

Well logging results from the Newark Rift Basin Coring Project

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Abstract. Wireline logs were acquired at seven sites in the Newark Rift basin using dipmeter, gamma ray, resistivity, velocity, porosity, density, magnetic susceptibility, temperature, and acoustic televiwer tools. The logs indicate that the formations are clay rich and dip on average 9°N-NW. Densities are relatively constant (2.60-2.80 g/cc) and compressional velocities vary from 4.2-5.5 km/s. Thin uranium-rich layers and basalt flows are clearly delineated. The boreholes are mostly in-gauge, but deviated, and borehole temperature gradients vary between 15 to 26°C/km. These data are potentially useful as indicators of fluid flow and regional stress, lithologic cycles, and for core orientation in the Newark Rift basin.

The composite stratigraphy of the core holes drilled through the Newark Rift Basin is shown in Figure 2.

The LDEO Borehole Research Group provided for the wireline logging in the NBCP through a commercial logging service, in-house televiwer and susceptibility logging equipment, and temperature logging equipment loaned by the U.S. Geological Survey. Based on the availability of logging instruments that fit into a narrow-gauge (4 in.) drill bore, BPB Inc. was contracted for the commercial service. The logging services they provided were: 3-arm dipmeter, hole deviation, natural gamma radiation, focused resistivity, 3-channel sonic velocity, neutron porosity, single-arm caliper and density. Magnetic susceptibility, temperature, and acoustic borehole televiwer logging services were recorded by LDEO, with collaboration by the U.S. Geological Survey for temperature logging. These logs and the core data from the NBCP are archived at LDEO. Resistivity and gamma ray logs were also recorded by the New Jersey Department of Environmental Protection, but are not presented here.

The purpose of this paper is to present the wireline logging results of the NBCP; work on the cores has been presented at meetings [e.g. Kent and Olsen, 1994] and papers are in preparation for journal publication. In view of the availability of a completely cored section, the logs provide a complementary data set which when integrated with the core enables the calibration of *in situ* and laboratory measurements. The NBCP logging program was designed to continuously measure fine-scale in-situ properties of the borehole and the formations. Core-log comparisons are extremely valuable, but should be made cautiously, because logging data are far-field observations and sample a larger volume of rock than core measurements. This difference, however, enables an intermediate-scale link to be made from core measurements to seismic boundaries, which can be used to investigate the origin, age, and cyclostratigraphy of paleoclimatic changes and seismic reflectors [e.g. Reynolds, 1993]. Vertically continuous logs also allow for depth registration and

Introduction

During an eight month period in 1990-1991 and two months in early 1993, a series of seven deep core holes were drilled through the Triassic lacustrine strata and lava flows of the eastern North American Newark rift basin. The prime objectives of the NSF-funded Newark Rift Basin Coring Project (NBCP) were to unlock the history of the region's ancient climate and tectonic history and to extend the geomagnetic polarity stratigraphy to the interval from about 200-230 Ma [Olsen and Kent, 1990]. An offset coring technique was used to take advantage of the eroded half-graben geometry of the basin (Fig. 1). In this method, the core holes were spudded in a mappable, easily recognized lithologic member and continuously cored through to another distinctive unit at a depth of 3000-4000 ft (~1-1.3 km). A suitable location of outcrop of the latter unit was identified updip as the next drill site, and so forth, until practically the entire Newark basin section was cored. This was done seven times in two transects. The offset drilling approach also avoided drilling through the Palisades diabase sill (Fig. 1). A narrow gauge, diamond coring system was used and achieved nearly 100% core recovery.

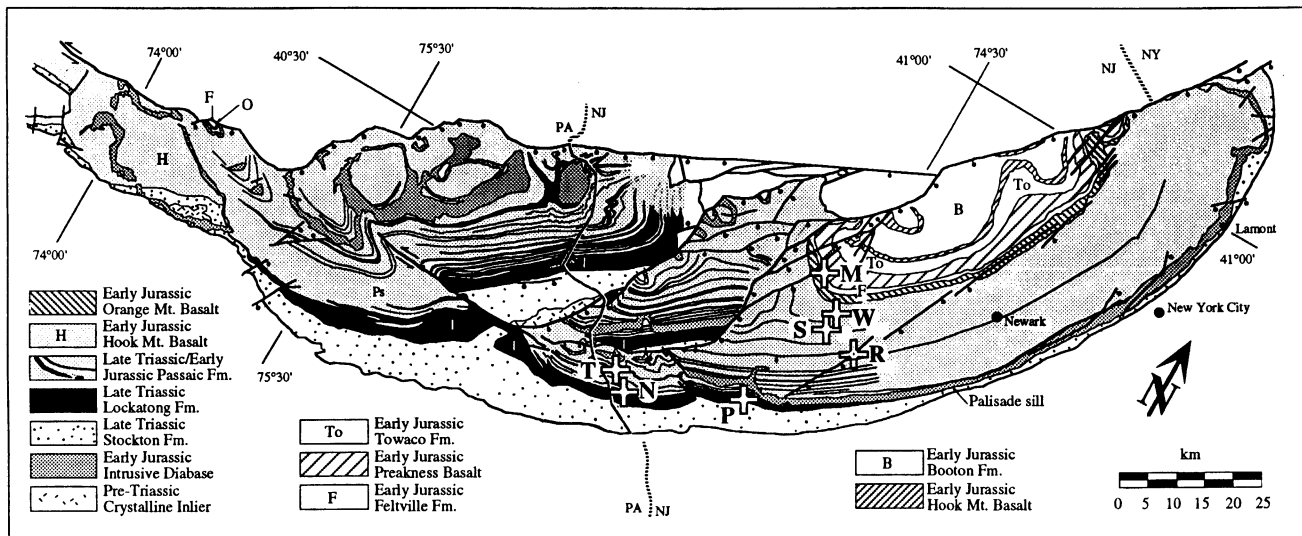


Fig. 1. Geological map of the Newark rift basin showing the locations of the seven coring sites. Most strata dip towards the northwest and black shading indicates the primarily gray and black Locketong Formation and mapped gray and black units in the overlying Passaic Formation. Several of the latter were units used to correlate between cores (see Figure 2). Coring sites are: M, Martinsville; W, Weston Canal; S, Somerset; R, Rutgers; T, Titusville, N, Nursery; and P, Princeton. Map adapted from Olsen and Kent (1990).

