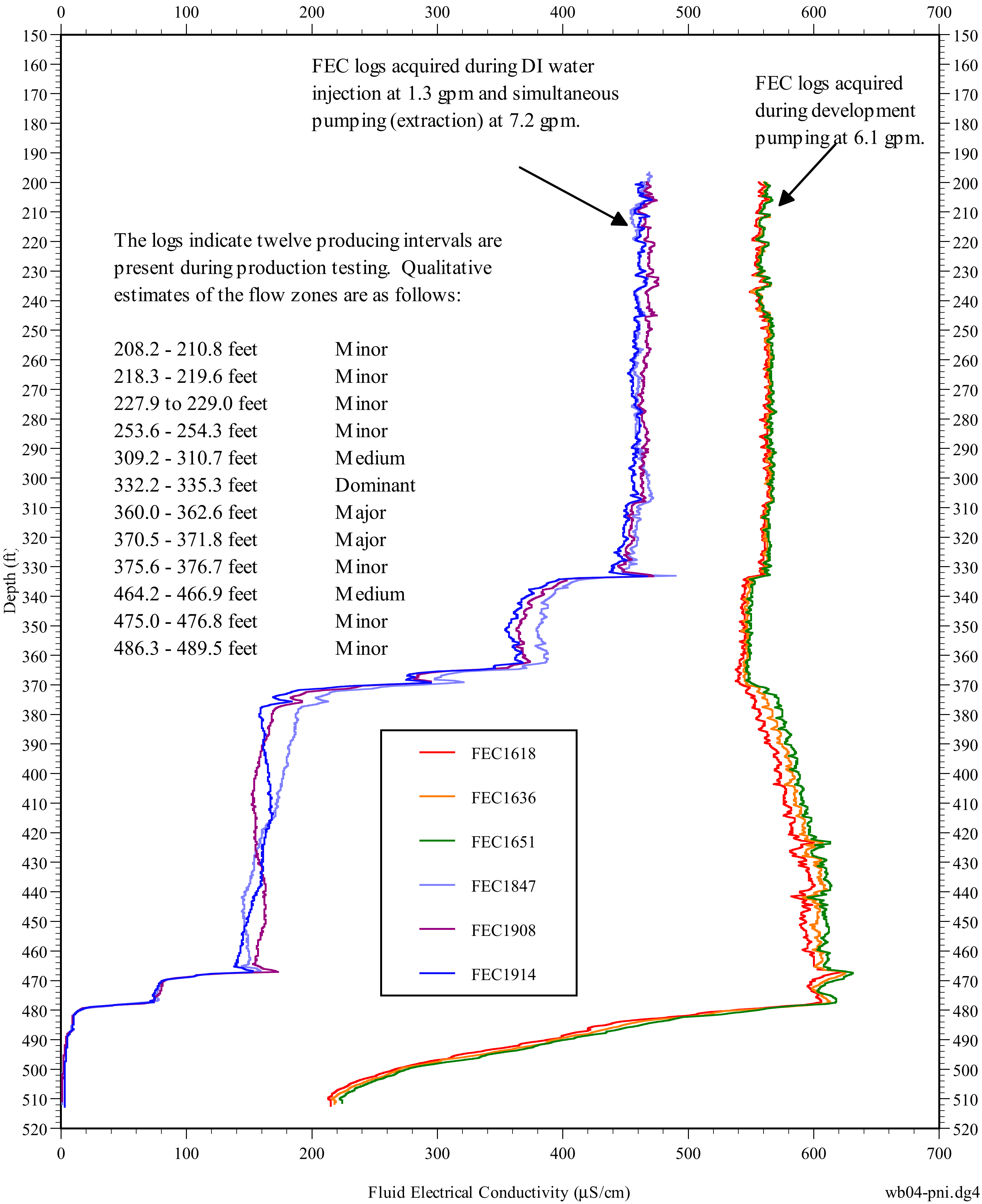

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TABLE WB-04:1. SUMMARY OF HYDROPHYSICAL™ LOGGING RESULTS WITH HYDRAULIC CONDUCTIVITY AND TRANSMISSIVITY ESTIMATIONS; PARSONS; CAMP STANLEY STORAGE FACILITY; WELL: WB-04.

Well name	WB-04
Ambient Depth to water (ft)	159.20
Diameter of Borehole (ft)	0.33
Maximum Drawdown (ft)	12.20
Effective Radius (ft)	100

Interval No.	Top of Interval (ft)	Bottom of Interval (ft)	Length of Interval (ft)	Ambient Flow[1] (gpm)	Darcy Velocity in Aquifer[2] (Specific Discharge) (ft/day)	Interval Specific Flow Rate (gpm)	Delta Flow[3] (gpm)	Delta Flow (ft^3/min.)	Interval Specific Hydraulic Conductivity[4] (ft/day)	Transmissivity (ft2/day)	Interval Specific Fluid Electrical Conductivity (microS/cm)
1	177.6	179.5	1.9	0.024	NA	NA	NA	NA	NA	NA	580
2	208.2	210.8	2.6	0.030	NA	0.033	0.003	0.00040	1.86E-02	4.83E-02	567
3	218.3	219.6	1.3	0.000	NA	0.068	0.068	0.00909	8.42E-01	1.09E+00	565
4	227.9	229.0	1.1	0.009	NA	0.198	0.189	0.02527	2.77E+00	3.04E+00	565
5	253.6	254.3	0.7	0.039	NA	0.175	0.166	0.02219	3.82E+00	2.67E+00	534
6	309.2	310.7	1.5	0.074	NA	0.313	0.239	0.03195	2.57E+00	3.85E+00	598
7	332.2	335.3	3.1	0.238	NA	2.73	2.487	0.33249	1.29E+01	4.00E+01	576
8	360.0	362.6	2.6	0.005	NA	1.00	0.995	0.13302	6.16E+00	1.60E+01	554
9	370.5	371.8	1.3	0.018	NA	0.721	0.703	0.09398	8.71E+00	1.13E+01	533
10	375.6	376.7	1.1	0.159	NA	0.165	0.006	0.00080	8.78E-02	9.66E-02	436
11	464.2	466.9	2.7	-0.597	NA	0.264	0.861	0.11511	5.13E+00	1.39E+01	614
12	475.0	476.8	1.8	0.000	NA	0.168	0.168	0.02246	1.50E+00	2.70E+00	612
13	486.3	489.5	3.2	0.000	NA	0.012	0.012	0.00160	6.04E-02	1.93E-01	464

[1] All ambient flow identified for this wellbore is downward vertical flow.

[2] Darcy Velocity is calculated using the observed volumetric flow rate, the cross-sectional area of the flow interval in the wellbore and a wellbore convergence factor of 2.5 (Drost, 1968). The Darcy Velocity is only applicable to ambient horizontal flow.

[3] Delta Flow is the difference between Interval-Specific Flow Rate (during pumping) and Ambient Flow Rate.

[4] Hydraulic conductivity and transmissivity estimates are based on single well drawdown data, a porus-medium equivilent model and Hvorslev's 1951 porosity equation.

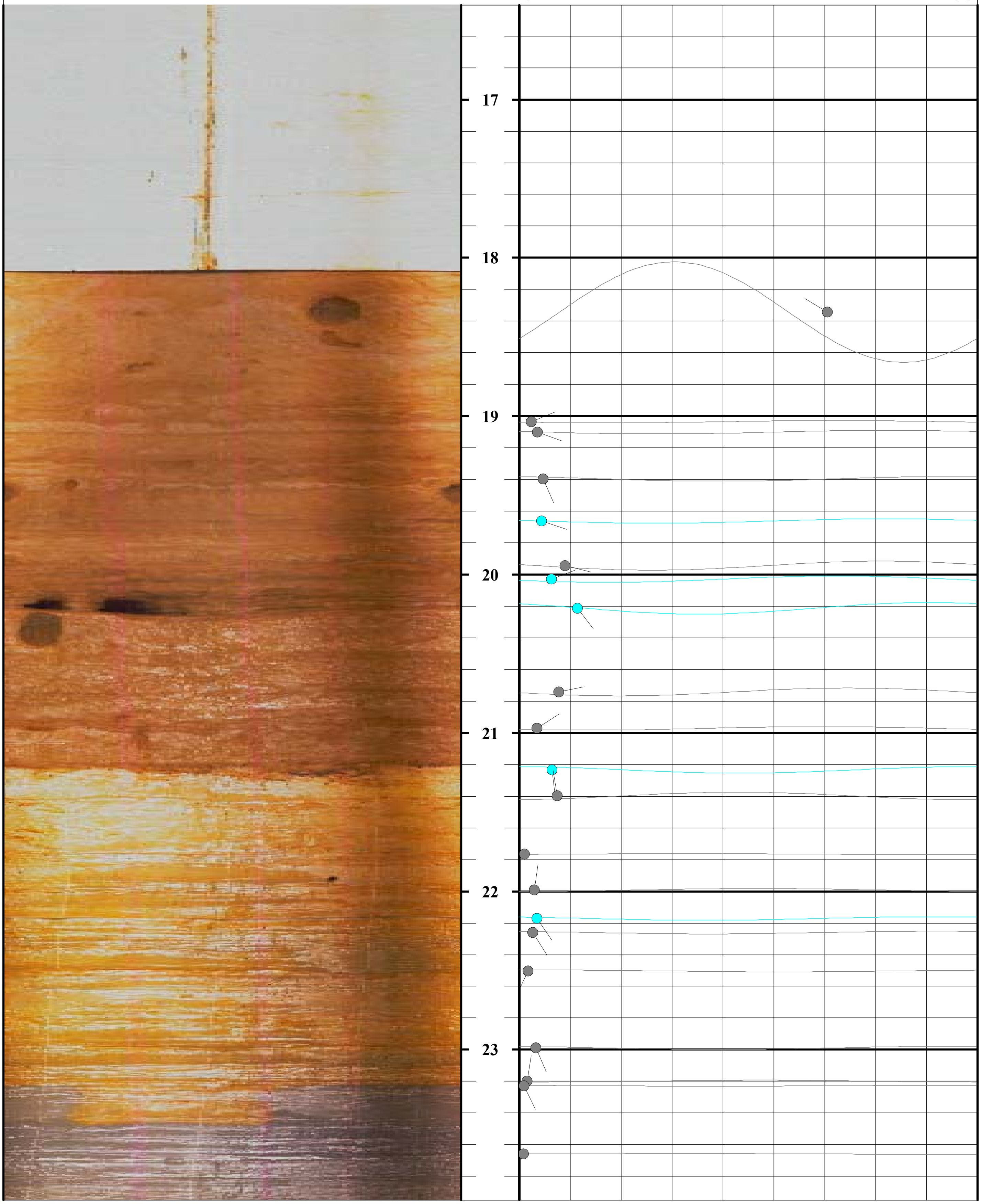
COLOG (BOREHOLE GEOPHYSICS & HYDROPHYSICS, A DIVISION OF LAYNE CHRISTENSEN COMPANY)	**Optical Borehole Image Plot**	**COLOG Main Office**
	COMPANY: Parsons — PROJECT: Camp Stanley	17301 W.Colfax Ave, Ste 265, Golden, CO 80401
	DATE LOGGED: 18 July 2003 — WELL: WB-04	Phone: (303) 279-0171, Fax: (303) 278-0135
		www.colog.com

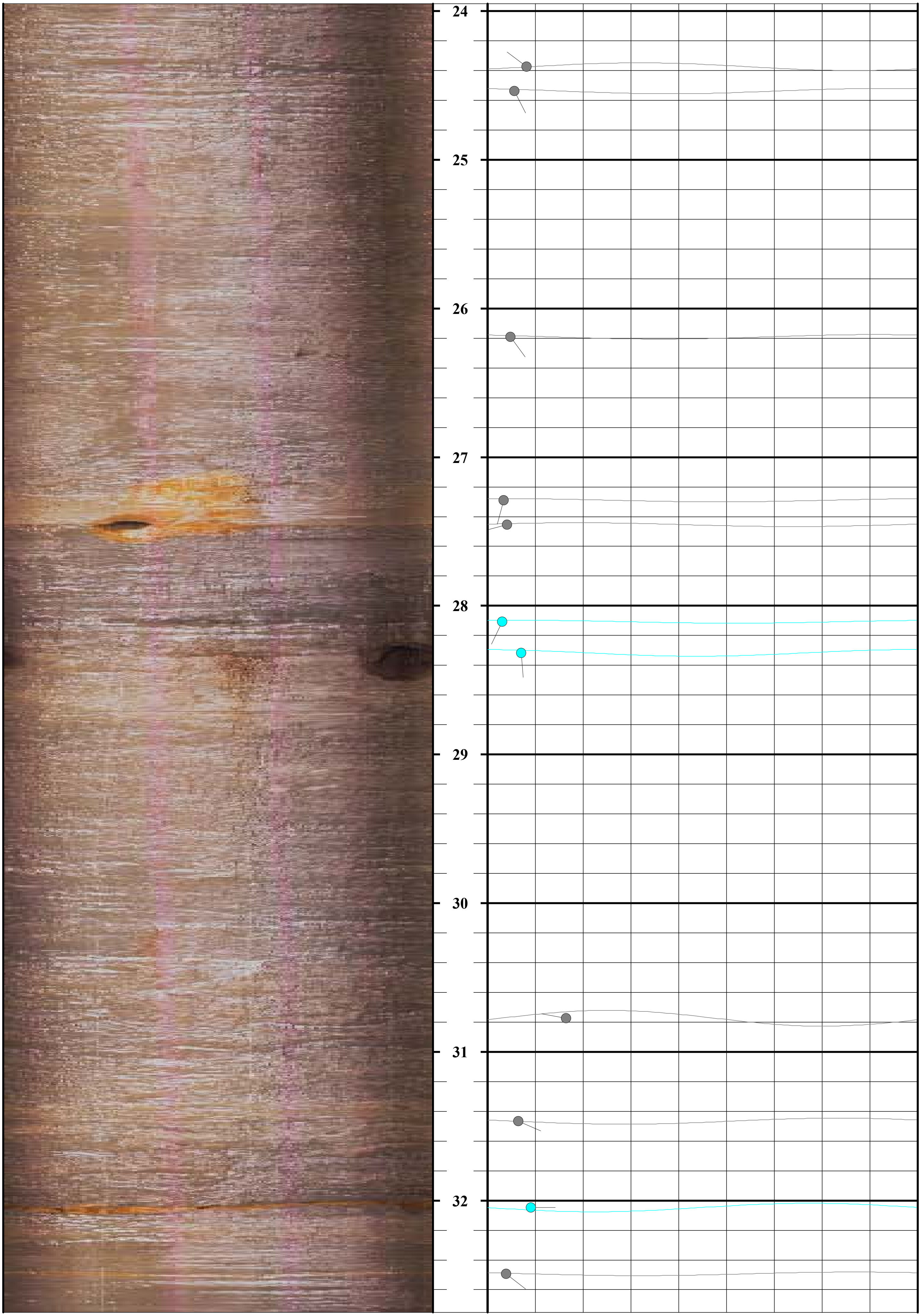
Optical Televiewer (BIPS) — **Depth** — **Projection**

0° 90° 180° 270° 0° | 0° 90° 180° 270° 0°

Tadpole (Degrees)

0 90

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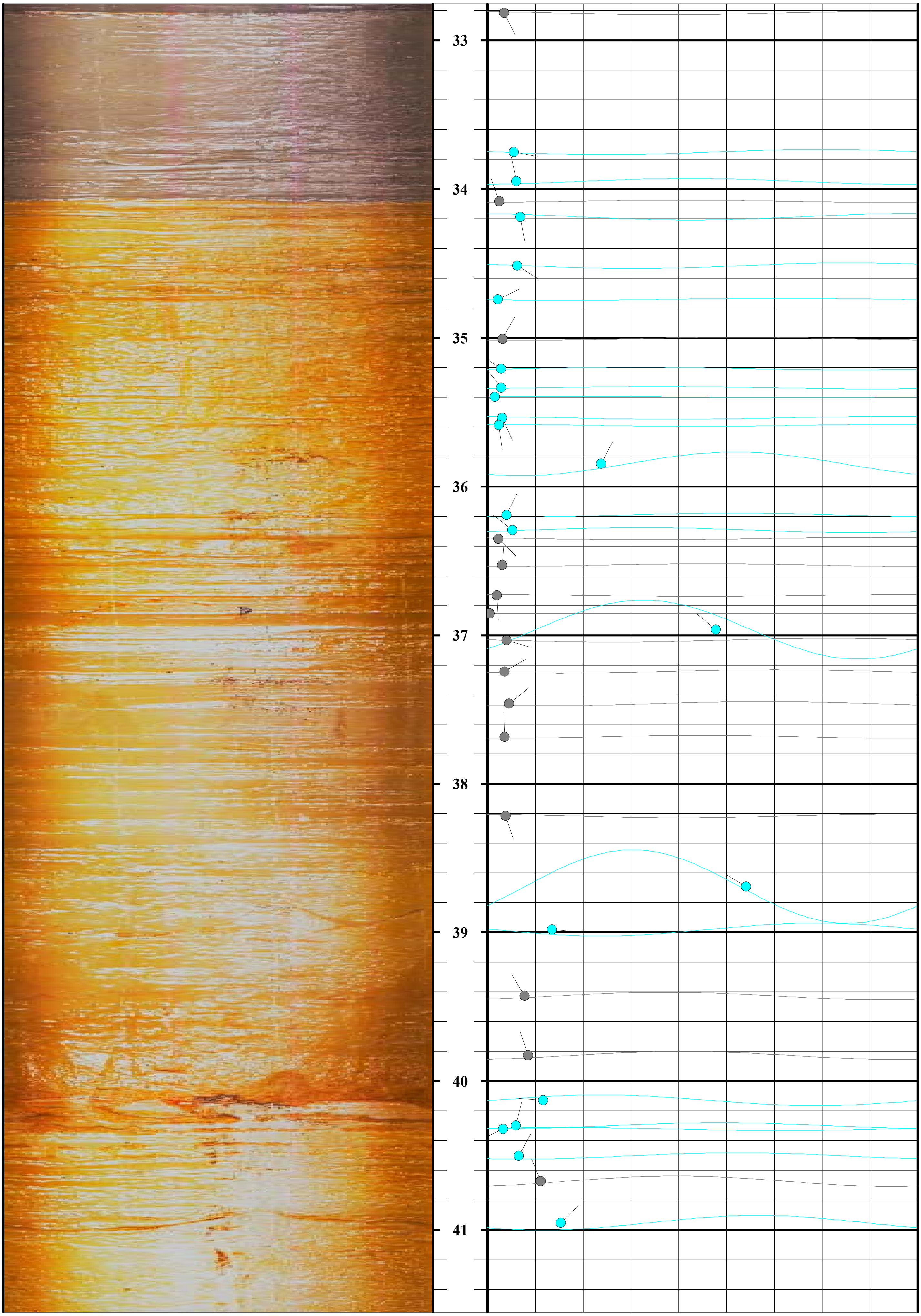
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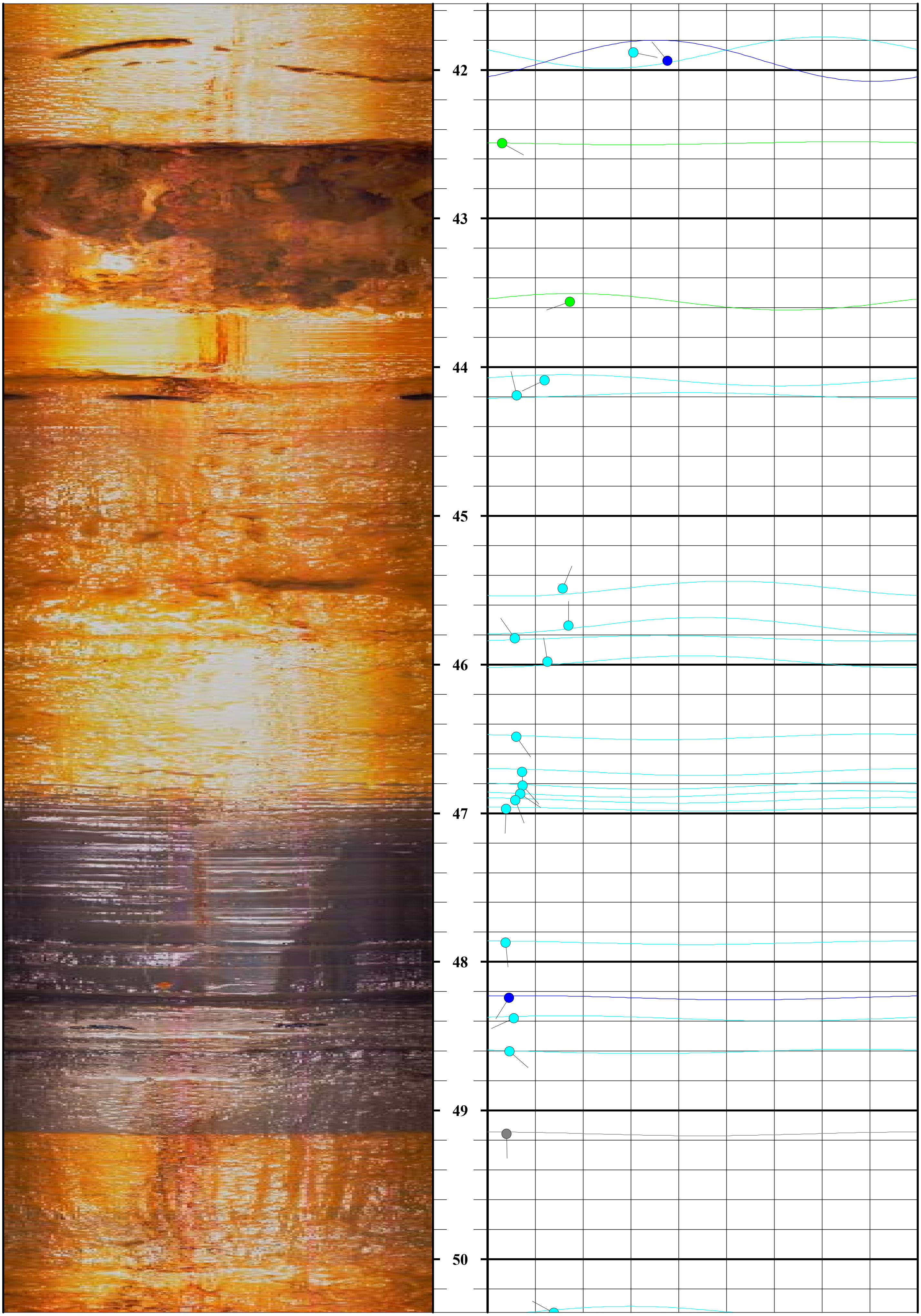

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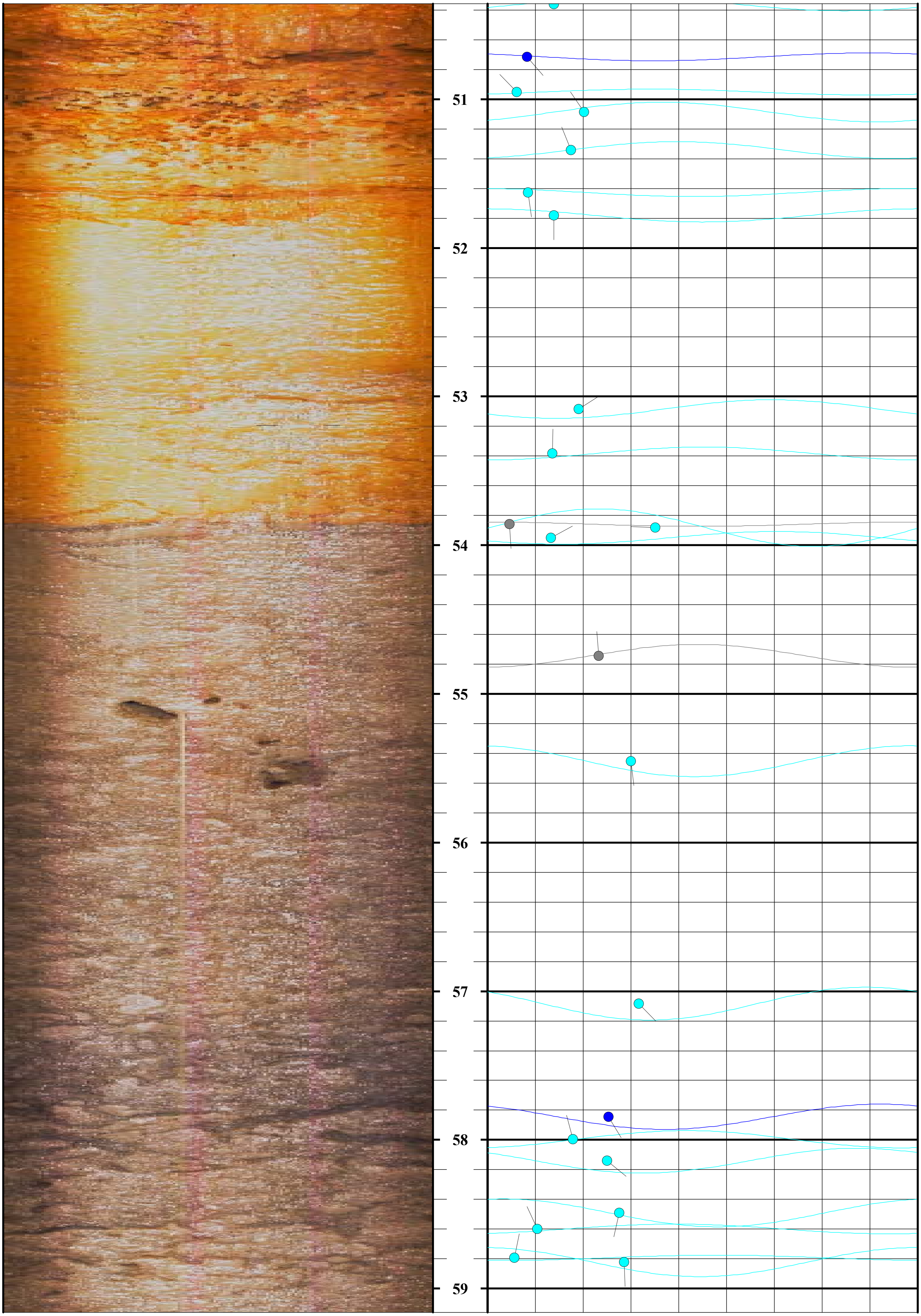
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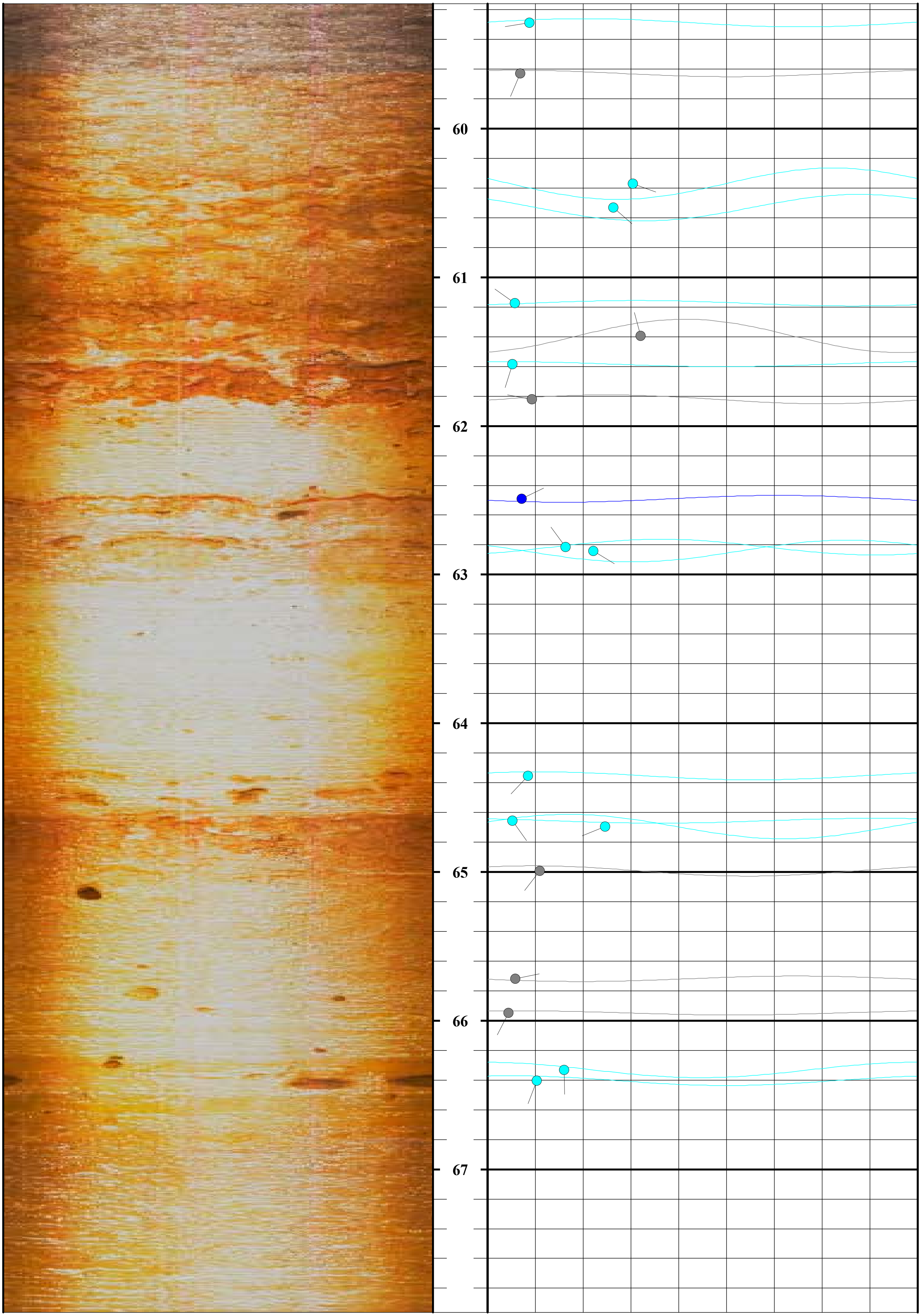

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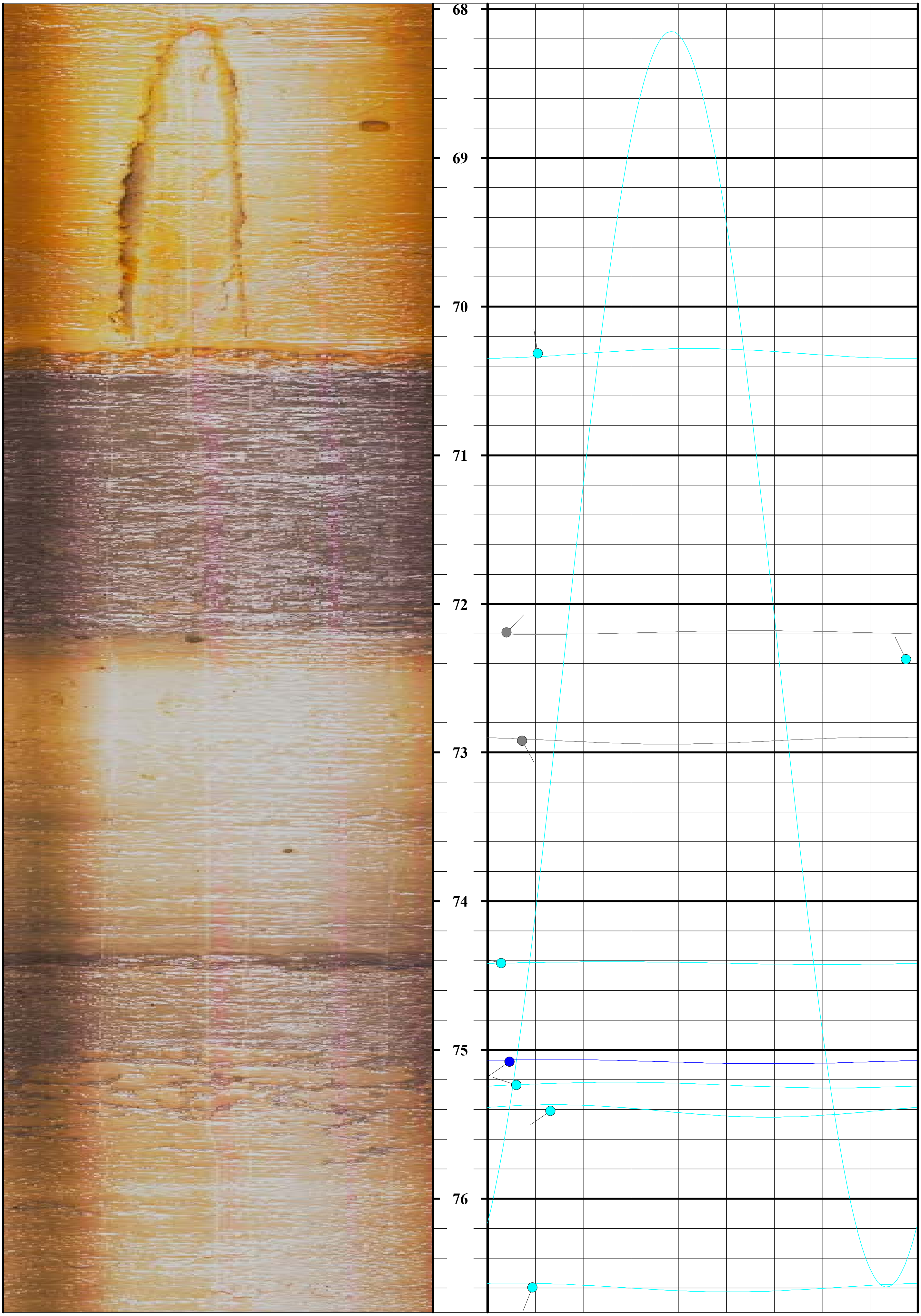
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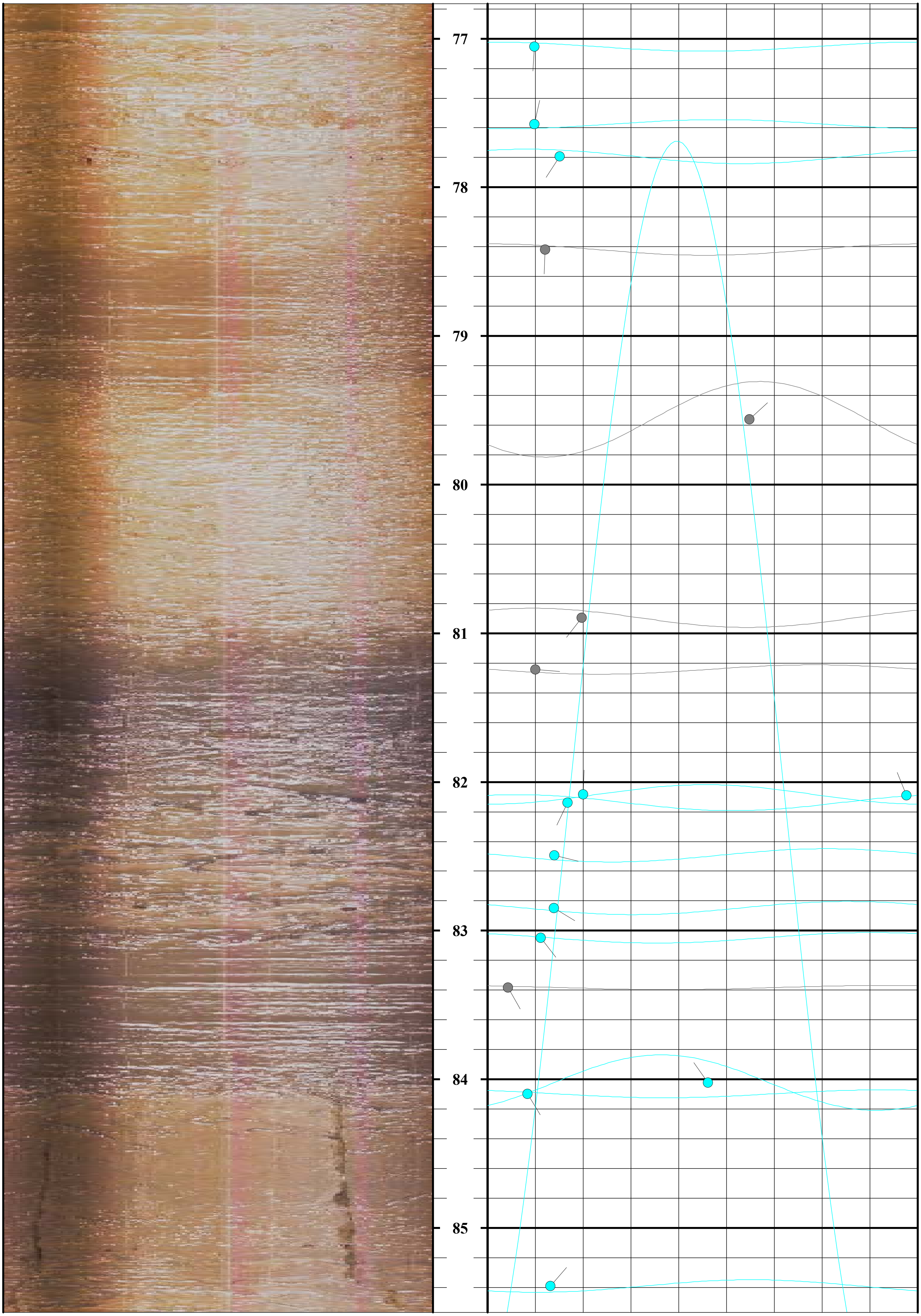