corrections of core deformation and loss as well as certain measurements, such as temperature and stress direction, which can only be made *in situ*. In particular cases, logs can be used for core orientation.

well, drilled with a conventional water well rig, needed to supply sufficient water for the coring rig. The procedure with the main core hole (called hole #1) was to conventionally drill an 8 in diameter hole with the water well rig to a depth of 300 ft and then case it with 4.5 ID steel pipe and grout it with cement. Coring with the high-speed coring rig was then begun at the base of the casing through to 3,000 to 4,000 ft (1.0 to 1.3 km), depending on the depth of the objective reference unit. At five sites (Weston Canal, Somerset, Rutgers, Titusville and Princeton), an adjacent 300 ft hole (called hole #2) was cored from the surface to sample the cased interval of the main core hole. A polymer-based drilling mud was used for the high-speed drilling, then fresh water was circulated for a full volume cycle to remove the polymer mud before logging. In total, 12 holes were drilled and logged to their total depth with the complete suite of tools summarized in Table 1. Total core recovered was about 22,100 ft (6730 m).

NEWARK BASIN DRILLING PROJECT CORES

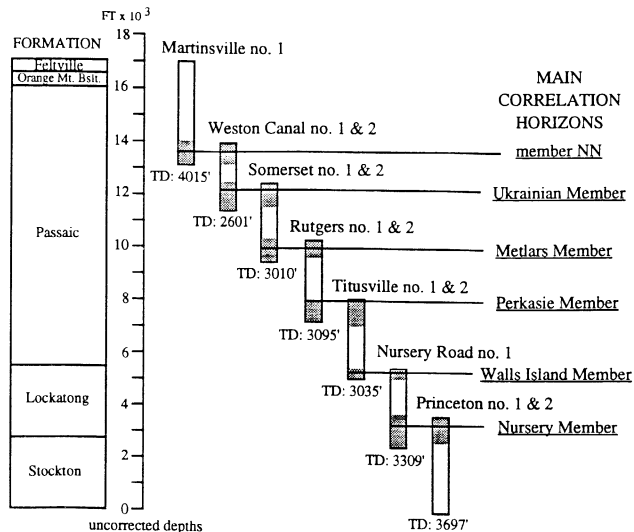


Fig. 2. Correlation between core holes from the Newark Rift Basin Coring Project. Shading indicates portions of the cores that stratigraphically overlap. Adapted from Olsen and Kent (1990).

Field operations

At each of the NBCP sites, it was necessary to drill two or three holes to comply with New Jersey Department of Environmental Protection guidelines. The first was a water

Six of seven sites were drilled by Amoco Production Company's SHADS (Scientific High-speed Advanced Drilling System) group in a cooperative agreement with LDEO. The SHADS system combined a wireline coring rig, a well-head control device, and a series of "geological modules" in which the core was initially processed, subjected to several pass-through natural gamma and magnetic susceptibility measurements, recorded on video, and described. The seventh site (Weston Canal) was cored by Longyear Drilling Co. The core was processed on site by contracted Exlog personnel using a converted and equipped 40-ft trailer. Continuous natural gamma, magnetic susceptibility, and video will be obtained at LDEO from the core from this last site.

Table 1. Summary of logging information acquired in the Newark Rift Basin Coring Project

Hole	Rutgers ^a		Somerset ^b		Nursery ^{b,c}	Martinsville ^b		Titusville ^b		Princeton ^{b,c,d}		Weston Canal ^{b,e}		
	#1	#2	#1	#2	#1	#1	#1	#2	#1	#2	#1	#2	#1	#2
Sonic velocity	X		X	X	X	X	X	X	X	X	X	X	X	X
Resistivity	X		X	X	X	X	X	X	X	X	X	X	X	X
Gamma ray	X		X	X	X	X	X	X	X	X	X	X	X	X
Density	X		X	X	X	X	X	X	X	X	X	X	X	X
Neutron	X		X	X	X	X	X	X	X	X	X	X	X	X
Caliper	X		X	X	X	X	X	X	X	X	X	X	X	X
Temp/salinity					X									
Dipmeter	X		X	X	X	X	X	X	X	X	X	X	X	X
BHTV	X	X	X	X	X	X	X	X	X	X	X	X		
Susceptibility			X	X	X	X	X	X	X	X	X	X		
Temperature	X		X		X	X	X	X	X	X	X		X	
TD: (logged)	3097'		3008'		3309'	4008'	3309'		(2350')		2606'			

^aThe SHADS rig was on site during logging of hole #1, which occurred immediately after drilling, and restricted access to hole #2 for logging. Only the borehole televiewer was later available to log hole #2 after the rig was moved. The susceptibility tool failed to equilibrate in extremely cold weather. The temperature log was recorded from the surface to TD in hole #1.

^bLogging operations proceeded after drilling operations had been completed and hole conditions had equilibrated for 2 to 4 weeks, allowing for direct access to both holes #1 and #2, a minimal use of rig time (hole circulation only), and a non-restrictive logging schedule. The temperature log was recorded from the surface to TD in hole #1.

^cThe temperature log was recorded by BPB.

^dHole #1 collapsed after drilling and limited logging from 2350 feet to the surface.

^eThe borehole televiewer and susceptibility logging tools were not deployed due to time constraints.