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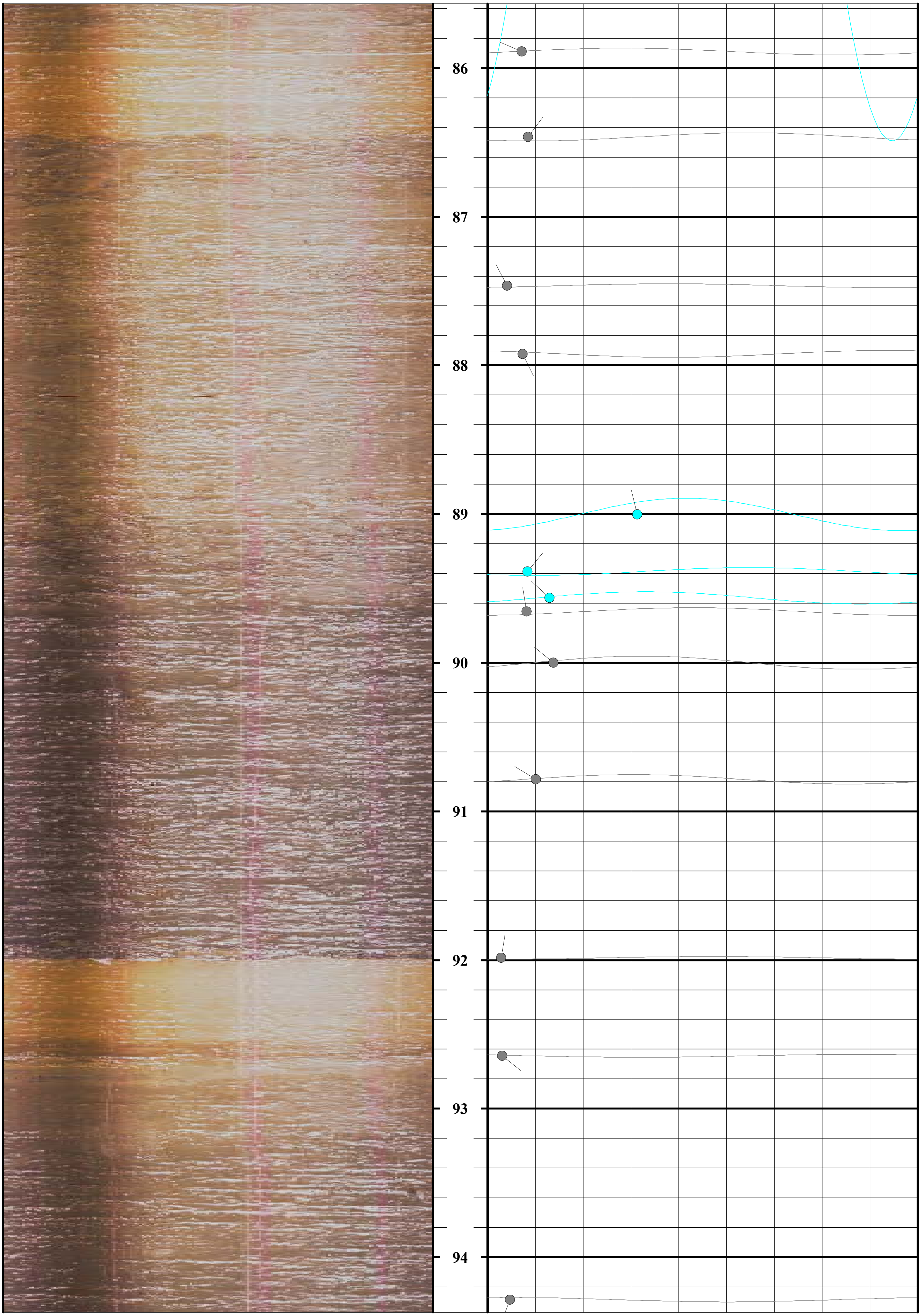
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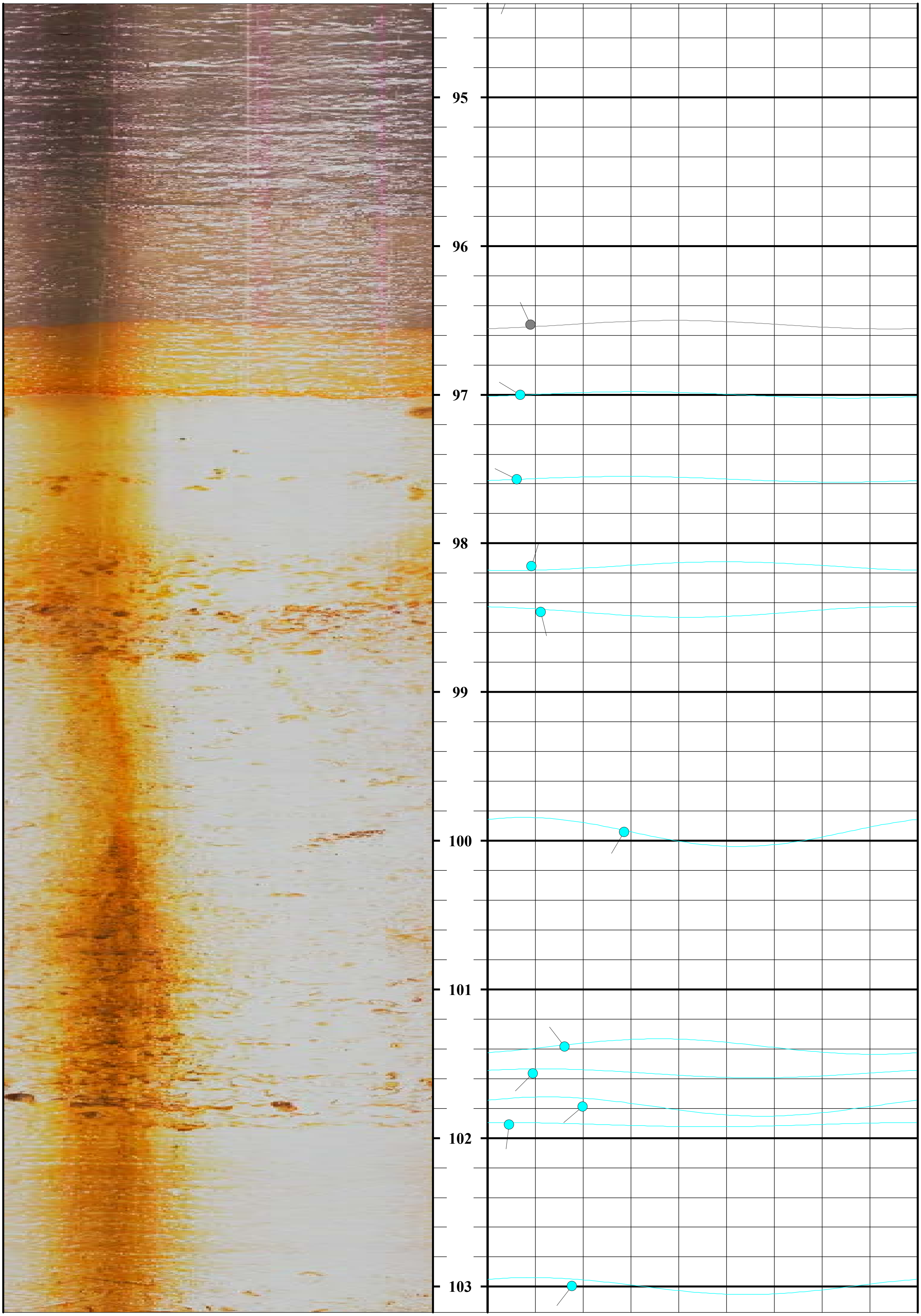
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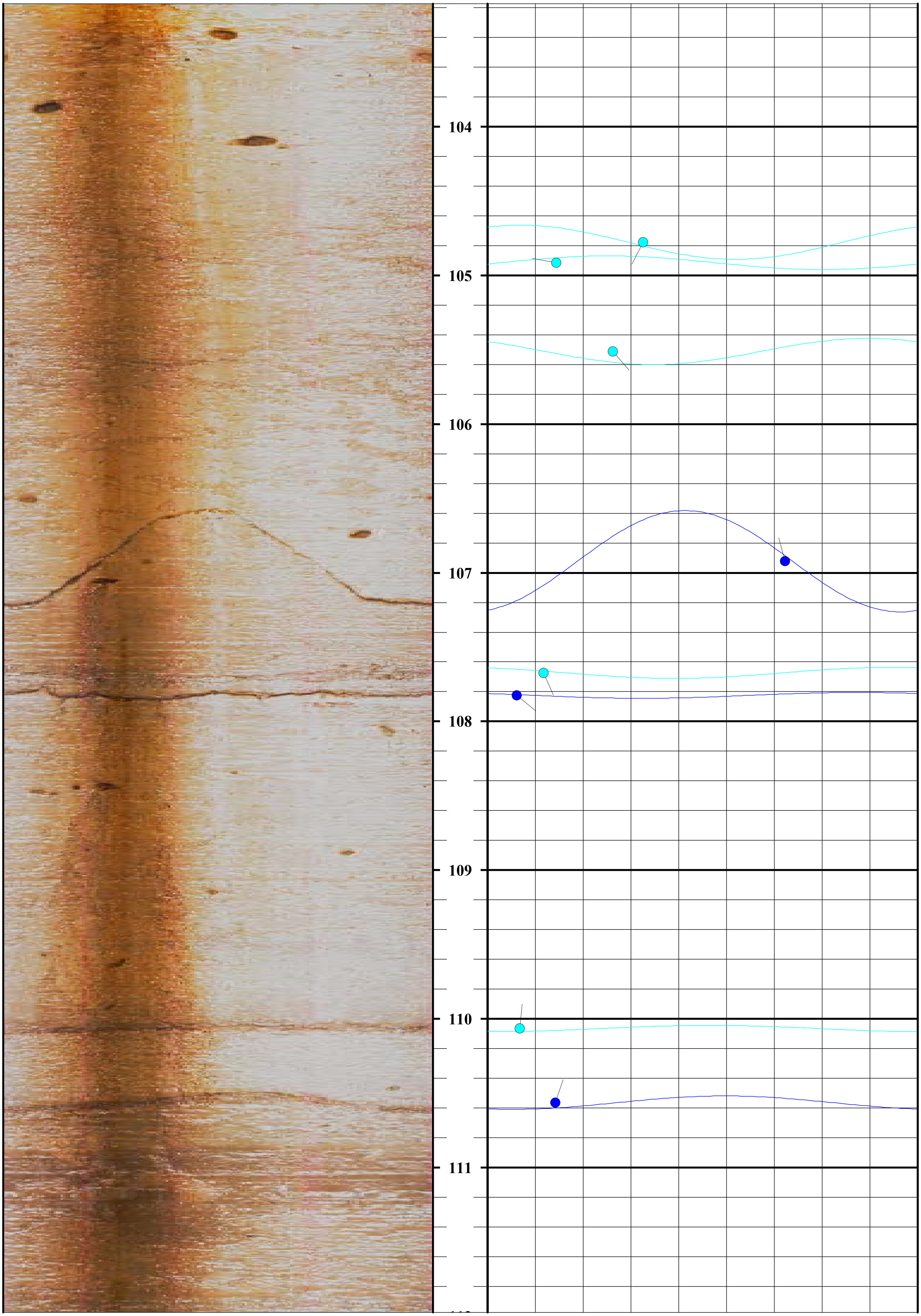
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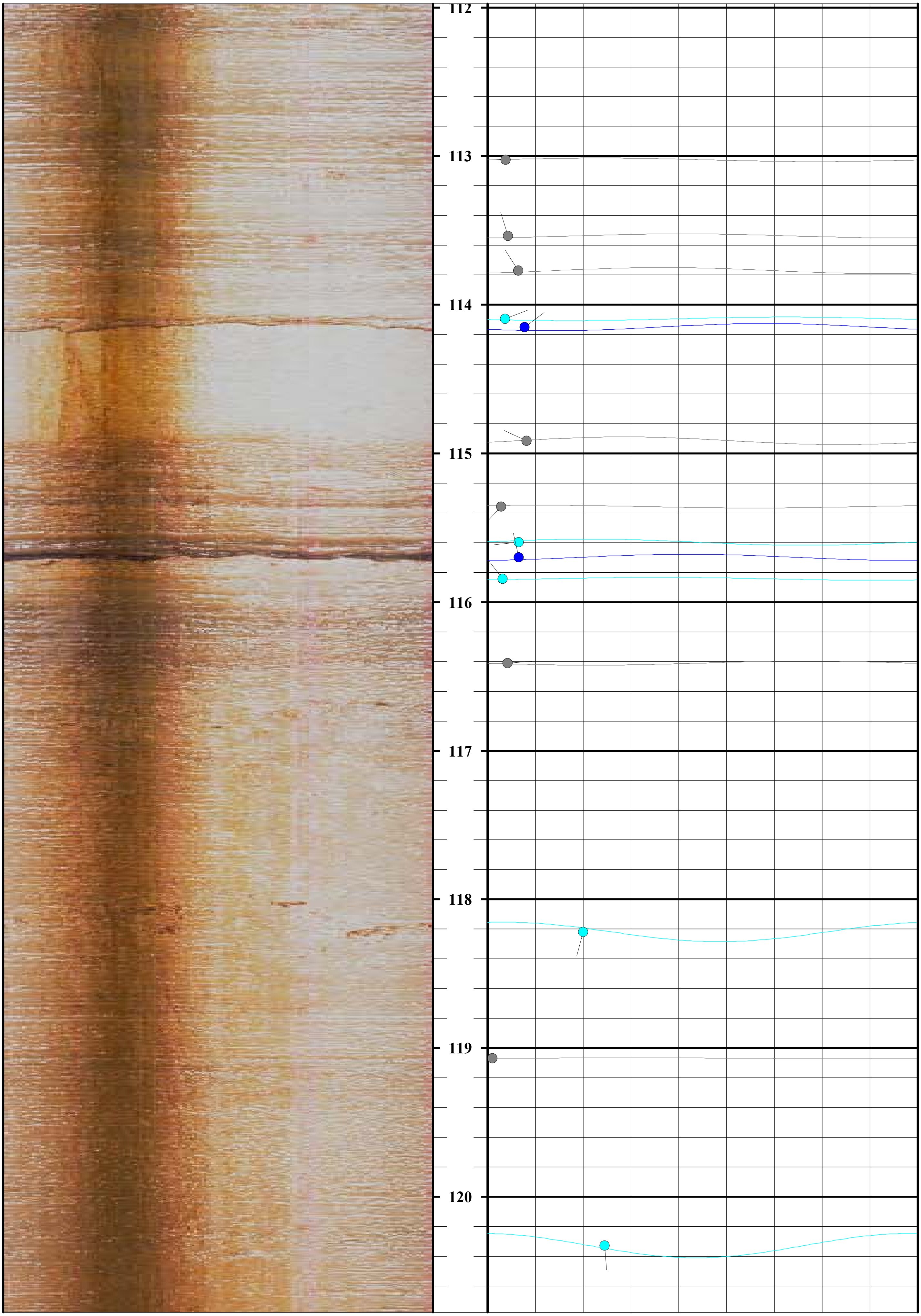
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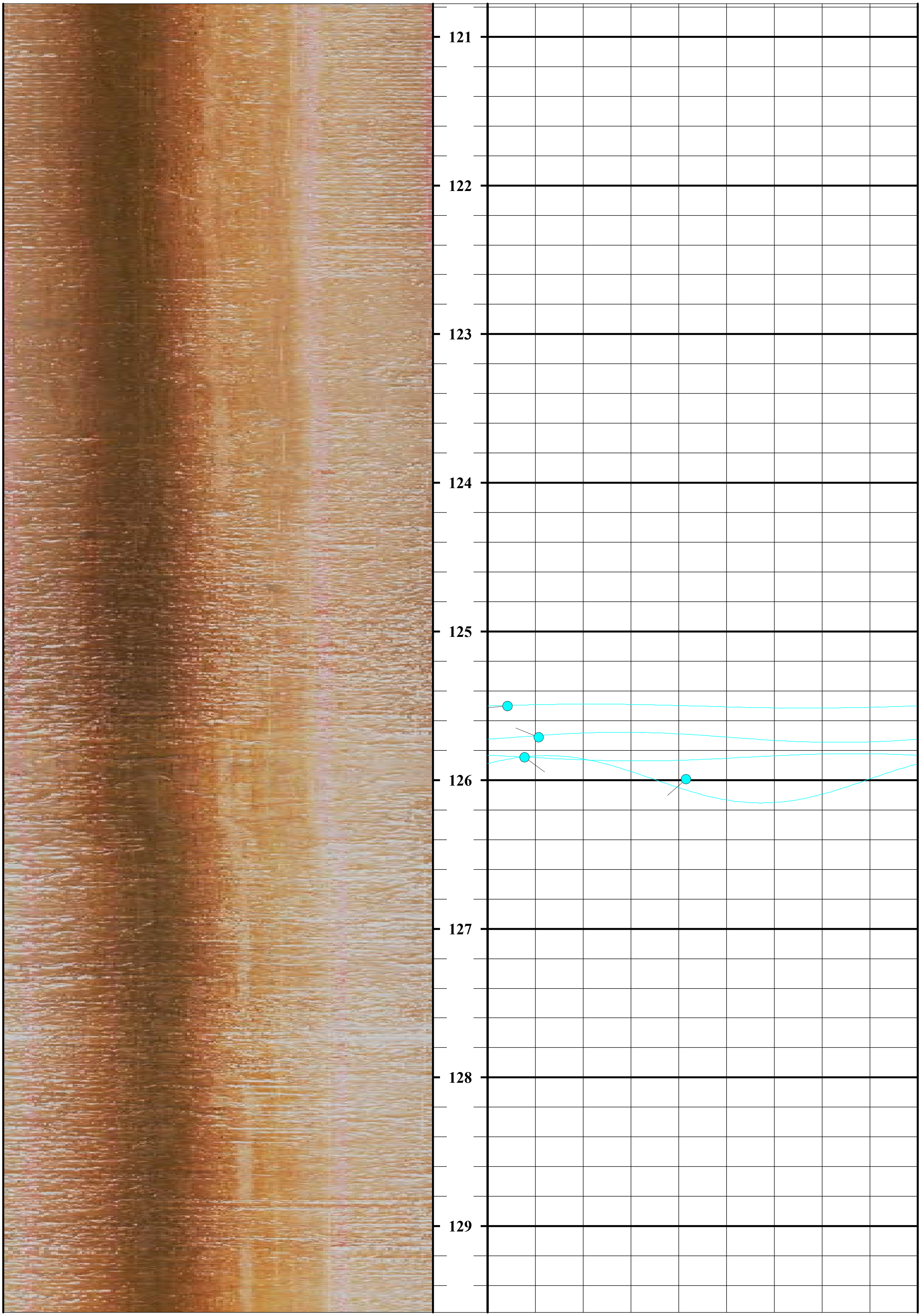
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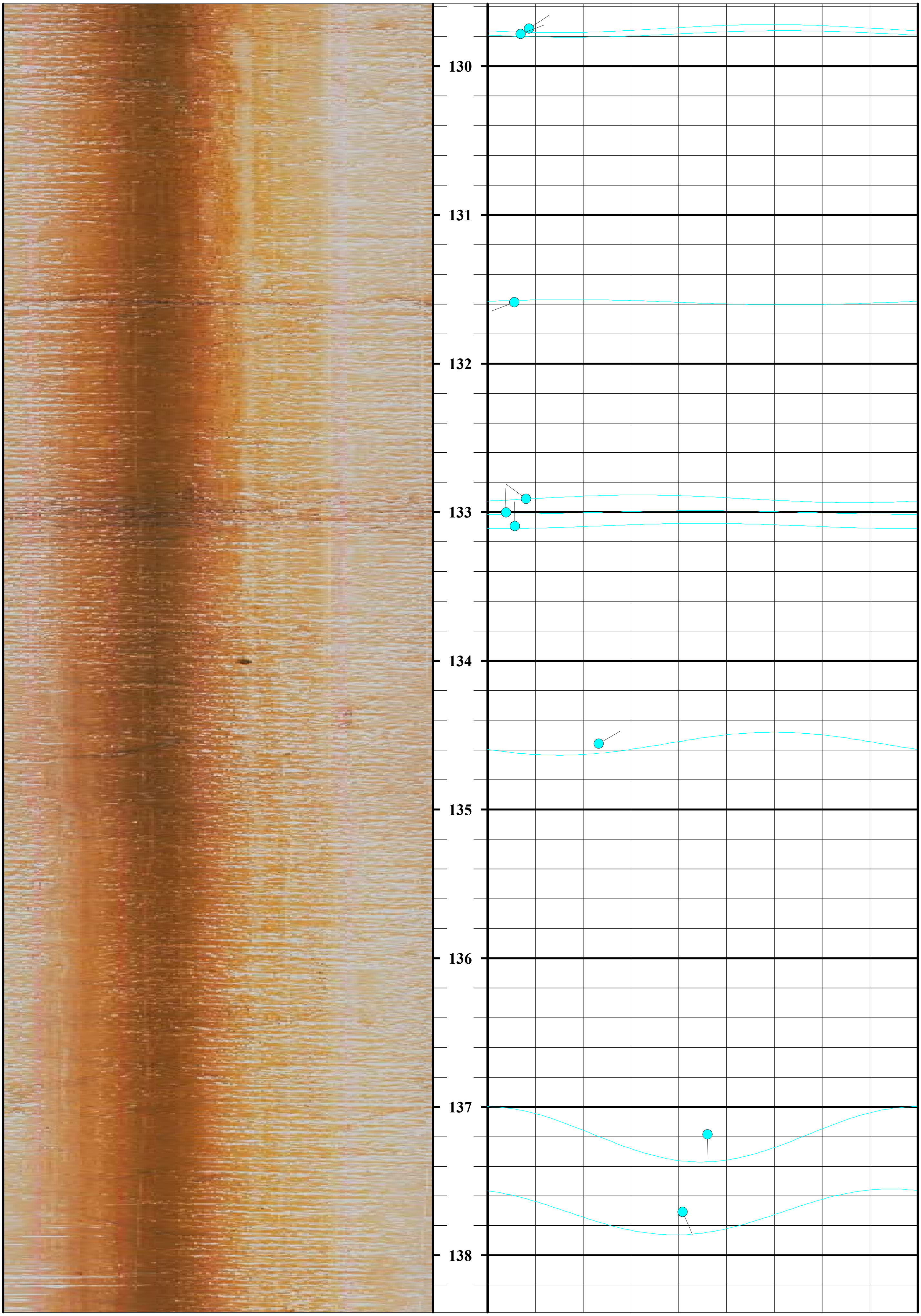
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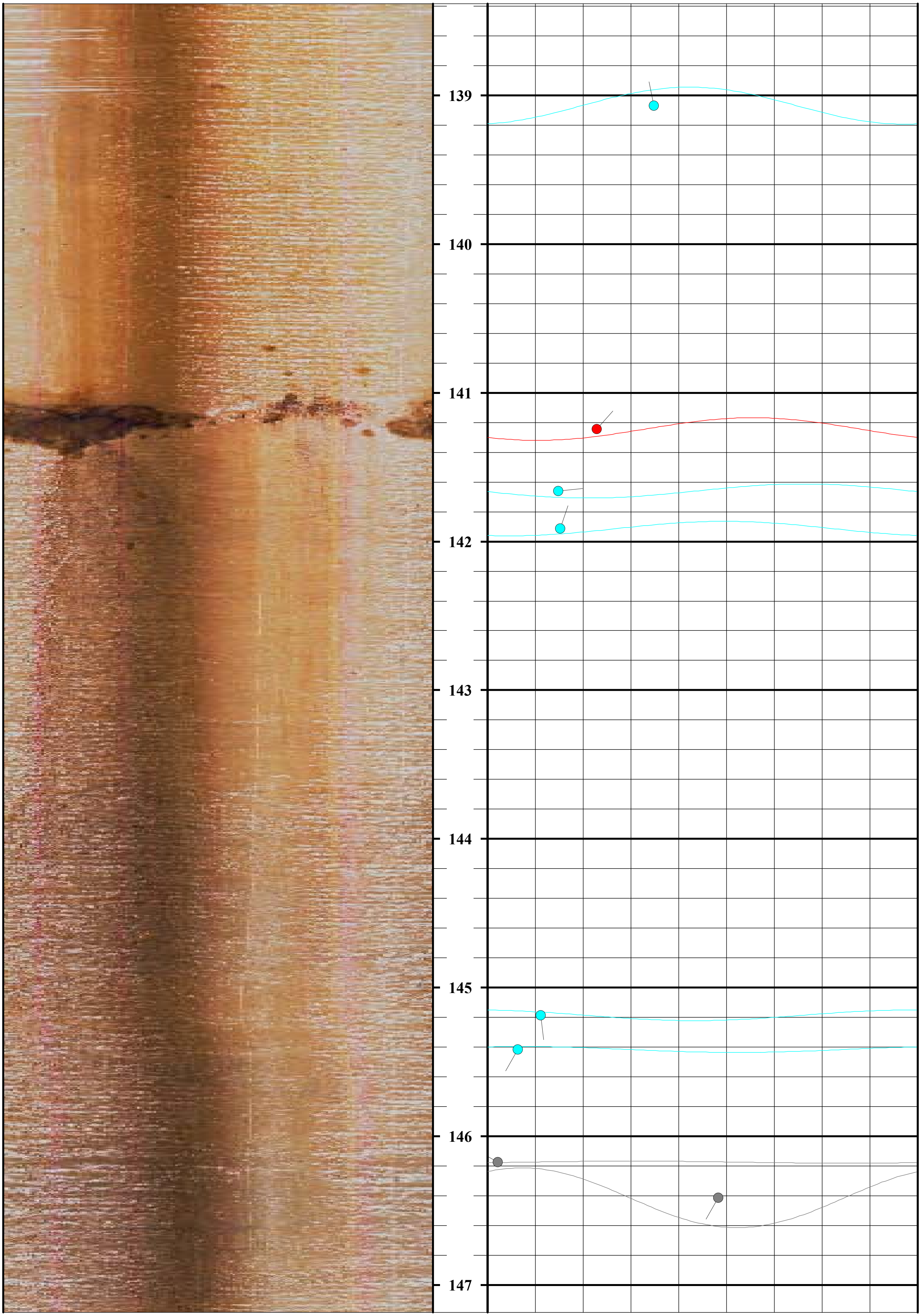
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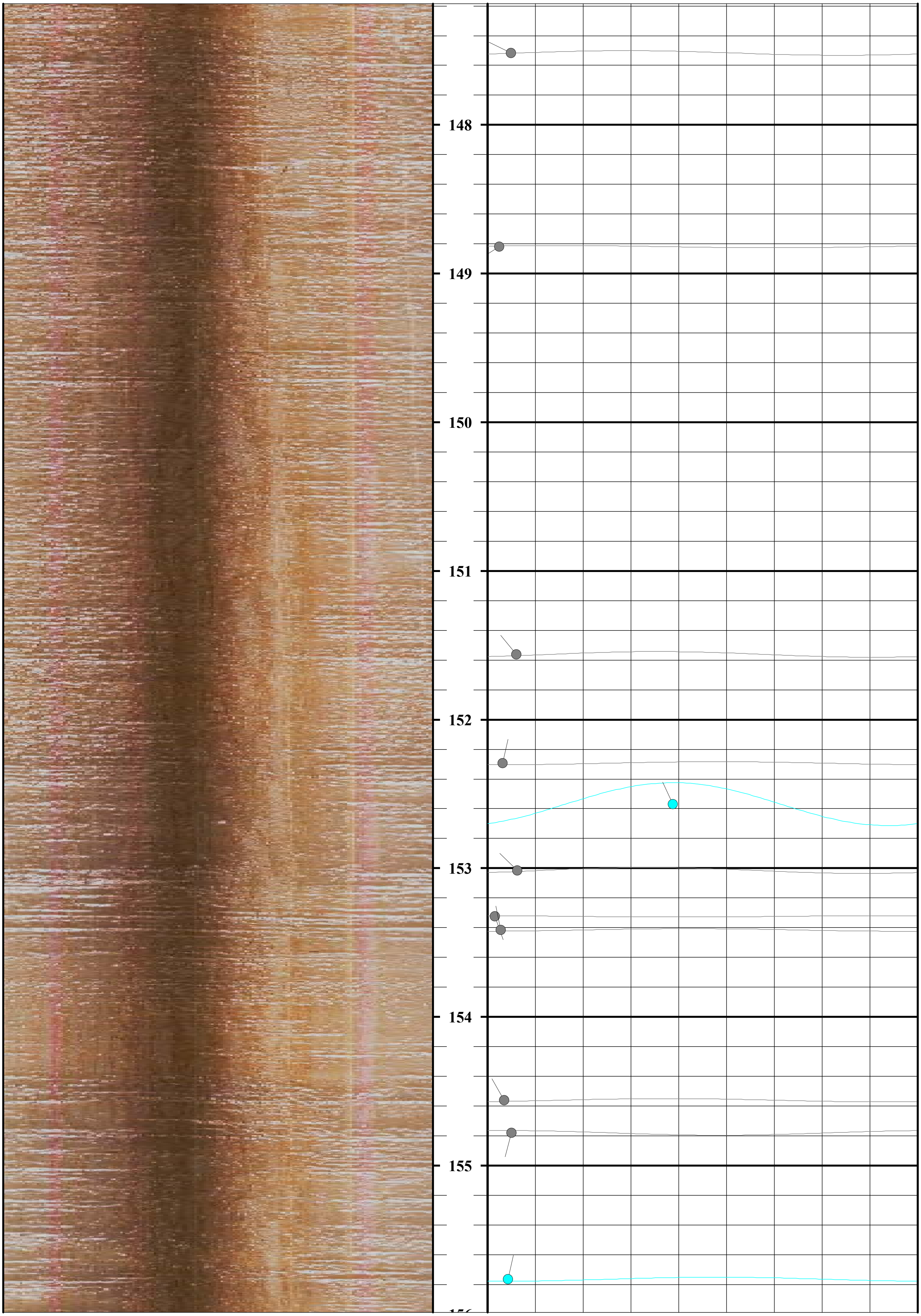
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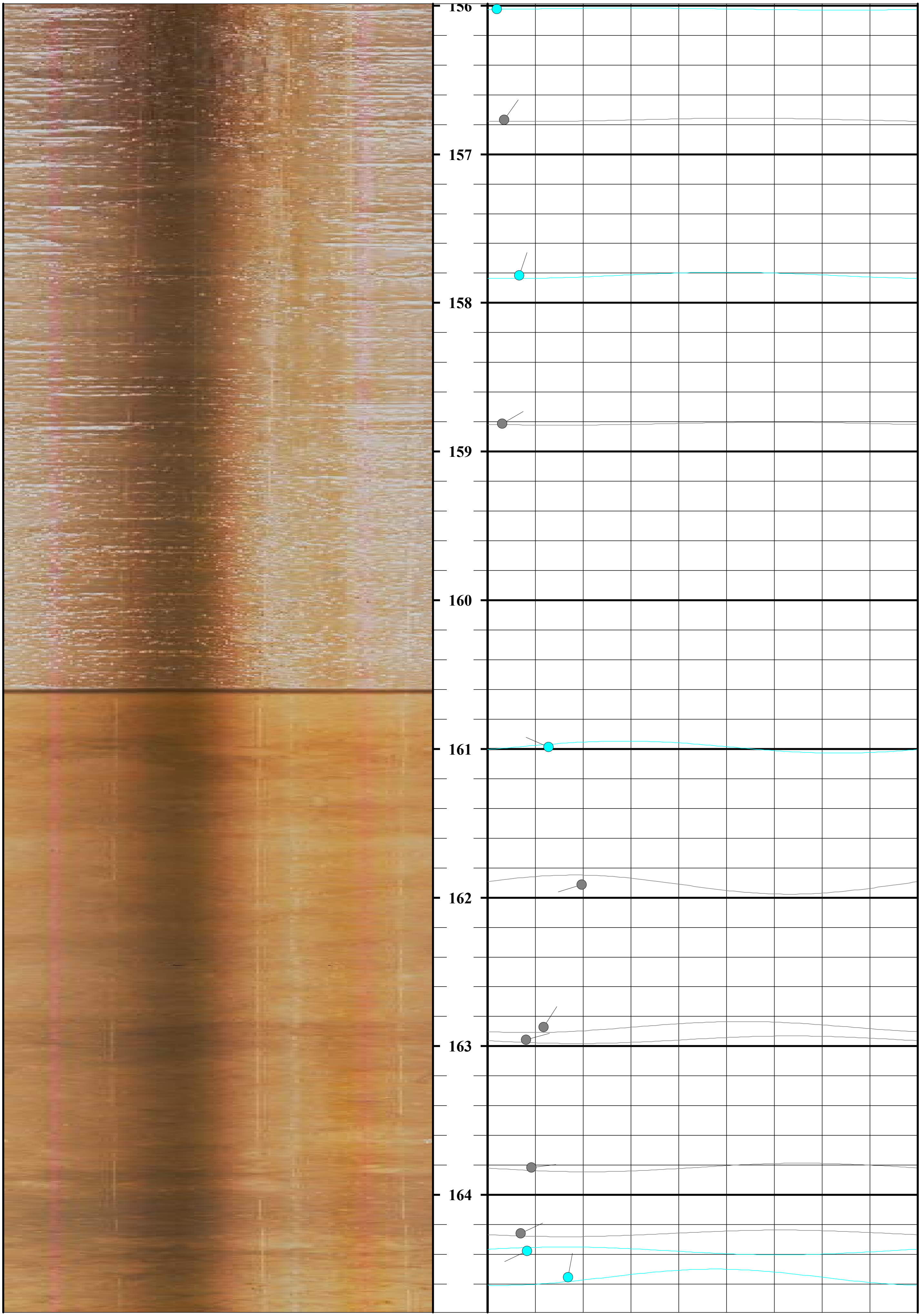
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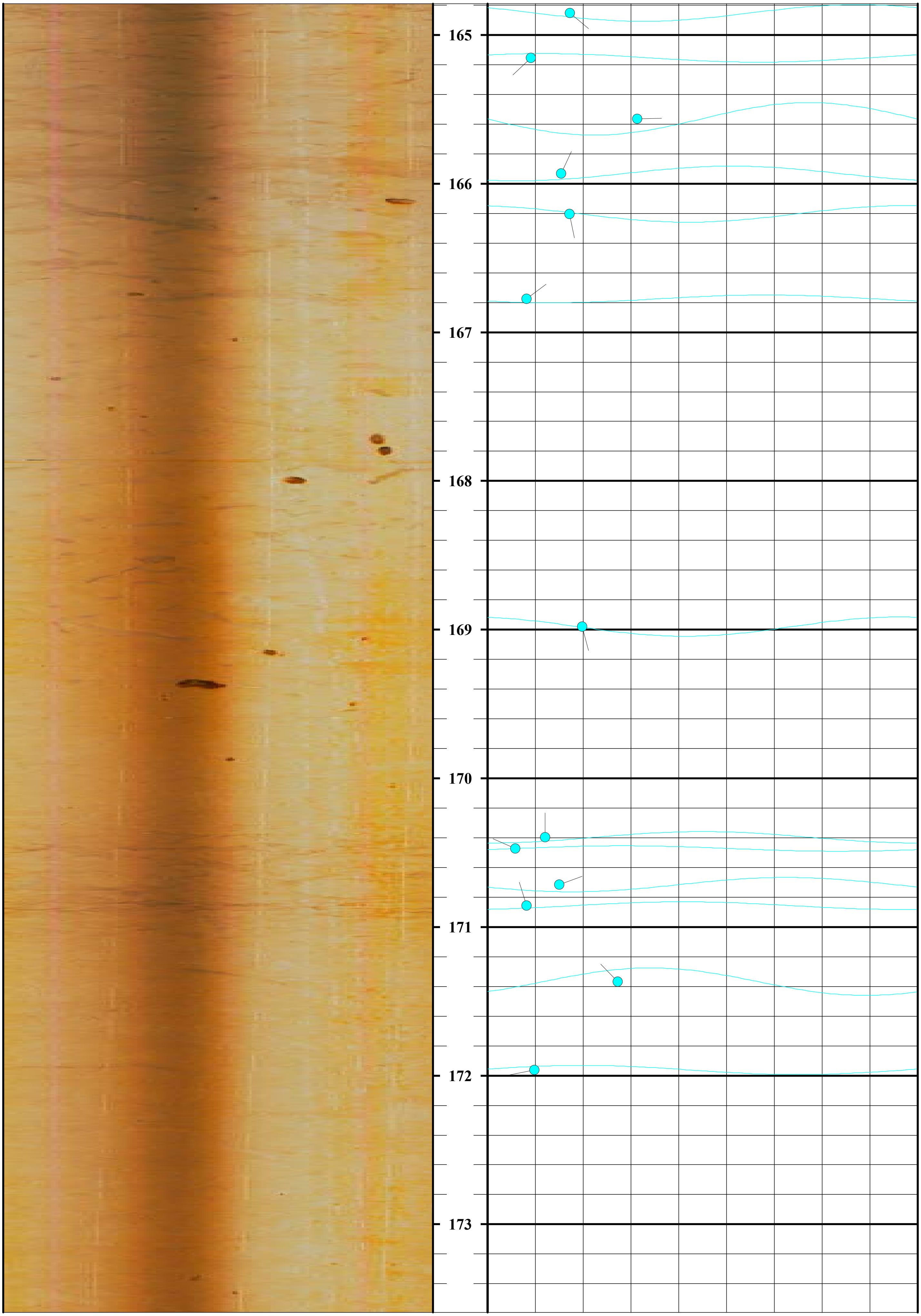
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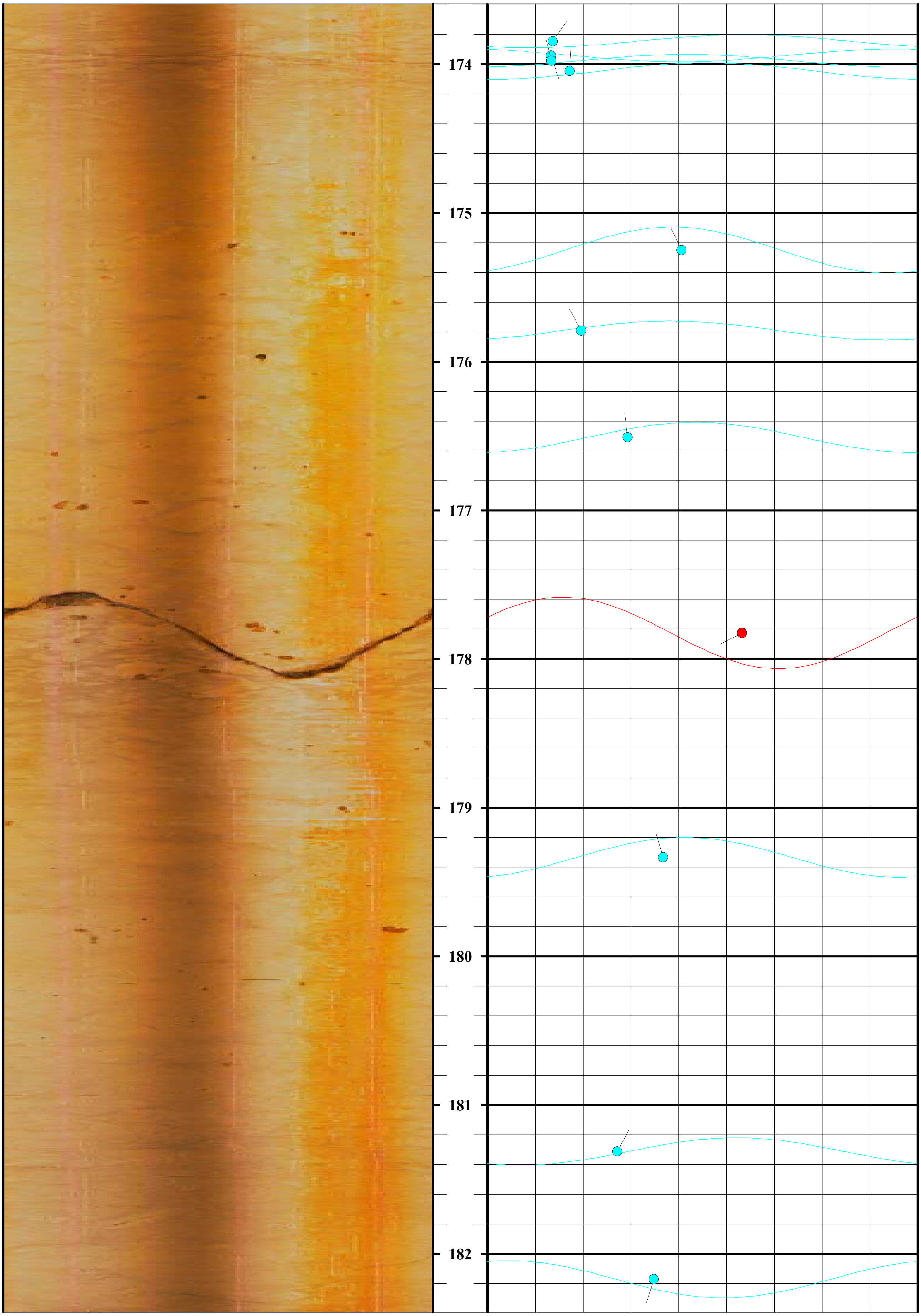
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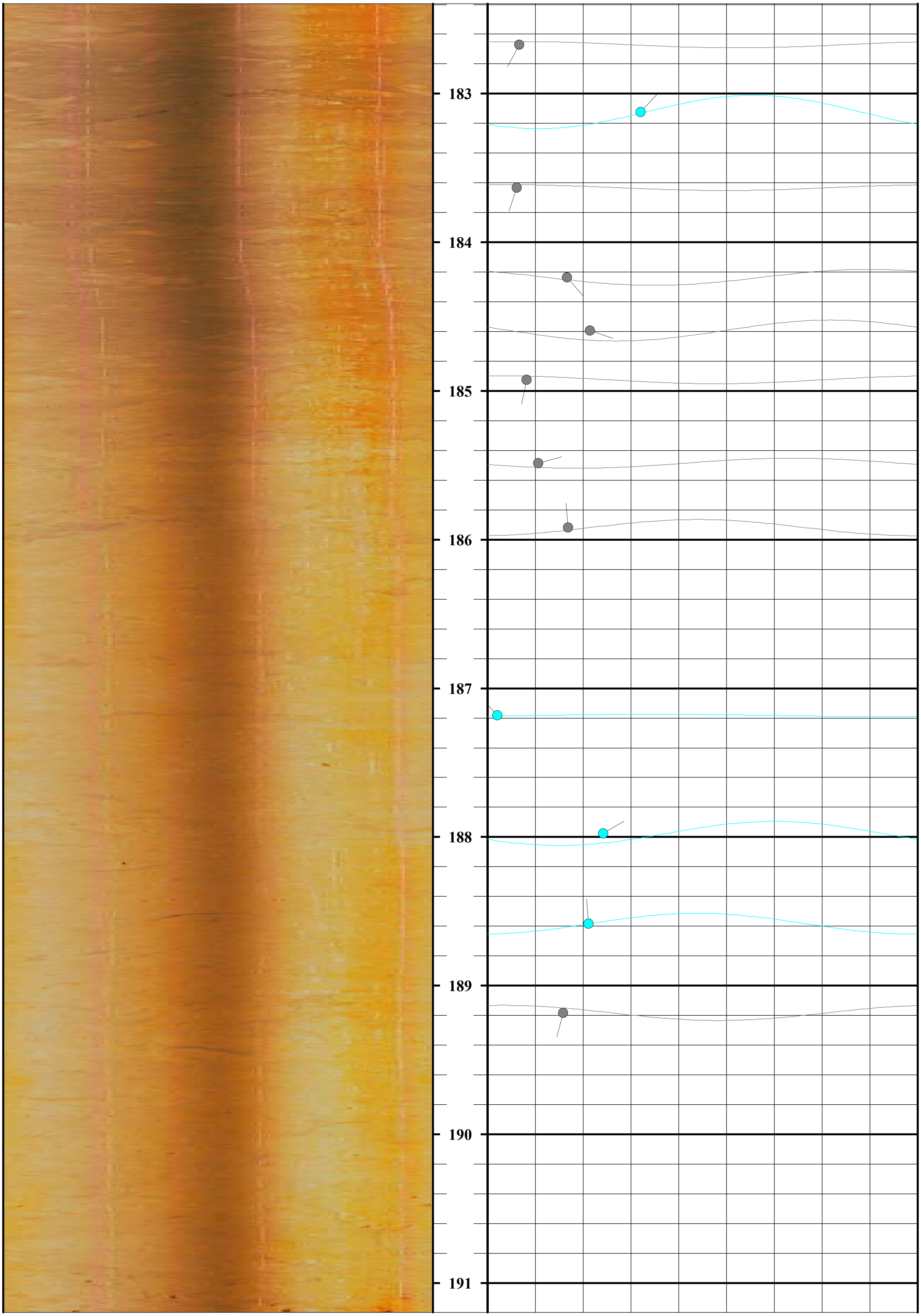
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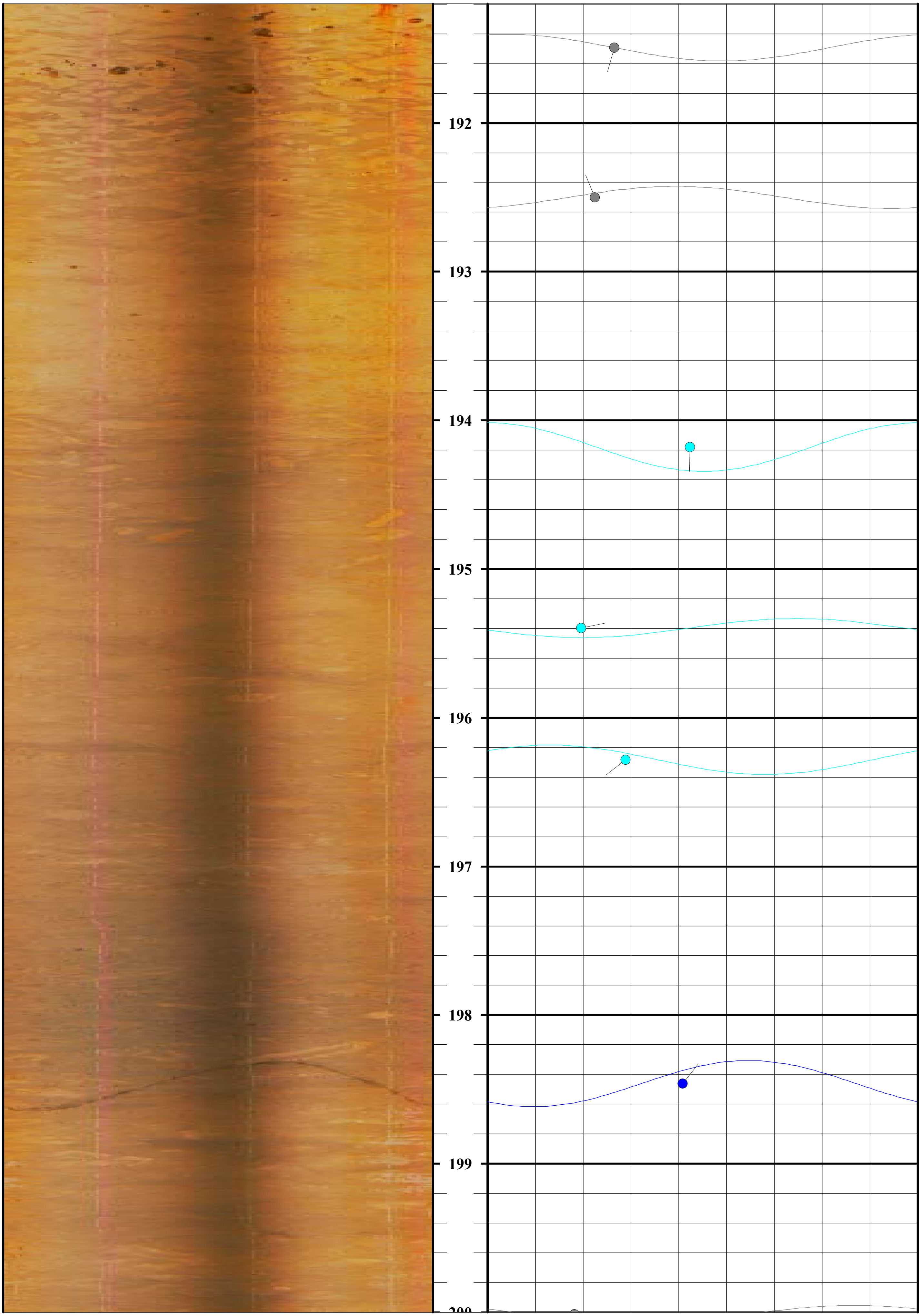
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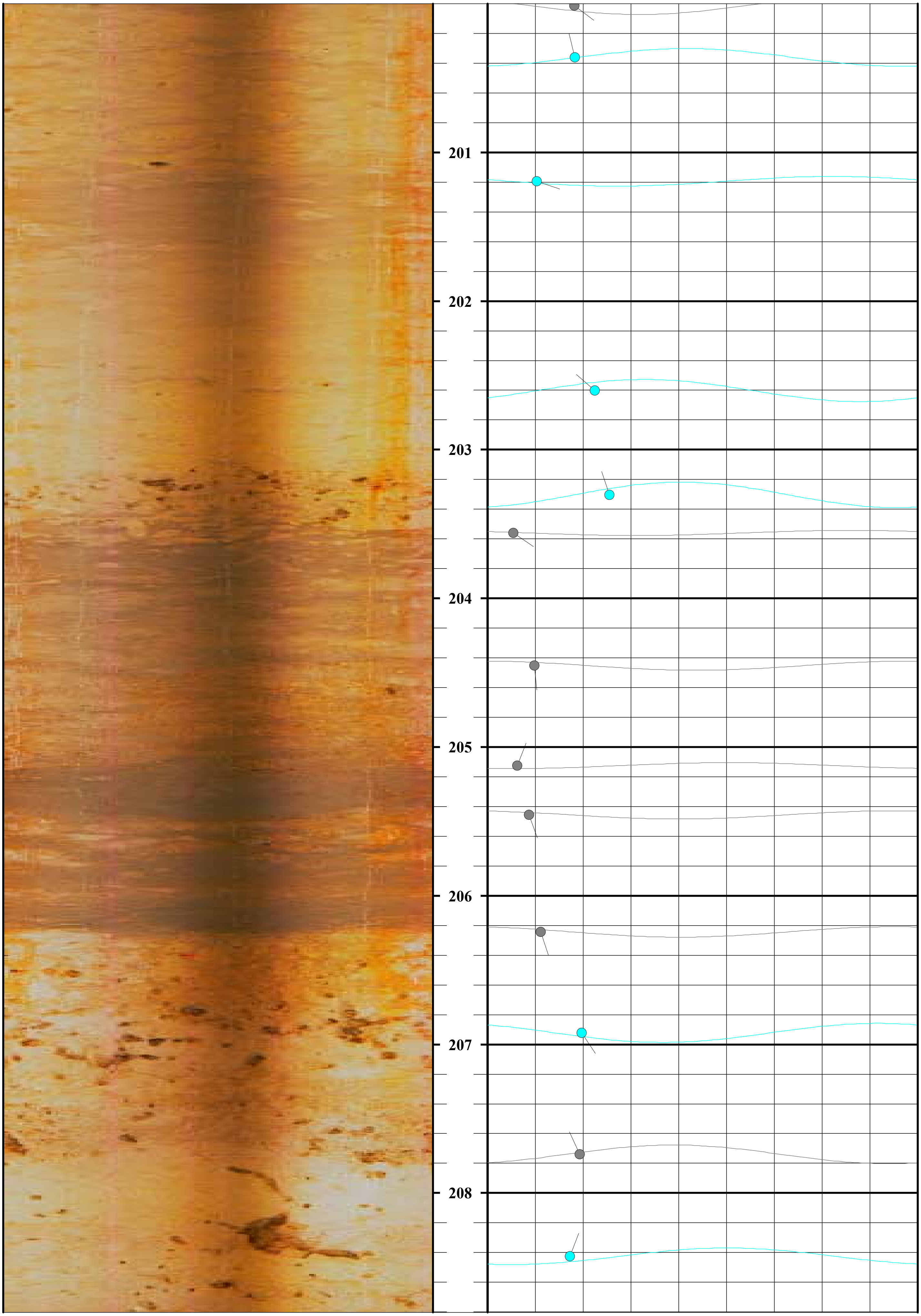
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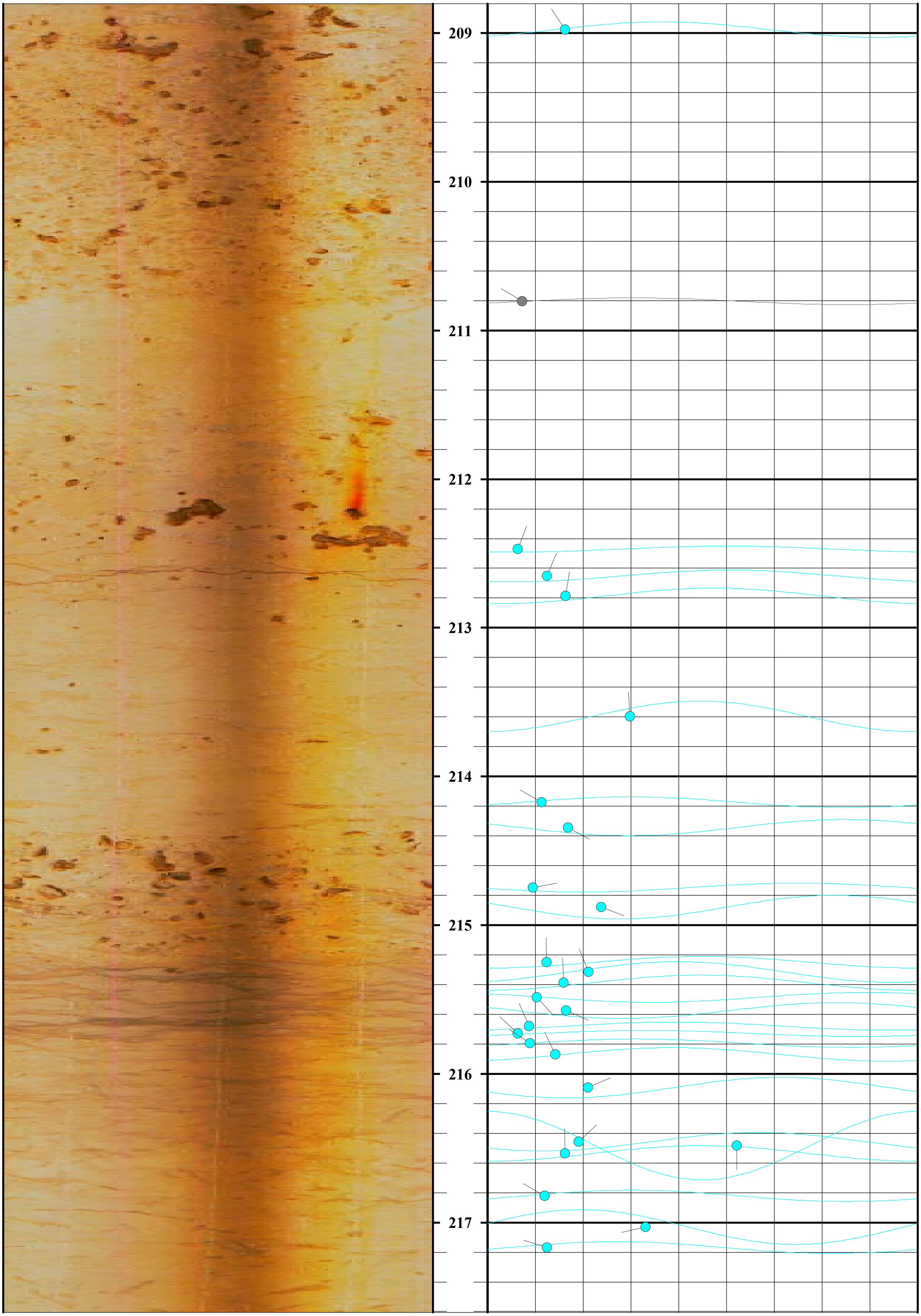
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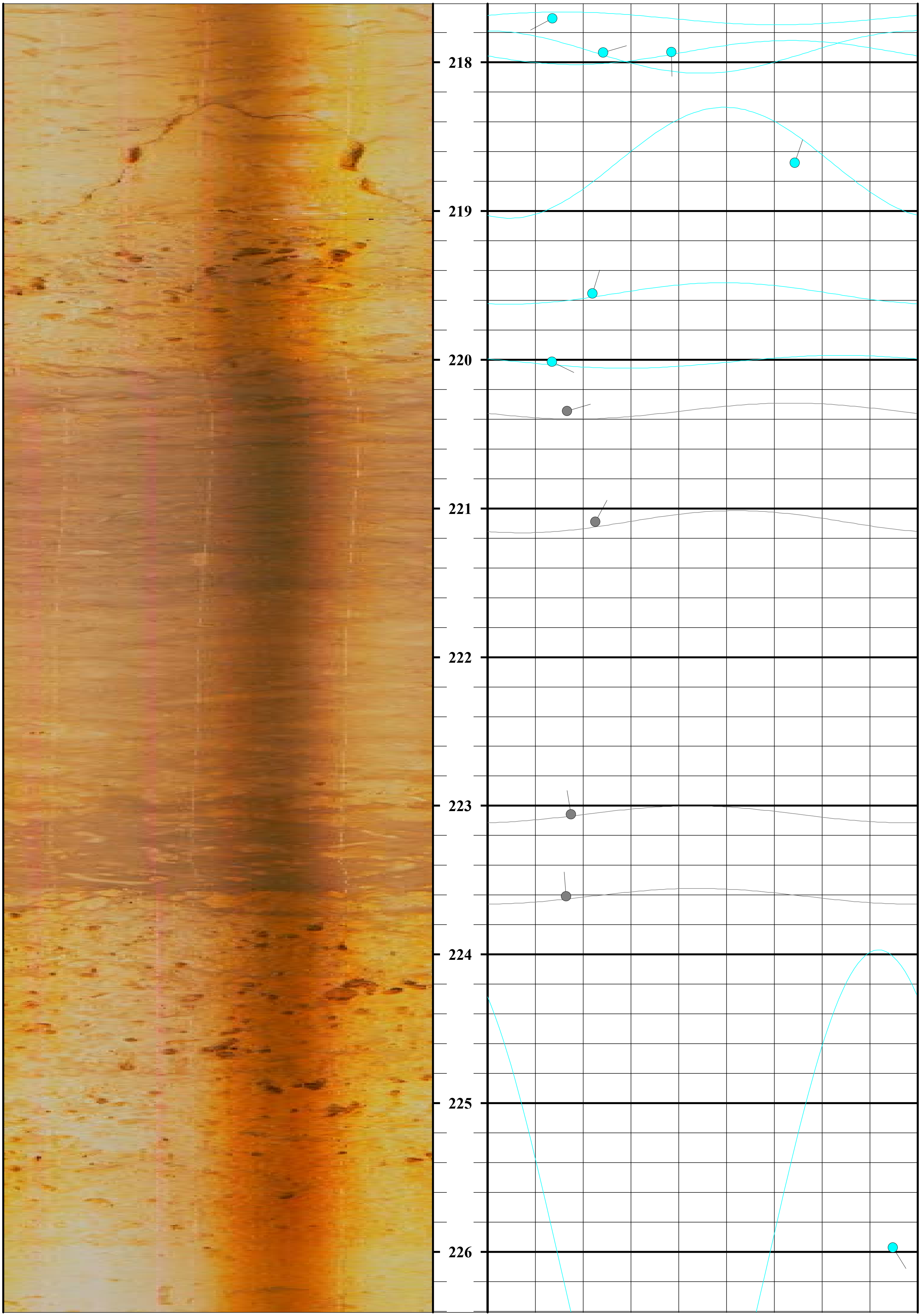
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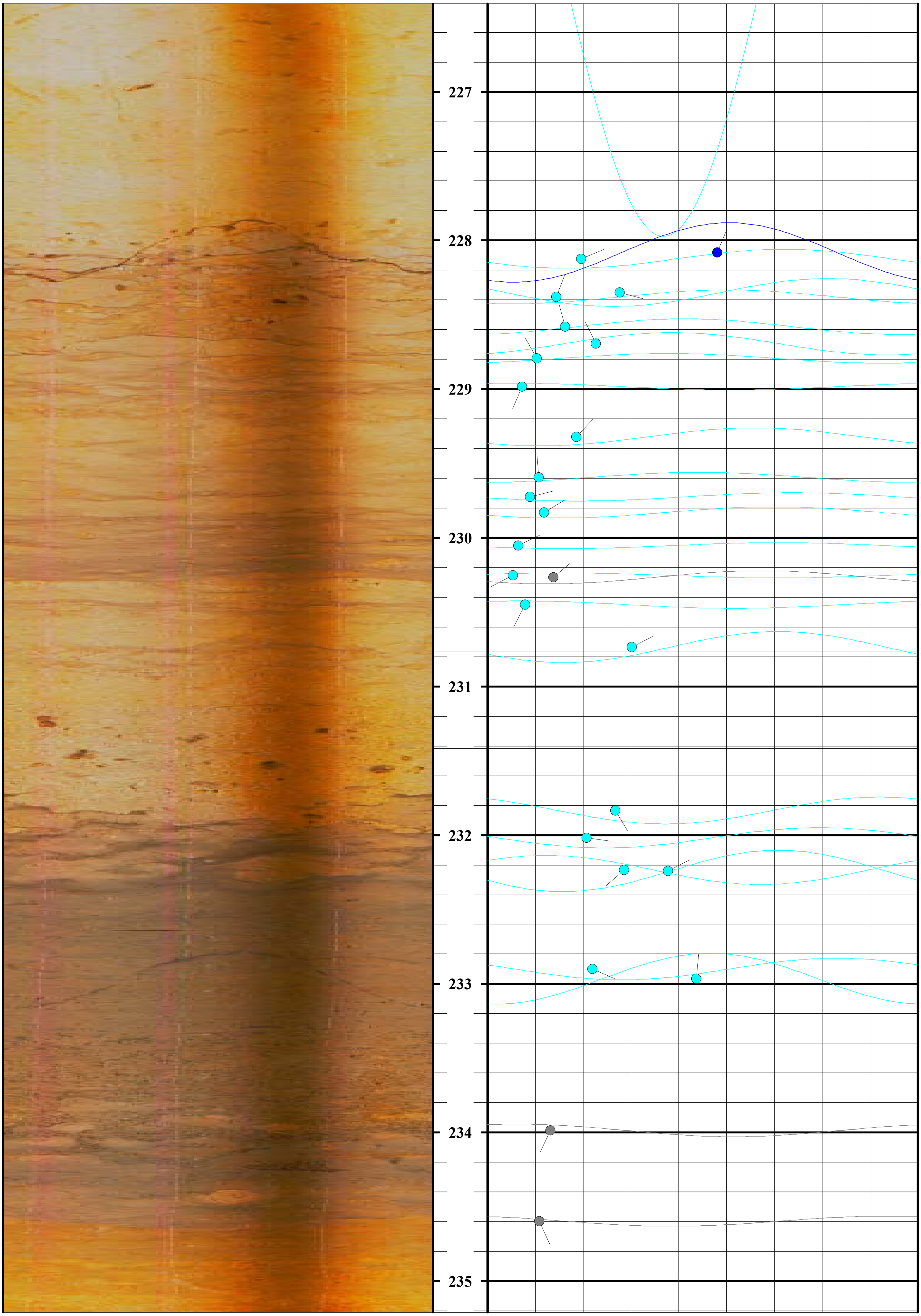
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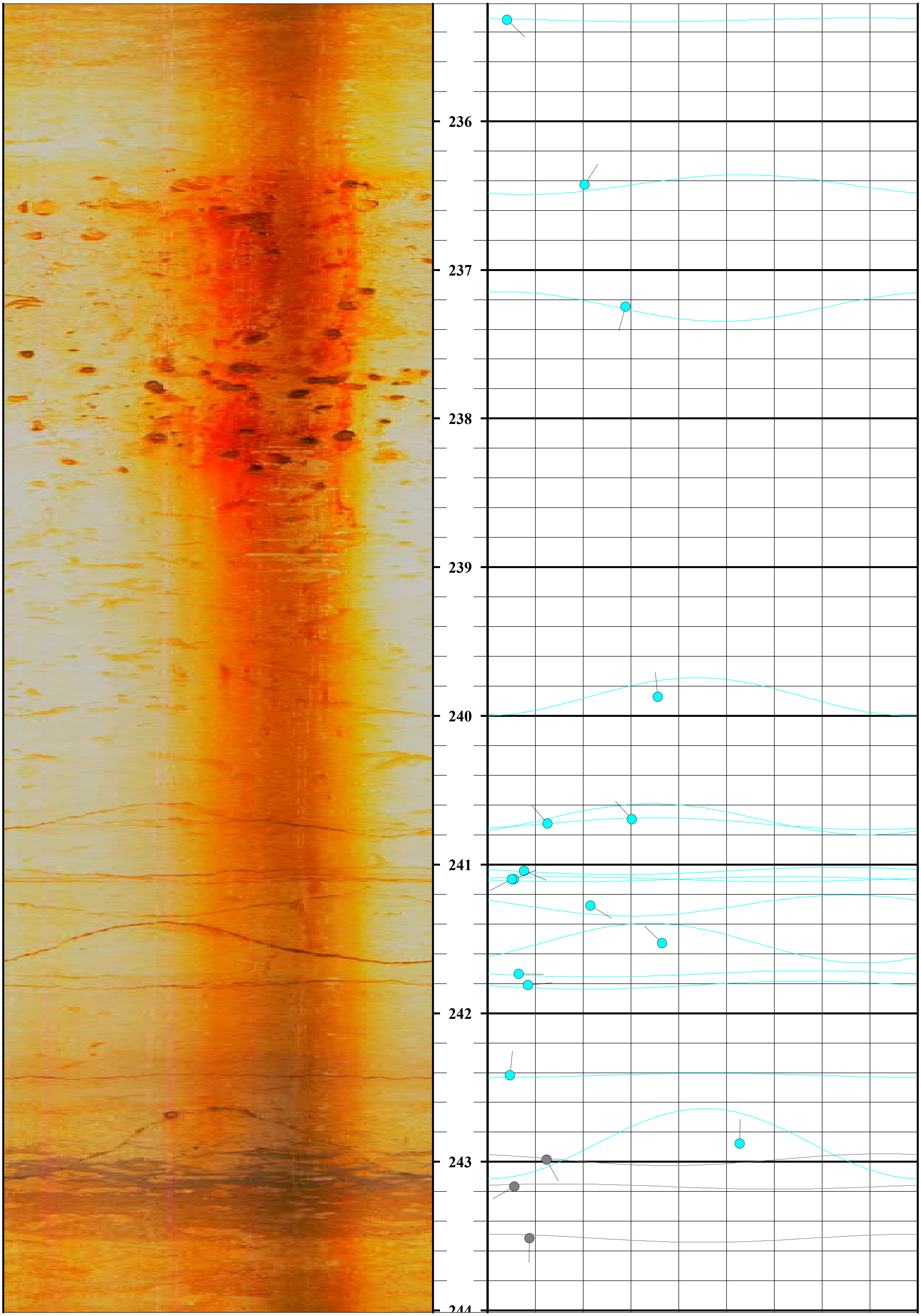
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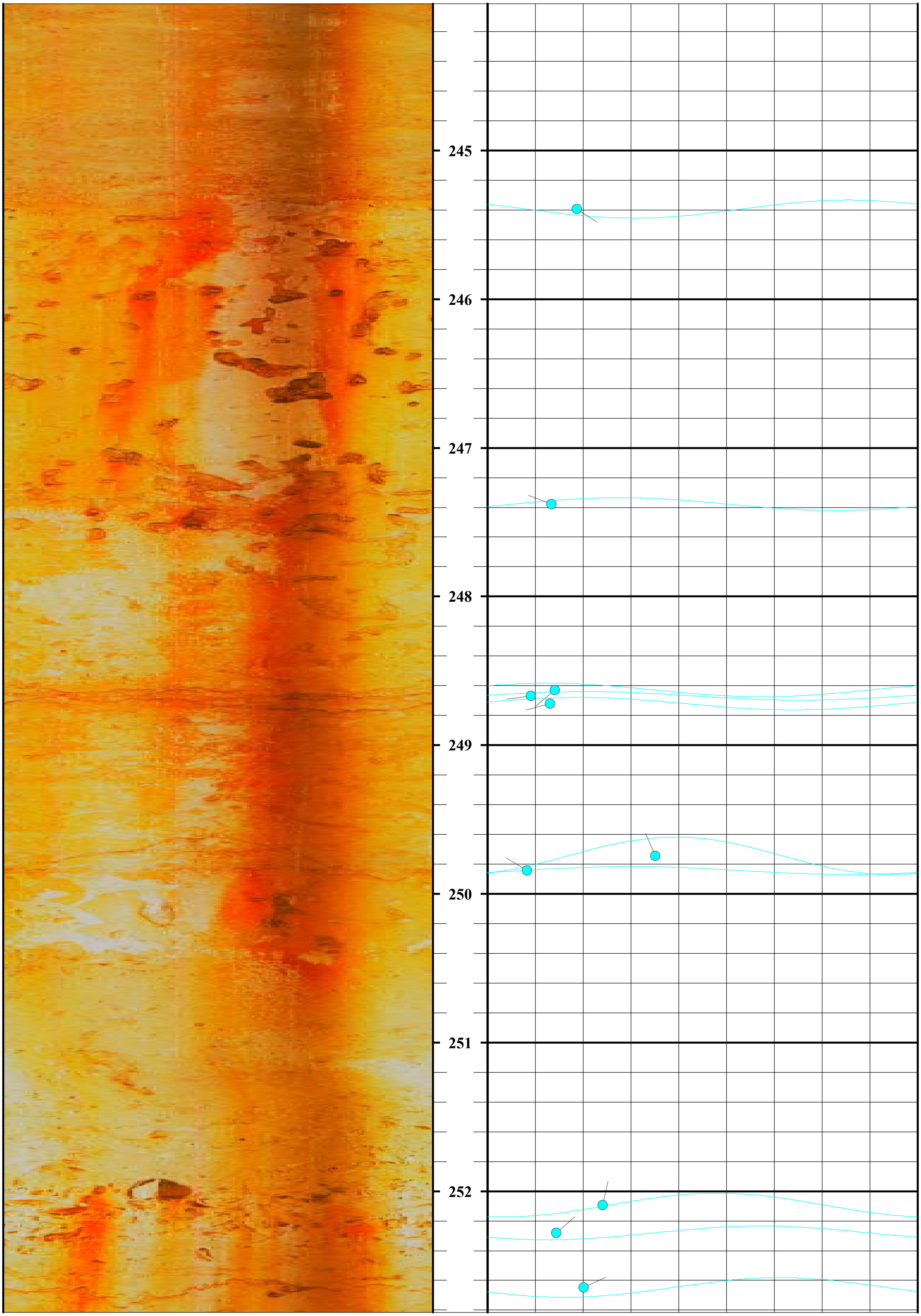
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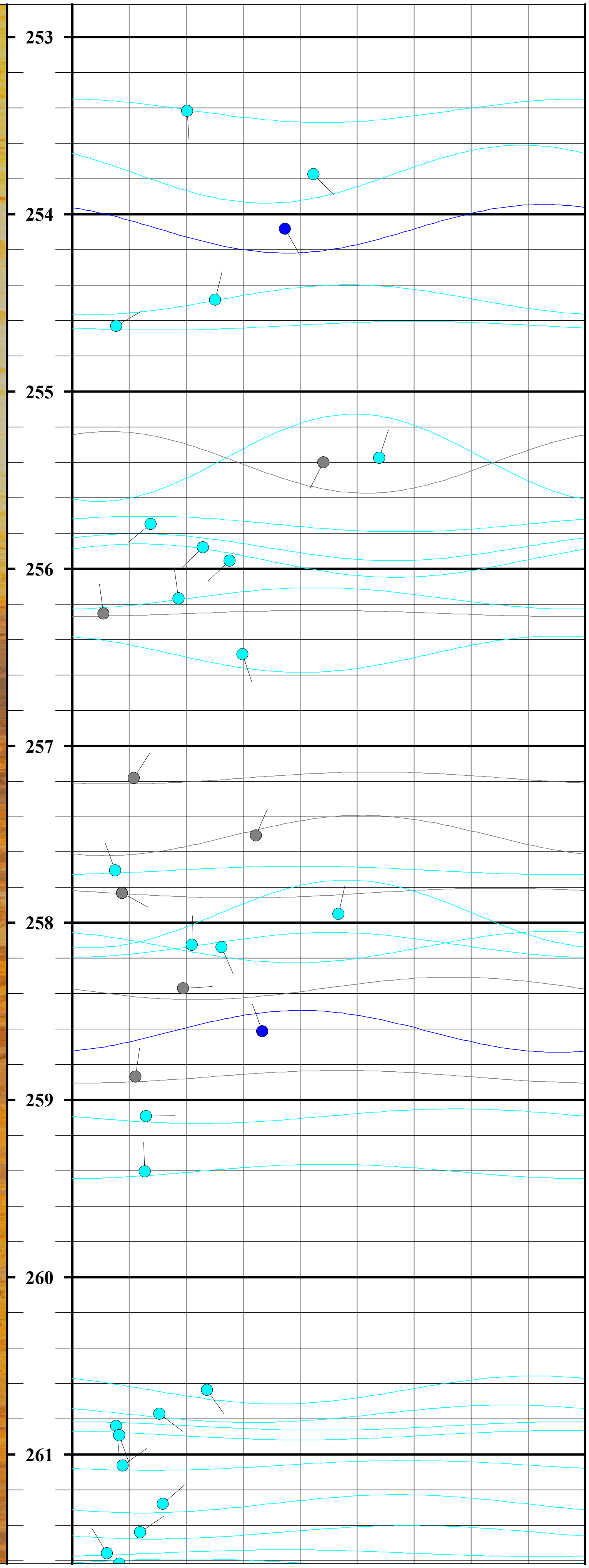

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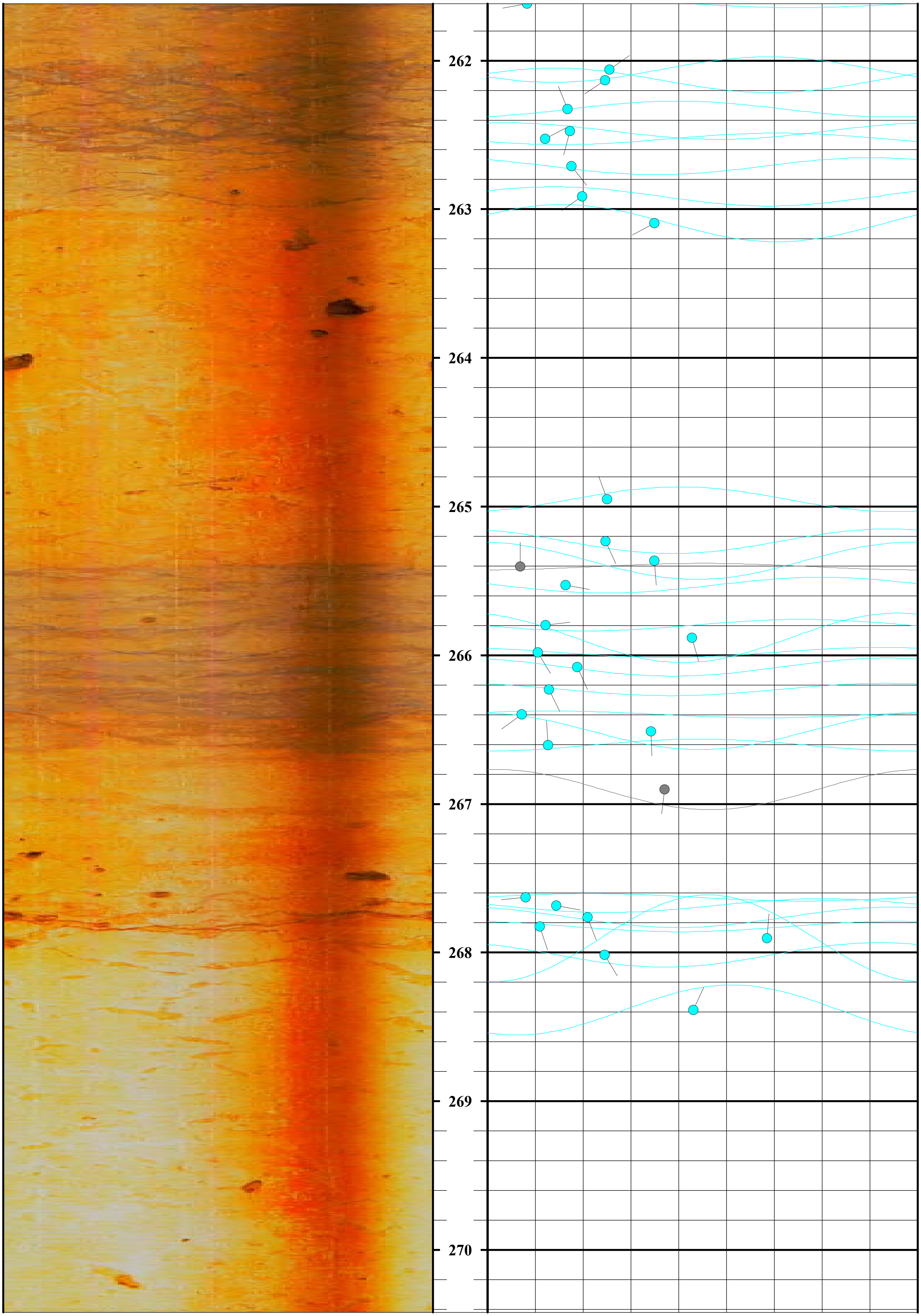
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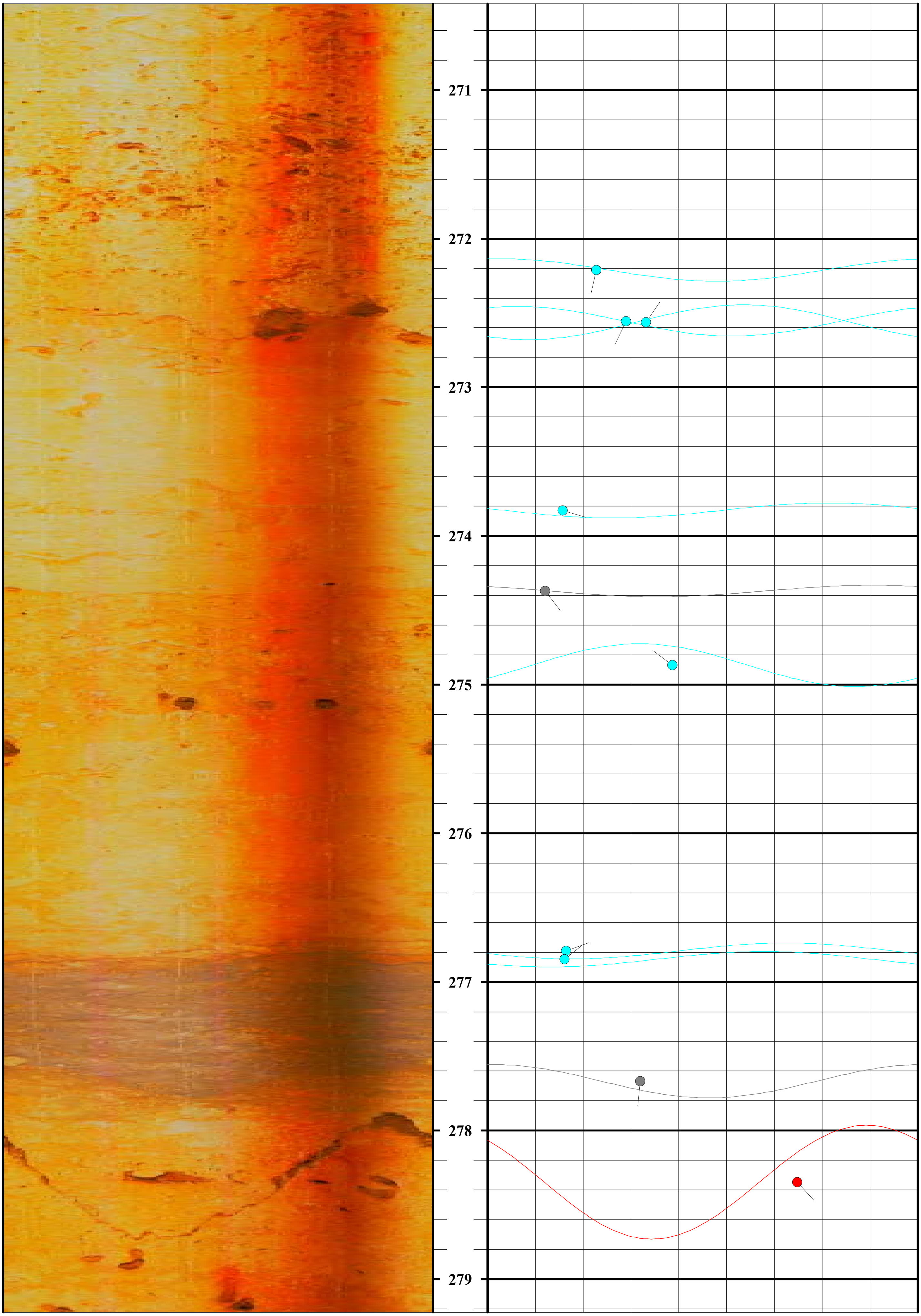
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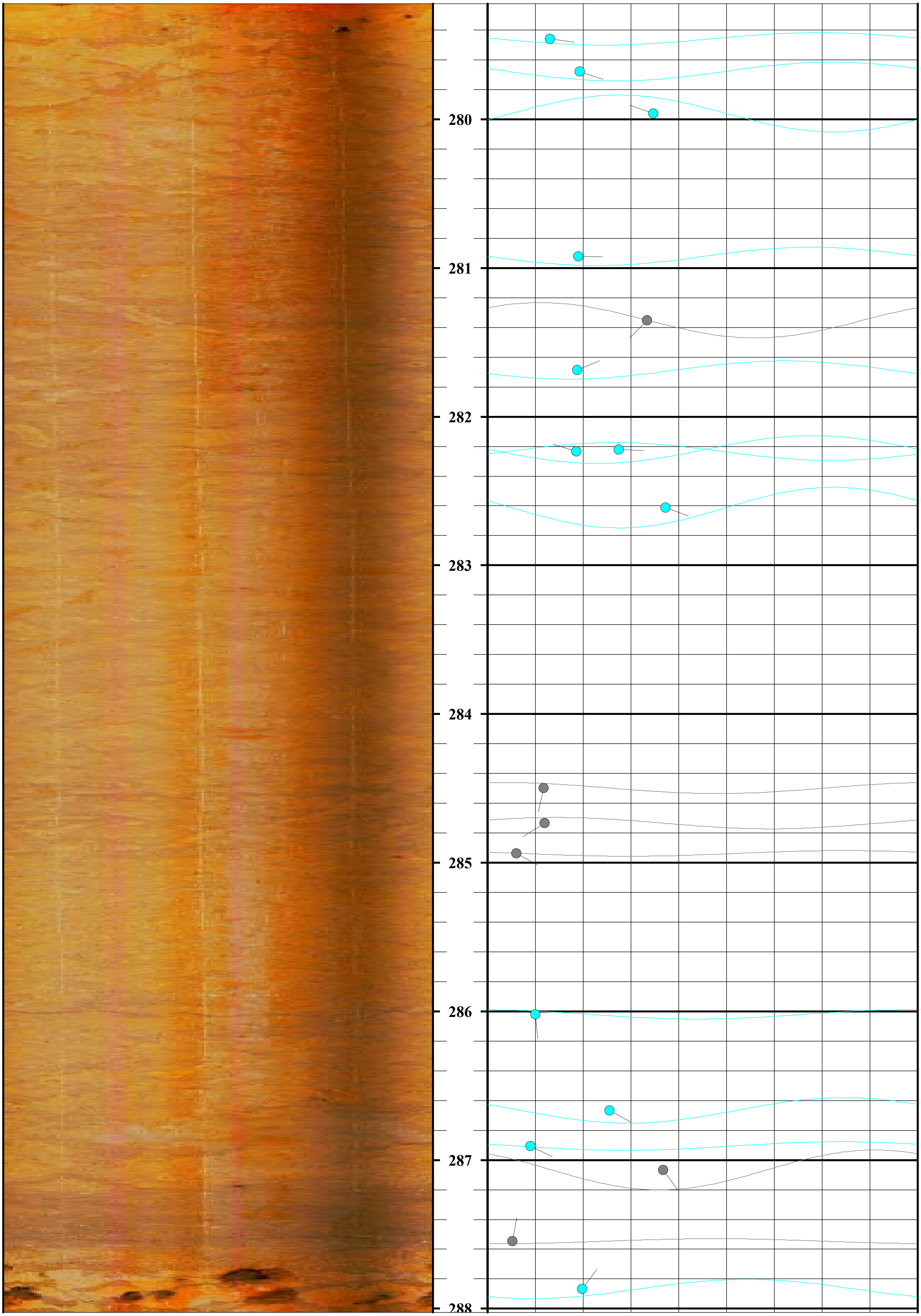
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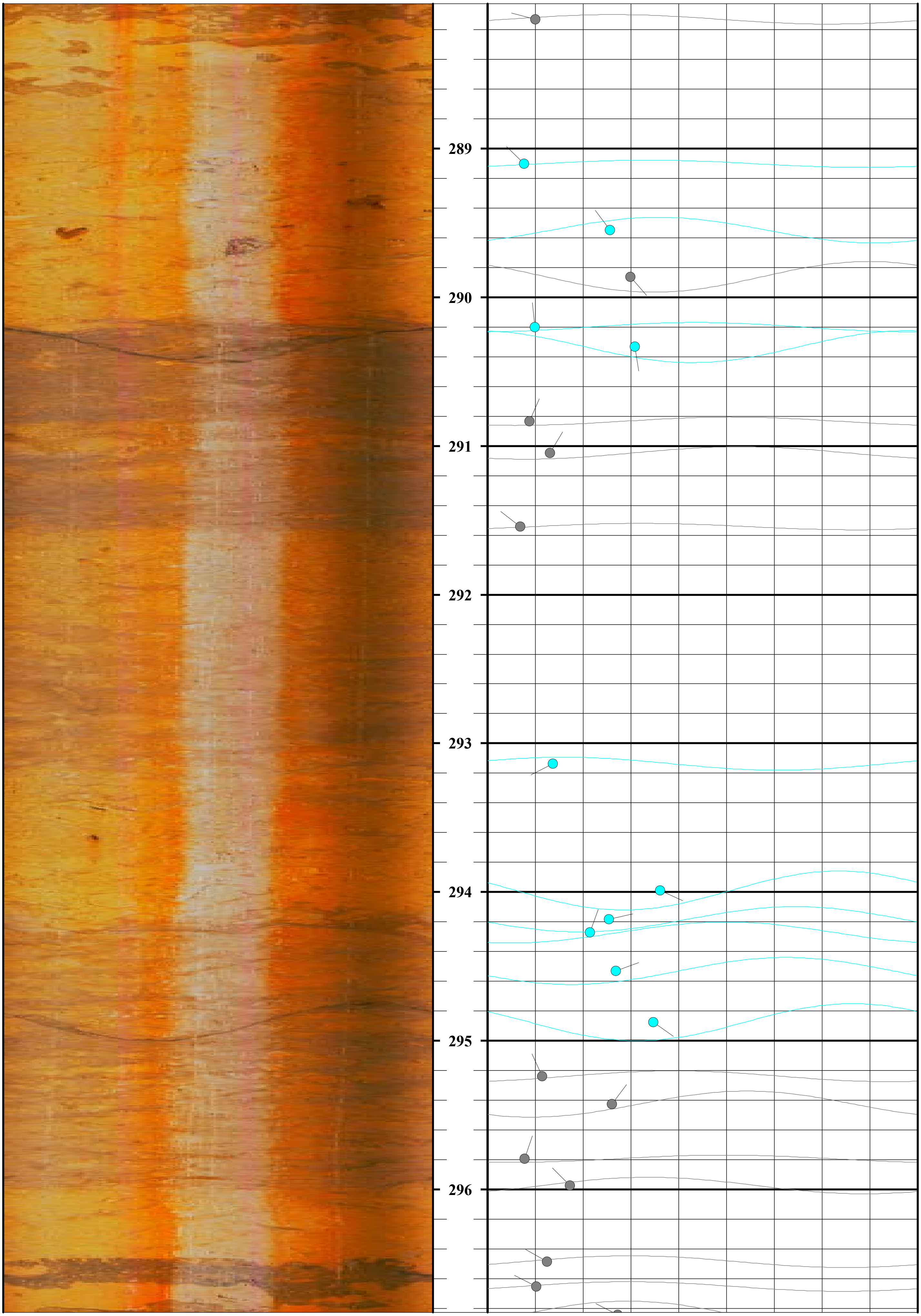
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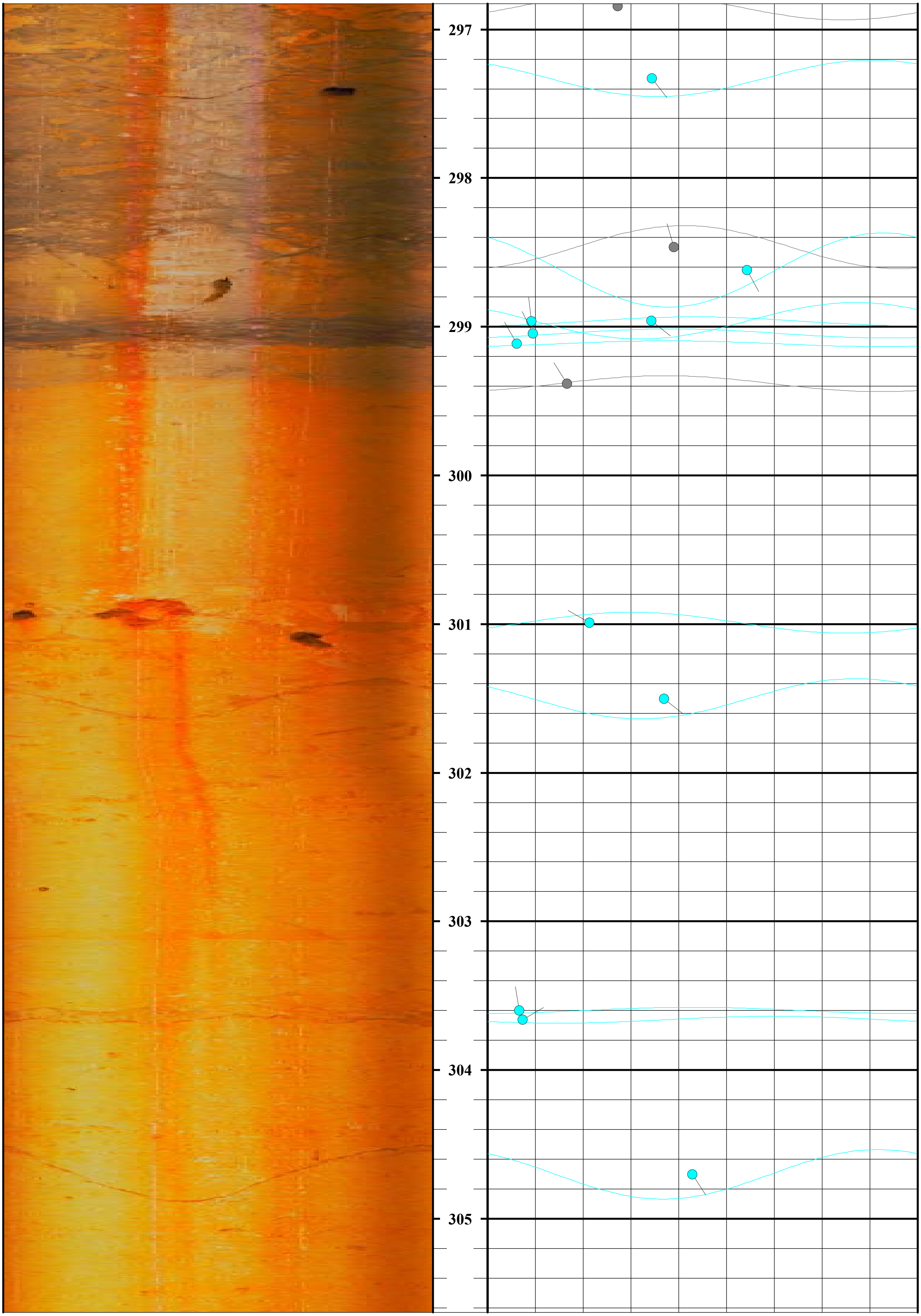
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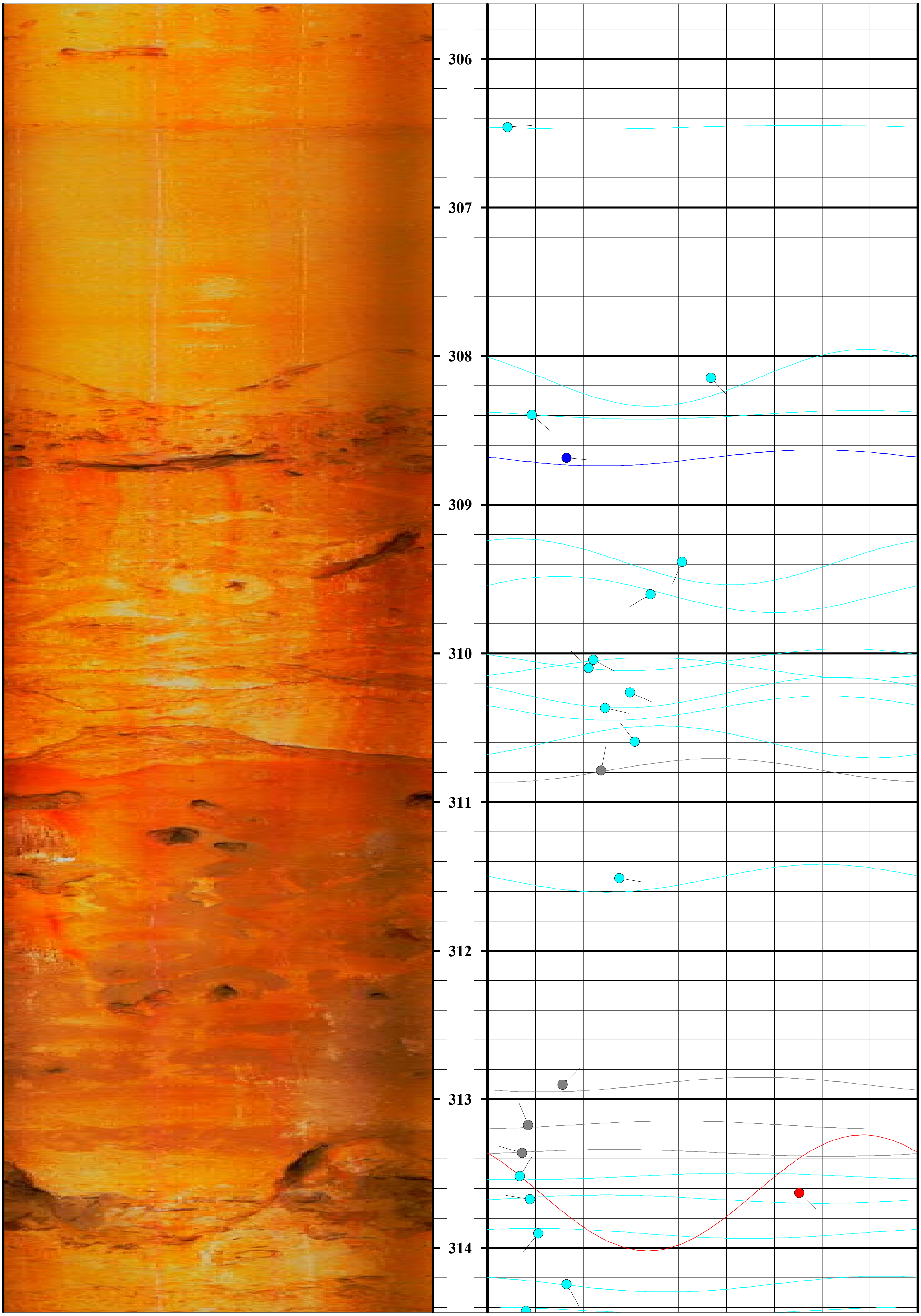
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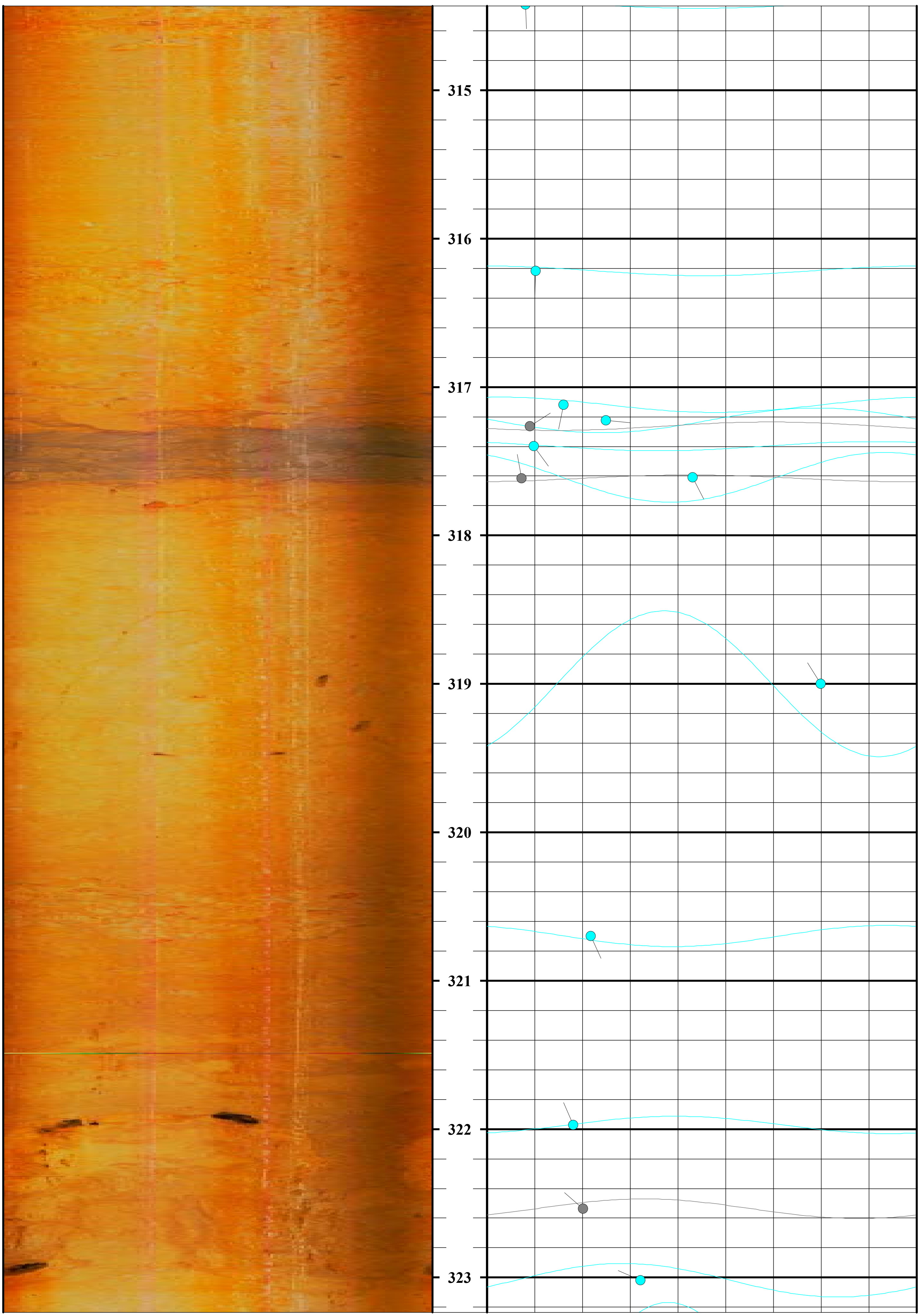