The usual sequence of logs run without the drill rig over the hole is presented in Table 2. This sequence of 20 to 25 logs in both holes #1 and #2 required on average 3.5 to 4.0 days to complete, including set-up, calibration, and trouble shooting. Over the course of the 10-month field program, log data recording was unsuccessful due to tool failure only once, at the Rutgers site, where the susceptibility tool calibration would not stabilize in subzero air temperature. Several other equipment failures were experienced due to cold weather and mechanical problems, however no data loss occurred. Due to one such failure, the USGS temperature log was recorded at single depth stations at the Nursery Road site, however a BPB temperature log was run continuously with depth and calibrated to the USGS temperature data.

Tools, calibrations, and data processing

The logging tools used in this project were 3-arm dipmeter, natural gamma radiation, resistivity, sonic velocity, neutron porosity, single-arm caliper and density, magnetic susceptibility, temperature, and borehole televiewer. The design and functionality of each device type is summarized in *Log Interpretation Principles* (Schlumberger, 1987) and

in the *ODP Logging Manual* (Borehole Research Group, 1990).

For the specific tools deployed in the NBCP, calibrations were made on site by BPB for neutron, density, and gamma ray devices by comparing the tool responses to count rates in known test standards, such as aluminum. Sonic, resistivity, and temperature tool responses were compared for consistency with known values in air or steel. Caliper calibrations were made by setting the tool responses to different casing diameters. The borehole televiewer was calibrated on site by LDEO using an oriented test tank. The magnetic susceptibility tool was calibrated in air, and at one site (Titusville), it was also calibrated with core measurements [Witte and Kent, in press]. The susceptibility logs presented here are not corrected for non-linear drift with temperature and time from the null calibration in air.

The logging data were all originally recorded on digital media, except for the borehole televiewer (photographic paper and videotape) and the magnetic susceptibility (paper) logs. All of the digital log data are stored at LDEO on 9-track, LIS-format magnetic tapes and in an ASCII-format, tabular database on diskette. The susceptibility logs were digitized from the original paper logs at the 0.4-ft database sample interval. The borehole televiewer data are

Table 2. Example sequence of logging operations

Run	Truck	Tool	Rig Time
Hole #2			
1	BPB	Dipmeter	
2	BPB	Gamma/dual-density/caliper	
3	BPB	Gamma/dual-neutron	6 hr
4	BPB	Sonic velocity	
5	BPB	Dual-focussed electric	
Hole #1			
6	BPB	Dipmeter	
7	BPB	Gamma/dual-density/caliper	
8	BPB	Gamma/dual-neutron	14 hr
9	BPB	Sonic velocity	
10	BPB	Dual-focussed electric	
Hole #2			
11	LDEO	Susceptibility	3 hr
12	LDEO	Acoustic Televiewer	4 hr
13	LDEO	USGS Temperature	2 hr
Hole #1			
14	LDEO	USGS Temperature	4 hr
15	LDEO	Susceptibility	4 hr
16	LDEO	Acoustic Televiewer	14 hr
Hole #2			
17	DEP	Fluid conductivity/Temperature	
18	DEP	IP/SP/Short-long normal	
19	DEP	Electric laterolog	6 hr
20	DEP	Natural Gamma	
Hole #1			
21	DEP	Fluid conductivity/Temperature	
22	DEP	IP/SP/Short-long normal	
23	DEP	Electric laterolog	14 hr
24	DEP	Natural Gamma	
		contingency	10 hr
24		TOTAL	90 hr

not presented here and will be digitized from videotape into image format and archived at LDEO.

The log database was created by translating and decimating the LIS-format data, which was acquired at a 0.04-ft (0.5-in) depth sampling interval. Depth shifts between logging runs were corrected by matching the gamma ray logs recorded during each run. Depth corrections were generally less than 2 ft.

Sonic and temperature logs were processed from raw data for the database at the LDEO and USGS, respectively. The three raw sonic travel-time logs, one for each source-receiver pair, were smoothed over 60 cm to coincide with the longest source-receiver spacing and then averaged to create a single log. Temperature gradient logs were computed by the temperature difference over 40-point offsets and excursions in these data were not excluded. The dipmeter logs were processed by BPB. Formation dip and formation azimuth estimates were computed by

automatic correlation between the three-arm microresistivity pads at 5-ft intervals. The dipmeter pad correlation is high when the coefficient is close to 1.0. Values less than 0.5 should be evaluated carefully because they represent a low statistical significance of the measurement.

Results and discussion

In Figures 3 through 9, the log database is presented graphically. The logs, except for dipmeter data, were smoothed using a 5-pt (2.0 ft) moving depth window for display. Each site is represented by a separate figure divided into two parts: (a) those logs measuring hole and geometrical properties, and (b) those measuring rock physical properties. Data from core hole #1 and from core hole #2 are superimposed on each figure, when applicable, occasionally generating short gaps in the intervals near 300 ft. Because the caliper log shows that the holes are mostly in gauge, corrections to the data for hole size effects were not made. In general, these logs have valid and continuous data over their depth intervals. Intervals where no data are available are annotated.

The physical properties of the holes and the formations encountered in the NBCP are generally similar at all 7 sites. The caliper logs clearly show that all of the deep holes are almost perfectly in gauge (4 in. diameter) to their total depth. Variations in borehole diameter more than 0.5-in over gauge can usually be attributed to the poor registration of the caliper arm in the vicinity of fractures, such as observed in Martinsville and Weston Canal. Fractures in these holes are also observed over the same depths in the core and televiewer images.

The borehole deviation and azimuth logs systematically exhibit an increasing trend with depth. Hole deviation increases from 0° at the surface to as much as 10° S-SE with depth in all the holes. This observation can be explained by a tendency of the drill pipe to align perpendicularly to the bedding planes of the strata while drilling, which dip 6 to 14 degrees N-NW to W through the basin sequence. These logs also exhibit a characteristic 50-100 ft sawtooth pattern over long intervals in several holes. This effect is attributed to tool rotation and a varying magnetometer response function, not the result of hole properties.