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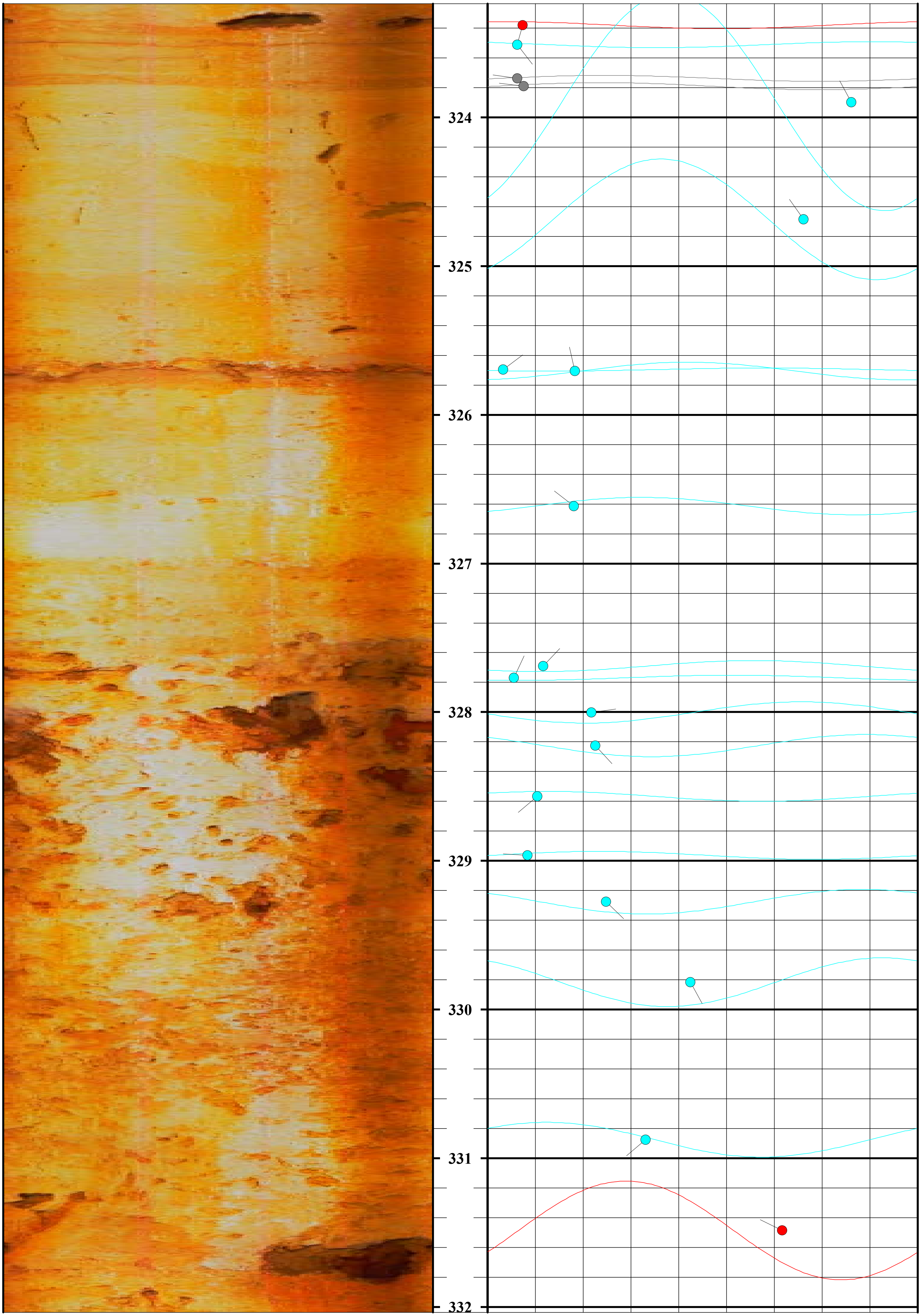
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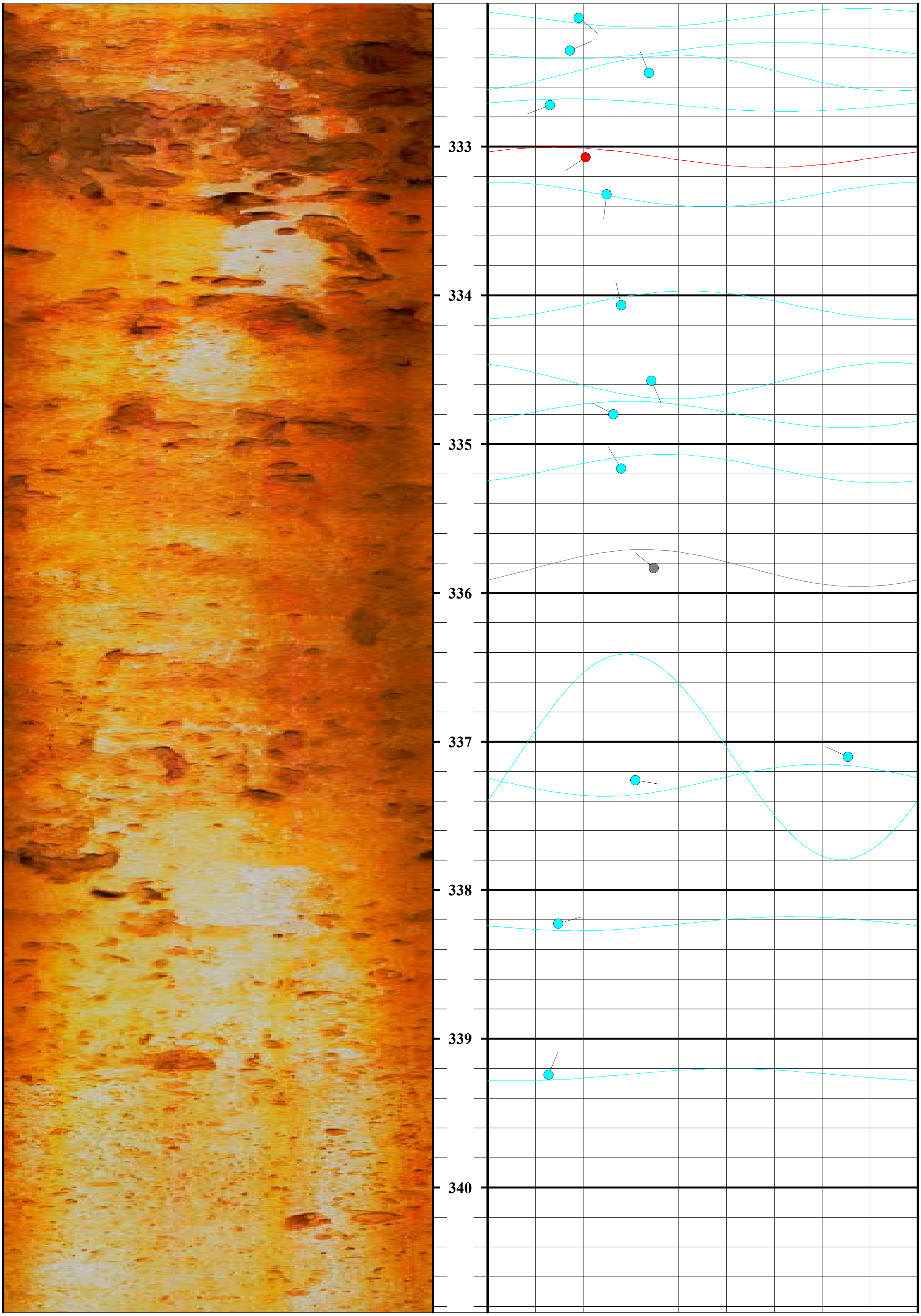

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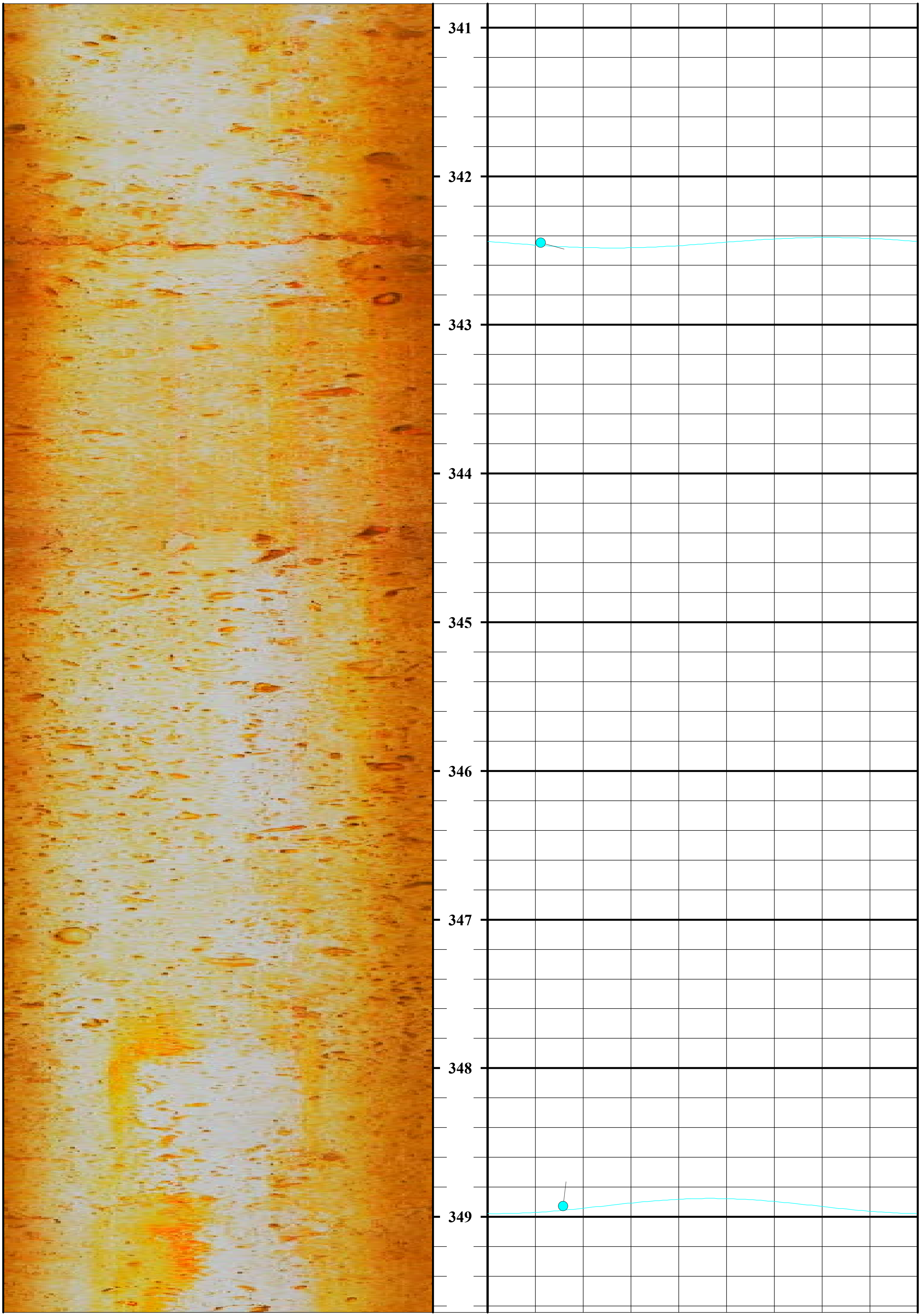
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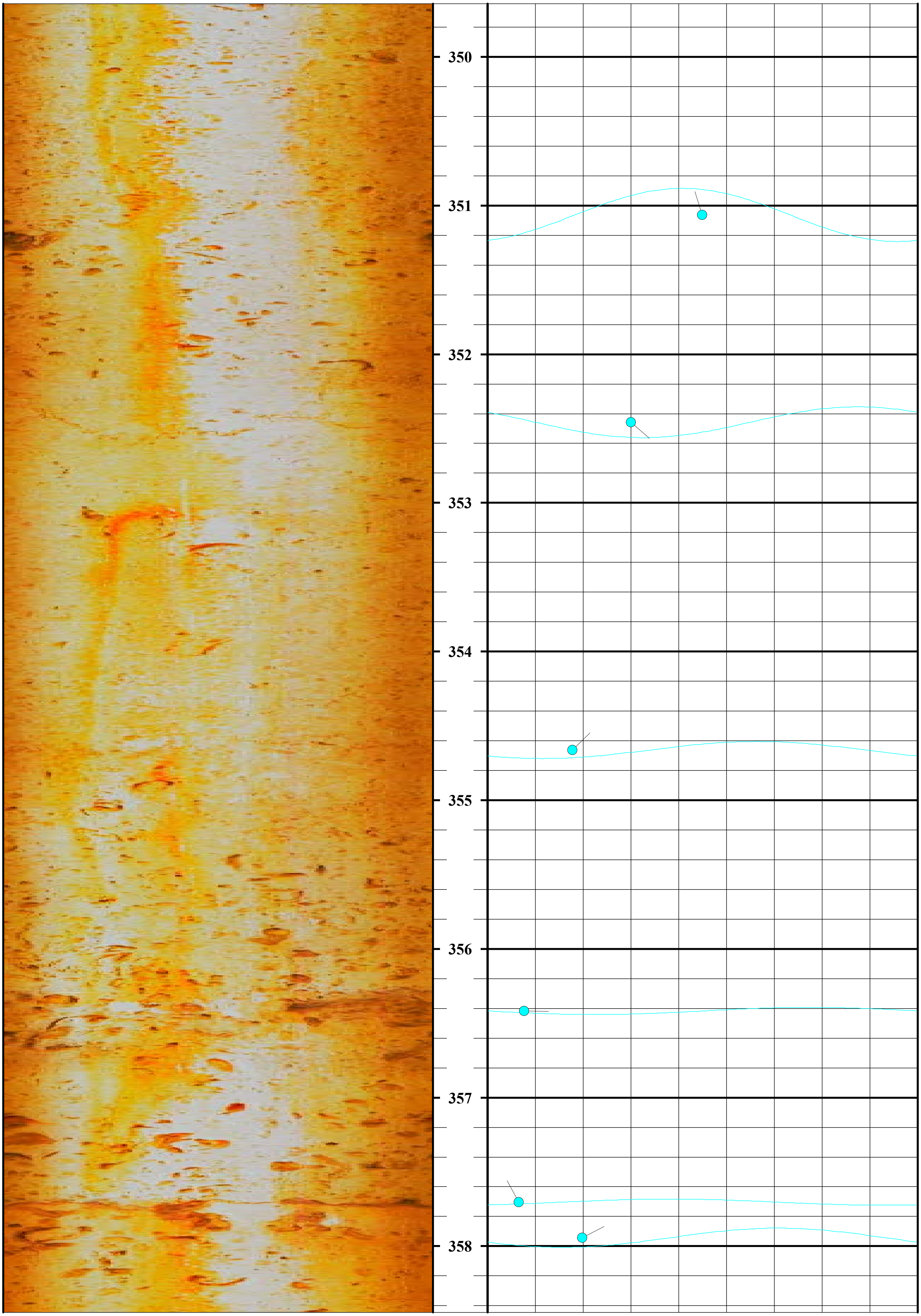
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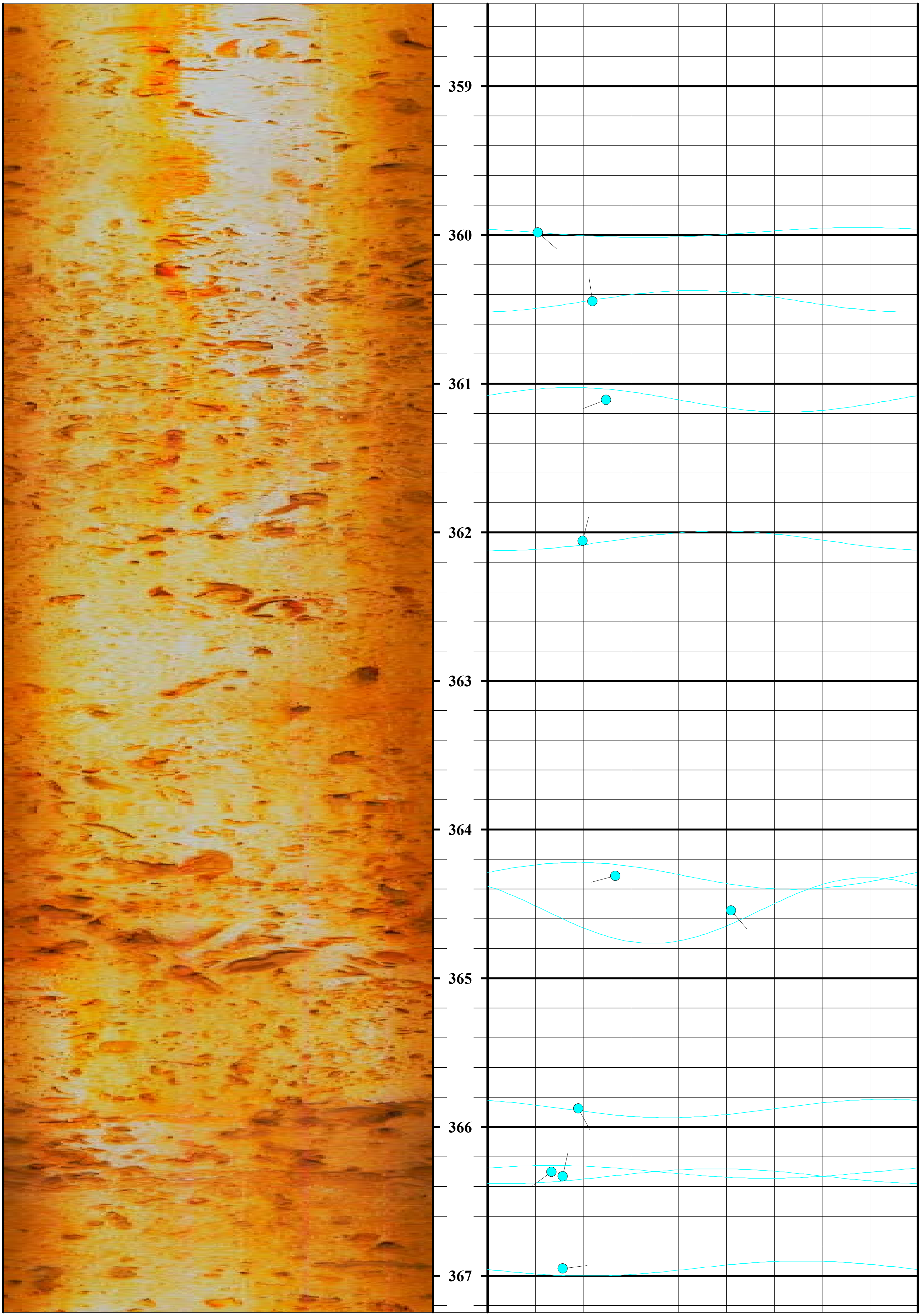
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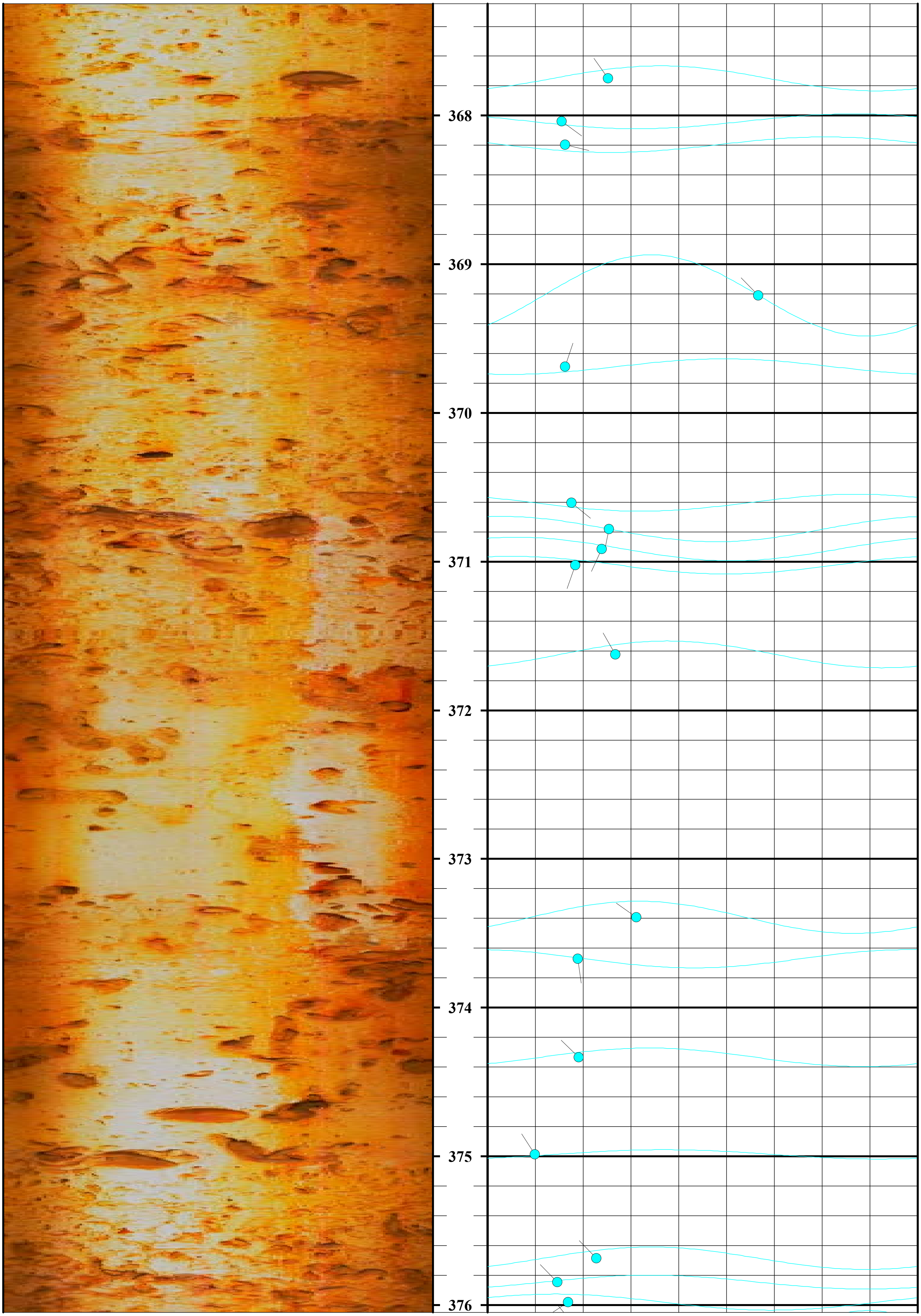
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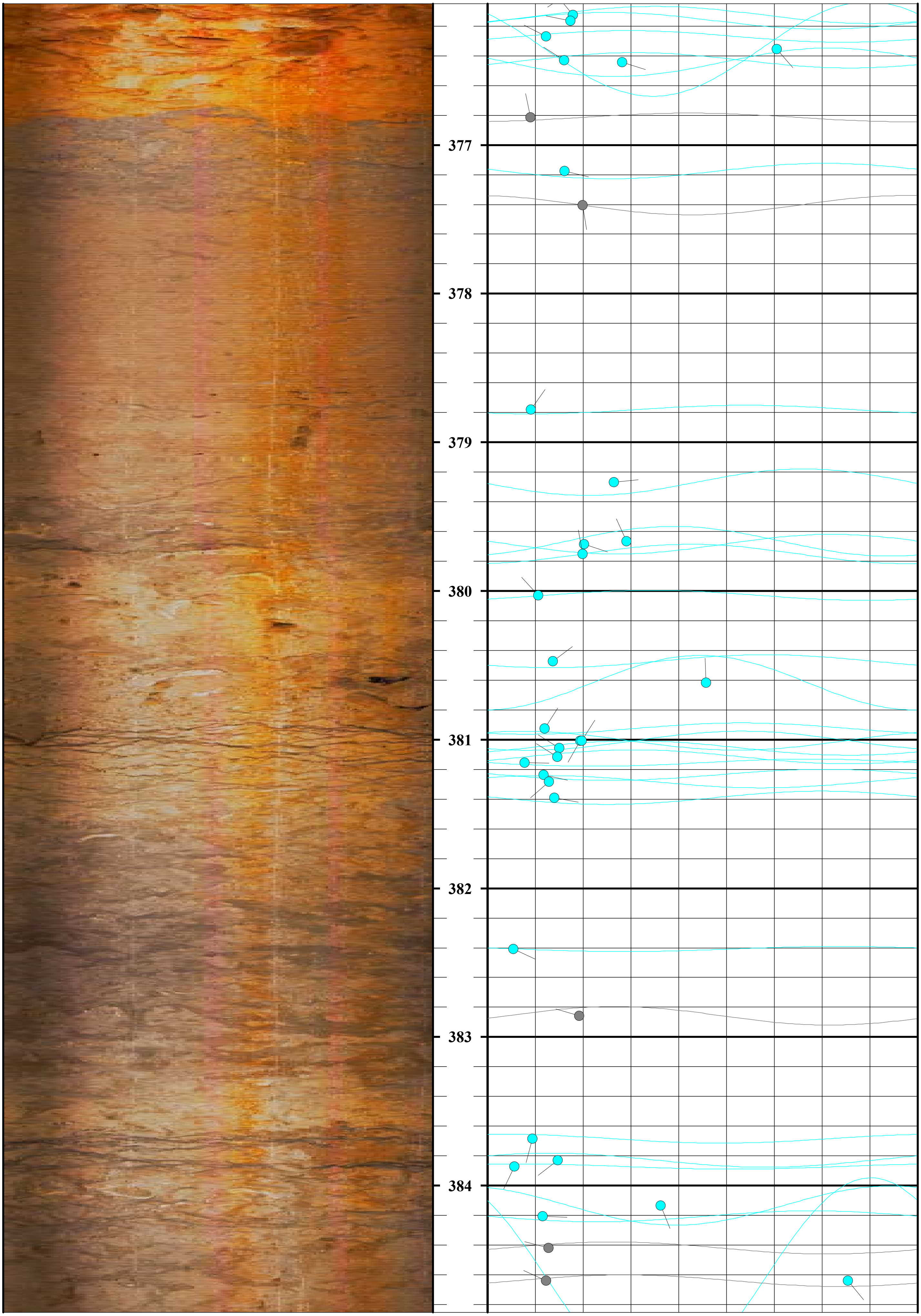
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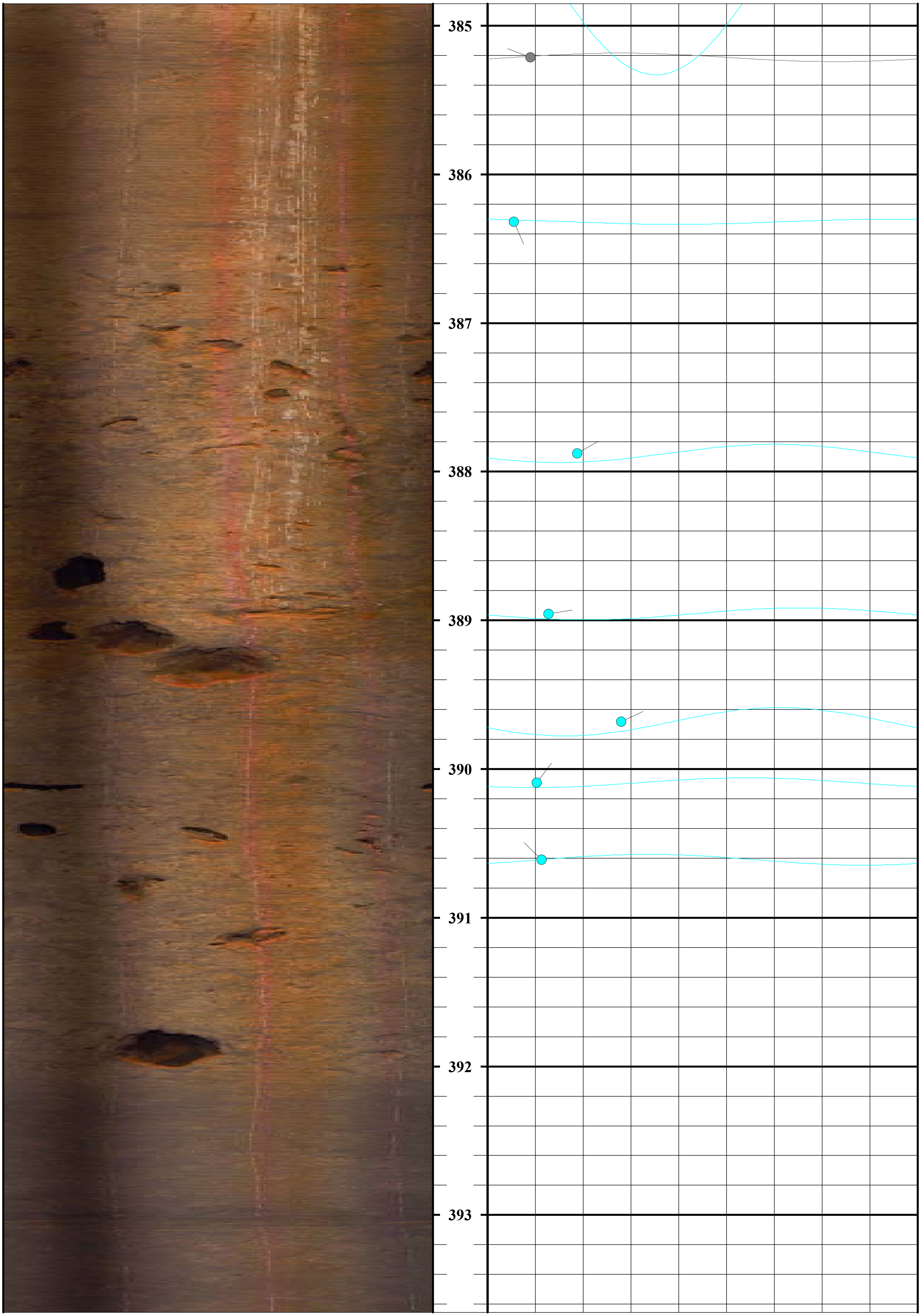
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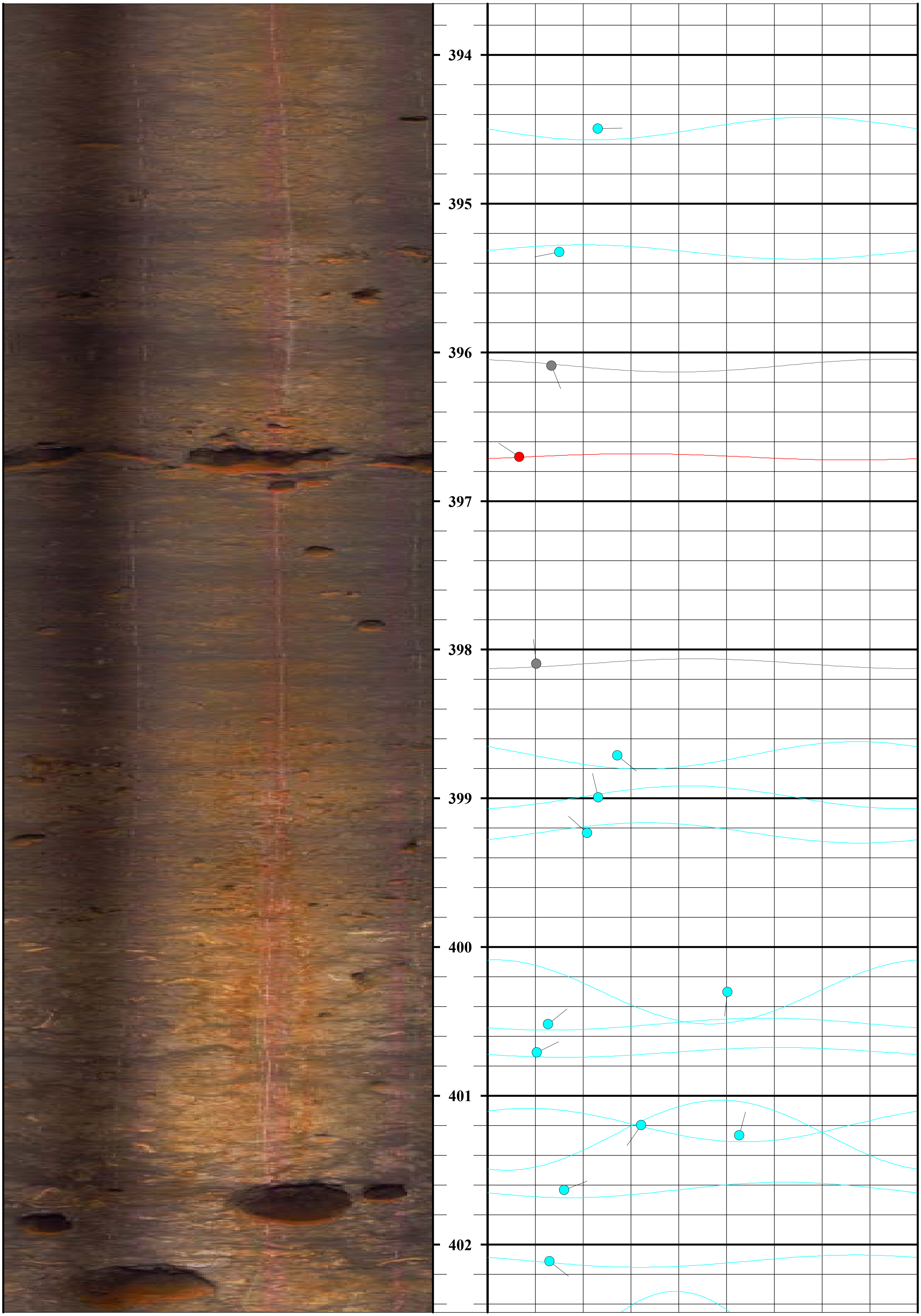