The typical temperature profile shows a significant hydrologic disturbance over the upper 200 to 300 m intervals with a conductive temperature gradient below the disturbance of 15 to 26 °C/km. Average thermal conductivity measured on core samples range from 1.6 to 2.7 W/m °K, controlled by the relative proportions of quartz and alteration minerals [Williams *et al.*, 1991]. Williams *et al.* [1991] also extrapolated the temperature measurement to the equilibrium profile, estimating preliminary heat flow values of 38 to 44 mW/m² at all of

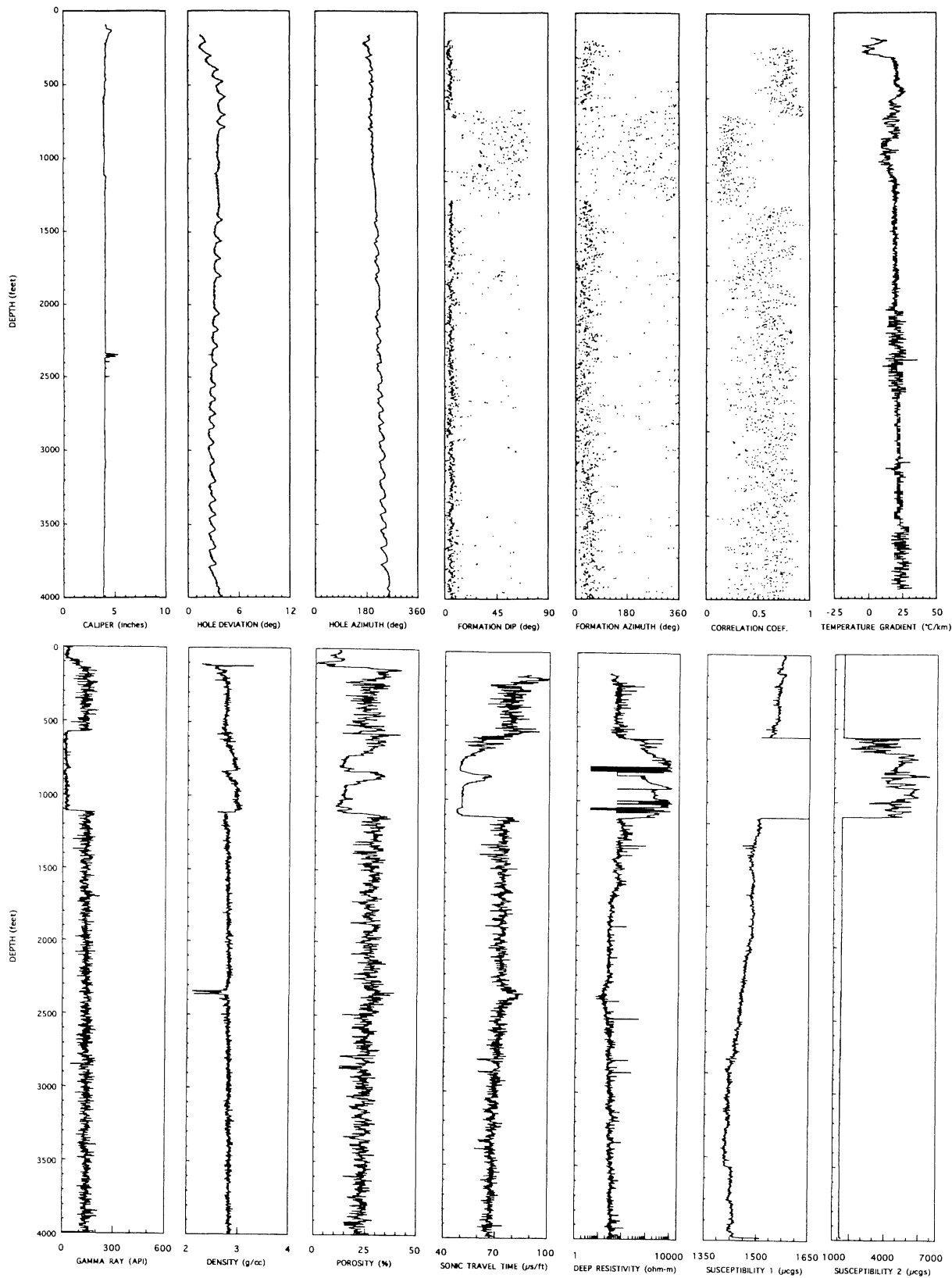


Fig. 3. Martinsville. Upper panel: Geophysical logs of hole properties (*L to R*): Caliper (in), Hole deviation (deg), Hole azimuth (deg), Formation dip (deg), Formation azimuth (deg), Dipmeter correlation coefficient (increasing from 0.0 to 1.0), and Temperature gradient (°C/km). The temperature gradient range for Titusville is expanded to show large variations. Lower panel: Geophysical logs of rock properties (*L to R*): Gamma ray (API), Bulk density (g/cc), Neutron porosity (%), Sonic travel time (µs/ft), Resistivity (Ωm), Magnetic susceptibility (µcgs). Susceptibility data are not corrected for temperature drift with time or for static calibration offsets, except for an expanded plot range for Martinsville (right-hand track). Log depth and core depth are referenced to the rig floor.