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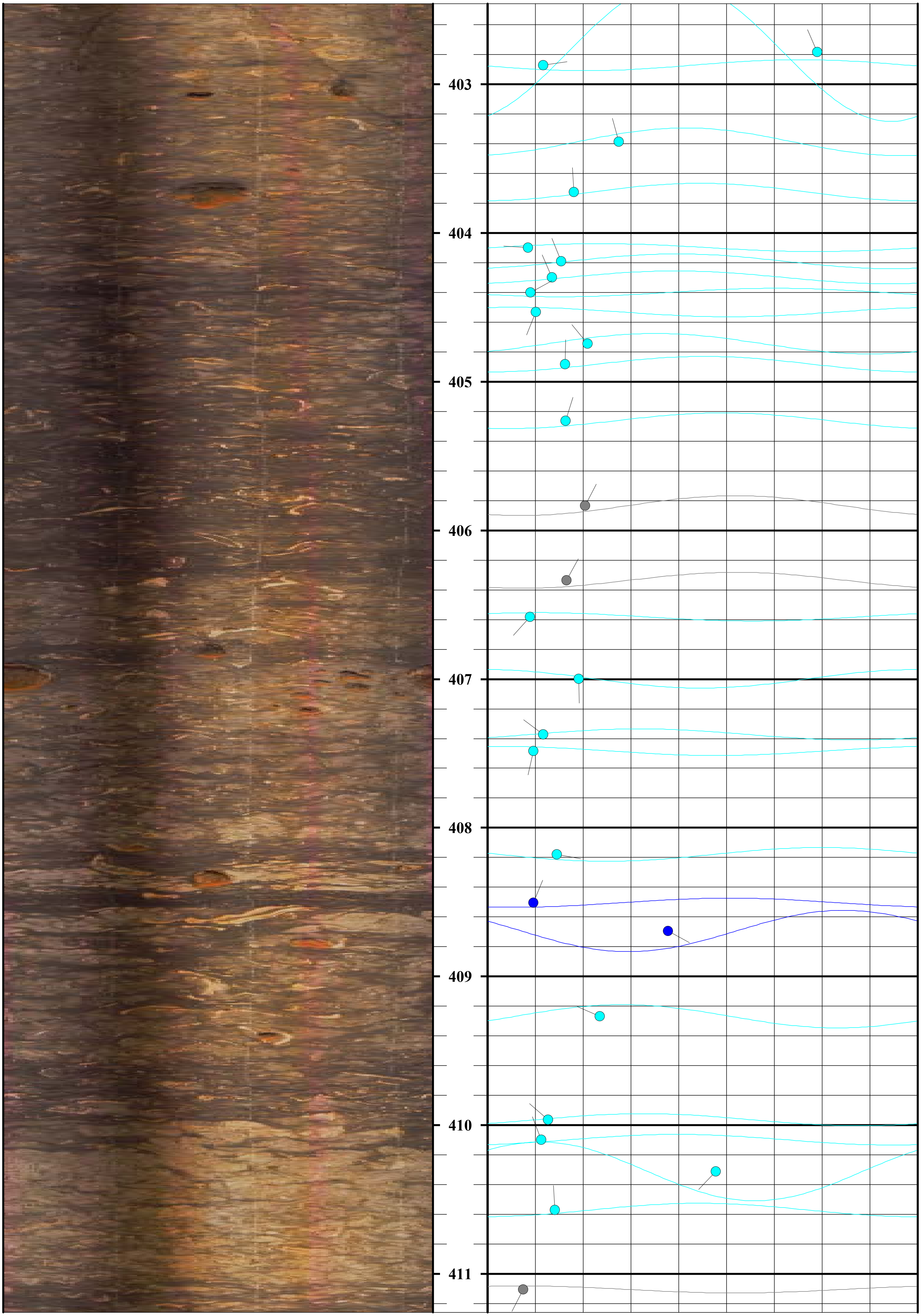
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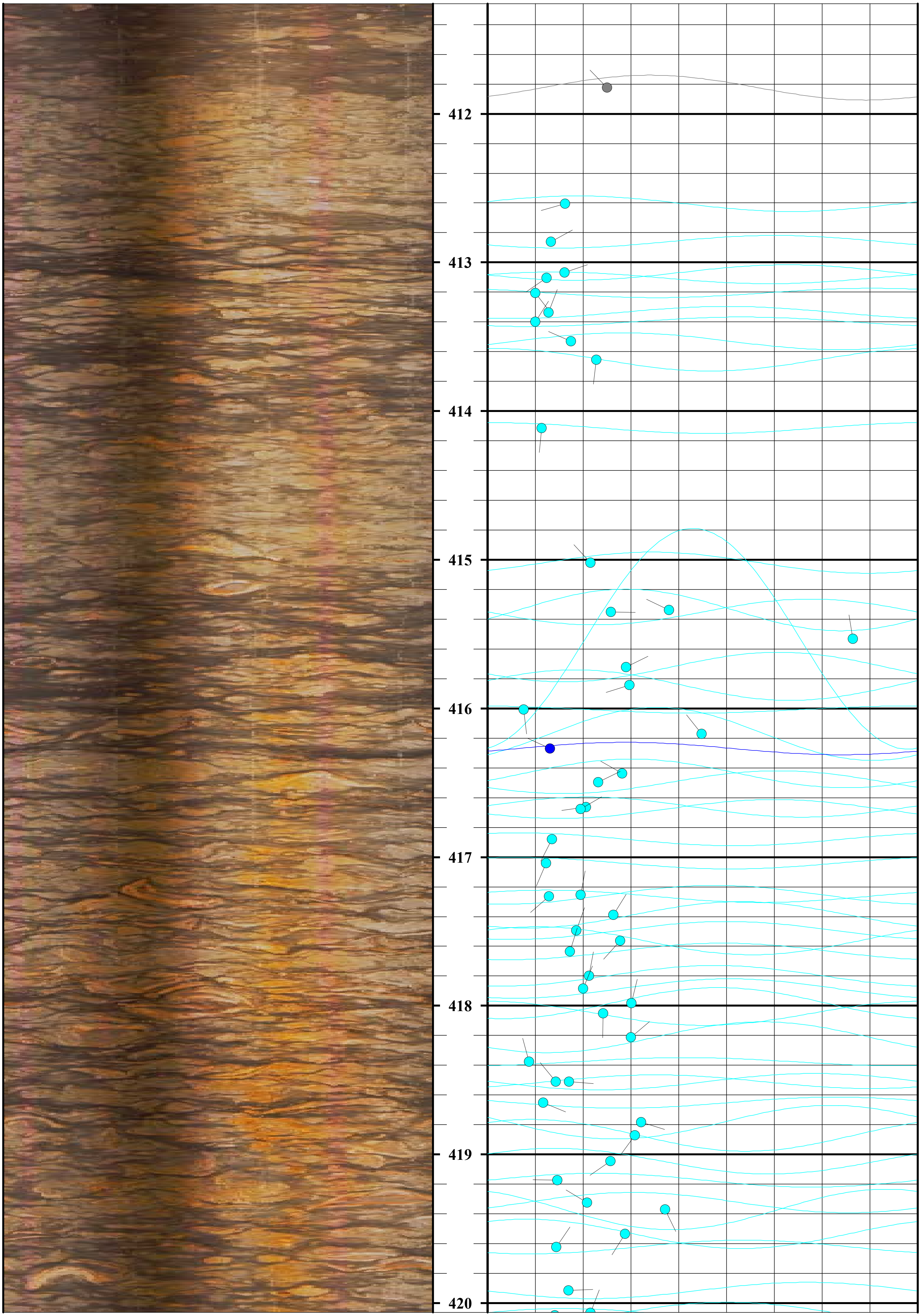
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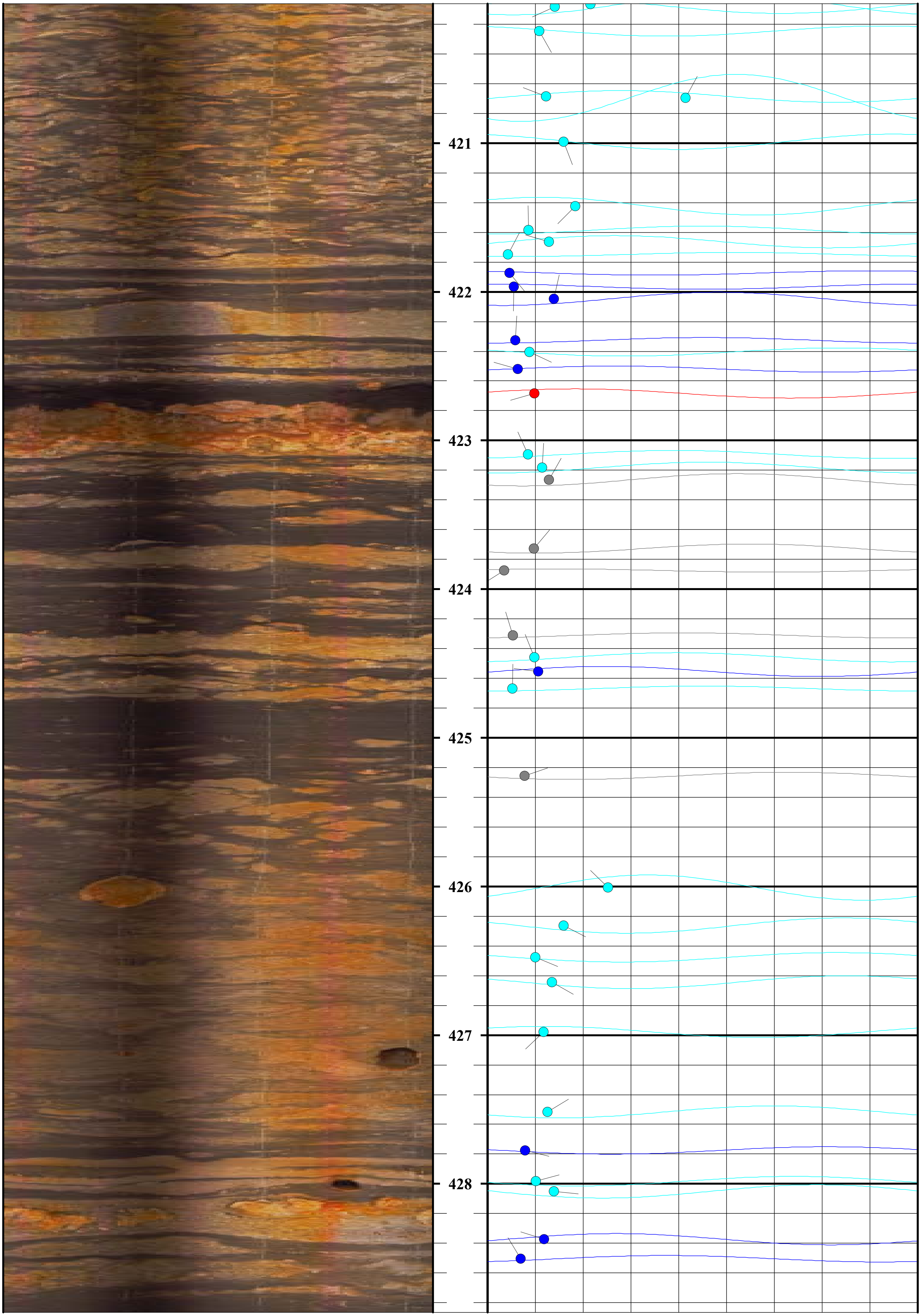
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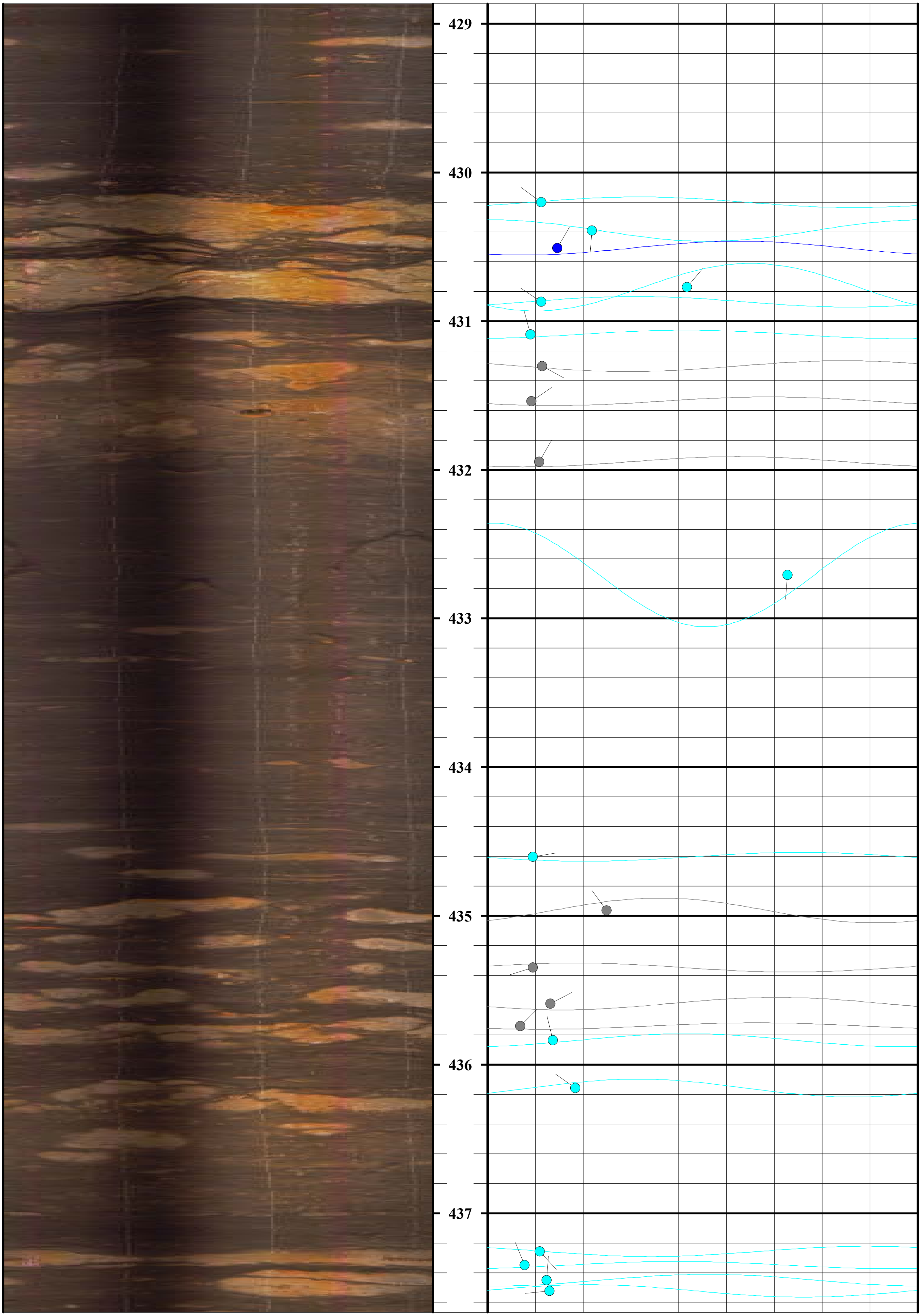
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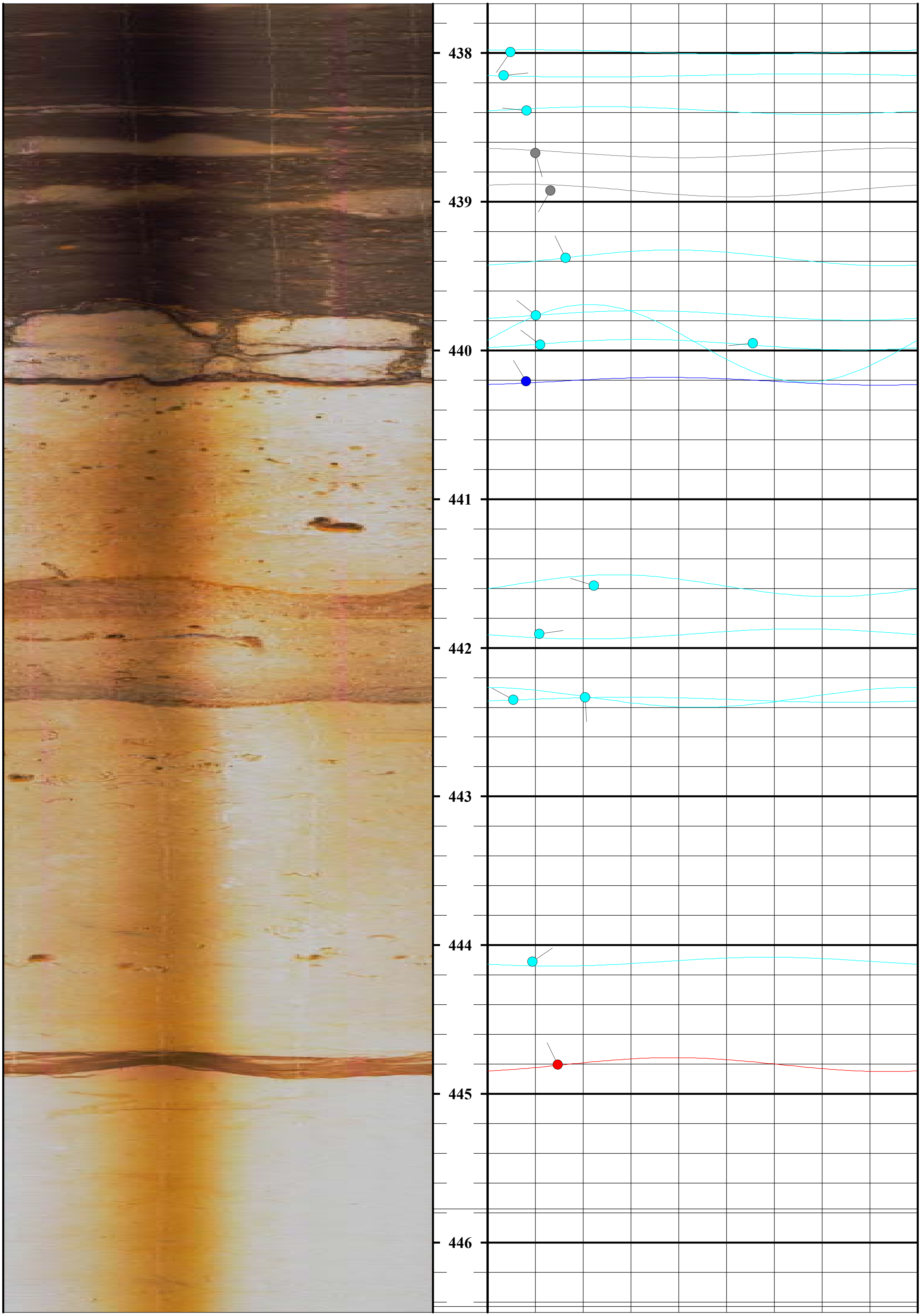
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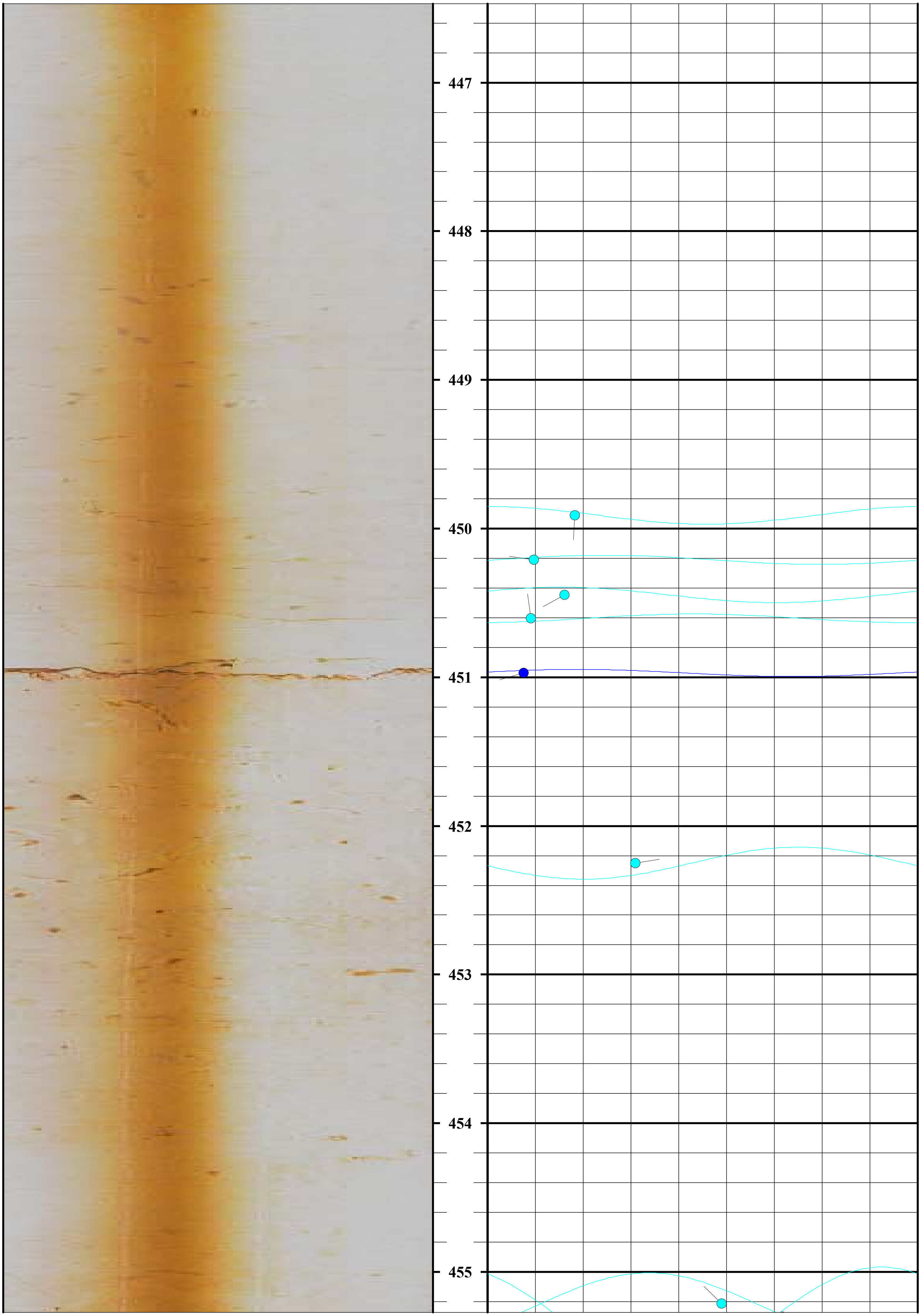
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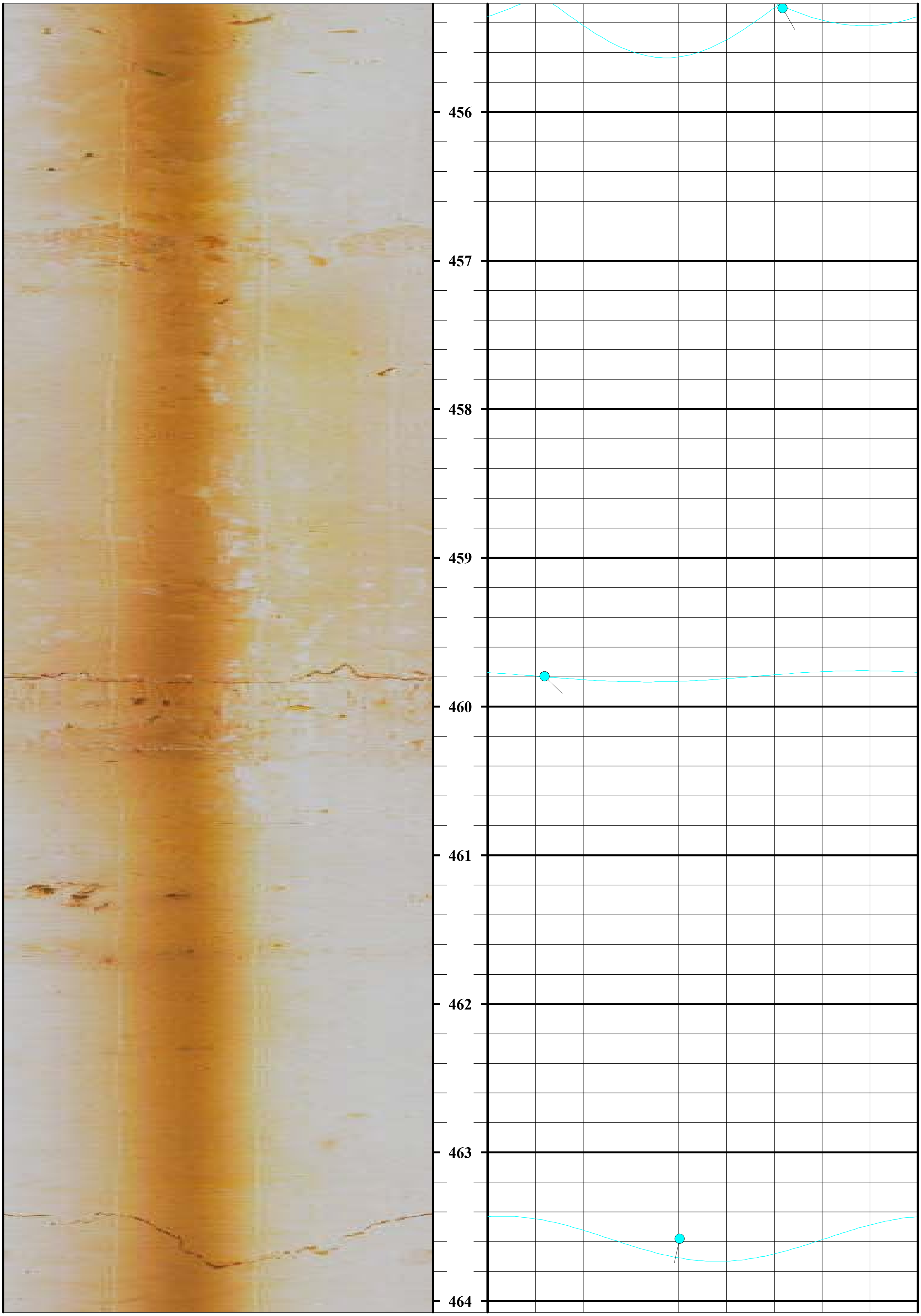
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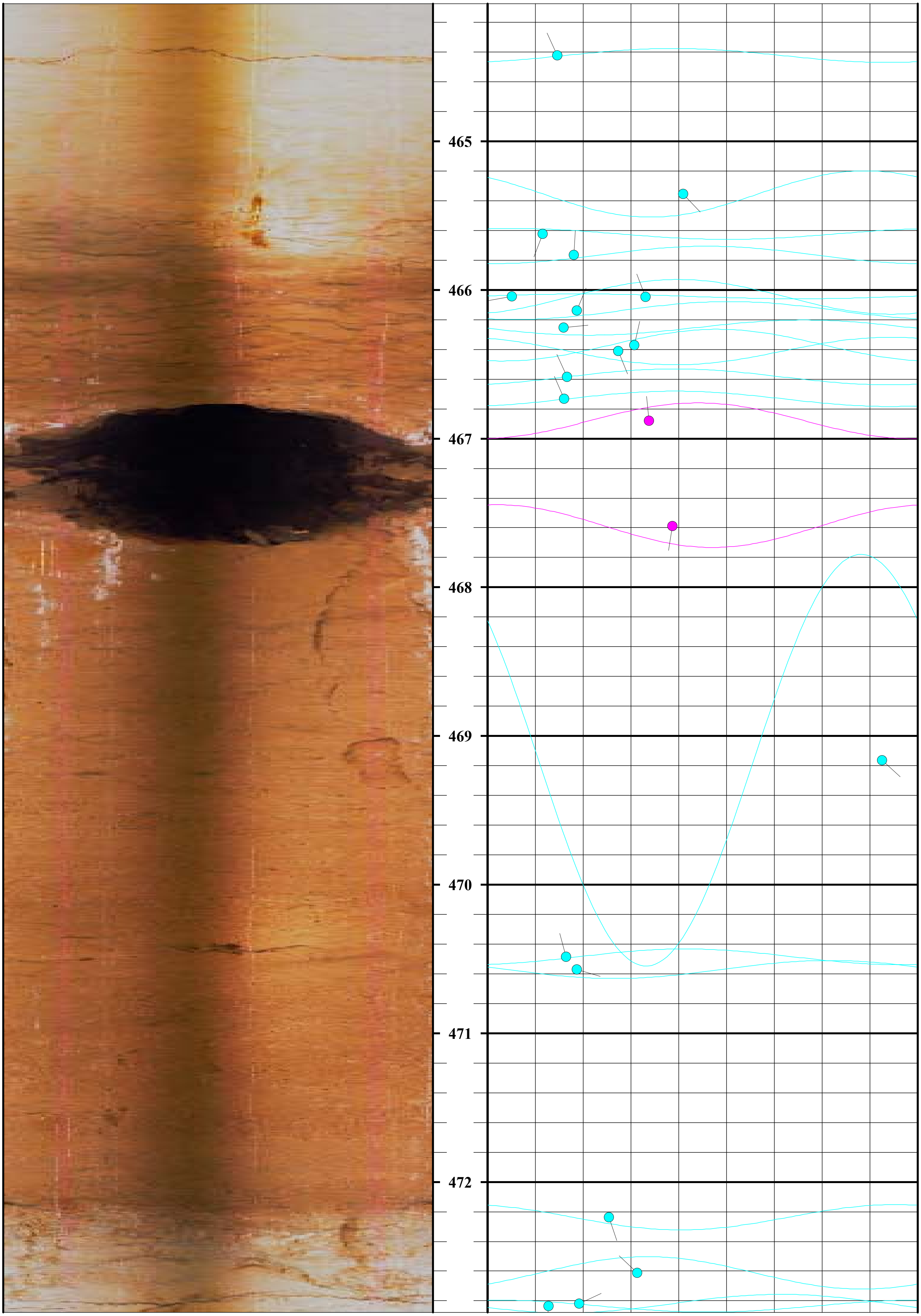
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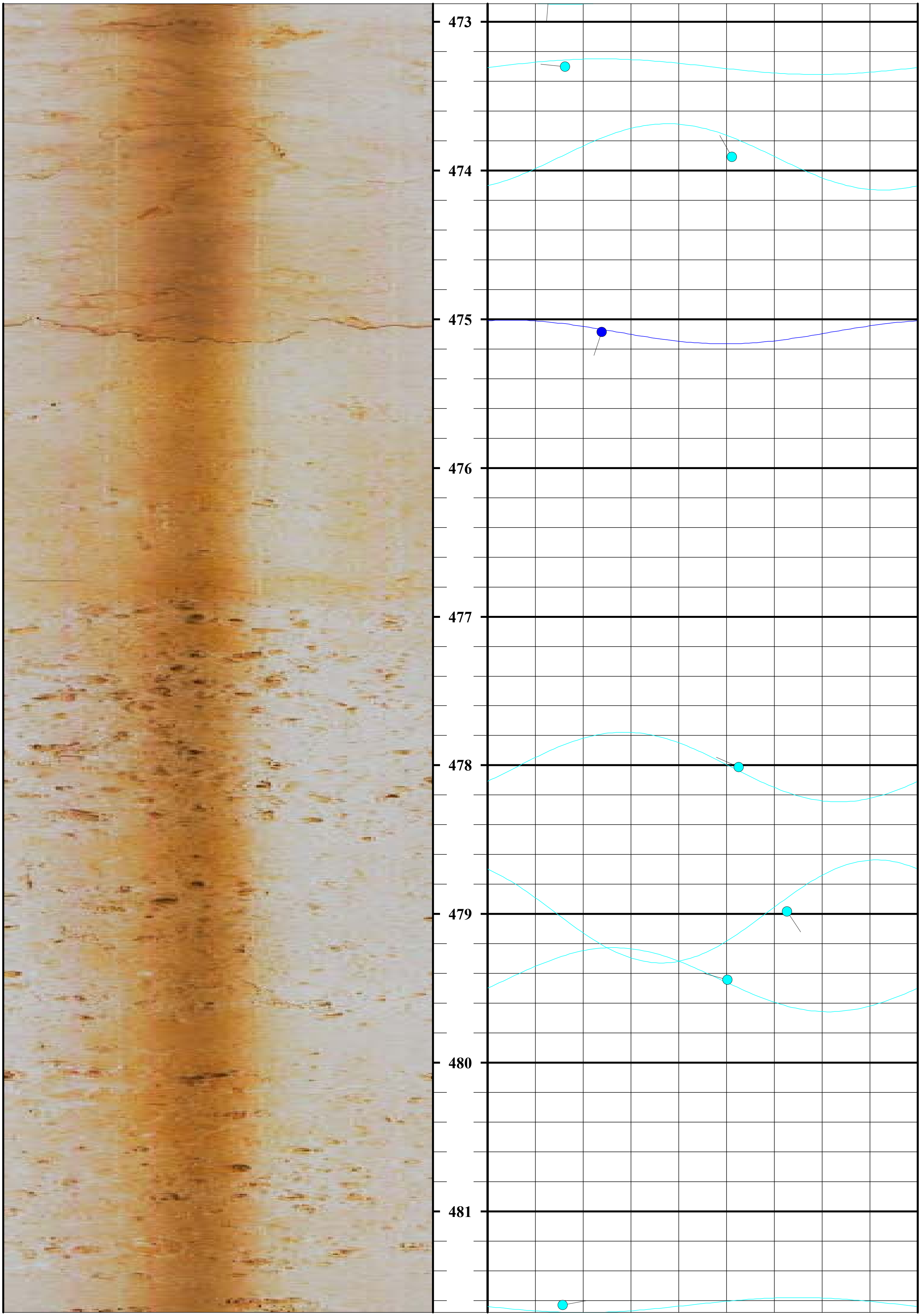
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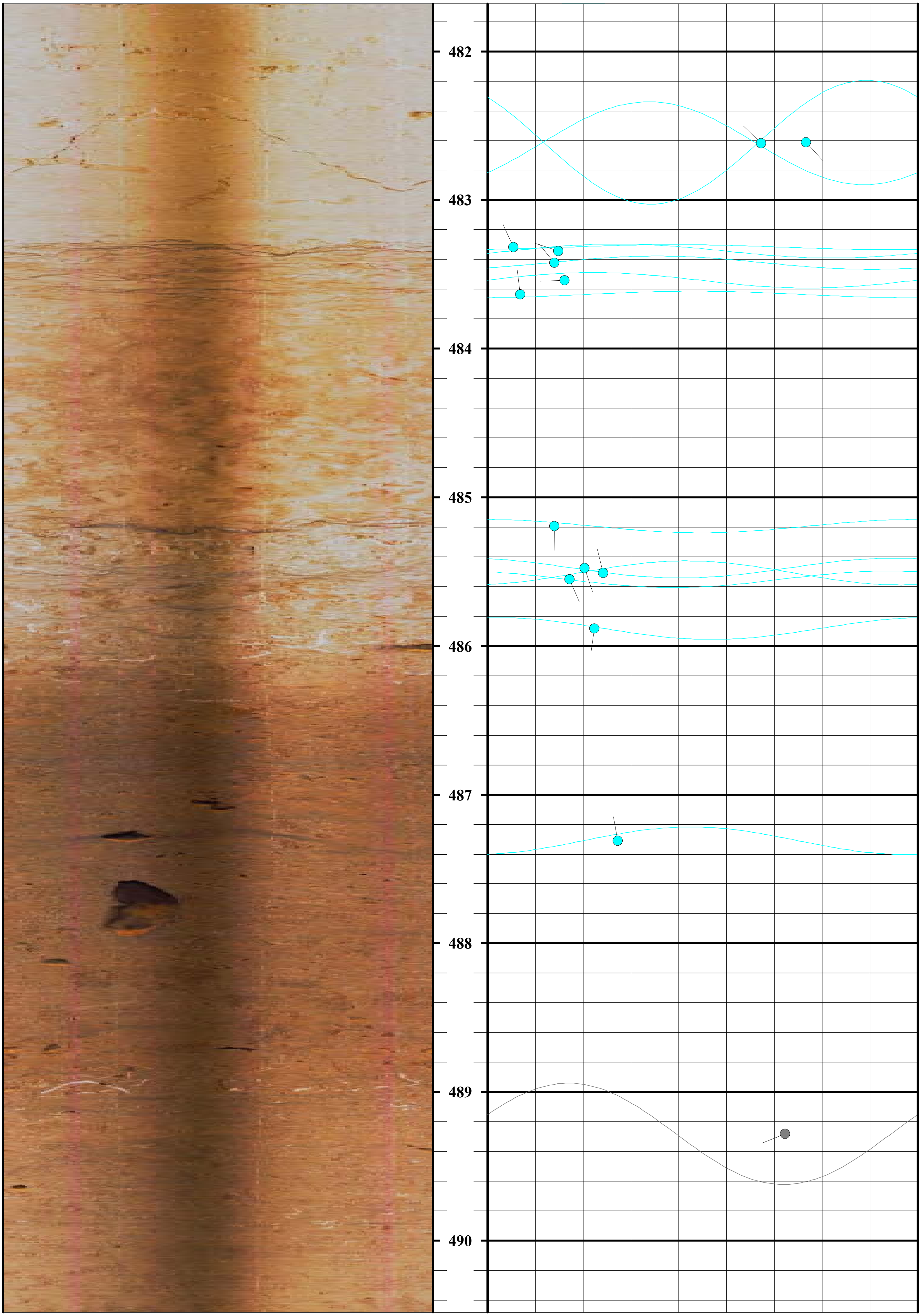
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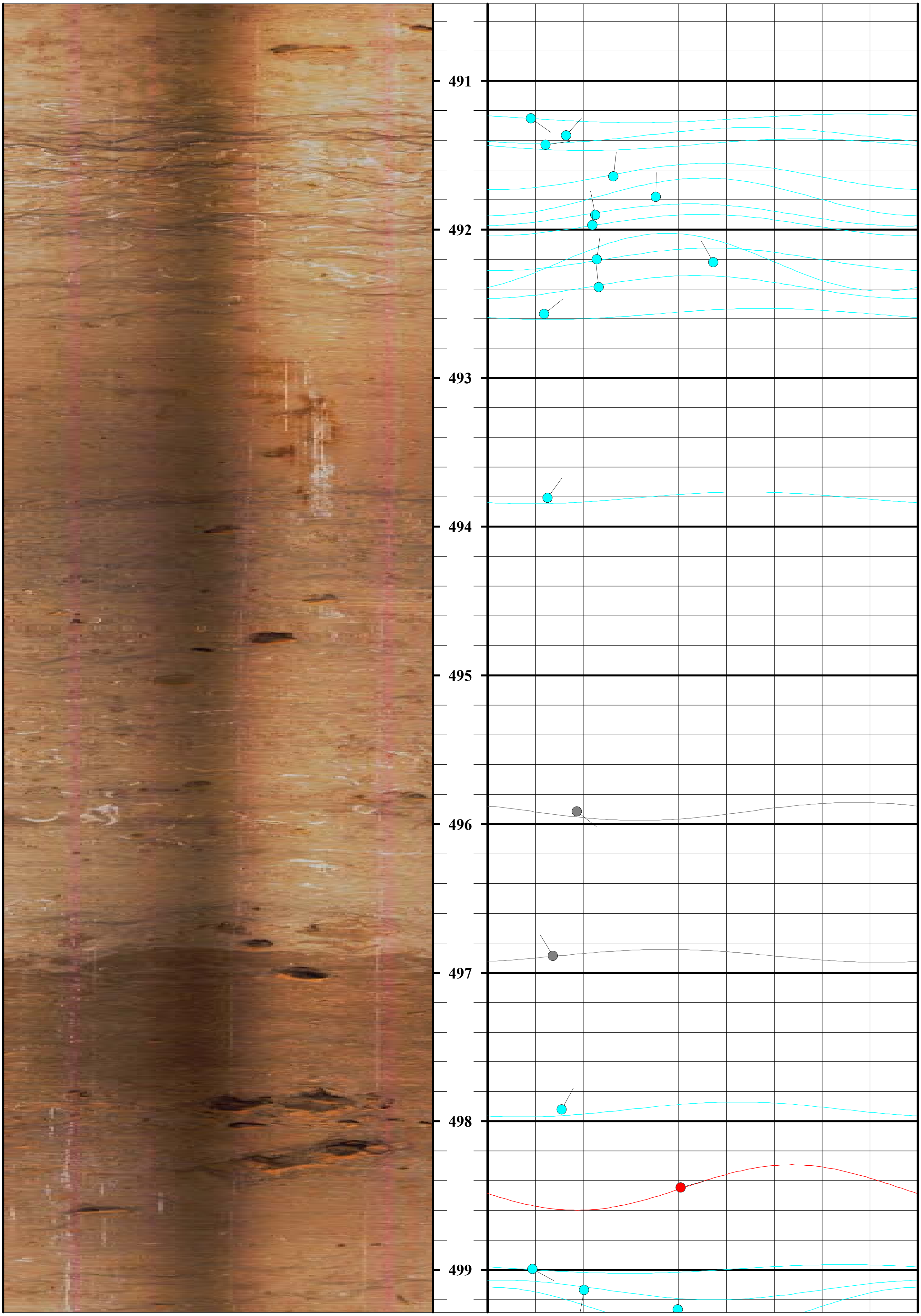
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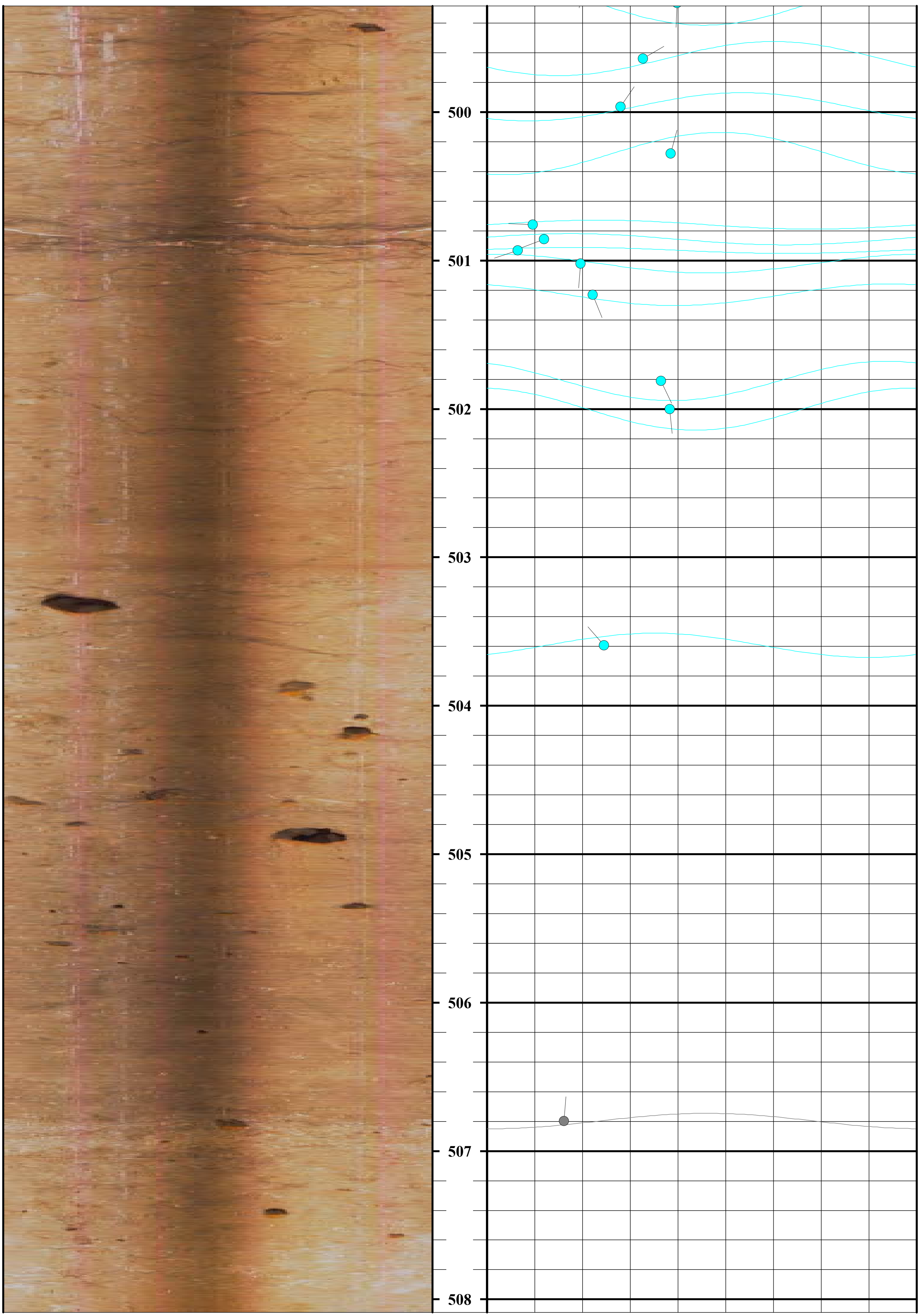
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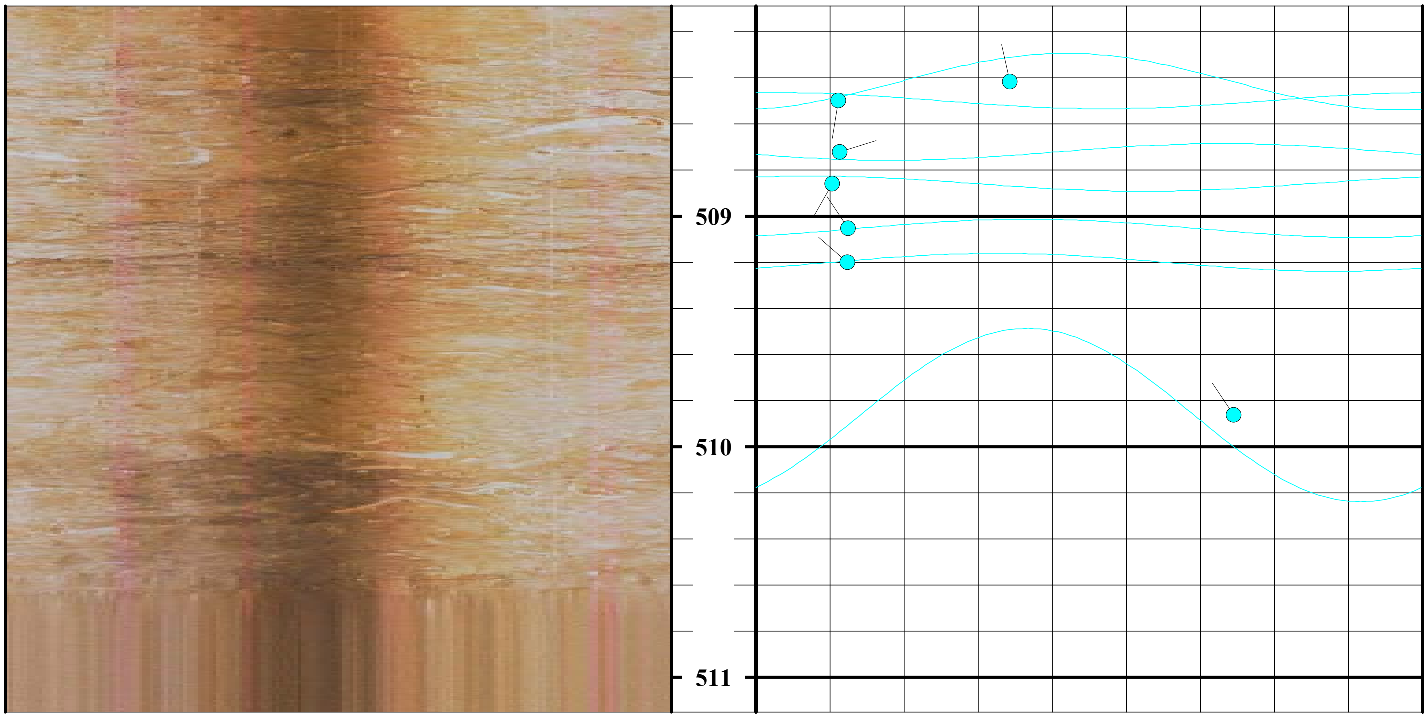
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Orientation Summary Table
Optical Image Features
Camp Stanley Storage Facility, Wellbore: WB-04
Parsons
July 18, 2003

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
1	5.59	18.3	302	61	0
2	5.80	19.0	68	2	0
3	5.82	19.1	109	4	0
4	5.91	19.4	157	5	0
5	5.99	19.7	108	4	1
6	6.08	19.9	104	9	0
7	6.11	20.0	69	6	1
8	6.16	20.2	142	11	1
9	6.32	20.7	78	8	0
10	6.39	21.0	57	4	0
11	6.47	21.2	174	7	1
12	6.52	21.4	351	8	0
13	6.63	21.8	313	1	0
14	6.70	22.0	8	3	0
15	6.76	22.2	145	3	1
16	6.78	22.3	147	3	0
17	6.86	22.5	205	2	0
18	7.01	23.0	156	3	0
19	7.07	23.2	10	2	0
20	7.08	23.2	154	1	0
21	7.21	23.7	314	1	0
22	7.43	24.4	307	8	0
23	7.48	24.5	152	6	0
24	7.98	26.2	144	5	0
25	8.32	27.3	194	3	0
26	8.37	27.5	255	4	0
27	8.57	28.1	206	3	1
28	8.63	28.3	175	7	1
29	9.38	30.8	281	16	0
30	9.59	31.5	114	6	0
31	9.77	32.1	90	9	1
32	9.90	32.5	127	4	0
33	10.00	32.8	153	4	0
34	10.29	33.8	99	6	1
35	10.35	34.0	350	6	1
36	10.39	34.1	341	3	0
37	10.42	34.2	169	7	1
38	10.52	34.5	122	6	1
39	10.59	34.7	65	2	1
40	10.67	35.0	28	3	0
41	10.73	35.2	303	3	1
42	10.77	35.3	322	3	1
43	10.79	35.4	254	2	1
44	10.83	35.5	156	3	1

All directions are with respect to magnetic north.

Orientation Summary Table
Optical Image Features
Camp Stanley Storage Facility, Wellbore: WB-04
Parsons
July 18, 2003

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
45	10.85	35.6	173	2	1
46	10.93	35.9	28	24	1
47	11.03	36.2	26	4	1
48	11.06	36.3	308	5	1
49	11.08	36.4	133	2	0
50	11.13	36.5	4	3	0
51	11.20	36.7	177	2	0
52	11.23	36.9	335	1	0
53	11.27	37.0	310	48	1
54	11.29	37.0	105	4	0
55	11.35	37.2	60	4	0
56	11.42	37.5	51	5	0
57	11.48	37.7	358	4	0
58	11.65	38.2	161	4	0
59	11.79	38.7	301	54	1
60	11.88	39.0	95	14	1
61	12.02	39.4	329	8	0
62	12.14	39.8	342	9	0
63	12.23	40.1	275	12	1
64	12.28	40.3	14	6	1
65	12.29	40.3	245	3	1
66	12.34	40.5	29	7	1
67	12.40	40.7	338	11	0
68	12.48	41.0	46	15	1
69	12.77	41.9	101	31	1
70	12.78	41.9	321	38	2
71	12.95	42.5	118	3	5
72	13.28	43.6	250	17	5
73	13.44	44.1	245	12	1
74	13.47	44.2	347	6	1
75	13.87	45.5	23	16	1
76	13.94	45.7	0	17	1
77	13.97	45.8	325	6	1
78	14.01	46.0	351	13	1
79	14.17	46.5	144	6	1
80	14.24	46.7	178	7	1
81	14.27	46.8	139	7	1
82	14.29	46.9	123	7	1
83	14.30	46.9	158	6	1
84	14.32	47.0	182	4	1
85	14.59	47.9	174	4	1
86	14.70	48.2	212	5	2
87	14.75	48.4	245	6	1
88	14.81	48.6	130	5	1

All directions are with respect to magnetic north.

Orientation Summary Table
Optical Image Features
Camp Stanley Storage Facility, Wellbore: WB-04
Parsons
July 18, 2003

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
89	14.98	49.2	179	4	0
90	15.35	50.4	299	14	1
91	15.46	50.7	138	8	2
92	15.53	51.0	316	6	1
93	15.57	51.1	326	20	1
94	15.65	51.3	339	18	1
95	15.74	51.6	172	9	1
96	15.78	51.8	180	14	1
97	16.18	53.1	58	19	1
98	16.27	53.4	1	14	1
99	16.42	53.9	177	5	0
100	16.42	53.9	272	35	1
101	16.44	54.0	62	13	1
102	16.68	54.7	356	23	0
103	16.90	55.5	173	30	1
104	17.40	57.1	136	32	1
105	17.63	57.9	148	25	2
106	17.68	58.0	346	18	1
107	17.72	58.1	130	25	1
108	17.83	58.5	192	28	1
109	17.86	58.6	336	10	1
110	17.92	58.8	11	6	1
111	17.93	58.8	178	29	1
112	18.07	59.3	261	9	1
113	18.18	59.6	203	7	0
114	18.40	60.4	109	30	1
115	18.45	60.5	131	26	1
116	18.64	61.2	305	6	1
117	18.71	61.4	345	32	0
118	18.77	61.6	196	5	1
119	18.84	61.8	280	9	0
120	19.05	62.5	64	7	2
121	19.14	62.8	324	16	1
122	19.15	62.8	121	22	1
123	19.61	64.4	223	9	1
124	19.71	64.7	144	5	1
125	19.72	64.7	248	25	1
126	19.81	65.0	218	11	0
127	20.03	65.7	78	6	0
128	20.10	66.0	206	4	0
129	20.22	66.3	179	16	1
130	20.24	66.4	200	10	1
131	21.43	70.3	352	11	1
132	22.00	72.2	44	4	0

All directions are with respect to magnetic north.

Orientation Summary Table
Optical Image Features
Camp Stanley Storage Facility, Wellbore: WB-04
Parsons
July 18, 2003

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
133	22.06	72.4	334	88	1
134	22.23	72.9	151	7	0
135	22.68	74.4	284	3	1
136	22.88	75.1	235	5	2
137	22.93	75.2	289	6	1
138	22.98	75.4	235	13	1
139	23.35	76.6	201	9	1
140	23.48	77.1	182	10	1
141	23.65	77.6	13	10	1
142	23.71	77.8	213	15	1
143	23.90	78.4	182	12	0
144	24.25	79.6	48	55	0
145	24.66	80.9	217	20	0
146	24.76	81.2	94	10	0
147	25.02	82.1	2	20	1
148	25.02	82.1	339	88	1
149	25.04	82.1	205	17	1
150	25.14	82.5	104	14	1
151	25.25	82.9	121	14	1
152	25.31	83.1	142	11	1
153	25.41	83.4	150	4	0
154	25.61	84.0	326	46	1
155	25.63	84.1	148	8	1
156	26.03	85.4	41	13	1
157	26.18	85.9	293	7	0
158	26.35	86.5	37	9	0
159	26.66	87.5	333	4	0
160	26.80	87.9	153	7	0
161	27.13	89.0	347	31	1
162	27.25	89.4	40	8	1
163	27.30	89.6	312	13	1
164	27.33	89.7	352	8	0
165	27.43	90.0	309	14	0
166	27.67	90.8	302	10	0
167	28.04	92.0	9	3	0
168	28.24	92.6	128	3	0
169	28.74	94.3	201	5	0
170	29.42	96.5	336	9	0
171	29.57	97.0	302	7	1
172	29.74	97.6	296	6	1
173	29.92	98.2	18	9	1
174	30.01	98.5	167	11	1
175	30.46	99.9	211	29	1
176	30.90	101.4	323	16	1

All directions are with respect to magnetic north.

Orientation Summary Table
Optical Image Features
Camp Stanley Storage Facility, Wellbore: WB-04
Parsons
July 18, 2003

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
177	30.96	101.6	225	10	1
178	31.03	101.8	230	20	1
179	31.06	101.9	186	5	1
180	31.39	103.0	217	18	1
181	31.94	104.8	207	33	1
182	31.98	104.9	281	14	1
183	32.16	105.5	138	26	1
184	32.59	106.9	345	62	2
185	32.82	107.7	156	12	1
186	32.86	107.8	129	6	2
187	33.55	110.1	6	7	1
188	33.70	110.6	19	14	2
189	34.45	113.0	274	4	0
190	34.61	113.5	343	4	0
191	34.68	113.8	327	7	0
192	34.78	114.1	69	4	1
193	34.79	114.2	53	8	2
194	35.03	114.9	294	8	0
195	35.16	115.4	223	3	0
196	35.23	115.6	265	7	1
197	35.27	115.7	348	7	2
198	35.31	115.8	323	3	1
199	35.48	116.4	86	4	0
200	36.03	118.2	194	20	1
201	36.29	119.1	301	1	0
202	36.68	120.3	175	25	1
203	38.25	125.5	266	4	1
204	38.32	125.7	293	11	1
205	38.36	125.9	126	8	1
206	38.40	126.0	229	42	1
207	39.55	129.8	56	9	1
208	39.56	129.8	69	7	1
209	40.11	131.6	249	6	1
210	40.51	132.9	307	8	1
211	40.54	133.0	358	4	1
212	40.57	133.1	360	6	1
213	41.01	134.6	60	23	1
214	41.82	137.2	179	46	1
215	41.97	137.7	157	41	1
216	42.39	139.1	349	35	1
217	43.05	141.2	42	23	3
218	43.18	141.7	85	15	1
219	43.25	141.9	18	15	1
220	44.25	145.2	173	11	1

All directions are with respect to magnetic north.