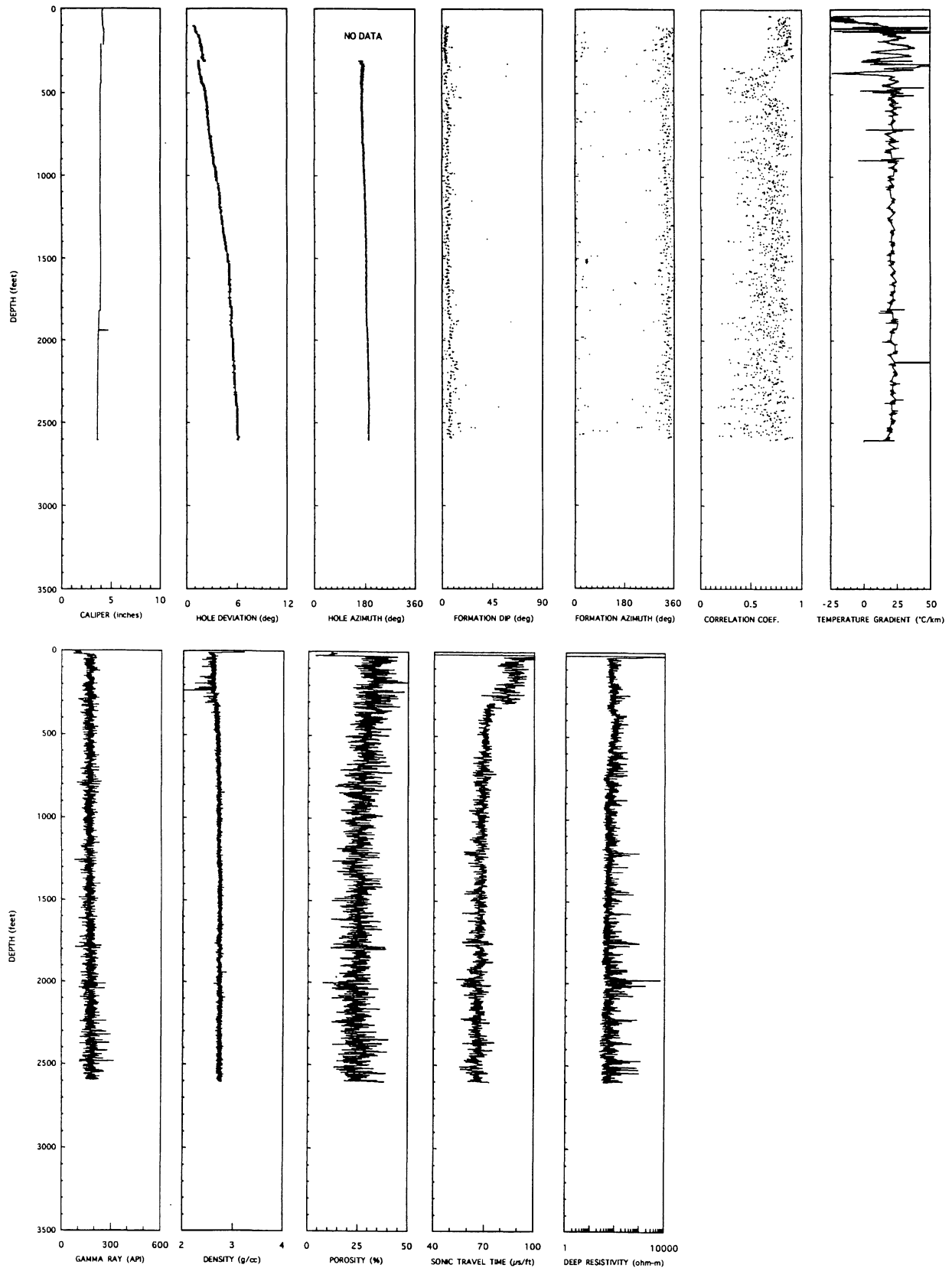


Fig. 4. Weston Canal. Upper panel: Geophysical logs of hole properties (*L to R*): Caliper (in), Hole deviation (deg), Hole azimuth (deg), Formation dip (deg), Formation azimuth (deg), Dipmeter correlation coefficient (increasing from 0.0 to 1.0), and Temperature gradient ($^{\circ}\text{C}/\text{km}$). The temperature gradient range for Titusville is expanded to show large variations. Lower panel: Geophysical logs of rock properties (*L to R*): Gamma ray (API), Bulk density (g/cc), Neutron porosity (%), Sonic travel time ($\mu\text{s}/\text{ft}$), Resistivity (Ωm). Data from hole #1 (cased above 300 ft) are replaced by data from hole #2 (open hole) where there is depth overlap. Log depth is referenced to the rig floor, like the core depth, and intervals where no data are available are annotated.

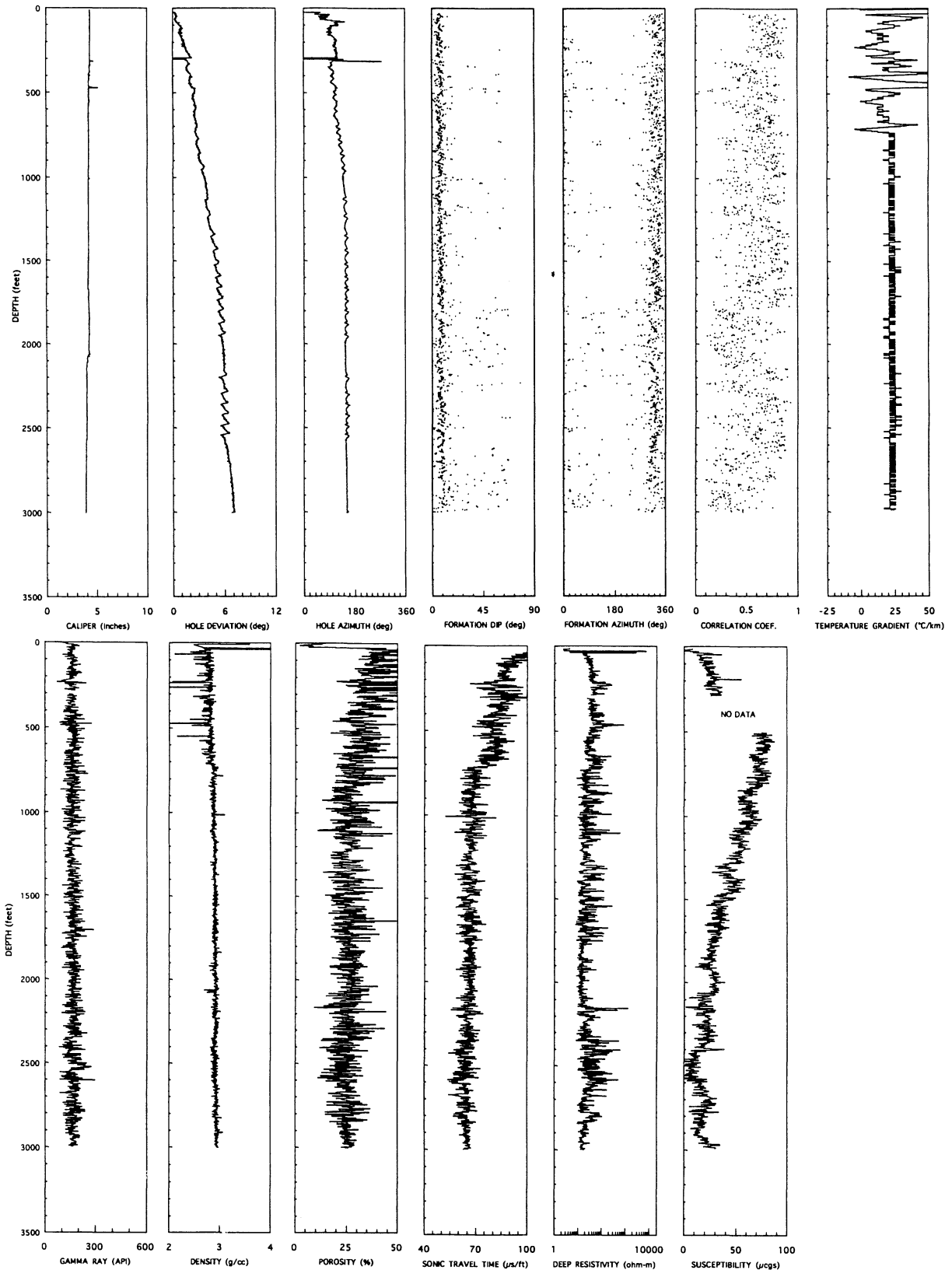


Fig. 5. Somerset. Upper panel: Geophysical logs of hole properties (*L to R*): Caliper (in), Hole deviation (deg), Hole azimuth (deg), Formation dip (deg), Formation azimuth (deg), Dipmeter correlation coefficient (increasing from 0.0 to 1.0), and Temperature gradient ($^{\circ}\text{C}/\text{km}$). The temperature gradient range for Titusville is expanded to show large variations. Lower panel: Geophysical logs of rock properties (*L to R*): Gamma ray (API), Bulk density (g/cc), Neutron porosity (%), Sonic travel time ($\mu\text{s}/\text{ft}$), Resistivity (Ωm), Magnetic susceptibility (μcgs). Susceptibility data are not corrected for temperature drift with time or for static calibration offsets. Data from hole #1 (cased above 300 ft) are replaced by data from hole #2 (open hole) where there is depth overlap. Log depth is referenced to the rig floor, like the core depth, and intervals where no data are available are annotated.