Orientation Summary Table
Optical Image Features
Camp Stanley Storage Facility, Wellbore: WB-04
Parsons
July 18, 2003

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
221	44.32	145.4	209	6	1
222	44.55	146.2	301	2	0
223	44.63	146.4	209	48	0
224	44.96	147.5	296	5	0
225	45.36	148.8	238	3	0
226	46.20	151.6	321	6	0
227	46.42	152.3	13	3	0
228	46.50	152.6	335	39	1
229	46.64	153.0	314	6	0
230	46.73	153.3	161	2	0
231	46.76	153.4	349	3	0
232	47.11	154.6	331	4	0
233	47.18	154.8	194	5	0
234	47.48	155.8	12	4	1
235	47.55	156.0	298	2	1
236	47.78	156.8	35	4	0
237	48.10	157.8	19	7	1
238	48.41	158.8	59	3	0
239	49.07	161.0	294	13	1
240	49.35	161.9	253	20	0
241	49.64	162.9	33	12	0
242	49.67	163.0	75	8	0
243	49.93	163.8	83	9	0
244	50.07	164.3	65	7	0
245	50.10	164.4	244	8	1
246	50.15	164.6	10	17	1
247	50.25	164.9	130	17	1
248	50.34	165.2	227	9	1
249	50.47	165.6	89	31	1
250	50.58	165.9	25	15	1
251	50.66	166.2	168	17	1
252	50.83	166.8	53	8	1
253	51.51	169.0	165	20	1
254	51.94	170.4	0	12	1
255	51.96	170.5	294	6	1
256	52.04	170.7	70	15	1
257	52.08	170.9	344	8	1
258	52.23	171.4	317	27	1
259	52.41	172.0	259	10	1
260	52.99	173.9	34	14	1
261	53.02	173.9	161	13	1
262	53.03	174.0	346	13	1
263	53.05	174.1	4	17	1
264	53.42	175.3	335	41	1

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Orientation Summary Table
Optical Image Features
Camp Stanley Storage Facility, Wellbore: WB-04
Parsons
July 18, 2003

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
265	53.58	175.8	333	20	1
266	53.80	176.5	354	29	1
267	54.20	177.8	243	53	3
268	54.66	179.3	345	37	1
269	55.26	181.3	28	27	1
270	55.53	182.2	197	35	1
271	55.68	182.7	208	7	0
272	55.81	183.1	43	32	1
273	55.97	183.6	198	6	0
274	56.15	184.2	139	17	0
275	56.26	184.6	108	22	0
276	56.37	184.9	191	8	0
277	56.54	185.5	75	11	0
278	56.67	185.9	356	17	0
279	57.05	187.2	318	2	1
280	57.30	188.0	60	24	1
281	57.48	188.6	356	21	1
282	57.66	189.2	194	16	0
283	58.37	191.5	196	27	0
284	58.67	192.5	338	23	0
285	59.19	194.2	181	42	1
286	59.56	195.4	79	20	1
287	59.83	196.3	232	29	1
288	60.49	198.5	39	41	2
289	60.96	200.0	127	18	0
290	61.07	200.4	346	18	1
291	61.32	201.2	109	10	1
292	61.75	202.6	312	23	1
293	61.97	203.3	342	26	1
294	62.05	203.6	124	5	0
295	62.32	204.5	174	10	0
296	62.52	205.1	22	6	0
297	62.62	205.5	160	9	0
298	62.86	206.2	161	11	0
299	63.07	206.9	147	20	1
300	63.32	207.7	336	19	0
301	63.53	208.4	21	17	1
302	63.70	209.0	326	16	1
303	64.25	210.8	302	7	0
304	64.76	212.5	21	6	1
305	64.82	212.7	23	12	1
306	64.86	212.8	9	16	1
307	65.10	213.6	357	30	1
308	65.28	214.2	300	11	1

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Orientation Summary Table
Optical Image Features
Camp Stanley Storage Facility, Wellbore: WB-04
Parsons
July 18, 2003

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
309	65.33	214.4	118	17	1
310	65.46	214.8	80	10	1
311	65.50	214.9	110	24	1
312	65.61	215.3	360	12	1
313	65.63	215.3	339	21	1
314	65.65	215.4	358	16	1
315	65.68	215.5	137	10	1
316	65.71	215.6	113	17	1
317	65.74	215.7	337	9	1
318	65.75	215.7	313	6	1
319	65.77	215.8	304	9	1
320	65.80	215.9	334	14	1
321	65.86	216.1	66	21	1
322	65.98	216.5	47	19	1
323	65.98	216.5	180	52	1
324	66.00	216.5	359	16	1
325	66.09	216.8	300	12	1
326	66.15	217.0	258	33	1
327	66.19	217.2	288	13	1
328	66.35	217.7	242	14	1
329	66.43	217.9	179	39	1
330	66.43	217.9	73	24	1
331	66.65	218.7	18	64	1
332	66.92	219.6	17	22	1
333	67.06	220.0	116	14	1
334	67.16	220.4	73	17	0
335	67.39	221.1	28	23	0
336	67.99	223.1	351	18	0
337	68.16	223.6	356	16	0
338	68.88	226.0	147	85	1
339	69.52	228.1	22	48	2
340	69.53	228.1	68	20	1
341	69.60	228.4	105	28	1
342	69.61	228.4	21	14	1
343	69.67	228.6	345	16	1
344	69.70	228.7	334	23	1
345	69.74	228.8	331	10	1
346	69.79	229.0	203	7	1
347	69.90	229.3	44	19	1
348	69.98	229.6	356	11	1
349	70.02	229.7	76	9	1
350	70.05	229.8	59	12	1
351	70.12	230.1	64	6	1
352	70.18	230.3	243	5	1

All directions are with respect to magnetic north.

Orientation Summary Table
Optical Image Features
Camp Stanley Storage Facility, Wellbore: WB-04
Parsons
July 18, 2003

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
353	70.18	230.3	50	14	0
354	70.24	230.5	207	8	1
355	70.33	230.7	63	30	1
356	70.66	231.8	149	27	1
357	70.72	232.0	98	21	1
358	70.79	232.2	229	29	1
359	70.79	232.2	63	38	1
360	70.99	232.9	112	22	1
361	71.01	233.0	6	44	1
362	71.32	234.0	206	13	0
363	71.51	234.6	155	11	0
364	71.73	235.3	134	4	1
365	72.06	236.4	32	20	1
366	72.31	237.3	195	29	1
367	73.11	239.9	355	36	1
368	73.36	240.7	318	30	1
369	73.37	240.7	319	13	1
370	73.47	241.0	112	8	1
371	73.49	241.1	68	6	1
372	73.49	241.1	243	5	1
373	73.54	241.3	121	22	1
374	73.62	241.5	315	37	1
375	73.68	241.7	90	7	1
376	73.70	241.8	85	9	1
377	73.89	242.4	6	5	1
378	74.03	242.9	2	53	1
379	74.06	243.0	151	12	0
380	74.12	243.2	240	6	0
381	74.22	243.5	181	9	0
382	74.79	245.4	122	19	1
383	75.40	247.4	291	13	1
384	75.78	248.6	230	14	1
385	75.79	248.7	262	9	1
386	75.81	248.7	256	13	1
387	76.12	249.8	337	35	1
388	76.15	249.8	301	8	1
389	76.84	252.1	12	24	1
390	76.89	252.3	49	14	1
391	77.01	252.7	65	20	1
392	77.24	253.4	176	20	1
393	77.35	253.8	136	42	1
394	77.44	254.1	151	37	2
395	77.57	254.5	14	25	1
396	77.61	254.6	60	8	1

All directions are with respect to magnetic north.

Orientation Summary Table
Optical Image Features
Camp Stanley Storage Facility, Wellbore: WB-04
Parsons
July 18, 2003

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
397	77.84	255.4	18	54	1
398	77.85	255.4	207	44	0
399	77.95	255.8	231	14	1
400	77.99	255.9	226	23	1
401	78.01	256.0	227	28	1
402	78.08	256.2	352	19	1
403	78.11	256.3	352	6	0
404	78.18	256.5	161	30	1
405	78.39	257.2	32	11	0
406	78.49	257.5	23	32	0
407	78.55	257.7	341	8	1
408	78.59	257.8	118	9	0
409	78.62	258.0	13	47	1
410	78.67	258.1	1	21	1
411	78.68	258.1	156	26	1
412	78.75	258.4	87	20	0
413	78.82	258.6	340	33	2
414	78.90	258.9	9	11	0
415	78.97	259.1	89	13	1
416	79.07	259.4	359	13	1
417	79.44	260.6	145	24	1
418	79.48	260.8	126	15	1
419	79.50	260.8	174	8	1
420	79.52	260.9	160	8	1
421	79.57	261.1	55	9	1
422	79.64	261.3	49	16	1
423	79.69	261.4	56	12	1
424	79.72	261.6	330	6	1
425	79.74	261.6	260	8	1
426	79.88	262.1	55	26	1
427	79.90	262.1	236	25	1
428	79.96	262.3	339	17	1
429	80.00	262.5	194	17	1
430	80.02	262.5	62	12	1
431	80.07	262.7	141	18	1
432	80.13	262.9	236	20	1
433	80.19	263.1	242	35	1
434	80.76	265.0	341	25	1
435	80.84	265.2	155	25	1
436	80.88	265.4	175	35	1
437	80.89	265.4	0	7	0
438	80.93	265.5	99	16	1
439	81.02	265.8	83	12	1
440	81.04	265.9	164	43	1

All directions are with respect to magnetic north.

Orientation Summary Table
Optical Image Features
Camp Stanley Storage Facility, Wellbore: WB-04
Parsons
July 18, 2003

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
441	81.07	266.0	149	11	1
442	81.10	266.1	155	19	1
443	81.15	266.2	153	13	1
444	81.20	266.4	233	7	1
445	81.23	266.5	178	34	1
446	81.26	266.6	357	13	1
447	81.35	266.9	186	37	0
448	81.57	267.6	265	8	1
449	81.59	267.7	100	14	1
450	81.61	267.8	159	21	1
451	81.63	267.8	161	11	1
452	81.66	267.9	4	59	1
453	81.69	268.0	148	25	1
454	81.81	268.4	24	43	1
455	82.97	272.2	192	23	1
456	83.08	272.6	205	29	1
457	83.08	272.6	34	33	1
458	83.46	273.8	105	16	1
459	83.63	274.4	142	12	0
460	83.78	274.9	307	39	1
461	84.37	276.8	70	17	1
462	84.38	276.9	52	16	1
463	84.63	277.7	185	32	0
464	84.84	278.4	137	65	3
465	85.18	279.5	98	13	1
466	85.25	279.7	108	19	1
467	85.33	280.0	290	35	1
468	85.62	280.9	91	19	1
469	85.76	281.4	224	33	0
470	85.86	281.7	68	19	1
471	86.02	282.2	92	27	1
472	86.03	282.2	287	19	1
473	86.14	282.6	110	37	1
474	86.72	284.5	193	12	0
475	86.79	284.7	237	12	0
476	86.85	284.9	118	6	0
477	87.18	286.0	175	10	1
478	87.38	286.7	118	26	1
479	87.45	286.9	115	9	1
480	87.50	287.1	144	37	0
481	87.65	287.6	10	5	0
482	87.74	287.9	37	20	1
483	87.82	288.1	285	10	0
484	88.12	289.1	314	8	1

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Orientation Summary Table
Optical Image Features
Camp Stanley Storage Facility, Wellbore: WB-04
Parsons
July 18, 2003

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
485	88.25	289.6	323	26	1
486	88.35	289.9	139	30	0
487	88.45	290.2	355	10	1
488	88.49	290.3	171	31	1
489	88.64	290.8	24	9	0
490	88.71	291.1	32	13	0
491	88.86	291.5	308	7	0
492	89.35	293.1	243	14	1
493	89.61	294.0	114	36	1
494	89.67	294.2	78	25	1
495	89.69	294.3	20	21	1
496	89.77	294.5	70	27	1
497	89.88	294.9	125	35	1
498	89.99	295.2	336	11	0
499	90.05	295.4	37	26	0
500	90.16	295.8	19	8	0
501	90.21	296.0	315	17	0
502	90.37	296.5	299	12	0
503	90.42	296.7	297	10	0
504	90.48	296.9	297	27	0
505	90.63	297.3	142	34	1
506	90.97	298.5	344	39	0
507	91.02	298.6	151	54	1
508	91.12	299.0	128	34	1
509	91.12	299.0	354	9	1
510	91.15	299.0	335	9	1
511	91.17	299.1	331	6	1
512	91.25	299.4	329	17	0
513	91.74	301.0	300	21	1
514	91.90	301.5	128	37	1
515	92.54	303.6	351	7	1
516	92.56	303.7	60	7	1
517	92.87	304.7	147	43	1
518	93.41	306.5	85	4	1
519	93.92	308.2	137	47	1
520	94.00	308.4	131	9	1
521	94.09	308.7	95	17	2
522	94.30	309.4	203	41	1
523	94.37	309.6	240	34	1
524	94.50	310.0	119	22	1
525	94.52	310.1	315	21	1
526	94.57	310.3	112	30	1
527	94.60	310.4	103	25	1
528	94.67	310.6	323	31	1

All directions are with respect to magnetic north.

Orientation Summary Table
Optical Image Features
Camp Stanley Storage Facility, Wellbore: WB-04
Parsons
July 18, 2003

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
529	94.73	310.8	10	24	0
530	94.95	311.5	99	28	1
531	95.37	312.9	45	16	0
532	95.45	313.2	339	9	0
533	95.51	313.4	286	7	0
534	95.56	313.5	32	7	1
535	95.59	313.6	134	65	3
536	95.61	313.7	279	9	1
537	95.68	313.9	219	11	1
538	95.78	314.2	150	17	1
539	95.84	314.4	177	8	1
540	96.38	316.2	182	10	1
541	96.66	317.1	191	16	1
542	96.69	317.2	96	25	1
543	96.70	317.3	57	9	0
544	96.74	317.4	144	10	1
545	96.81	317.6	153	43	1
546	96.81	317.6	350	7	0
547	97.23	319.0	329	70	1
548	97.75	320.7	155	22	1
549	98.14	322.0	337	18	1
550	98.31	322.5	311	20	0
551	98.46	323.0	294	32	1
552	98.57	323.4	195	7	3
553	98.61	323.5	142	6	1
554	98.68	323.7	278	6	0
555	98.69	323.8	276	8	0
556	98.72	323.9	332	76	1
557	98.96	324.7	325	66	1
558	99.27	325.7	52	3	1
559	99.28	325.7	347	18	1
560	99.55	326.6	308	18	1
561	99.88	327.7	43	12	1
562	99.90	327.8	25	6	1
563	99.97	328.0	82	22	1
564	100.04	328.2	137	23	1
565	100.15	328.6	230	10	1
566	100.27	329.0	273	8	1
567	100.36	329.3	133	25	1
568	100.53	329.8	151	42	1
569	100.85	330.9	230	33	1
570	101.04	331.5	296	62	3
571	101.23	332.1	129	19	1
572	101.30	332.4	66	17	1

All directions are with respect to magnetic north.

Orientation Summary Table
Optical Image Features
Camp Stanley Storage Facility, Wellbore: WB-04
Parsons
July 18, 2003

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
573	101.35	332.5	338	34	1
574	101.41	332.7	249	13	1
575	101.52	333.1	236	21	3
576	101.60	333.3	186	25	1
577	101.82	334.1	347	28	1
578	101.98	334.6	157	34	1
579	102.05	334.8	299	26	1
580	102.16	335.2	329	28	1
581	102.36	335.8	310	35	0
582	102.75	337.1	295	75	1
583	102.80	337.3	98	31	1
584	103.09	338.2	74	15	1
585	103.40	339.2	23	13	1
586	104.38	342.5	104	11	1
587	106.35	348.9	7	16	1
588	107.00	351.1	343	45	1
589	107.43	352.5	130	30	1
590	108.10	354.7	46	18	1
591	108.64	356.4	90	8	1
592	109.03	357.7	333	7	1
593	109.10	357.9	63	20	1
594	109.72	360.0	131	11	1
595	109.87	360.5	352	22	1
596	110.07	361.1	250	25	1
597	110.36	362.1	14	20	1
598	111.04	364.3	255	27	1
599	111.11	364.5	138	51	1
600	111.52	365.9	152	19	1
601	111.65	366.3	233	13	1
602	111.66	366.3	12	16	1
603	111.85	367.0	83	16	1
604	112.09	367.8	325	25	1
605	112.18	368.0	126	16	1
606	112.23	368.2	103	16	1
607	112.54	369.2	317	57	1
608	112.68	369.7	18	16	1
609	112.96	370.6	128	18	1
610	113.01	370.8	191	25	1
611	113.06	370.9	204	24	1
612	113.09	371.0	200	18	1
613	113.27	371.6	331	27	1
614	113.81	373.4	306	31	1
615	113.89	373.7	172	19	1
616	114.10	374.3	314	19	1

All directions are with respect to magnetic north.

Orientation Summary Table
Optical Image Features
Camp Stanley Storage Facility, Wellbore: WB-04
Parsons
July 18, 2003

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
617	114.30	375.0	328	10	1
618	114.51	375.7	317	23	1
619	114.56	375.9	317	15	1
620	114.60	376.0	237	17	1
621	114.64	376.1	320	18	1
622	114.66	376.2	281	17	1
623	114.69	376.3	298	12	1
624	114.71	376.4	138	61	1
625	114.74	376.4	303	16	1
626	114.74	376.4	107	28	1
627	114.85	376.8	349	9	0
628	114.96	377.2	103	16	1
629	115.03	377.4	170	20	0
630	115.45	378.8	36	9	1
631	115.60	379.3	85	26	1
632	115.72	379.7	336	29	1
633	115.73	379.7	108	20	1
634	115.75	379.8	350	20	1
635	115.83	380.0	318	11	1
636	115.97	380.5	53	14	1
637	116.01	380.6	358	46	1
638	116.10	380.9	33	12	1
639	116.13	381.0	209	19	1
640	116.13	381.0	33	20	1
641	116.14	381.1	303	15	1
642	116.17	381.1	302	15	1
643	116.18	381.2	90	8	1
644	116.20	381.2	102	12	1
645	116.21	381.3	229	13	1
646	116.25	381.4	99	14	1
647	116.56	382.4	115	5	1
648	116.70	382.9	286	19	0
649	116.95	383.7	195	9	1
650	116.99	383.8	232	15	1
651	117.00	383.9	205	6	1
652	117.08	384.1	158	36	1
653	117.11	384.2	92	12	1
654	117.17	384.4	285	13	0
655	117.24	384.6	141	75	1
656	117.24	384.6	295	12	0
657	117.41	385.2	291	9	0
658	117.75	386.3	157	6	1
659	118.23	387.9	60	19	1
660	118.56	389.0	81	13	1

All directions are with respect to magnetic north.

Orientation Summary Table
Optical Image Features
Camp Stanley Storage Facility, Wellbore: WB-04
Parsons
July 18, 2003

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
661	118.77	389.7	65	28	1
662	118.90	390.1	38	10	1
663	119.06	390.6	314	11	1
664	120.24	394.5	88	23	1
665	120.49	395.3	259	15	1
666	120.73	396.1	158	13	0
667	120.91	396.7	304	7	3
668	121.34	398.1	353	10	0
669	121.53	398.7	129	27	1
670	121.61	399.0	347	23	1
671	121.69	399.2	312	21	1
672	122.01	400.3	186	50	1
673	122.08	400.5	52	13	1
674	122.14	400.7	64	10	1
675	122.29	401.2	214	32	1
676	122.31	401.3	15	53	1
677	122.42	401.6	69	16	1
678	122.56	402.1	128	13	1
679	122.77	402.8	337	69	1
680	122.79	402.9	82	12	1
681	122.95	403.4	345	27	1
682	123.05	403.7	357	18	1
683	123.17	404.1	274	8	1
684	123.20	404.2	339	15	1
685	123.23	404.3	337	14	1
686	123.26	404.4	61	9	1
687	123.30	404.5	202	10	1
688	123.36	404.7	320	21	1
689	123.41	404.9	2	16	1
690	123.52	405.3	17	16	1
691	123.70	405.8	28	20	0
692	123.85	406.3	29	17	0
693	123.93	406.6	222	9	1
694	124.05	407.0	179	19	1
695	124.17	407.4	307	12	1
696	124.20	407.5	192	10	1
697	124.41	408.2	99	15	1
698	124.51	408.5	23	10	2
699	124.57	408.7	118	38	2
700	124.75	409.3	293	24	1
701	124.96	410.0	311	13	1
702	125.00	410.1	339	11	1
703	125.06	410.3	224	48	1
704	125.14	410.6	357	14	1

All directions are with respect to magnetic north.

Orientation Summary Table
Optical Image Features
Camp Stanley Storage Facility, Wellbore: WB-04
Parsons
July 18, 2003

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
705	125.30	411.1	207	8	0
706	125.52	411.8	316	25	0
707	125.76	412.6	255	16	1
708	125.84	412.9	61	13	1
709	125.90	413.1	72	16	1
710	125.91	413.1	235	12	1
711	125.95	413.2	142	10	1
712	125.99	413.3	21	13	1
713	126.00	413.4	33	10	1
714	126.04	413.5	293	18	1
715	126.08	413.7	186	23	1
716	126.22	414.1	186	11	1
717	126.50	415.0	317	22	1
718	126.60	415.3	296	38	1
719	126.60	415.4	90	26	1
720	126.65	415.5	352	76	1
721	126.71	415.7	63	29	1
722	126.75	415.8	253	30	1
723	126.80	416.0	173	8	1
724	126.85	416.2	322	45	1
725	126.88	416.3	295	13	2
726	126.93	416.4	300	28	1
727	126.95	416.5	63	23	1
728	127.00	416.7	263	21	1
729	127.00	416.7	60	20	1
730	127.07	416.9	206	14	1
731	127.11	417.0	203	12	1
732	127.18	417.3	11	20	1
733	127.18	417.3	229	13	1
734	127.22	417.4	32	26	1
735	127.25	417.5	20	19	1
736	127.27	417.6	221	28	1
737	127.30	417.6	17	17	1
738	127.35	417.8	11	21	1
739	127.37	417.9	22	20	1
740	127.40	418.0	13	30	1
741	127.42	418.1	181	24	1
742	127.47	418.2	50	30	1
743	127.52	418.4	345	9	1
744	127.56	418.5	94	17	1
745	127.56	418.5	321	14	1
746	127.60	418.7	112	12	1
747	127.64	418.8	107	32	1
748	127.67	418.9	216	31	1

All directions are with respect to magnetic north.

Orientation Summary Table
Optical Image Features
Camp Stanley Storage Facility, Wellbore: WB-04
Parsons
July 18, 2003

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
749	127.73	419.1	236	26	1
750	127.76	419.2	271	15	1
751	127.81	419.3	301	21	1
752	127.82	419.4	154	37	1
753	127.87	419.5	212	29	1
754	127.90	419.6	35	14	1
755	127.99	419.9	87	17	1
756	128.04	420.1	21	22	1
757	128.04	420.1	245	14	1
758	128.09	420.3	150	11	1
759	128.23	420.7	292	12	1
760	128.23	420.7	29	41	1
761	128.32	421.0	159	16	1
762	128.45	421.4	225	18	1
763	128.50	421.6	360	9	1
764	128.52	421.7	286	13	1
765	128.55	421.8	27	4	1
766	128.59	421.9	140	5	2
767	128.61	422.0	181	6	2
768	128.64	422.1	13	14	2
769	128.73	422.3	3	6	2
770	128.75	422.4	115	9	1
771	128.78	422.5	286	6	2
772	128.83	422.7	254	10	3
773	128.96	423.1	336	9	1
774	128.99	423.2	4	12	1
775	129.01	423.3	30	13	0
776	129.15	423.7	40	10	0
777	129.20	423.9	237	3	0
778	129.33	424.3	344	5	0
779	129.38	424.5	339	10	1
780	129.40	424.6	277	11	2
781	129.44	424.7	1	5	1
782	129.62	425.3	71	8	0
783	129.85	426.0	315	25	1
784	129.92	426.3	116	16	1
785	129.99	426.5	112	10	1
786	130.04	426.6	119	14	1
787	130.14	427.0	227	12	1
788	130.31	427.5	59	13	1
789	130.39	427.8	103	8	2
790	130.45	428.0	75	10	1
791	130.47	428.1	95	14	1
792	130.57	428.4	287	12	2

All directions are with respect to magnetic north.

Orientation Summary Table
Optical Image Features
Camp Stanley Storage Facility, Wellbore: WB-04
Parsons
July 18, 2003

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
793	130.61	428.5	329	7	2
794	131.12	430.2	307	11	1
795	131.18	430.4	184	22	1
796	131.22	430.5	31	15	2
797	131.30	430.8	40	42	1
798	131.33	430.9	304	11	1
799	131.40	431.1	346	9	1
800	131.46	431.3	119	11	0
801	131.53	431.5	55	9	0
802	131.66	432.0	30	11	0
803	131.89	432.7	183	63	1
804	132.47	434.6	81	10	1
805	132.58	435.0	324	25	0
806	132.69	435.4	253	10	0
807	132.77	435.6	62	13	0
808	132.81	435.7	45	7	0
809	132.84	435.8	346	14	1
810	132.94	436.2	306	18	1
811	133.28	437.3	137	11	1
812	133.30	437.4	338	8	1
813	133.33	437.5	5	12	1
814	133.36	437.5	264	13	1
815	133.50	438.0	215	5	1
816	133.55	438.2	85	3	1
817	133.62	438.4	276	8	1
818	133.71	438.7	164	10	0
819	133.78	438.9	210	13	0
820	133.92	439.4	335	16	1
821	134.04	439.8	309	10	1
822	134.10	440.0	265	56	1
823	134.10	440.0	307	11	1
824	134.18	440.2	329	8	2
825	134.59	441.6	287	22	1
826	134.69	441.9	82	11	1
827	134.82	442.3	176	20	1
828	134.83	442.4	299	5	1
829	135.36	444.1	55	9	1
830	135.58	444.8	335	15	3
831	137.13	449.9	183	18	1
832	137.22	450.2	278	10	1
833	137.30	450.5	241	16	1
834	137.34	450.6	353	9	1
835	137.46	451.0	255	8	2
836	137.85	452.3	80	31	1

All directions are with respect to magnetic north.

Orientation Summary Table
Optical Image Features
Camp Stanley Storage Facility, Wellbore: WB-04
Parsons
July 18, 2003

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
837	138.75	455.2	315	49	1
838	138.78	455.3	150	62	1
839	140.15	459.8	133	12	1
840	141.30	463.6	192	40	1
841	141.56	464.4	336	15	1
842	141.84	465.4	136	41	1
843	141.92	465.6	201	12	1
844	141.96	465.8	4	18	1
845	142.05	466.0	260	5	1
846	142.05	466.1	339	33	1
847	142.08	466.1	23	19	1
848	142.11	466.3	85	16	1
849	142.15	466.4	12	31	1
850	142.16	466.4	157	27	1
851	142.22	466.6	336	17	1
852	142.26	466.7	337	16	1
853	142.31	466.9	355	34	4
854	142.52	467.6	188	39	4
855	143.00	469.2	133	83	1
856	143.41	470.5	346	16	1
857	143.43	470.6	106	19	1
858	143.94	472.2	162	25	1
859	144.05	472.6	314	31	1
860	144.12	472.8	65	19	1
861	144.12	472.8	184	13	1
862	144.26	473.3	276	16	1
863	144.45	473.9	331	51	1
864	144.81	475.1	198	24	2
865	145.70	478.0	294	53	1
866	145.99	479.0	145	63	1
867	146.13	479.4	285	50	1
868	146.80	481.6	79	16	1
869	147.10	482.6	137	67	1
870	147.10	482.6	315	57	1
871	147.32	483.3	336	5	1
872	147.32	483.3	289	15	1
873	147.35	483.4	321	14	1
874	147.38	483.5	268	16	1
875	147.41	483.6	353	7	1
876	147.89	485.2	179	14	1
877	147.97	485.5	161	20	1
878	147.98	485.5	346	24	1
879	148.00	485.6	156	17	1
880	148.10	485.9	188	22	1

All directions are with respect to magnetic north.

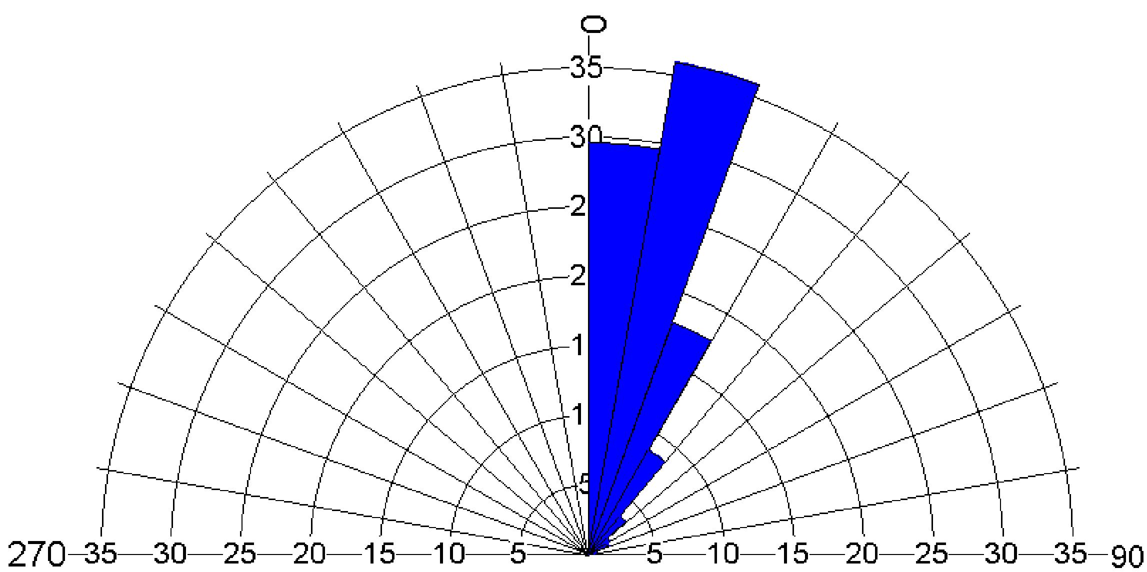
Orientation Summary Table
Optical Image Features
Camp Stanley Storage Facility, Wellbore: WB-04
Parsons
July 18, 2003

Feature No.	Depth (meters)	Depth (feet)	Dip Direction (degrees)	Dip Angle (degrees)	Feature Rank (0 to 5)
881	148.53	487.3	350	27	1
882	149.13	489.3	248	62	0
883	149.73	491.3	124	9	1
884	149.77	491.4	42	16	1
885	149.79	491.4	82	12	1
886	149.85	491.7	7	26	1
887	149.89	491.8	2	35	1
888	149.93	491.9	350	23	1
889	149.95	492.0	360	22	1
890	150.02	492.2	8	23	1
891	150.03	492.2	331	47	1
892	150.08	492.4	354	23	1
893	150.14	492.6	51	12	1
894	150.51	493.8	36	13	1
895	151.16	495.9	128	19	0
896	151.45	496.9	329	14	0
897	151.77	497.9	28	16	1
898	151.93	498.5	75	40	3
899	152.09	499.0	118	9	1
900	152.13	499.1	190	20	1
901	152.18	499.3	182	40	1
902	152.29	499.6	60	33	1
903	152.39	500.0	34	28	1
904	152.49	500.3	15	39	1
905	152.63	500.8	273	10	1
906	152.66	500.9	249	12	1
907	152.68	500.9	252	7	1
908	152.71	501.0	184	20	1
909	152.77	501.2	157	22	1
910	152.95	501.8	154	36	1
911	153.01	502.0	174	38	1
912	153.49	503.6	320	25	1
913	154.47	506.8	4	16	0
914	154.97	508.4	348	34	1
915	154.99	508.5	188	11	1
916	155.06	508.7	72	11	1
917	155.10	508.9	209	10	1
918	155.16	509.1	326	12	1
919	155.20	509.2	311	12	1
920	155.41	509.9	326	65	1

All directions are with respect to magnetic north.

Figure WB-04:5
Rose Diagram of Optical Televiewer Features
Parsons
Camp Stanley Storage Facility: Wellbore WB-04
July 18, 2003

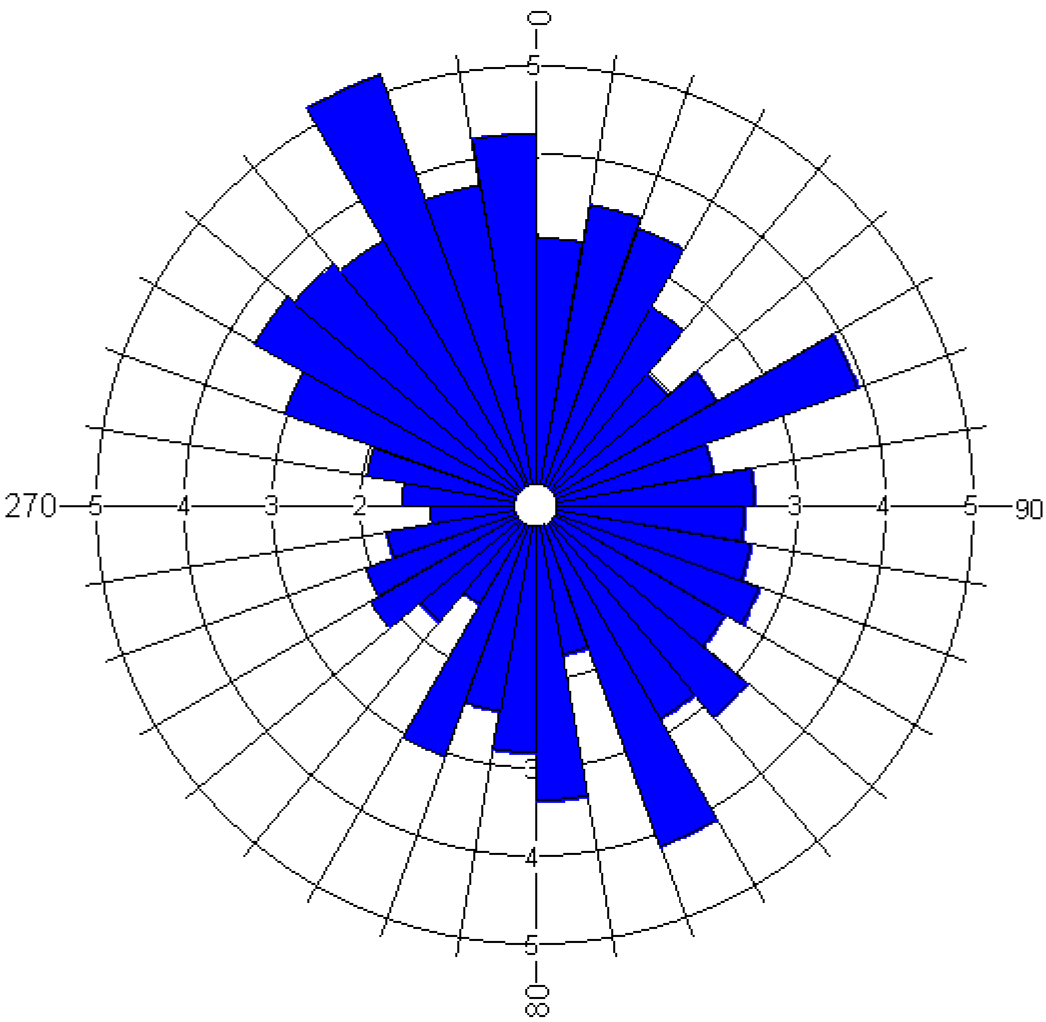
Dip Angles



Shown as *percent* of features with observed dip angle

Figure WB-04:6
Rose Diagram of Optical Televiewer Features
Parsons
Camp Stanley Storage Facility: Wellbore WB-04
July 18, 2003

Dip Direction

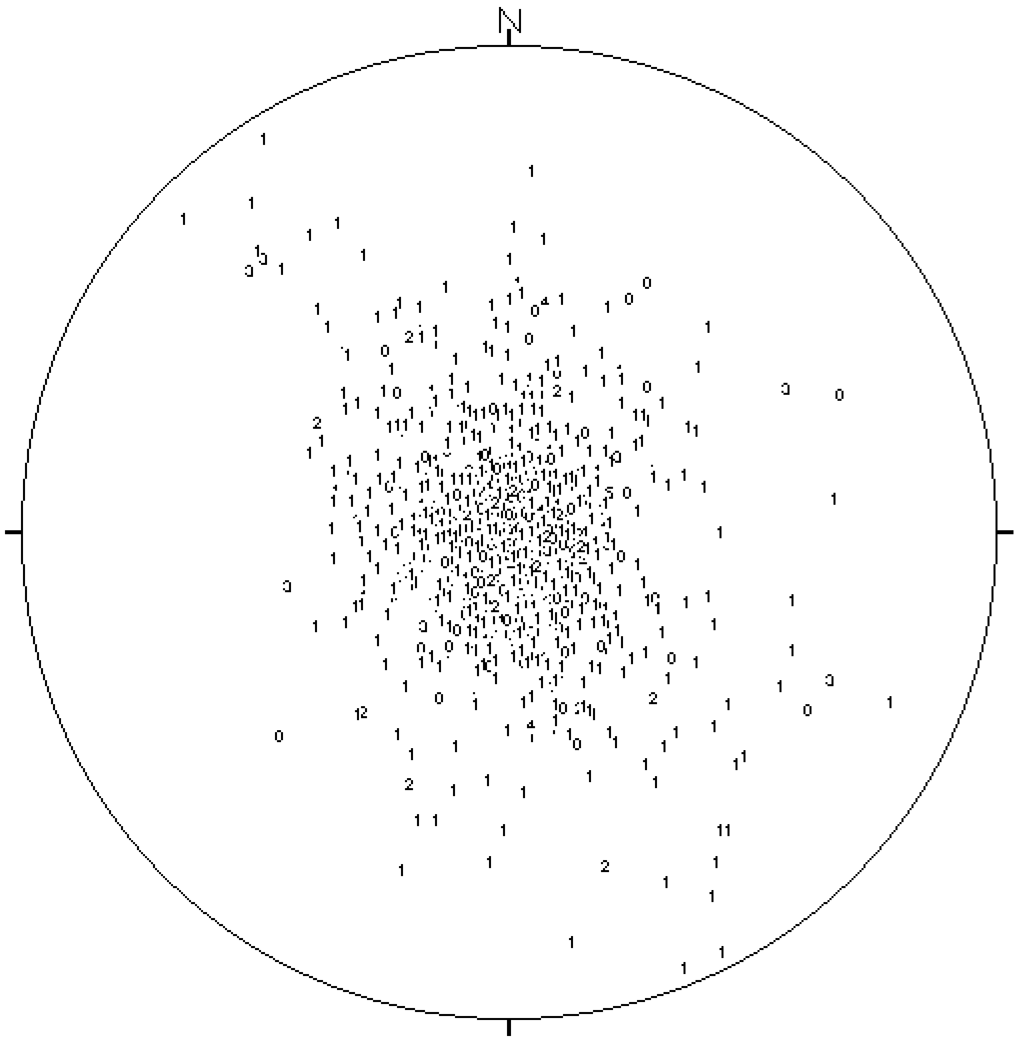


Shown as *percent* of features with observed dip direction

All directions are with respect to magnetic north.

Figure WB-04:7
Stereonet of Optical Televiewer Features
Parsons
Camp Stanley Storage Facility: Wellbore WB-04
July 18, 2003

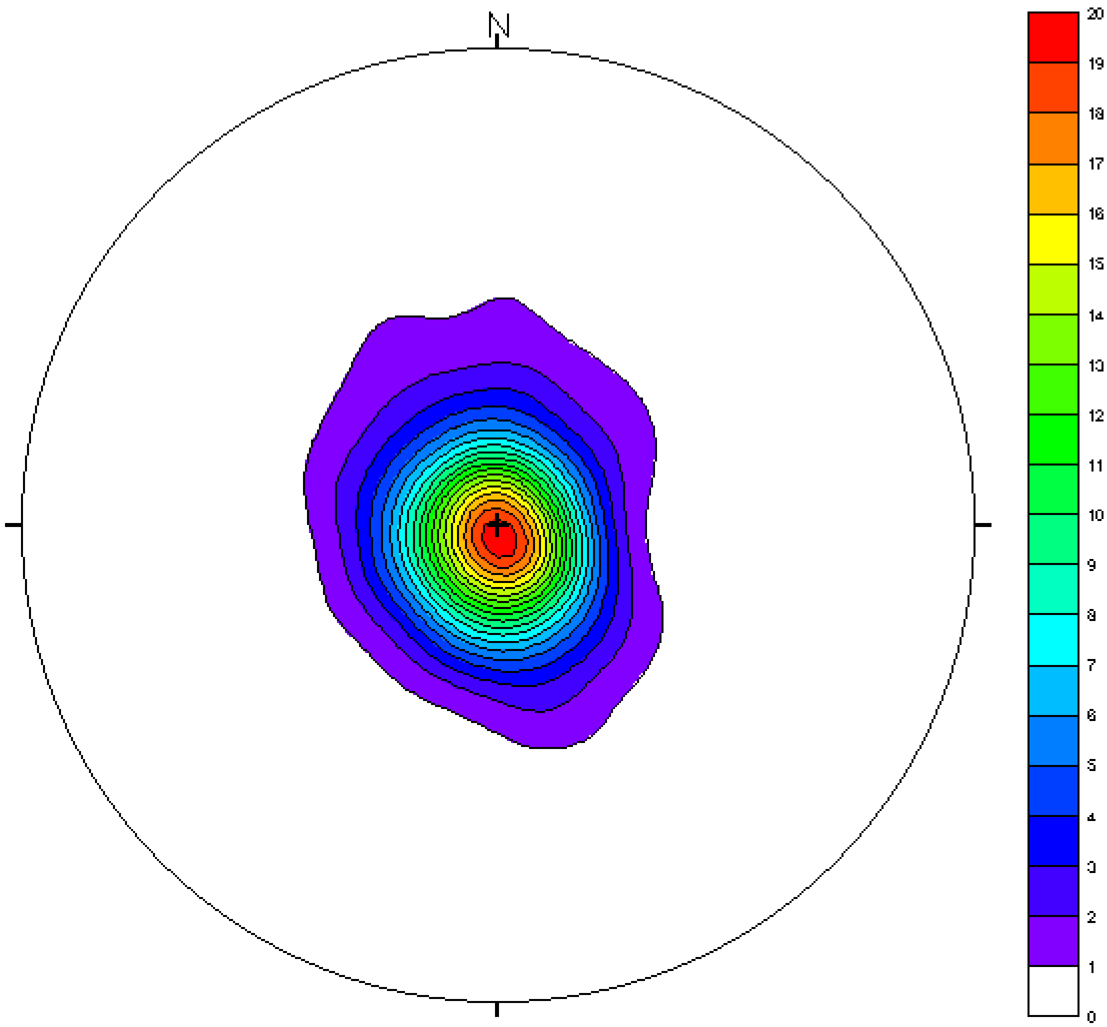
Schmidt Projection with Feature Ranks



All directions are with respect to magnetic north.

Figure WB-04:8
Stereonet of Optical Televiewer Features
Parsons
Camp Stanley Storage Facility: Wellbore WB-04
July 18, 2003

Schmidt Projection with Feature Ranks



All directions are with respect to magnetic north.

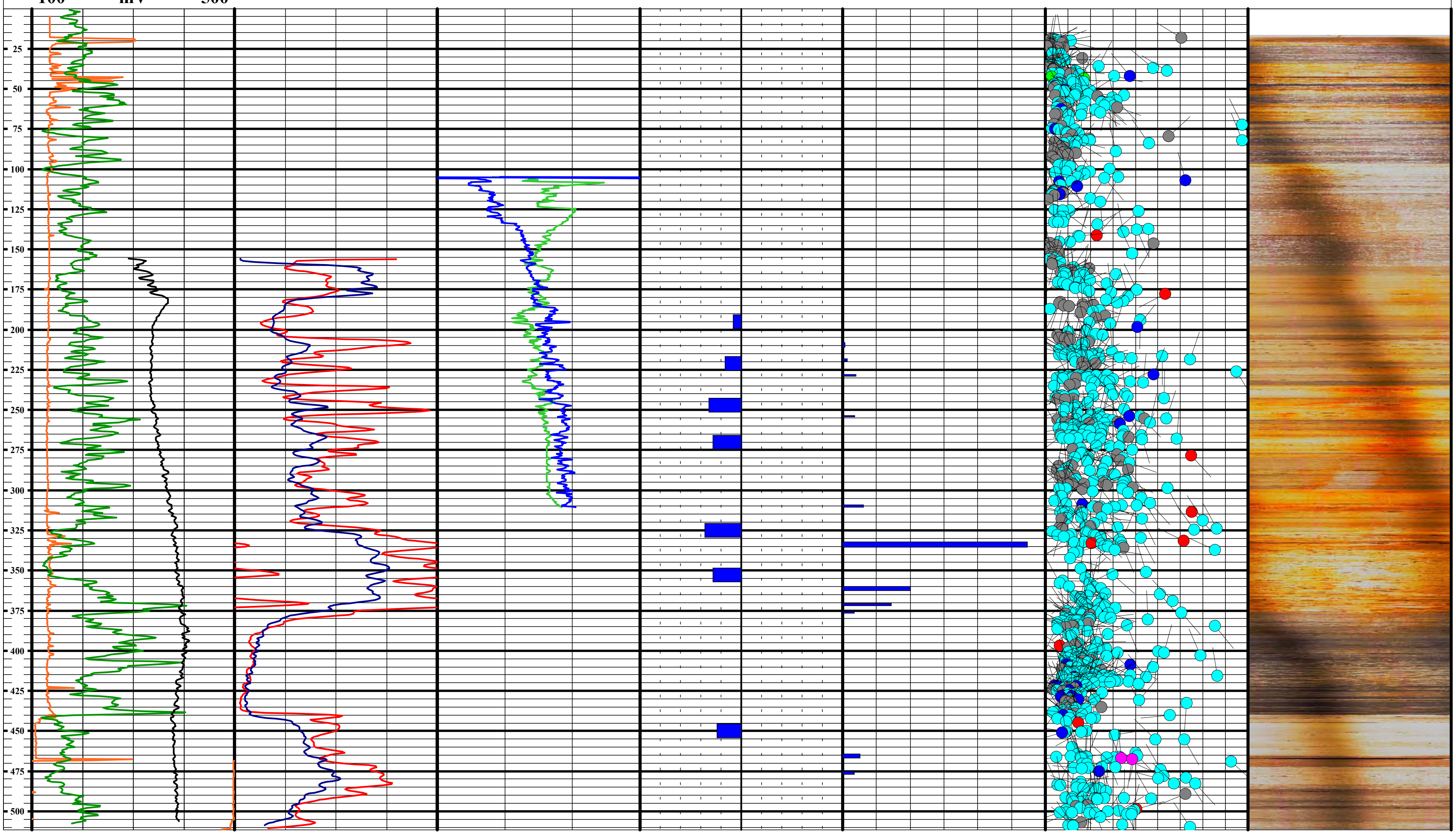
Geophysical Summary Plot

COLOG — Borehole Geophysics & Hydrophysics — A Division of Layne Christensen Company

COMPANY: Parsons	PROJECT: Camp Stanley
DATE LOGGED: 18 July 2003	WELL: WB-04

COLOG Main Office
17301 W.Colfax Ave, Ste 265, Golden, CO 80401
Phone: (303) 279-0171, Fax: (303) 278-0135
E-mail: colog@colog.com

Depth	3-Arm Caliper	16" Resistivity	Fluid Temperature	Heat-Pulse Flow Meter	HpL Flow (Stressed)	Tadpole (Degrees)	Optical Image (BIPS)
	4 inches 8	0 ohm-m 400	21.5 23	-0.25 gpm 0.25	0 gpm 3	0 90	0° 90° 180° 270° 0°
	Natural Gamma	64" Resistivity	Fluid Conductivity				
	0 cps 80	0 ohm-m 400	510 600				
	Spontaneous Potential						
	100 mV 500						



APPENDIX A

STANDARD OPERATING PROCEDURES FOR HYDROPHYSICAL™ LOGGING

Standard Operating Procedures
HydroPhysical™ Logging for Aquifer Characterization

By

COLOG Division of Layne Christensen Co.

Standard Operating Procedures
HydroPhysical™ Logging for Aquifer Characterization

1. Purpose

Application of the HydroPhysical™ (HpL™) logging method to analyze and determine:

- The location of hydraulically conductive intervals within a wellbore
- The interval specific rate of inflow during well production, in conjunction with the drawdown data, can be used to estimate interval specific hydraulic conductivity or transmissivity
- Ambient (non-pumping) flow conditions (inflow and outflow rates, and locations)
- The hydrochemistry (fluid electrical conductivity (FEC) and temperature) of the associated formation waters

In addition, when downhole, discrete point fluid sampling is coupled with the HydroPhysical™ Logging technique, analysis of the actual contaminant concentrations associated with each identified conductive interval is accomplished for any aqueous phase contaminant.

2. Equipment and Materials

This SOP specifically applies to application of the technique using COLOG's HydroPhysical™ Logging Truck 16, which has been specially configured to handle those field conditions associated with small diameter, low-moderate yield wells The maximum capability of the van is to a total depth of 700 ft and 350 ft total drawdown (maximum depth to water) . In the event of high yield wells, the wireline capability of any COLOG truck can be used to accompany fluid management equipment.

- HydroPhysical™ logging truck field equipment includes:

- Fluid management system
  - Back Pressure Regulator or orifices
  - Rubber hose (0.75-inch i.d.) for injection
  - Submersible Pump
  - Evacuation Line
  - Storage tanks (as required) with inlet/outlet valves
  - Surface Pump
  - Fluid management manifold/Monitoring Panel
  - Data Acquisition System (for recording volumes, flow rates, time)
  - Wireline System
  - Wireline winch unit
  - Depth encoder

- Water level indicator
- Computer System
    - HydroPhysical™ Logging tool
    - Downhole Fluid Sampler
- Deionizing Units
- Deionized water (prepared with wellbore fluids or transported on-site)
- Standard Reference Solutions - Electrical conductivity reference solutions (set of 3 solutions).

3. Procedures

1.) Review well construction details and complete general well information sheet. The HydroPhysical™ logging technique involves dilution of the wellbore fluids with DI water and profiling of the wellbore dynamics using a HydroPhysical™ logging tool. Significant aberrations or reductions in the borehole diameter should be identified as the downhole equipment can become lodged in the borehole. Additionally, application of the technique requires certain wellbore conditions:

- In open bedrock boreholes, casing must be installed through the overburden and grouted at the rock/alluvium interface to inhibit water leakage into the borehole from the saturated alluvium. For cased boreholes, the well should be fully cased and gravel packed with single or multiple screened intervals;
- The diameter of the borehole must be approximately 4 inches or greater for application with the slim-tool (1.5-inch o.d.). Two inch i.d. boreholes may be tested using the slug test approach described in Section 5.
- For newly drilled wells, cuttings and drill fluids must be removed from the affected fractures by standard well development procedures.

2.) Review and record additional wellbore construction/site details and fill out the general well information form which includes the following information:

- Ambient depth-to-water
- Depth of casing
- Total depth of well
- Lithology (if available)
- Estimated well yield and any available drawdown data
- Type and concentration of contamination

3.) Prepare the deionized (DI) water. Consult with DI water tank firm for assistance if necessary. If DI water has not been transported to the site, surface or groundwater may be used if it is of suitable quality Generally source water containing less than 1000 micro Siemens per centimeter (µS/cm) and less then 200 ppb VOCs will not significantly affect the deionizing units, but this should be confirmed with DI water firm. If the groundwater from the well under construction cannot be used for DI water generation, then DI water must be transported to the site and containerized at the wellhead.

Depending on the amount of HydroPhysical™ testing to be performed (ambient and/or during production) the typical volume of DI water required for each borehole is approximately three times the volume of the standing column of formation water in the wellbore per type of HydroPhysical™ characterization.

If preparation takes place on site, pump the source water through a pre-filter, to the deionizing units, and into the storage tanks.

Monitor the FEC of the DI water in-line to verify homogeneity; the target value is 5 to 25 μS/cm.

4.) Calibrate the HydroPhysical™ logging tool using standard solutions prepared and certified by a qualified chemical supply manufacturer. Fill out tool calibration form following the steps defined in the software program, "tools" under the directory, calibration. Also use a separate field temperature / FEC / pH meter to support calibration data. Record the results of the tool calibrations, specifically noting any problems on the tool calibration form. Also record the certification number of the standard solutions.

5.) Set datum on the depth encoder with the FEC sensor on the tool as 0 depth at the top of casing. If inadequate space is available at the wellhead, measure 10 feet from the FEC sensor up the cable (using measuring tape) and reference with a wrap of electrical tape. Lower the tool down the hole to the point where the tape equals the elevation at the top of the casing and reference that as 10 feet depth on the depth encoder.

6.) Place the top of the tool approximately 3 feet below the free-water surface to allow it to achieve thermal equilibrium. Monitor the temperature output until thermal stabilization is observed at approximately ± .02 °C.

7.) After thermal stabilization of the logging tool is observed, log the ambient conditions of the wellbore (temperature and FEC). Fill out the water quality log form. During the logging run, the data are plotted in real time in log format on the computer screen and, the data string is simultaneously recorded on the hard drive.

Log the ambient fluid conditions in both directions (i.e. record down and up). The ideal logging speed is 5 feet per minute (fpm). For deeper wells the logging speed can be adjusted higher, but the fpm should not exceed 20.

At completion of the ambient log, place the tool approximately 10 feet below the free water surface. The tool will remain there during equipment set up as long as borehole conditions permit. Establish and record ambient depth to water using top of protective casing as datum.

8.) Attach back pressure regulator or orifice, if used, and weighted boot, to end of emplacement line and secure. Insure that the injection line is of adequate length to reach the bottom of the wellbore.

9.) Lower the flexible emplacement line to the bottom of the well allowing one foot of clearance from the well bottom to the outlet of the injection line.

10.) Lower tool about 10 feet below the water surface. The tool will be stationed beneath the submersible pump during non-logging times.

11.) Lower submersible pump in the well to a depth just above the logging tool. Record approximate depth of the pump location.

12.) Record all initial readings of gauges at elapsed time 0.0 minutes. Fill out well testing data form.

13.) Mark hoses with a round of electrical tape for reference. In addition, establish datum for tool depth to the nearest foot and mark on wire with wrap of tape. Reset datum on optical encoder for this depth.

14.) When ambient flow characterization is to be conducted, it should be done now, before disturbing the aquifer (i.e. by pumping). Fill out ambient flow characterization (AFC) form. Skip to Section 17 for procedures.

15.) After AFC, if performed, conduct a controlled, short term well production test (pump test) to characterize the overall hydraulics of the wellbore (drawdown at given pumping rate provides total well transmissivity or yield) and to make an initial assessment of formation water hydrochemistry. Begin pumping at a total extraction flow rate appropriate for wellbore under investigation (see Section 4 Special Notes). During this period, record elapsed time of pumping, depth to water, total gallons extracted, and extraction flow rate at approximately one minute intervals.

During extraction, log the fluid column continuously until at least three wellbore volumes have been extracted from the wellbore, or a stabilized water level elevation is obtained.

Review fluid logging results to verify that true formation water is present within the affected borehole interval and that the vertical distribution of water quality parameters within this interval is stable.

16.) Review data obtained during the pumping test to determine DI water emplacement and pumping/logging procedures. Extraction procedures for detection and characterization of hydraulically conductive intervals and the formation water hydrochemistry are determined based on the pumping test information. The emplacement, testing and pumping procedures will differ depending upon well yield and determined lengths of intervals of interest. In wellbore situations where intervals of interest are small (less than 30 feet) and hydraulic characteristics observed during borehole advancement and preliminary hydraulic testing indicate hydraulically conductive intervals with extremely low flow rates (i.e. <0.10 gpm/foot of drawdown), a slug testing procedure can be employed. In wellbore cases where the preliminary hydraulic testing indicates low to moderate total yield (i.e. 0.10 < Q < 4 gpm/foot of drawdown), constant low flow rate pumping after DI water emplacement procedures can be employed. In wellbore situations where intervals of interest are large, and high total yield (i.e. > 4 gpm/foot of drawdown) is observed, constant pumping during DI water injection procedures will be employed.

17.) When the fluid column is to be replaced with DI water, (vertical flow characterization, slug testing, logging during pumping after DI water emplacement) the following emplacement procedures apply:

Pump the DI water to the bottom of the wellbore using the surface pump and the injection riser. Simultaneously use the submersible pump to maintain a stable, elevated total head by extracting groundwater from near the free-water surface. When groundwater from the subject well is used for DI water generation, generate DI water from the extracted formation water and re-circulated to the well bottom via the solid riser.

Use the water level meter to observe the elevated total head during emplacement. If borehole conditions permit (i.e. the absence of constricted borehole intervals), the logging tool is used to monitor the advancement of the fluid up the borehole as it displaces the standing formation water. Draw the logging tool up the wellbore in successive increments as the DI water is emplaced. Monitor the electrical conductivity of the fluid expelled from the evacuation pump during emplacement procedures. When FEC values are representative of the DI water, or sufficiently diluted formation water, terminate emplacement procedures.

Emplacement is complete when DI water, or sufficiently diluted formation water, is observed from the evacuation pump or when logging tool stationed near the pump indicates DI water or sufficiently diluted formation water.

Upon completion, turn off the evacuation pump. Then turn off the injection line.

18.) Record volumes of extracted and injected fluids on the well testing data form. Calculate the volume of DI water lost to the formation.

19.) Take initial background HydroPhysical™ log, or begin continuous logging depending upon extraction method (i.e. slug vs. continuous).

20.) Pumping and testing procedures vary depending upon wellbore hydraulics and construction detail.

21.) Continuous logging is conducted until stabilized and consistent diluted FEC logs are observed. If inflow characterization at a second pumping rate is desired, increase extraction rate and assure the proper DI water injection rate. Perform continuous logging until stabilized and consistent FEC logs are observed and all diluted formation water is re-saturated with formation water.

22.) After stabilized and consistent FEC traces are observed, terminate DI water injection. Reduce the total extraction flow rate to the net formation rate and conduct continuous logging. Conduct logging until stable and consistent FEC values are observed.

23.) Conduct depth specific sampling at this time.

24.) At the conclusion of the above procedures, assess the wellbore fluid conditions and compare them with those observed during the original pumping (Step 14).

25.) Turn all pumps off. First remove the extraction pump from the borehole. During removal, thoroughly clean the evacuation line (2-inch o.d.) with a brush and alconox and rinse DI water. Also clean the outside of the pump. Place the pump in a drum of DI water and flush DI water through the system.

Remove the tool. Clean the wireline for the tool in a similar manner during its withdrawal from the borehole.

Remove the injection line from the well. Follow the same procedures when cleaning the injection line as for the evacuation line.

Store the pumps and logging tools properly for transport.

Place cover on well and lock (if available).

4. Special Notes

On-site pre-treatment of groundwater using activated carbon, can be conducted prior to DI water generation, if there is a contaminated groundwater source. In addition, on-site treatment can also be considered to handle extracted fluids that would require containerization and treatment prior to disposal.

The rate(s) of pumping are determined by drawdown information previously obtained or at rate(s) appropriate for the wellbore diameter and saturated interval thickness. The appropriate extraction rate is a function of length of saturated interval, borehole diameter, and previous well yield knowledge. The appropriate pumping procedures to be employed are also dictated by the length of the exposed rock interval. In general, the extraction flow rate should be sufficient to induce adequate inflow from the producing intervals. The concern is that the extraction flow rate does not cause extreme drawdown within the well i.e. lowering the free water surface to within the interval of investigation.

5. Discussion

LOW YIELD: Extraction Slug Test After DI water Emplacement

In wells with very low total flow capability (i.e. < 0.10 gpm/foot of drawdown), perform a slug test in accordance with procedures developed by Hvorslev (1951). Rapidly extract a small volume of water from near the free water surface using the extraction riser and pump. A drop in piezometric head of about 2 feet should be adequate for the initial test. Record the rise in the free water surface with time and develop a conventional time-lag plot.

When the free water surface has recovered to a satisfactory elevation, log the wellbore fluid conditions. Repeat the procedures described above with successive increases in the drop of piezometric head (or volume extracted). Let the wellbore recover and record the rise in the free water surface. Repeat logging of the wellbore fluid after the free water surface has recovered to a satisfactory elevation. The number of slug tests performed is determined in the field after review of previous logging results.

MODERATE YIELD: Time Series HydroPhysical™ Logging During Continuous Pumping After DI water Emplacement

In the case of moderate yield wells (i.e. 0.10 < Y < 4 gpm/foot of drawdown), maintain a constant flow rate from the evacuation pump and record the total volume of groundwater evacuated from the wellbore. Employ a continuous reading pressure transducer (or equivalent device) to monitor the depressed total head during pumping, along with the associated pumping rate.

Hold the flow rate from the evacuation pump constant at a rate determined for the specific borehole. Drawdown of the free water surface produced during pumping should not overlap any identified water producing interval. Conduct hydrophysical logging continuously. The time interval is a function of flow rate and is specific to each well. The number of logging runs and the length of time required to conduct all loggings is a function of the particular hydraulic conditions. Logging and pumping is continued until the fluid column is re-saturated with formation water (i.e. all DI water is removed from the borehole).

HIGH YIELD: Time Series Wellbore Fluid Logging During Continuous Pumping and Simultaneous DI Water Injection

When wells exhibit high yield (> 4 gpm/foot of drawdown), as determined by a review of the interval of interest, the borehole diameter and the results obtained from previous information and preliminary hydraulic testing, the appropriateness of time series fluid logging during continuous pumping and simultaneous DI water injection is determined.

In this case, maintain a constant flow rate from the evacuation pump and record this rate and the associated drawdown. During this period, conduct hydrophysical logging until reasonably similar HydroPhysical™ logs are observed and stabilized drawdown is achieved. After reasonably similar downhole fluid conditions are observed and simultaneous with extraction pumping, inject DI water at the bottom of the well at a constant rate of 10 to 20% of that employed for extraction. Increase the total rate of extraction to maintain total formation production reasonably similar to that prior to DI water injection (i.e. increase the total extraction by amount equal to the DI water injection rate).

Periodically record the total volume and flow rate of well fluids evacuated and the total volume and flow rate of DI water injected. Use a continuous reading pressure transducer or similar device to monitor the depressed total head during pumping. Record the depressed total head (piezometric surface) periodically, with the associated pumping and injection data.

The evacuation and DI water injection flow rates are held constant at a rate determined for the specific wellbore. Drawdown of the free water surface during pumping must not overlap any identified water producing intervals. HydroPhysical™ Logging is conducted continuously. The number of logging runs and the length of time required to conduct all loggings is a function of the particular hydraulic conditions exhibited by the well under investigation.

APPENDIX B

BOREII MODELING SOFTWARE

LBNL-46833

BORE II – A Code to Compute Dynamic Wellbore Electrical Conductivity Logs with Multiple Inflow/Outflow Points Including the Effects of Horizontal Flow across the Well

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Abstract

Dynamic wellbore electrical conductivity logs provide a valuable means to determine the flow characteristics of fractures intersecting a wellbore, in order to study the hydrologic behavior of fractured rocks. To expedite the analysis of log data, a computer program called BORE II has been developed that considers multiple inflow or outflow points along the wellbore, including the case of horizontal flow across the wellbore. BORE II calculates the evolution of fluid electrical conductivity (FEC) profiles in a wellbore or wellbore section, which may be pumped at a low rate, and compares model results to log data in a variety of ways. FEC variations may arise from inflow under natural-state conditions or due to tracer injected in a neighboring well (interference tests). BORE II has an interactive, graphical user interface and runs on a personal computer under the Windows operating system. BORE II is a modification and extension of an older code called BORE, which considered inflow points only and did not provide an interactive comparison to field data. In this report, we describe BORE II capabilities, provide a detailed user's guide, and show a series of example applications.

1. Introduction

The variation of formation permeability surrounding a wellbore is useful information not only for identifying hydraulically conducting fractures or other high-conductivity features intercepted by the well, but also for quantifying the heterogeneity of the medium. These are essential data in the evaluation of in-situ flow and transport characteristics at a given site.

Methods to evaluate permeability values along the depth of a well include the packer method, in which constant pressure, constant flow, or pulse tests are conducted in packed-off intervals in a wellbore, and various downhole flow meters. The packer method has the disadvantage that it is very time consuming and costly, and the vertical resolution is limited by the interval between the two packers that can be set in the well. Flow meter methods such as spinners and heat pulse flow meters generally allow better vertical resolution than the packer method, but they are not as accurate in determining permeability, because they mostly measure the wellbore fluid velocity, which is very sensitive to variations in the wellbore radius.

In 1990, Tsang et al. (1990) proposed a method using logs of fluid electric conductivity (FEC) at successive times under constant-pumping conditions to obtain inflow from the formation into the well as a function of depth in the well. In this method, the wellbore is first filled by de-ionized water or water of a constant salinity (i.e., ion concentration) distinct from that of the formation water. This is usually done by passing the de-ionized water down a tube to the bottom of the wellbore at a given rate while simultaneously pumping at the top of the well at the same rate. After this is done, the well is pumped at a constant flow rate, which can be adjusted to optimize wellbore flow conditions. An electric resistivity probe is lowered into the wellbore to scan FEC as a function of depth along the wellbore. This is what is called fluid conductivity logging. A series of five or six such logs are obtained at time intervals over a one- or two-day period. At the depth levels where water enters the wellbore, the conductivity log displays peaks, which grow with time and become skewed in the direction of water flow. By analyzing these logs, it is possible to obtain the permeability and salinity of each hydrologic layer transmitting water. The method has been very successful, being much more accurate than flow meters and much more efficient (much cheaper) than packer tests (Tsang et al. 1990), particularly in low permeability formations. A typical 1000-m section in a deep hole can be tested in two or three days at a spatial resolution of ~0.10 m all along the length of the wellbore section. The method is now being widely used in Europe and the U.S. (Marschall and Vomvoris, 1995; Pedler et al., 1992; Bauer and LoCoco, 1996), both under natural-state flow conditions and while tracer is injected in a neighboring well (i.e., interference tests).

Along with the method, a code was developed called BORE (Hale and Tsang, 1988), which performed the forward calculation to produce wellbore FEC profiles given different inflow positions, rates, and concentrations. The code has been well used over the last decade. However, it appears now that there is a need to revise the code to make it more suitable for current computer environments and to add new capabilities. Thus, the code has been updated to run under current operating systems, provide interactive modification of model parameters, and produce graphical comparisons between model and field data. More importantly, the revised code allows the possible inclusion of both flows into and out of the well at various depths, a feature that has been observed in real field conditions when different layers penetrated by the well have different hydraulic heads. Furthermore, the new code allows the calculation of the case with equal inflow and outflow at the same depth level, which is effectively the special case of horizontal flow across the wellbore. Drost (1968) proposed a measurement of solute dilution in the wellbore to evaluate ambient horizontal flow velocity in the formation and it has become a well-accepted method. The new code provides the opportunity to analyze such cases and to identify the depth interval of horizontal flow to within ~0.1 m as well as to estimate the flow rate. Moreover, one can analyze the combination of horizontal flow across the wellbore and vertical diffusion or dispersion along the length of the wellbore, which is not possible with Drost's solution.

The report is organized as follows. In Section 2, the basic capabilities of the revised code, called BORE II, are described, and the key parameters associated with BORE II are defined. Details of the mathematical background and numerical approach are described in Appendix 1, which is adapted from Hale and Tsang (1988). A user's guide is presented in Section 3, which includes a description of BORE II's interactive user interface, required input items, and options available when running BORE II. Four example applications are given in Section 4 to conclude the report.

We are still open to further improvements of BORE II; any suggestions and comments are invited and should be addressed to the authors.

2. BORE II Capabilities

BORE II calculates FEC as a function of space and time in a wellbore containing multiple feed points given the pumping rate of the well, the inflow or outflow rate of each feed point, its location and starting time, and, for inflow points, its ion concentration. A simple polynomial correlation between ion concentration, C, and FEC is assumed. Ion transport occurs by advection and diffusion along the wellbore, with instantaneous mixing of feed-point fluid throughout the wellbore cross-section. These assumptions allow use of a one-dimensional model. BORE II divides the wellbore section under study into equal height cells and solves the advection/diffusion equation using the finite difference method. Further details of the mathematical and numerical approach are given in Appendix 1.

Inflow and Outflow Feed Points

The original BORE code (Hale and Tsang, 1988) considered inflow points only, so flow through the wellbore was upward at all depths. BORE II allows both inflow and outflow points, so flow in the wellbore can be upward, downward, or horizontal at different depths and flow at either end of the wellbore section being studied can be into or out of the wellbore section or be zero. By convention, upward flow in the wellbore is positive and flow into the wellbore is positive.

Steady and Varying Fluid Flow

The original BORE code considered steady fluid flow, so feed points had constant flow rates. They also had constant concentrations, but delayed starting times for feed-point concentration to enter the wellbore were allowed. BORE II permits both steady and varying fluid flow. For the steady-flow case, the user specifies flow rate, concentration, and concentration start time for each feed point, but for outflow points (those with negative flow rates) the concentration and concentration start time are not used. Variable flow rate or concentration can be specified for feed points by interpolating from a table of time, flow rate, and concentration. If a table includes both positive and negative flow rates (i.e., a feed point alternates between inflow and outflow), the concentration for the positive flow rate is used when interpolating between positive and negative flow rates.

Concentration Boundary Conditions

If the flow at the top of the wellbore section under study is into the wellbore, the initial concentration for the uppermost cell in the wellbore is used as the inflow concentration. Analogously, if flow at the bottom of the wellbore section is a flow up from greater depths, the initial concentration for the lowermost cell in the wellbore is used as the inflow concentration. Furthermore, for inflow points with a concentration start time greater than zero, the initial concentration of the wellbore is used as the inflow concentration for times less than concentration start time.

Horizontal Flow

The special case of horizontal flow through the wellbore, as described by Drost (1968), can also be considered, by locating an inflow point and an outflow point with equal magnitude flow rates at the same depth. The flow rates may be specified as either (1) the Darcy velocity through the aquifer or (2) the volumetric flow rate into/out of the wellbore. BORE II multiplies Darcy velocity by the cross-sectional area of the feed point (wellbore diameter times cell height) and Drost's α_h convergence factor to convert it to a volumetric flow rate. The value of α_h can range from 1 (no convergence) to 4 (maximum possible convergence, which occurs for the case of a thick, highly-permeable well screen). Drost suggested that for a uniform aquifer with no well screen, $\alpha_h = 2$, and that for typical applications, a good choice for α_h is 2.5. Horizontal flow feed points may have time-varying flow rates, but for Darcy-velocity calculations to make sense, the inflow and outflow rates must be equal and opposite at any time. Thus, if a feed point location changes from a horizontal flow point to a non-horizontal flow point with time, volumetric flow rates must be specified rather than Darcy velocities.

BORE II Parameters

The key parameters associated with BORE II are defined below.

Parameter	I/O units*	Description
C	g/L	Ion concentration in the wellbore; converted to FEC using FEC = $\gamma + \beta C + \alpha C^2$, where α, β, and γ are user-specified constants (default values are provided in the code, see Section 3)
C_i	g/L	Ion concentration of *i*th feed point
C_0	g/L	Initial ion concentration in wellbore
D_0	m^2/s	Diffusion coefficient (may include dispersive effects as well molecular diffusion)
d_w	cm	Wellbore diameter (assumed constant)
FEC	µS/cm	Fluid electrical conductivity
q	L/min	Fluid flow rate in wellbore (upward flow is positive)
q_i	L/min	Fluid flow rate of *i*th feed point; positive for inflow and negative for outflow
q_w	L/min	Fluid flow rate in wellbore at $x_{\max}$, specified by the user
q_0	L/min	Fluid flow rate in wellbore at $x_{\min}$ (or any depth of interest), calculated internally
T or TEMP	^{o}C	Temperature (assumed constant)
t	hr	Time
$t_{\max}$	hr	Maximum simulation time
t_{0i}	hr	Concentration start time of *i*th feed point
v_d	m/day	Darcy velocity through aquifer for horizontal flow ($q_i = v_d\, \alpha_h\, \Delta x\, d_w$)
x	m	Depth (positive, increases down the wellbore)
$x_{\min}$, $x_{\max}$	m	Top and bottom, respectively, of wellbore interval being studied
Δx	m	Cell height for wellbore discretization
α_h	–	Drost (1968) convergence factor for horizontal flow

*I/O units are chosen for convenience; all quantities are converted to SI units before BORE II calculations.

3. BORE II User's Guide

Operating System

BORE II may be run under Windows 95, 98, or 2000 by double-clicking the executable icon (BOREII.EXE) in Windows Explorer, by double-clicking on a desktop shortcut key to BOREII.EXE, or by typing BOREII in the Run command in the Start Menu or in a DOS-prompt window. BORE II will not run in stand-alone DOS or in the DOS-mode of Windows. BORE II was compiled using Microsoft Fortran PowerStation™ Version 4.0, but this software is not necessary to run the program.

BORE II Graphical Output

The primary user interface with BORE II is interactive, with the user responding to on-screen prompts to modify model parameters and choose options (described below) for the real-time graphical display of model results and data. The basic BORE II output screen consists of three windows.

- The borehole profile window shows FEC profiles as a function of depth and time. Simulation time t is shown in the upper left corner. Fluid flow rate at a user-specified depth in the wellbore, q_0, is shown in the middle of the top line (the depth at which q_0 is calculated is set by option P). The depth of a C-t plot is also shown.

- The inflow parameters window shows the feed-point characteristics for the model that can be modified with option M (location, flow rate, and concentration). Often there are more feed points than can be displayed at once on the screen. BORE II starts out showing the first few (deepest) feed points, then shows the feed points in the neighborhood of any point that is being modified.

- The dialog window allows the user to select options (described below) when running BORE II.

On computers with small screens, it may be desirable to run BORE II in full-screen mode, so that the entire BORE II screen can be seen at once without scrolling. Full-screen mode is entered by pressing Alt-VF (or on some computers by pressing Alt-Enter). Pressing Esc (or

Alt-Enter) terminates full-screen mode. There are three potential problems associated with the use of full-screen mode.

(1) The status line describing what BORE II is doing (e.g., running, waiting for input) is not visible.

(2) Drawing an *x-t* plot (options X, S, D, F, and I), which creates a new window, may be very slow and the graphics quality poor.

(3) On some computers, text is difficult to read after closing the *x-t* plot window.

To address the latter two problems, one may terminate full-screen mode before using options X, S, D, F, and I. The new window will be small, but after drawing is complete it may be expanded by pressing Alt-VF to enter full-screen mode. Full-screen mode should be terminated before the new window is closed to avoid the final problem.

To print an image of the screen, press Alt-PrintScreen to copy the screen image into the clipboard. Then open a program such as Microsoft Paint and paste in the image. It can be manipulated, saved in a variety of graphics formats, or printed from Paint. The image can also be pasted directly into another Windows application such as MS Word.

Input/Output File Overview

Running BORE II requires one or two external files: a file with an initial set of model input parameters (mandatory, known as the input file) and a file with observed data (optional, known as the data file). These files are plain ASCII text, and must reside in the same folder as the BORE II executable. The input file contains model parameters such as the depth interval being studied, feed point characteristics, problem simulation time, and *C*-to-FEC conversion factors. The data file contains observed values of FEC and temperature, and optionally contains other fluid properties such as pH. Detailed instructions for preparing an input file and a data file are given below.

BORE II always creates a temporary file, called BOREII.TMP (see options C and R), and optionally creates a new input file (see option V), which is useful if model parameters have been changed during the BORE II run.

Line-by-line Instructions for Input File

After starting BORE II, the user is prompted to choose the input file from the list of files residing in the folder where the BORE II executable is. Input file names with more than 8 characters before a period or blanks will appear in the list of files in an abbreviated form. File names can be at most 20 characters long.

A sample input file is provided that can be modified as needed using a text editor such as Notepad or a word processor such as MS Word. If a word processor is used to create or modify an input file, be sure that the file is saved as plain ASCII text.

The input file is designed to be self-documenting, with header lines preceding data lines. These header lines must be present, but BORE II does not use the text on them. Data entries are read in free format, with individual entries on a given line separated by blanks, tabs, or commas. This means that entries cannot be left blank, even if they are not being used (e.g., concentration for an outflow point). Unused entries may be set to zero or any convenient value. Comments may be added on data lines, after the requisite number of entries. In the sample input file, comments begin with an exclamation point.

Item	**Computer Variables**	**Unit**	**Description**
1.	TITLE	–	A description of the problem, 80 characters maximum
2 header for wellbore geometry			
2.	RXMIN	m	Top of study area, $x_{\min}$
	RXMAX	m	Bottom of study area, $x_{\max}$
	RDIAM	cm	Wellbore diameter, d_w
3 header for flow parameters			
3.	RQW	L/min	Flow into (positive) or out of (negative) the bottom of the study area, q_w
	HALPHA	–	Factor to account for convergence of horizontal flow lines toward the wellbore, α_h (Drost, 1968) Range: 1.0 – 4.0; default value: 2.5 Only used for horizontal flow

4 header for feed points			
4.	IINFN	–	Number of feed points (maximum 180)
	IQFLAG	–	Variable flow-rate flag – a 3 digit integer used to identify feed points with variable flow (suggested value 999)
5 header for constant- flow-rate feed points			
5. Repeat IINFN times	RINFX	m	Location of feed point, x_i * For horizontal flow put two feed points at the same location, with equal magnitude, opposite sign flow rates
	RINFQ	L/min (m/day if IINFV=1)	Constant inflow rate (positive) or outflow rate (negative) of feed point, q_i For a variable flow rate, set RINFQ = IIIJJ, where III = IQFLAG, and JJ is a two digit integer giving the number of times in the variable-flow-rate table, which follows in 5a For horizontal flow, v_d replaces q_i if IINFV = 1
	RINFC	g/L	Constant feed point concentration, C_i - only used for inflow points For a variable concentration, set RINFQ = IIIJJ, where III = IQFLAG, and JJ is a two digit integer giving the number of times in the variable-flow-rate table, which follows in 5a
	RINFT	hr	Start time for constant feed point concentration, t_{0i} - only used for inflow points Feed point concentration is C_0 of cell containing feed point for $t < t_{0i}$
	IINFV	–	Horizontal flow Darcy-velocity flag (must be zero for non-horizontal flow case): = 0: RINFQ is flow rate q_i into/out of the wellbore in L/min = 1: RINFQ is +/−Darcy velocity v_d through the aquifer in m/day

5a header for variable-flow-rate table (only when RINFQ = IQFLAGJJ)			
5a. Repeat JJ times when RINFQ = IQFLAGJJ	RINFQT	hr	Time t_j (set $t_1 = 0$, set $t_{JJ} > t_{max}$)
	RINFQQ	L/min (m/day if IINFV=1)	Volumetric flow rate q_j at time t_j For horizontal flow, v_d replaces q_j if IINFV = 1
	RINFCC	g/L	Concentration C_j at t_j
6 header for misc. parameters			
6.	TMAX	hr	Maximum simulation time, t_{max}
	DPYMAX	μS/cm	Maximum FEC for plots
	RK	m^2/s	Diffusion coefficient, D_0
7 header for C-to-FEC conversion			
7.	RGAMMA	μS/cm	Conversion from C in g/L to FEC in μS/cm: $FEC = \gamma + \beta C + \alpha C^2$
	RBETA	[μS/cm]/[g/L]	Default values (for 20°C): $\gamma = 0$, $\beta = 1870$, $\alpha = -40$
	RALPHA	[μS/cm]/$[g/L]^2$	Set $\gamma = 0$, $\beta = 1$, $\alpha \approx$ 1.e-8 for FEC $\approx C$
8 header for initial conditions			
8.	IC0FLAG	–	Initial concentration flag: = 0: $C_0 = 0$, no further input for item 8 < 0: read uniform non-zero C_0 in 8a > 0: read IC0FLAG $(x, C_0(x))$ pairs in 8b to describe variable initial concentration
8a header for uniform initial conditions (only when IC0FLAG < 0)			
8a. when IC0FLAG<0	RC0	g/L	Uniform non-zero C_0
8b header for non-uniform initial conditions (only when IC0FLAG > 0)			
8b. repeat IC0FLAG times when IC0FLAG>0	RX	m	x value*
	RC0	g/L	$C_0(x)$
9 header for data file name			
9.	CFDATA	–	Name of data file, 20 characters maximum; 'NONE' if there is no data file

*see Appendix 1, Section A1.5, for additional information on locating feed points and specifying non-uniform initial conditions

Sample Input File

An input file illustrating many of these options is shown below. Text or numbers following an exclamation point (!) are comments, and are not used by BORE II.

```
TITLE: Sample Input File with flow from below, horizontal flow, variable flow
XMIN(m)      XMAX(m)      DIAM(cm)
.0000        60.00        7.600
QW(L/min)    HALPHA       !QW=flow from below; HALPHA=hor. flow constriction
 0.50        0.           !default value of HALPHA will be used
#FEED_PTS    VARIABLE_FLOWRATE_IDENTIFIER
   4                999
DEPTH(m)     Q (L/min)     C(g/L)      T0(hr)      Q/V_FLAG
 25.         +1.           6.0         .0000       1 !1st 2 feed pts-hor. flow
 25.         -1.           6.0         .0000       1 !C & T0 not used (outflow)
 30.         99905.        6.0         .0000       0 !C & T0 not used (table)
     T(hr)       Q(L/min)    C(g/L)      !#entries is two digits after  999
      .0000       .0000       6.         !first time in table is zero
      .3000       .2800E-01   5.
      .5000       .3200       4.
      1.000       .4600       3.
      1.500       .4600       2.         !last time in table is > tmax
 35.         .5            4.0         .2000       0 !final feed pt
TMAX(hr)     FECMAX       DIFFUSION_COEF.(m2/s)
 1.000       5000.        .7500E-09
RGAMMA       RBETA        RALPHA      !FEC = RGAMMA + C*RBETA + C*C*RALPHA
0.           0.           0.          !default values will be used
IC0FLAG      !If 0, C0=0; If <0, read one C0; If >0,read IC0FLAG (X,C0) pairs
    1
X(m)         C0(g/L)           !#entries is IC0FLAG
60.          2.                !Concentration associated with Qw
DATA_FILE    !'NONE' if there is no data file
NONE
```

The first two feed points represent constant horizontal flow, and since the Q/V flag (IINFV) is one, flow rate is given as Darcy velocity through the aquifer in m/day. The third feed point has variable flow rate and concentration, with a five-entry table specifying the variation with time. The fourth feed point is an inflow point with constant flow rate and concentration and a non-zero concentration start time.

Note that the flow from below, q_w, is positive (into the wellbore section), so the corresponding concentration is specified as the initial condition of the lowermost cell in the wellbore (at $x = x_{\min}$) by using IC0FLAG = 1. If IC0FLAG = 0, the concentration associated with q_w would be zero, and if IC0FLAG = -1, the concentration associated with q_w would be the uniform non-zero initial concentration in the wellbore.

When BORE II writes an input file (option V), it changes several things to the file form shown above. Comments found in the original input file are not reproduced, but two comments are added. First, the cell height and the equation used to calculate it are shown on the line with $x_{\min}$, $x_{\max}$, and d_w. Second, if feed points represent horizontal flow, then the flag IINVF is set to 0, flow rate is given in L/min, and the corresponding Darcy velocity through the aquifer in m/day is added as a comment. Finally, if IC0FLAG > 0, BORE II sets IC0FLAG to the number of wellbore cells, and explicitly shows every (x, $C_0(x)$) pair. This option is useful for identifying the x values of various cells, which may expedite assignment of feed point locations or initial conditions. Part of the input file created by BORE II for the above sample is shown below.

```
TITLE: Sample Input File with flow from below, horizontal flow, variable flow
XMIN(m)     XMAX(m)     DIAM(cm)    !DX(m) = MAX(|XMIN - XMAX|/180, DIAM/100)
 .0000       60.00       7.600      ! .3333
QW(L/min)   HALPHA      !QW=flow from below; HALPHA=hor. flow constriction
 .5000       2.500
#FEED_PTS   VARIABLE_FLOWRATE_IDENTIFIER
    4               999
DEPTH(m)    Q(L/min)    C(g/L)      T0(hr)      Q/V_FLAG    !Vd(m/day)
 35.00       .5000       4.000       .2000         0
 30.00      99905.       6.000       .0000         0
     T(hr)       Q(L/min)    C(g/L)      !#entries is two digits after  999
      .0000       .0000       6.000
      .3000       .2800E-01   5.000
      .5000       .3200       4.000
      1.000       .4600       3.000
      1.500       .4600       2.000
 25.00       .4398E-01   6.000       .0000         0          ! 1.000
 25.00      -.4398E-01   6.000       .0000         0          !-1.000
TMAX(hr)    FECMAX      DIFFUSION_COEF.(m2/s)
 1.000       5000.       .7500E-09
RGAMMA      RBETA       RALPHA      !FEC = RGAMMA + C*RBETA + C*C*RALPHA
 .0000       1870.      -40.00
IC0FLAG     !If 0, C0=0; If <0, read one C0; If >0,read IC0FLAG (X,C0) pairs
  179
X(m)        C0(g/L)           !#entries is IC0FLAG
 59.83       2.000
 59.50       .0000
 59.17       .0000
 58.83       .0000
…(169 entries with C0=0 not shown)…
 2.167       .0000
 1.833       .0000
 1.500       .0000
 1.167       .0000
 .8333       .0000
 .5000       .0000
DATA_FILE   !'NONE' if there is no data file
NONE
```

Line by Line Instructions for Data File

The data file is read in the fixed format shown below. If data are available in a different format, an auxiliary program should be used to convert it to this form (a simple preprocessor called PREBORE, described in Appendix 2, converts the data file format used by BORE to the new format shown below). Note that because a fixed format is used, blank entries are allowed; they are interpreted as zero.

Lines 1-8 are header lines, not used by BORE II.

Each line of the remainder of the file contains:

Variable	*x*	FEC	TEMP	DAT3	DAT4	DAT5	HR	MIN	SEC
Units	m	μS/cm	°C				–	–	–
Format	F10.3	F10.3	F10.3	E10.3	E10.3	E10.3	I3	I2	I2
Columns	1-10	11-20	21-30	31-40	41-50	51-60	62-64	66-67	69-70

The entries DAT3, DAT4, and DAT5 represent optional data types that may be collected with certain logging tools, such as pH and dissolved oxygen (see options A and Y for ways to display this data). Note that there is one blank column before each of the HR, MIN, and SEC entries, to make the data file more readable. The first time entry corresponds to $t = 0$ for the model.

BORE II Options

The following options are available on the BORE II main menu. Either uppercase or lowercase letters may be used, and should be followed by pressing ENTER.

C – (C)-x plot – Displays FEC versus depth for data and/or model continuously in time (an animation); stores [x (m), t (sec), data FEC (μS/cm), model FEC (μS/cm)] in file BOREII.TMP for later use by option R or post-processing.

T – c-(T) plot – Displays FEC versus time for data and model for a chosen depth.

R – d/m cu(R)ve – Displays FEC versus depth plots for data and model at a series of times (snapshots of the option C display); uses results of most recent option C, read from BOREII.TMP. Does not work if there is no data file or if there are only data at one depth in data file.

N – i(N)flow-c – Displays inflow FEC for a chosen feed point as a function of time.

A – p(A)ram display – Displays all data profiles (FEC, TEMP, DAT3, DAT4, DAT5) simultaneously, using user-specified plot limits (selections 3-6). For selection 1, all points are connected on one continuous curve; for selection 2, points that are beyond depth or time limits start new curve segments.

X – (X)-t plot – Displays a color-coded plot of model FEC versus depth and time in a new window, then repeats the plot in the borehole profile window.

S – tool (S)tudy x-t plot – Same as X, but limits display to what would be obtained with a tool whose parameters (number of probes, gap between probes, and tool velocity) are specified by the user.

D – (D)ata x-t – Displays a color-coded plot of data traces versus depth and time in a new window, then repeats the plot in the borehole profile window (data type specified by option Y, default is FEC).

F – (F)ill data x-t – Same as D, except that data traces are interpolated to fill the *x-t* plane.

I – d/m d(I)ff x-t – Displays a color-coded plot of the difference between model and data FEC versus depth and time in a new window, then repeats the plot in the borehole profile window. User selects whether to show data traces (mode 1) or filled data (mode 2).

M – (M)odify inp– Opens interactive session for modifying location, flow rate, and concentration of feed points, or adding new feed points. User is prompted to enter feed point number and given the chance to modify or maintain current parameters. To add a new feed point, specify a feed point number greater than that for any existing feed point. If horizontal flow is implemented using option M, flow rate must be specified as volumetric flow rate through the wellbore in L/min.

P – (P)lot adjust – Sets new values of parameter minimum and maximum; t_{max}; difference range for option I; and depth for which wellbore flow rate q_0 is displayed in borehole profile window (default depth is x_{min}).

G – (G)rid – Sets grid spacing for new window showing *x-t* plots.

Y – data t(Y)pe – Chooses data type (FEC, TEMP, DAT3, DAT4, DAT5) to display in options C, T, D, and F. Model results always show FEC, so option C and T plots, which show both model and data, must be read carefully. Note that options R and I are not affected by the choice of data type, but always compare model and data FEC.

Z – print – Displays instructions for printing a screen image.

V – sa(V)e – Creates a new input file with current model parameters. User is prompted for new file name.

Q – (Q)uit – Terminates BORE II program.

4. Example Applications

Five example applications are presented to illustrate the capabilities of BORE II. Although BORE II simulates the forward problem (it produces wellbore FEC profiles given different inflow positions, rates, and concentrations), it is most commonly used in an inverse mode, in which inflow positions, rates and concentrations are varied by trial and error until the model matches observed values of wellbore FEC profiles. Initial guesses for the trial and error process may be obtained using direct integral methods (Tsang and Hale, 1989; Tsang et al., 1990) or other means (see example 2 below). Example applications 3, 4, and 5 demonstrate such comparisons to real data provided to us as typical field data sets by G. Bauer (private communication, 2000). The results of these example applications do not necessarily provide physically realistic flow rates and inflow concentrations, because they employ the artificial equality FEC = *C*. Furthermore, rough matches to real data, as are obtained here, can often be obtained equally well with a variety of different parameters (i.e., the solution of the inverse problem is non-unique). The input files for the example applications are shown in Appendix 3.

	Problem	Data File	Input File	Features
1	Up flow	up_num.dbt (numerically simulated)	up_num.inp	Advection and dilution, diffusion/dispersion minor
2	Horizontal flow	hor_an.dbt (analytical solution)	hor_an.inp	Dilution only, no advection or diffusion/dispersion One pair inflow/outflow points
3	Horizontal flow	hor_real.dbt (real data)	hor_real.inp	Dilution and diffusion/dispersion Multiple pairs inflow/outflow points Initial time added to data
4	Down flow	down_c.dbt (real data)	down_c.inp	Advection, dilution, and diffusion/dispersion Variable inflow concentration
5	Combination flow	comb_ic.dbt (real data)	comb_ic.inp	Advection, dilution, and diffusion/dispersion Non-uniform initial conditions

1. Up Flow – Numerically Simulated Data

Perhaps the most common application of BORE II is to the case of up flow - when one pumps from the top of the wellbore section, and fluid enters the wellbore at one or more feed points. Figure 1 shows *C* versus *x* for several times for a typical up flow case (obtained with BORE II option R). Each feed point has the same inflow rate and the same concentration, and there is also up flow from below. At early times, the feed points show up as individual FEC peaks, but as time passes, the deeper peaks merge with those above them, creating a step-like structure. The data set for this example is not real, but the results of a numerical simulation using the flow and transport simulator TOUGH2 (Pruess, 1987; 1991; 1995; 1998). TOUGH2 has been verified and validated against analytical solutions, other numerical models, and laboratory and field data. The TOUGH2 simulation uses a one-dimensional model with the same cell spacing as BORE II and constant mass sources located at the BORE II feed points. Thus, BORE II and TOUGH2 are solving the same problems, and comparing the results for wellbore FEC profiles verifies that the BORE II calculations are done correctly.

2. Horizontal Flow – Analytical Solution and Numerically Simulated Data

For horizontal flow in the absence of diffusion/dispersion along the wellbore, an analytical solution for the concentration observed in the wellbore as a function of time, *C*(*t*), is given by (Drost, 1968):

$$C(t) = C_i - [C_i - C(0)]\exp\left(\frac{-2tv_d\alpha_h}{\pi r_w}\right), \tag{1}$$

where C_i is the formation (inflow) concentration, *t* is time (s), v_d is the Darcy velocity through the aquifer (m/s), α_h is the aquifer-to-wellbore convergence factor, and r_w is the wellbore radius (m). Figure 2 shows the analytical solution and the BORE II results for this problem, obtained using option T. The agreement is excellent. Note that for small values of v_d, if C(0) = 0, the analytical solution becomes approximately

$$C(t) = C_i\left[1 - \exp\left(\frac{-2tv_d\alpha_h}{\pi r_w}\right)\right] \approx C_i\left[1 - \left(1 - \frac{2tv_d\alpha_h}{\pi r_w}\right)\right] = \frac{C_i\,2tv_d\alpha_h}{\pi r_w}. \tag{2}$$

Thus, any combination of C_i and v_d whose product is a constant gives the same value of C. This condition corresponds to the early-time straight-line portion of Figure 2. The analytical solution may be implemented in a spreadsheet to expedite the choice of BORE II parameters, by examining the solution for various values of v_d and C_i. Note that care must be taken to use a consistent set of units for t, v_d, and r_w in Equations (1) and (2). For example, when time is in seconds, BORE II input parameters v_d in m/day and r_w in cm must be converted to m/s and m, respectively.

Figure 2 also shows the evolution of concentration at and near a horizontal flow layer when diffusion/dispersion along the wellbore is significant ($D_0 = 10^{-5}$ m^2/s). For this case, the analytical solution is not applicable, but BORE II results compare very well to numerically simulated data obtained using TOUGH2. When dispersion is significant, use of the Drost solution generally results in an underestimation of C_i and an overestimation of v_d. These errors do not arise when using BORE II, since diffusion/dispersion can be explicitly included.