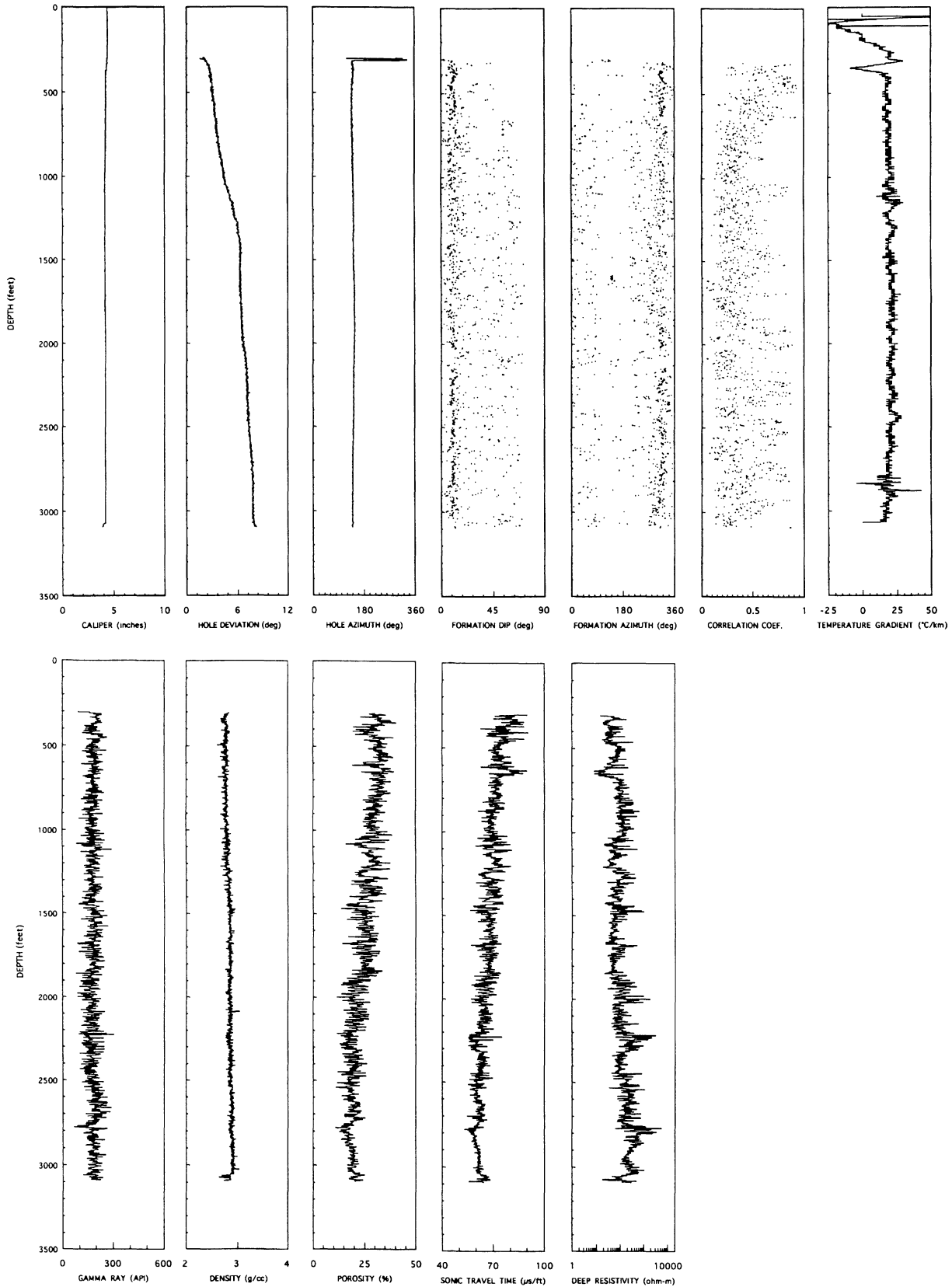


Fig. 6. Rutgers. Upper panel: Geophysical logs of hole properties (*L to R*): Caliper (in), Hole deviation (deg), Hole azimuth (deg), Formation dip (deg), Formation azimuth (deg), Dipmeter correlation coefficient (increasing from 0.0 to 1.0), and Temperature gradient ($^{\circ}\text{C}/\text{km}$). The temperature gradient range for Titusville is expanded to show large variations. Lower panel: Geophysical logs of rock properties (*L to R*): Gamma ray (API), Bulk density (g/cc), Neutron porosity (%), Sonic travel time ($\mu\text{s}/\text{ft}$), Resistivity (Ωm). Log depth and core depth are referenced to the rig floor.