3. Horizontal Flow – Real Data

As indicated in Figure 2, the addition of diffusion or dispersion modifies the depth-FEC profile arising from a thin layer of horizontal flow, by widening the base of the FEC peak. A thick layer of horizontal flow produces a distinct signature, with an FEC response that has a wide peak as well as a wide base. To model a thick layer of horizontal flow, one may use several adjacent inflow/outflow point pairs in the model. Figure 3 compares model and data profiles (G. Bauer, private communication, 2000) of C versus x for several times, using option R. Seven pairs of inflow/outflow points are used, assigned to seven adjacent cells. By multiplying the number of inflow/outflow pairs by cell thickness, one may estimate the thickness of the layer of horizontal flow, in this case 2.3 m. See Appendix 1, Section A1.5, for additional information about assigning feed points to specific cells.

For this particular data set, the earliest observations show a variable FEC profile. One possible way to address this is to specify a non-uniform initial concentration distribution in the wellbore. An alternative approach (used here) is to add a dummy entry to the data file, specifying a time prior to the first real data time, at which the FCE distribution in the wellbore is assumed to be uniform. In general, it is not possible to determine when, if ever, the FEC distribution in the wellbore is uniform, but the approach can work quite well, as shown in Figure

4, which shows *C* versus *t* at the center of the horizontal flow zone (option T). The data zero time taken from the header of the data file, where the date and time of the logging run are specified.

4. Down Flow – Real Data

Figure 5 compares model and data profiles (G. Bauer, private communication, 2000) of *C* versus *x* for several times (option R) for a case with primarily down flow. A uniform non-zero initial concentration is used (IC0FLAG < 0) to approximate the low, slightly variable initial concentration. Two shallow inflow points have variable concentrations that increase in time, which suggests that de-ionized water penetrated into the fractures when it was introduced into the wellbore to establish low-concentration initial conditions for logging. A low-concentration feed point at $x = 158.5$ m creates up flow above it, but the remainder of the wellbore section shows down flow.

5. Combination Flow – Real Data

Figure 6 compares model and data profiles (G. Bauer, private communication, 2000) of *C* versus *x* for several times (option R) for a case with combination flow. A non-uniform initial condition has been used, which is extracted from the data file using the preprocessor PREBORE (see Appendix 2). Note that there are more entries in the initial condition specification (232) than there are cells in the model (179). Thus, some cells are assigned more than one initial condition. For cells where this occurs, only the final initial condition assigned is used. See Appendix 1, Section A1.5, for additional information on specifying non-uniform conditions. Figure 7 shows the same information as Figure 6, but plotted in a different way, with the difference between data and model FEC plotted as an *x-t* plot (option I). The blue and orange diagonal features indicate that the largest discrepancy between model and data gradually deepens with time.

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Appendix 1: Mathematical Background and Numerical Approach

The principal equation governing wellbore FEC variation is the equation for the transport of mass (or ion concentration) in the wellbore. However, additional consideration must be given to the determination of FEC as a function of ion concentration and the temperature dependence of FEC.

A1.1 FEC as a Function of Concentration

The relationship between ion concentration and FEC is reviewed, for example, by Shedlovsky and Shedlovsky (1971), who give graphs and tables relating these two quantities. Hale and Tsang (1988) made a sample fit for the case of NaCl solution at low concentrations and obtained

$$\text{FEC} = 1{,}870\ C - 40\ C^2, \qquad \text{(A.1)}$$

where C is ion concentration in kg/m^3 ($\approx$ g/L) and FEC is in μS/cm at 20^{o}C. The expression is accurate for a range of C up to $\approx$ 6 kg/m^3 and FEC up to 11,000 μS/cm. The quadratic term can be dropped if one is interested only in values of C up to $\approx$ 4 kg/m^3 and FEC up to 7,000 μS/cm, in which case the error will be less than 10%.

Fracture fluids typically contain a variety of ions, the most common being Na^+, Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-}, and HCO_3^-. If a hydrochemical analysis has been completed, various methods are available for computing an equivalent NaCl concentration for other ions. Schlumberger (1984) presents charts of multiplicative factors that convert various solutes to equivalent NaCl concentrations with respect to their effect on electric conductivity.

A1.2 Temperature Dependence of FEC

BORE II calculations are made assuming a uniform temperature throughout the wellbore. Actual wellbore temperatures generally vary with depth, so temperature corrections must be applied to field FEC data to permit direct comparison with model output.

The effect of temperature T on FEC can be estimated using the following equation (Schlumberger, 1984)

$$\mathrm{FEC}(20^{\circ}\mathrm{C}) = \frac{\mathrm{FEC}(\mathrm{T})}{1 + \mathrm{S}(\mathrm{T} - 20^{\circ}\mathrm{C})}, \qquad \text{(A.2)}$$

where $S = 0.024$.

Generally, temperature increases with depth below the land surface. If full temperature logs are available, these data can be used to correct the corresponding FEC values. However, if no complete logs are available, a simplifying assumption may be made that the temperature variation in the wellbore is linear and can be modeled by:

$$T = Ax + B, \qquad \text{(A.3)}$$

where A and B are parameters determined by fitting any available temperature versus depth data. If the fit is unsatisfactory, other relationships with higher order terms must be used.

A1.3 Governing Equation

The differential equation for mass or solute transport in a wellbore is:

$$\frac{\partial}{\partial \mathrm{x}}\left(\mathrm{D}_{\mathrm{o}} \frac{\partial \mathrm{C}}{\partial \mathrm{x}}\right) - \frac{\partial}{\partial \mathrm{x}}(\mathrm{Cv}) + \mathrm{S} = \frac{\partial \mathrm{C}}{\partial \mathrm{t}}, \qquad \text{(A.4)}$$

where x is depth, t is time, and C is ion concentration. The first term is the diffusion term, with D_0 the diffusion/dispersion coefficient in m^2/s, the second term is the advective term, with v the fluid velocity in m/s, and S is the source term in kg/m^3s. This one-dimensional partial differential equation is solved numerically using the finite difference method, with upstream weighting used in the advective term. The following initial and boundary conditions are specified:

$$C(x,0) = C_0(x), \qquad \text{(A.5)}$$

$C(x_{min},t) = C_0(x_{min})$ for flow into the wellbore from above,

$C(x_{max},t) = C_0(x_{max})$ for flow into the wellbore from below,

$D_0 = 0$ for $x < x_{min}$ and $x > x_{max}$.

The first condition allows for the specification of initial ion concentrations in the wellbore. The second and third conditions allow for advective flow of ions into the wellbore interval from above and below. The final condition indicates that diffusion and dispersion do not take place across the boundaries of the wellbore interval. In general, advection will be the dominant process at the boundaries. If diffusion or dispersion is dominant for a particular problem, the boundaries should be extended in order to prevent improper trapping of electrolyte.

A1.4 Discretization in Time

Time stepping is explicit, with the time step Δt determined by stability constraints for advection

$$\Delta t \leq \frac{\pi d_w^{\,2} \Delta x}{8 q_{max}}, \qquad (A.6)$$

and diffusion

$$\Delta t \leq \frac{\Delta x^2}{4 D_0}, \qquad (A.7)$$

where q_{max} (m^3/s) is the maximum fluid flow rate anywhere in the wellbore. BORE II starts its calculation at $t = 0$. The first time in the data file is also identified with $t = 0$. If it is apparent that model and data times are not synchronized, then one may insert an additional line into the data file after the header lines, with an earlier time than the first real data time, in order to reset the data zero time. On the inserted line, FEC, x, and other data entries may be left blank or copied from the first real data line.

A1.5 Discretization in Space

The wellbore interval between x_{min} and x_{max} is uniformly divided into N cells and it is assumed that the wellbore has uniform diameter, d_w. Cell height Δx is determined as the larger of $(x_{max} - x_{min})/180$ and d_w. Position values indicate depth in the wellbore and thus x is zero at the surface and increases downward. The cell index increases upward, with cells 1 and N located at the bottom and top, respectively, of the wellbore interval. In general, the ith node (the center of the ith cell) is located at

$$x_i = x_{max} - (i\text{-}1/2)\Delta x, \qquad (A.8)$$

with the ith cell extending from $x_{max} - (i - 1)\Delta x$ to $x_{max} - i\Delta x$.

BORE II assigns feed points and initial concentrations to cell i if the location of the feed point or $C_0(x)$ value lies within the boundaries of the ith cell. If multiple feed points are assigned to the same cell, they will all be accounted for, but if multiple initial conditions are assigned to the same cell, only the final one assigned will be used. By definition, the lower boundary of cell

1 is at x_{max}, but due to round-off errors, the upper boundary of cell N may not be at x_{min}. Hence, it is often useful to know the x coordinates of each node. These are displayed in the input file written by BORE II (option V) when IC0FLAG > 0. Thus, if the user sets IC0FLAG = 1, inputs one (x, $C_0(x)$) pair, and uses option V, then a new input file will be created with IC0FLAG = N and a complete list of the x coordinates for all nodes, with $C_0 = 0$ for all cells except the one identified in the original input file. Alternatively, if the initial conditions are taken from the data file with PREBORE (or taken from any source that is independent of the nodal coordinates), then using option V will create an input file that shows the actual initial conditions assigned to each cell.

The list of nodal x coordinates may be useful when modeling a thick fracture zone or aquifer, in order to place one feed point in each cell over a given depth range. Similarly, when using IC0FLAG > 0 to specify non-uniform initial concentrations, one must assign a C_0 value to each cell in the interval of interest in order to obtain a continuous C profile, because no interpolation is done between scattered initial concentrations. Finally, knowing the coordinate of the top cell in the model is useful for assigning the initial concentration that serves as the boundary condition for inflow into the wellbore interval from above. For inflow from below, either $x = x_1$ or $x = x_{max}$ may be used.

A1.6 Calculation of Flow Rates

Feed point flow rates may be constant in time, in which case a steady-state flow field is assumed in the wellbore, or variable, with feed point flow rates determined by linear interpolation between tabulated values. Although feed point flow rate may vary, true transient wellbore flow including fluid compressibility effects is not considered. Rather, the wellbore fluid flow field is assumed to change instantly from one steady-state flow field to another. In other words, the flow rate out of cell i is always the sum of the flow rates from all feed point locations within the boundaries of cell i plus the flow rate out of cell i-1.

Appendix 2: The Preprocessor PREBORE

PREBORE is a simple Fortran program that does preprocessing for BORE II. It runs under either Windows or DOS. PREBORE converts the old BORE data file format into the new BORE II data file format. Depth is converted from feet to meters, and other data columns are realigned. PREBORE can also create a file with (x,C_0) pairs to be added to the BORE II input file as initial conditions (this option requires that x values steadily increase or steadily decrease in each profile).

If data file conversion is being done, the user is prompted to enter the old and new data file names.

If a file with initial conditions is being created, the user is prompted for the following information: the name of the BORE II data file; a name for the initial condition file; which profile in the data file to use; the direction of logging (downward assumes x values increase in the data file, upward assumes they decrease, and both assumes the profiles alternately increase and decrease in x); and the conversion factors (γ, β, α) between FEC and C (default values 0, 1870, -40). In addition to creating an ASCII text file with (x,C_0) pairs, which may be added to the BORE II input file using a text editor or word processor, PREBORE prints out the number of pairs on the screen, which should be used for IC0FLAG. Note that IC0FLAG may be greater than the number of cells in the model (usually about 180), but that in this case not all the C_0 values will be used (see Appendix 1, Section A1.5).

Data file conversion and initial condition creation can be done in the same PREBORE run. In this case the user must specify both old and new data file names in addition to the parameters describing the creation of initial conditions.

Appendix 3: Input Files for Example Applications

A2.1 Example Application 1 – Up Flow – up_num.inp

```
TITLE: up flow with flow from below, compare to synthetic data
XMIN(m)      XMAX(m)      DIAM(cm)     !DX(m) = MAX(|XMIN - XMAX|/180, DIAM/100)
 .0000        180.0        14.00       ! 1.000
QW(L/min)    HALPHA       !QW=flow from below; HALPHA=hor. flow constriction
 .7500        2.500
#FEED_PTS    VARIABLE_FLOWRATE_IDENTIFIER
    3                999
DEPTH(m)     Q(L/min)     C(g/L)       T0(hr)       Q/V_FLAG     !Vd(m/day)
 160.5        .7500        100.0        .0000          0
 130.5        .7500        100.0        .0000          0
 50.50        .7500        100.0        .0000          0
TMAX(hr)     FECMAX       DIFFUSION_COEF.(m2/s)
 24.00        100.0        .7500E-09
RGAMMA       RBETA        RALPHA       !FEC = RGAMMA + C*RBETA + C*C*RALPHA
 .0000        1.000        .1000E-07
IC0FLAG      !If 0, C0=0; If <0, read one C0; If >0,read IC0FLAG (X,C0) pairs
    0
DATA_FILE    !'NONE' if there is no data file
up_num.dbt
```

A2.2 Example Application 2 – Horizontal Flow Analytical Solution – hor_an.inp

```
TITLE: Horizontal Flow - Compare to Analytical Solution
XMIN(m)      XMAX(m)      DIAM(cm)
0.000        50.000       7.600
QW(L/min)    HALPHA
0.           2.850000
#FEED_PTS    VARIABLE_FLOWRATE_IDENTIFIER
       2     999
DEPTH(m)     Vd(m/d)      C(g/L)       T0(hr)       Q/V_FLAG
  25.0000      1.         1000.      .0000           1
  25.0000     -1.         1000.      .0000           1
TMAX(hr)     FECMAX       DIFFUSION_COEF.(m2/s)
3.0000       1000.        1.e-10
RGAMMA       RBETA        RALPHA
0.000000     1.000000     1.e-08
IC0FLAG
0
DATA_FILE
hor_an.dbt
```

The input file for the case with significant dispersion is identical, except that the diffusion coefficient is increased from 10^{-10} m^2/s to 10^{-5} m^2/s.

A2.3 Example Application 3 – Horizontal Flow - hor_real.inp

```
TITLE: Horizontal Flow Example
XMIN(m)      XMAX(m)      DIAM(cm)     !DX(m) = MAX(|XMIN - XMAX|/180, DIAM/100)
 .0000        60.00        7.600       ! .3333
QW(L/min)    HALPHA       !QW=flow from below; HALPHA=hor. flow constriction
 .0000        2.500
#FEED_PTS    VARIABLE_FLOWRATE_IDENTIFIER
   14                999
DEPTH(m)     Q(L/min)     C(g/L)       T0(hr)       Q/V_FLAG     !Vd(m/d)
 26.73        .5295E-02    730.0        .0000          0          ! .1204
 26.73       -.5295E-02    .0000        .0000          0          !-.1204
 26.39        .5295E-02    730.0        .0000          0          ! .1204
 26.39       -.5295E-02    .0000        .0000          0          !-.1204
 26.06        .5295E-02    730.0        .0000          0          ! .1204
 26.06       -.5295E-02    .0000        .0000          0          !-.1204
 25.73        .5295E-02    730.0        .0000          0          ! .1204
 25.73       -.5295E-02    .0000        .0000          0          !-.1204
 25.39        .5295E-02    730.0        .0000          0          ! .1204
 25.39       -.5295E-02    .0000        .0000          0          !-.1204
 25.06        .5295E-02    730.0        .0000          0          ! .1204
 25.06       -.5295E-02    .0000        .0000          0          !-.1204
 24.73        .5295E-02    730.0        .0000          0          ! .1204
 24.73       -.5295E-02    .0000        .0000          0          !-.1204
TMAX(hr)     FECMAX       DIFFUSION_COEF.(m2/s)
 4.000        400.0        .7500E-04
RGAMMA       RBETA        RALPHA       !FEC = RGAMMA + C*RBETA + C*C*RALPHA
 .0000        1.000        .1000E-07
IC0FLAG      !If 0, C0=0; If <0, read one C0; If >0,read IC0FLAG (X,C0) pairs
    0
DATA_FILE    !'NONE' if there is no data file
hor_real.dbt
```

A2.4 Example Application 4 – Down Flow – down_c.inp

```
TITLE: downflow, variable source conc., uniform non-zero initial conc.
XMIN(m)     XMAX(m)     DIAM(cm)    !DX(m) = MAX(|XMIN - XMAX|/180, DIAM/100)
 140.0       240.0       7.600      ! .5556
QW(L/min)   HALPHA      !QW=flow from below; HALPHA=hor. flow constriction
 .0000       2.850
#FEED_PTS   VARIABLE_FLOWRATE_IDENTIFIER
   12               999
DEPTH(m)    Q(L/min)    C(g/L)      T0(hr)      Q/V_FLAG    !Vd(m/day)
 239.0      -.7000       .0000       .4000         0
 212.0      -1.000       .0000       .4000         0
 187.0       .7500       1800.       .4000         0
 183.0       .1900       1900.       .4000         0
 181.0       .1200       1900.       .4000         0
 178.0       .5000E-01   1900.       .4000         0
 176.0       .4000E-01   1900.       .4000         0
 174.0       .3000E-01   1900.       .4000         0
 171.0       .1000E-01   1900.       .4000         0
 164.4      99905.       1900.       .4000         0
     T(hr)       Q(L/min)    C(g/L)      !#entries is two digits after  999
      .0000       .4400       80.00
      .4000       .4400       100.0
      1.200       .4400       1100.
      1.900       .4400       1650.
      4.500       .4400       1950.
 162.0      99904.       1800.       .0000         0
     T(hr)       Q(L/min)    C(g/L)      !#entries is two digits after  999
      .0000       .6000E-01   80.00
      .4000       .6000E-01   200.0
      1.900       .6000E-01   1650.
      4.500       .6000E-01   1950.
 158.5       .1000       80.00       .0000         0
TMAX(hr)    FECMAX      DIFFUSION_COEF.(m2/s)
 4.400       1700.       .1000E-02
RGAMMA      RBETA       RALPHA      !FEC = RGAMMA + C*RBETA + C*C*RALPHA
 .0000       1.000       .1000E-07
IC0FLAG     !If 0, C0=0; If <0, read one C0; If >0,read IC0FLAG (X,C0) pairs
   -1
C0 (g/L)    !Uniform, non-zero C0
 80.00
DATA_FILE   !'NONE' if there is no data file
down_c.dbt
```

A2.5 Example Application 5 – Combination Flow – comb_ic.inp

```
TITLE: Combination flow example, non-uniform initial concentration
XMIN(m)      XMAX(m)      DIAM(cm)     !DX(m) = MAX(|XMIN - XMAX|/180, DIAM/100)
 .00000       50.000       7.6000      ! .2778
QW(L/min)    HALPHA       !QW=flow from below; HALPHA=hor. flow constriction
 .00000       2.8500
#FEED_PTS    VARIABLE_FLOWRATE_IDENTIFIER
   12                999
DEPTH(m)     Q(L/min)     C(g/L)       T0(hr)       Q/V_FLAG     !Vd(m/day)
 45.000      -.13000       .00000       .00000        0
 33.300       .11000       800.00       .15000        0
 33.300      -.31000       .00000       .00000        0
 27.500      -1.0500       .00000       .00000        0
 25.700       .30000       810.00       .15000        0
 25.400       .30000       810.00       .15000        0
 25.140       .30000       810.00       .15000        0
 24.900       .30000       810.00       .15000        0
 23.500       .12000       800.00       .15000        0
 21.500       .40000E-01  800.00       .15000        0
 14.000       .15000E-01  750.00       .15000        0
 12.200       .10000E-01  750.00       .15000        0
TMAX(hr)     FECMAX       DIFFUSION_COEF.(m2/s)
 1.0000       1000.0      .50000E-03
RGAMMA       RBETA        RALPHA       !FEC = RGAMMA + C*RBETA + C*C*RALPHA
 .00000       1.0000       .10000E-07
IC0FLAG      !If 0, C0=0; If <0, read one C0; If >0,read IC0FLAG (X,C0) pairs
  232
X(m)         C0(g/L)            !#entries is IC0FLAG
1.524        2
1.615        2
1.707        3
1.829        3
1.951        3
2.073        3
2.225        3
2.377        3
2.53         3
2.713        3
2.865        3
3.018        3
3.353        589
3.536        597
3.719        588
3.871        583
4.054        584
…(208 entries not shown)…
43.282       2
43.8         2
43.983       2
44.166       1
44.318       1
44.501       1
44.684       1
DATA_FILE    !'NONE' if there is no data file
comb_ic.dbt
```

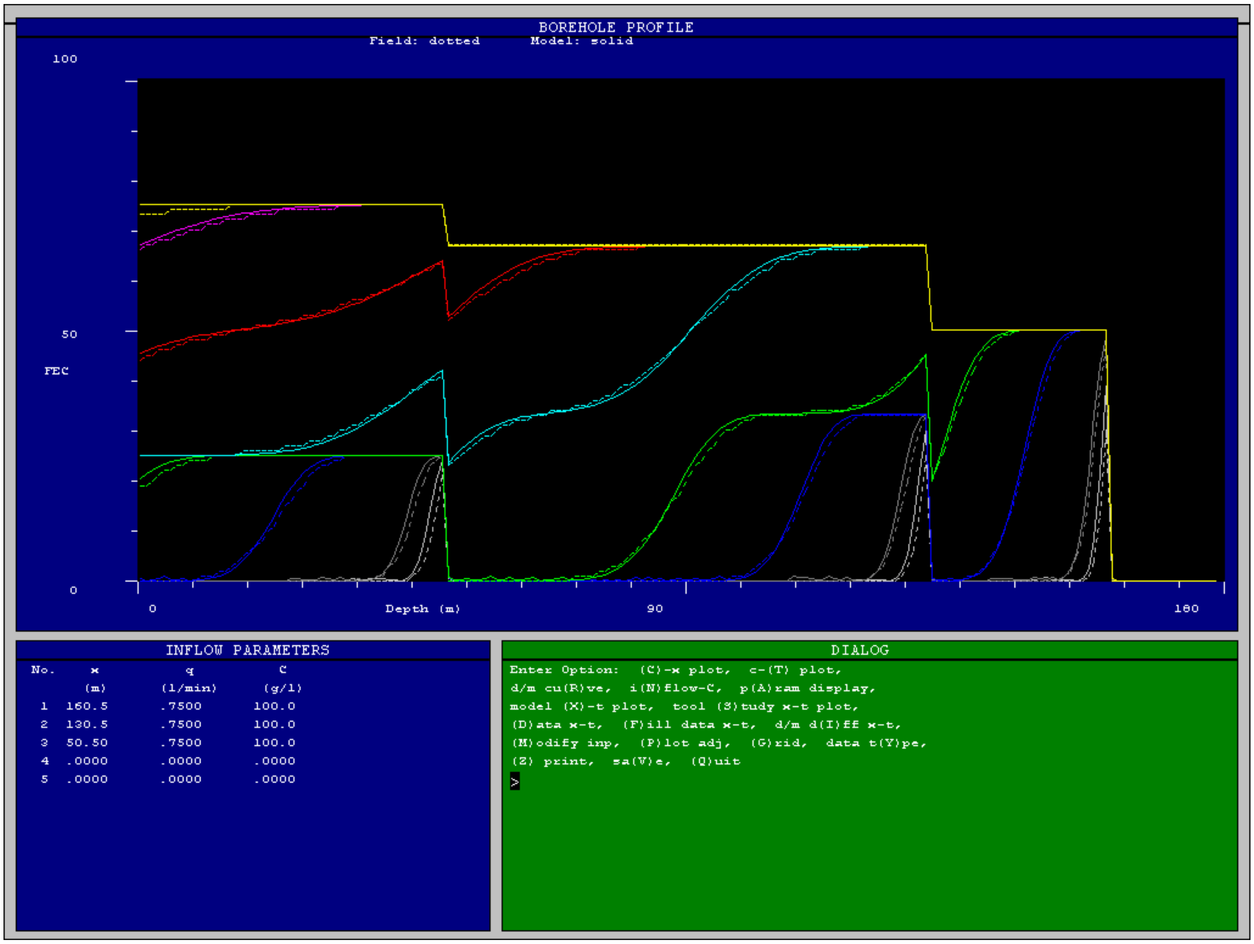

Figure 1. Concentration (=FEC) versus depth at a series of times for example application 1 - up flow. Data are numerically simulated using the TOUGH2 code. Figure is a BORE II screen-print after running option R.

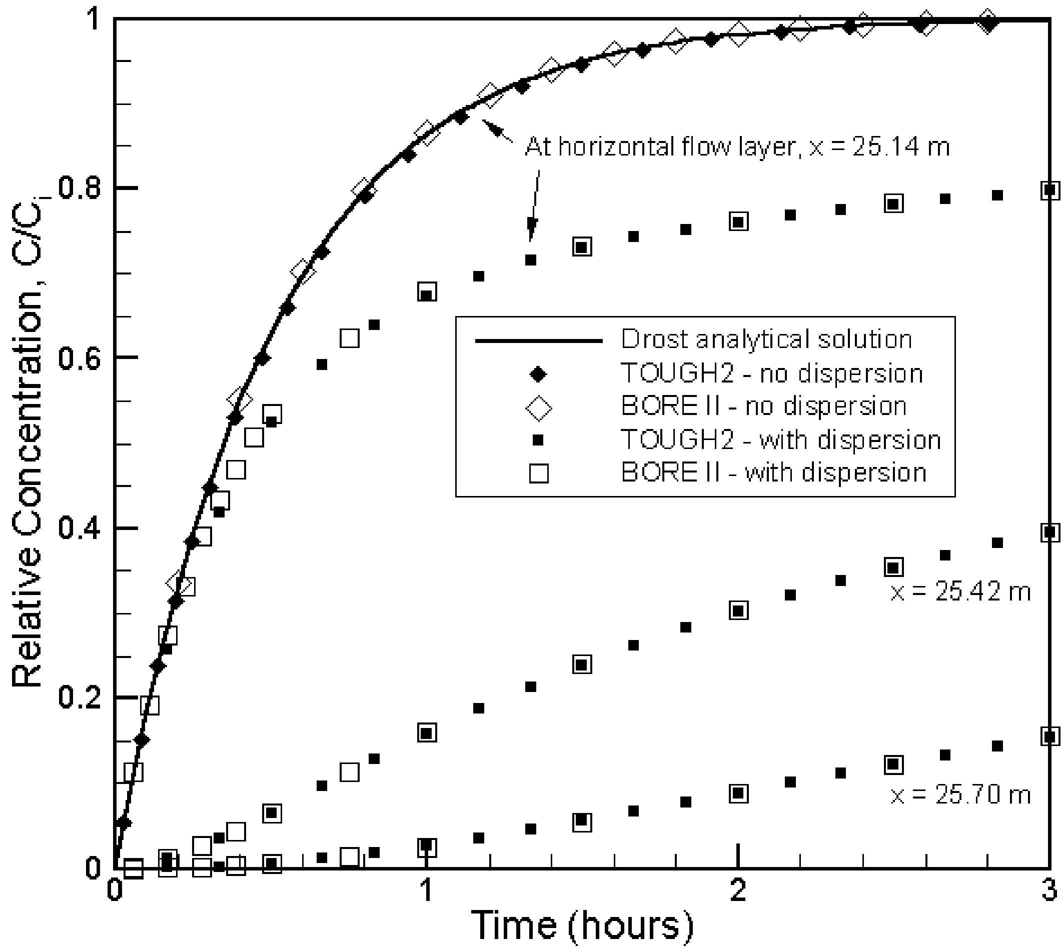

Figure 2. Relative concentration versus time for example application 2 – horizontal flow. When diffusion/dispersion is negligible, the concentration increase only occurs at the depth of the horizontal flow layer. The solid line shows the analytical solution as given by Drost (1968), Equation (1).

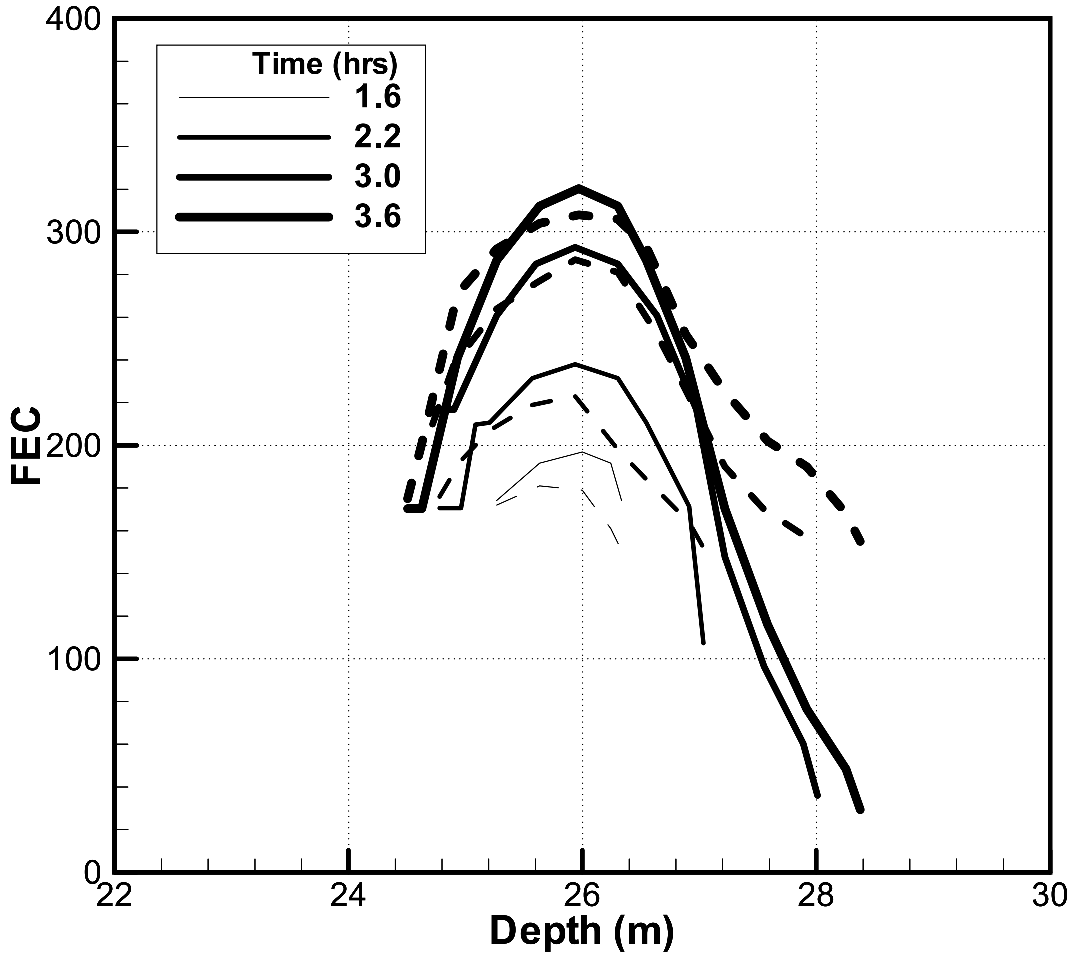

Figure 3. Concentration (= FEC) versus depth at a series of times for example application 3 – a thick layer of horizontal flow. Dashed lines represent field data, solid lines represent BORE II results. Diffusion/dispersion is significant.

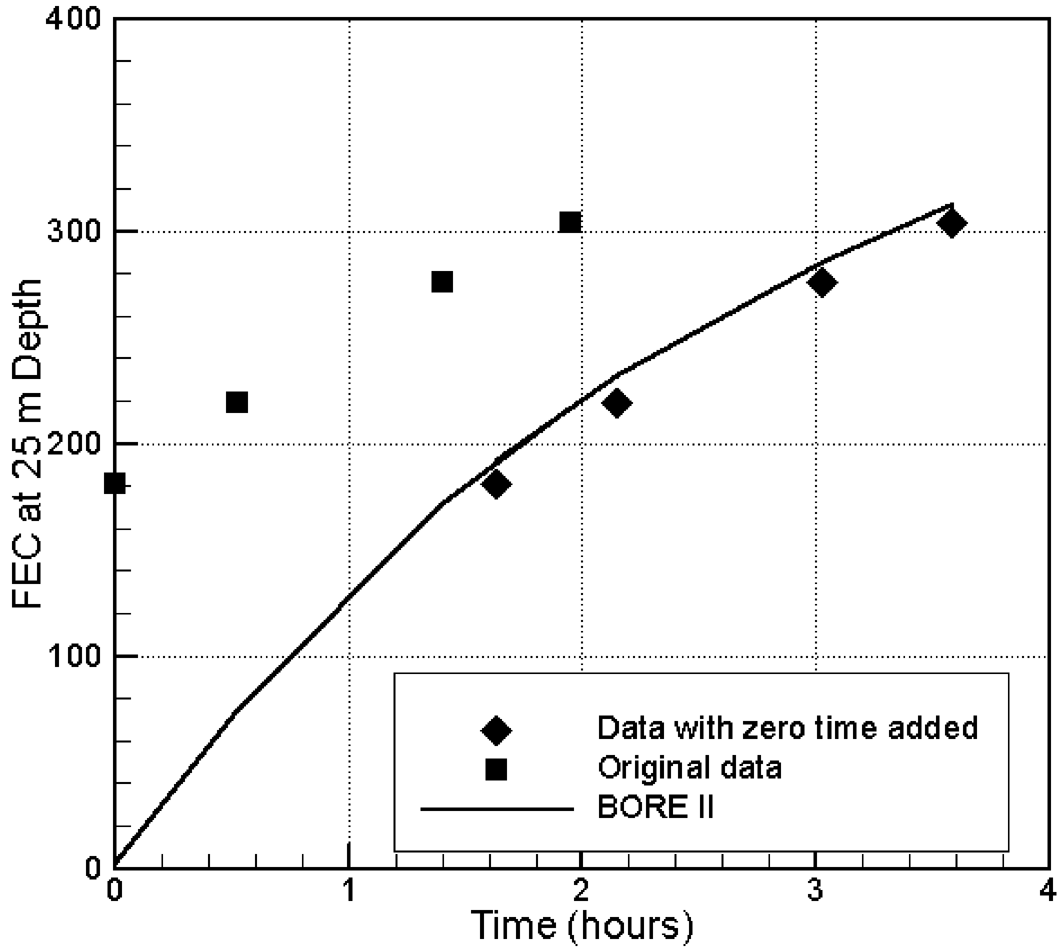

Figure 4. Concentration (= FEC) versus time at the center of the horizontal flow zone of example application 3, illustrating the addition of a data zero time.

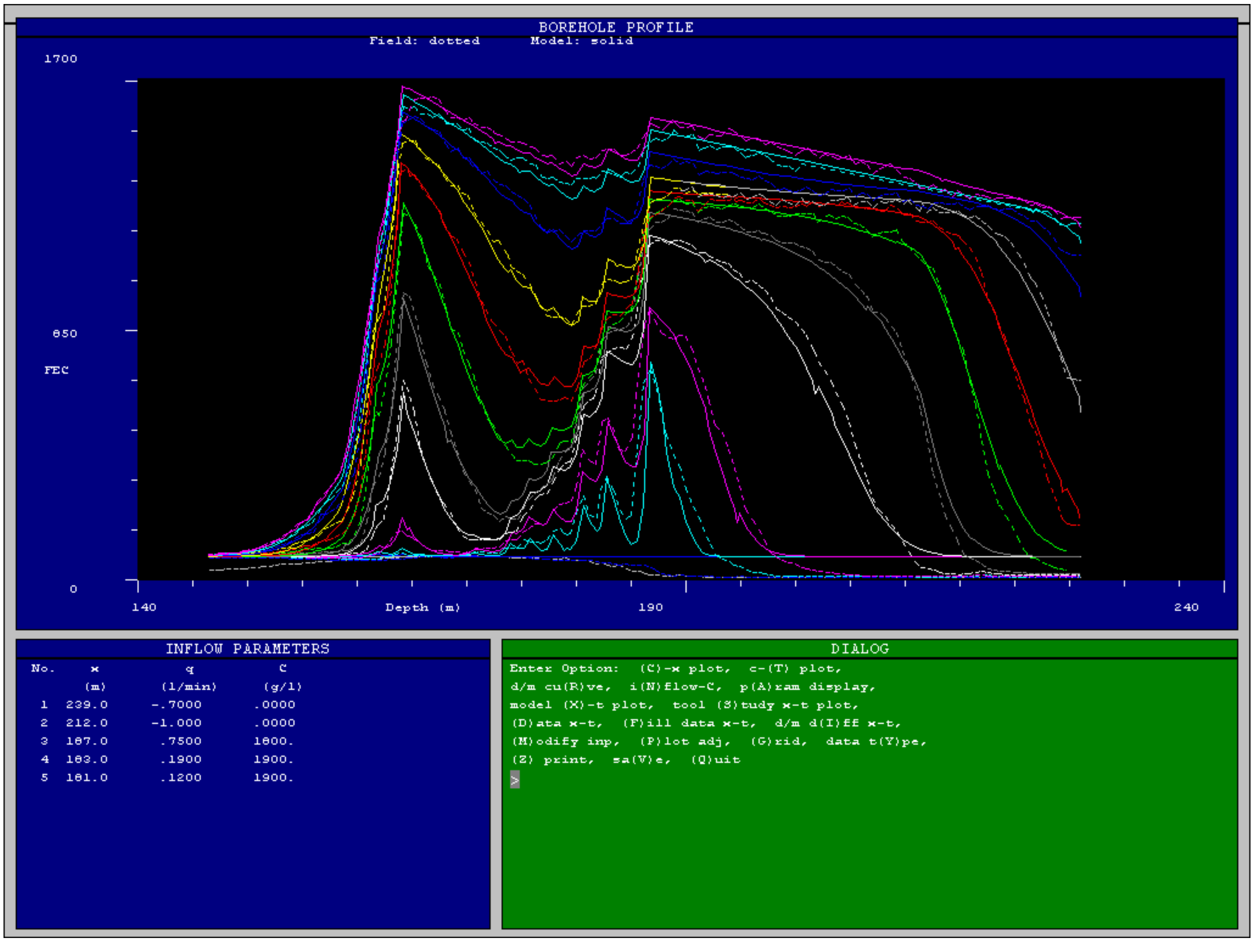

Figure 5. Concentration (= FEC) versus depth at a series of times for example application 4 – down flow. Figure is a BORE II screen-print after running option R.

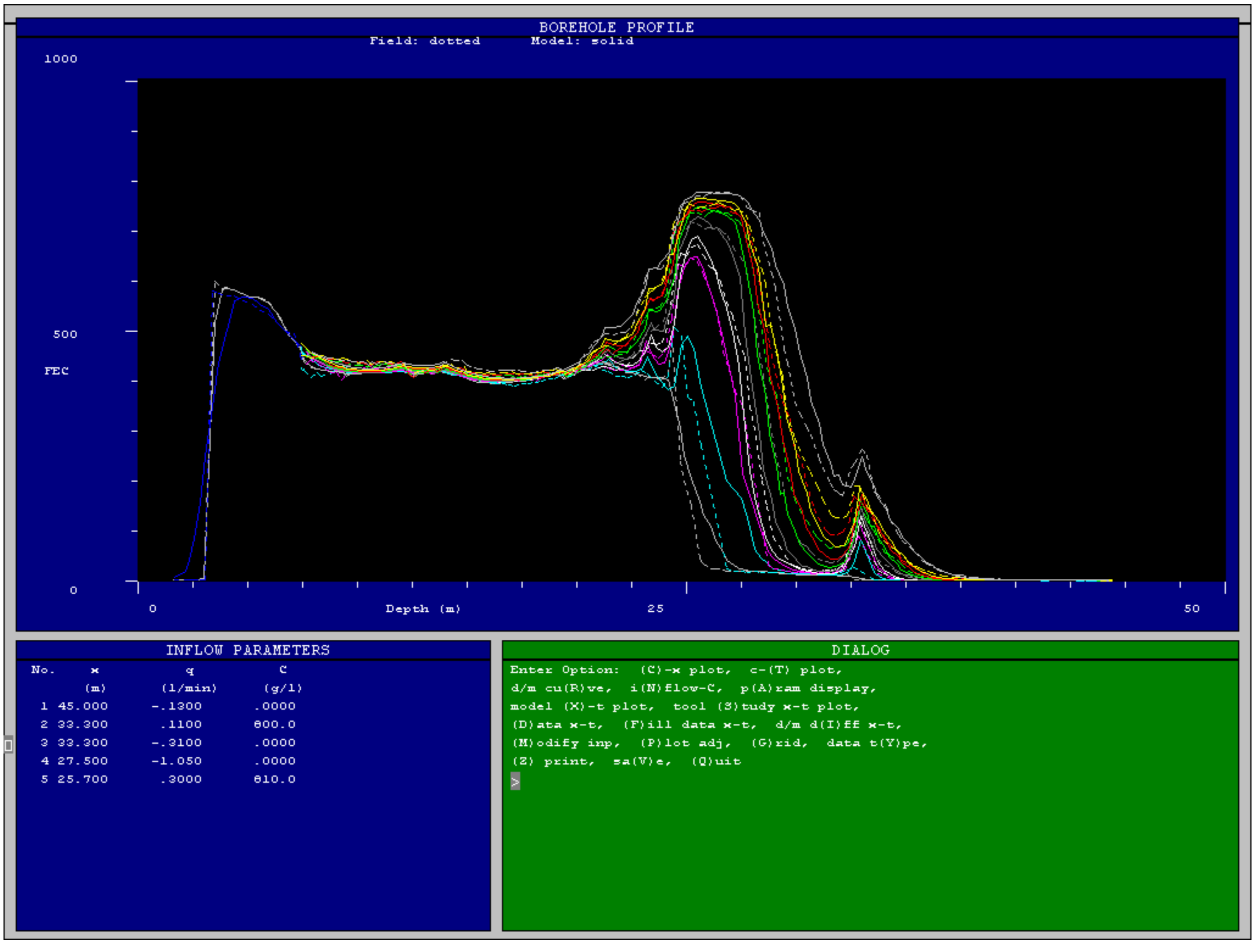

Figure 6. Concentration (= FEC) versus depth at a series of times for example application 5 – combination flow. Figure is a BORE II screen-print after option R.

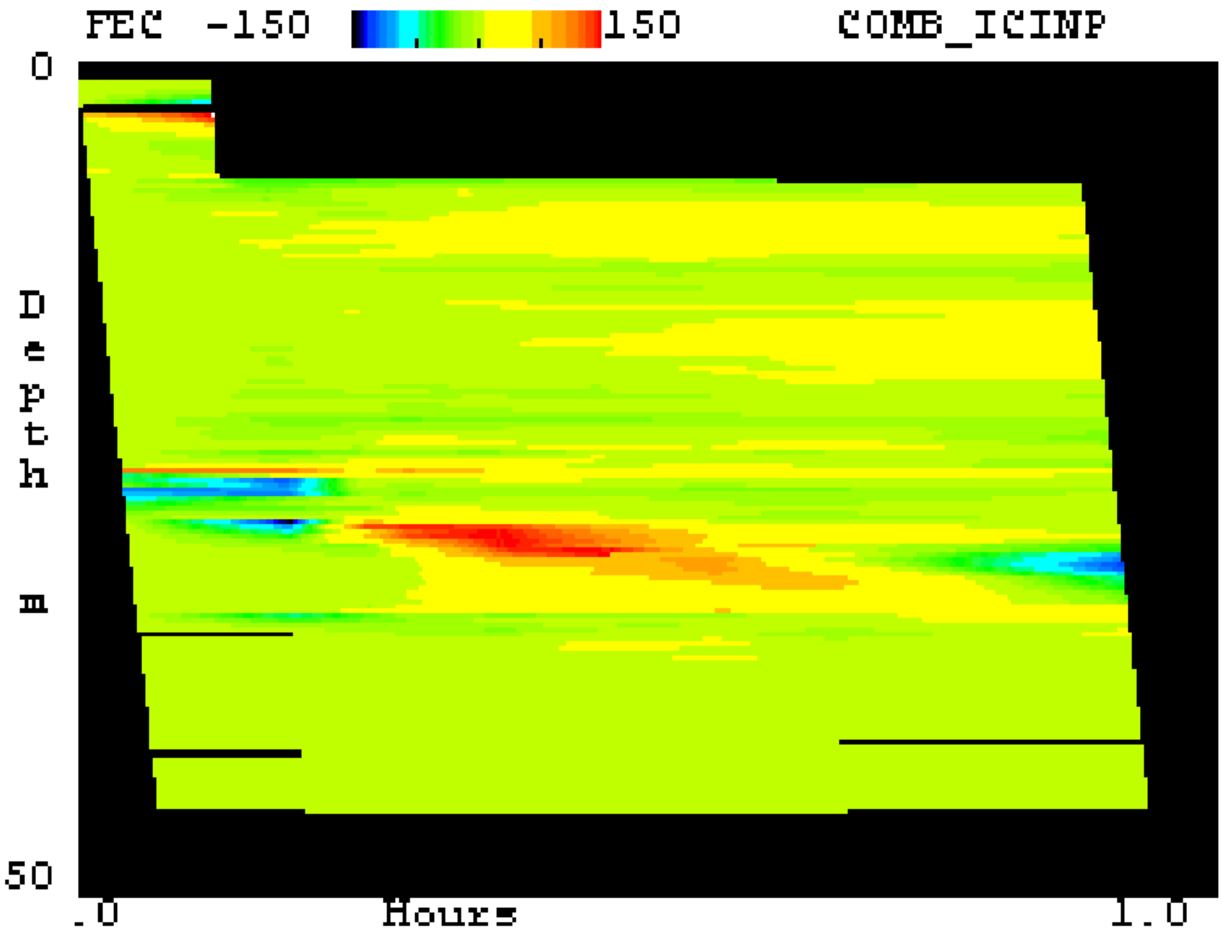

Figure 7. FEC difference between model and data as a function of depth and time (an *x-t* plot) for example application 5 – combination flow. Figure is a BORE II screen-print after option I, mode 2.

APPENDIX C

LIMMITATIONS

LIMITATIONS

COLOG's logging was performed in accordance with generally accepted industry practices. COLOG has observed that degree of care and skill generally exercised by others under similar circumstances and conditions. Interpretations of logs or interpretations of test or other data, and any recommendation or hydrogeologic description based upon such interpretations, are opinions based upon inferences from measurements, empirical relationships and assumptions. These inferences and assumptions require engineering judgment, and therefore, are not scientific certainties. As such, other professional engineers or analysts may differ as to their interpretation. Accordingly, COLOG cannot and does not warrant the accuracy, correctness or completeness of any such interpretation, recommendation or hydrogeologic description.

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