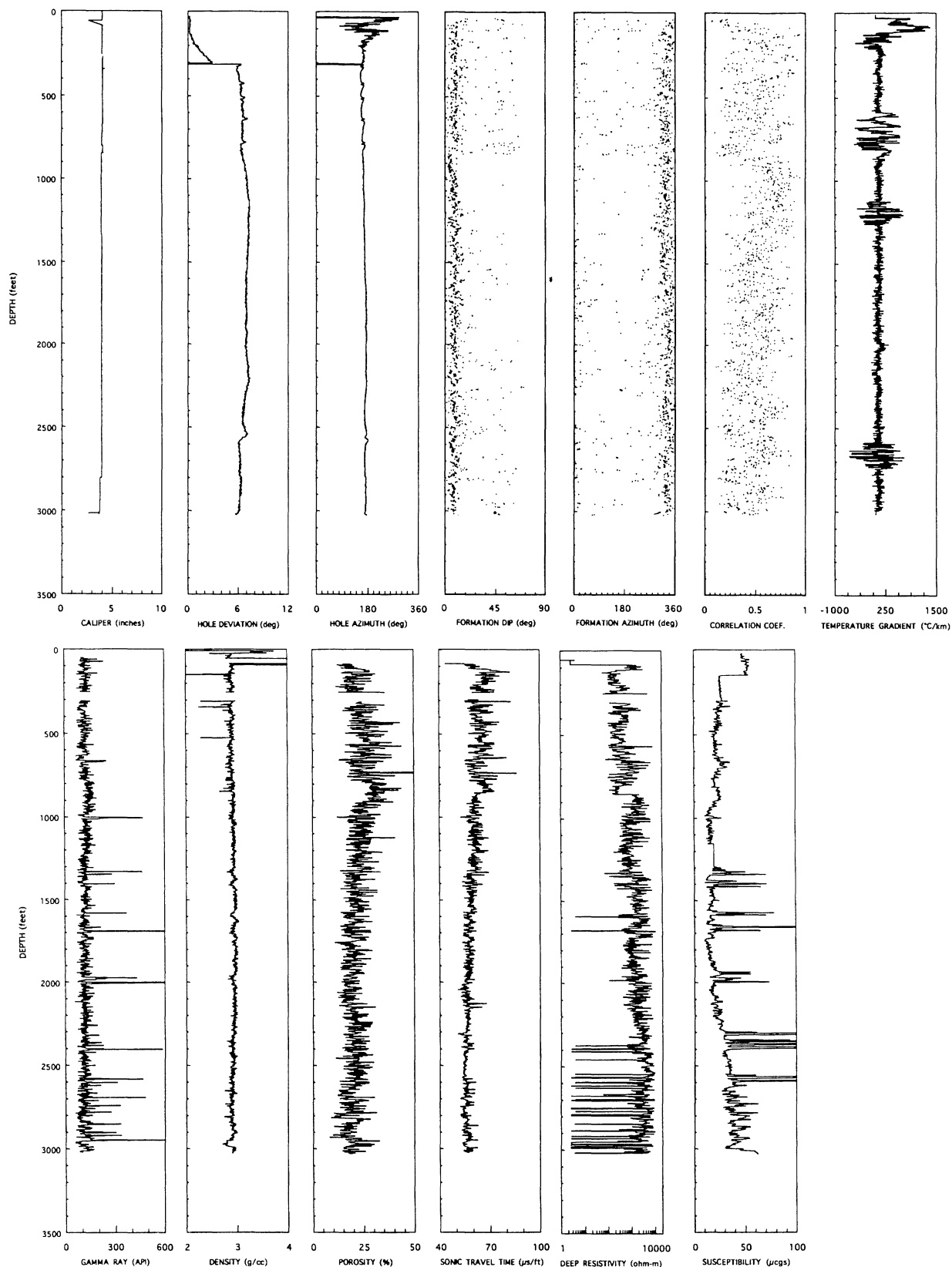


Fig. 7. Titusville. Upper panel: Geophysical logs of hole properties (*L to R*): Caliper (in), Hole deviation (deg), Hole azimuth (deg), Formation dip (deg), Formation azimuth (deg), Dipmeter correlation coefficient (increasing from 0.0 to 1.0), and Temperature gradient ($^{\circ}\text{C}/\text{km}$). The temperature gradient range for Titusville is expanded to show large variations. Lower panel: Geophysical logs of rock properties (*L to R*): Gamma ray (API), Bulk density (g/cc), Neutron porosity (%), Sonic travel time ($\mu\text{s}/\text{ft}$), Resistivity (Ωm), Magnetic susceptibility (μcgs). Susceptibility data are not corrected for temperature drift with time or for static calibration offsets. Data from hole #1 (cased above 300 ft) are replaced by data from hole #2 (open hole) where there is depth overlap. Log depth and core depth are referenced to the rig floor.

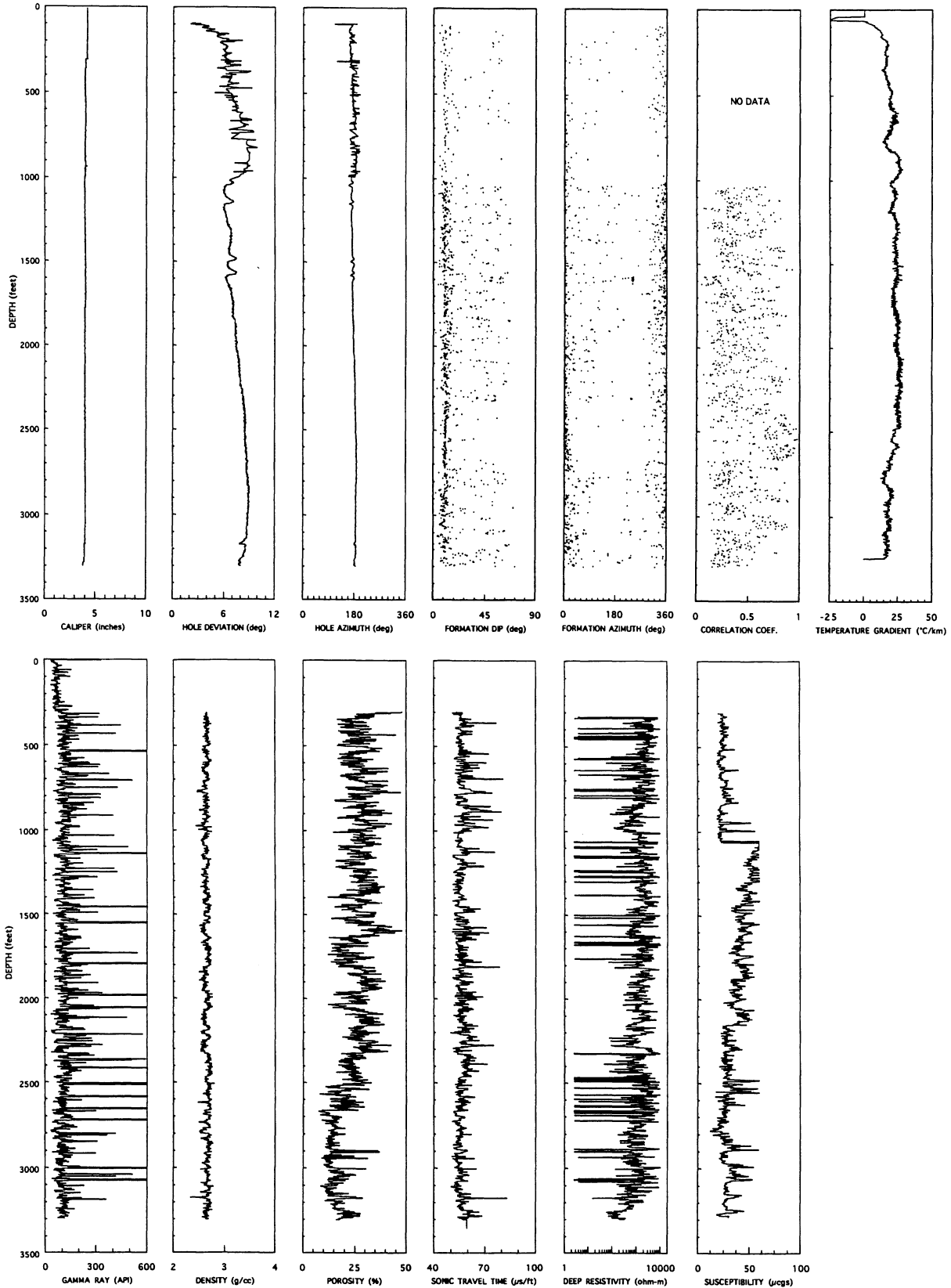


Fig. 8. Nursery Rd. Upper panel: Geophysical logs of hole properties (*L to R*): Caliper (in), Hole deviation (deg), Hole azimuth (deg), Formation dip (deg), Formation azimuth (deg), Dipmeter correlation coefficient (increasing from 0.0 to 1.0), and Temperature gradient (°C/km). The temperature gradient range for Titusville is expanded to show large variations. Lower panel: Geophysical logs of rock properties (*L to R*): Gamma ray (API), Bulk density (g/cc), Neutron porosity (%), Sonic travel time (µs/ft), Resistivity (Ωm), Magnetic susceptibility (µcgs). Susceptibility data are not corrected for temperature drift with time or for static calibration offsets. Log depth is referenced to the rig floor, like the core depth, and intervals where no data are available are annotated.

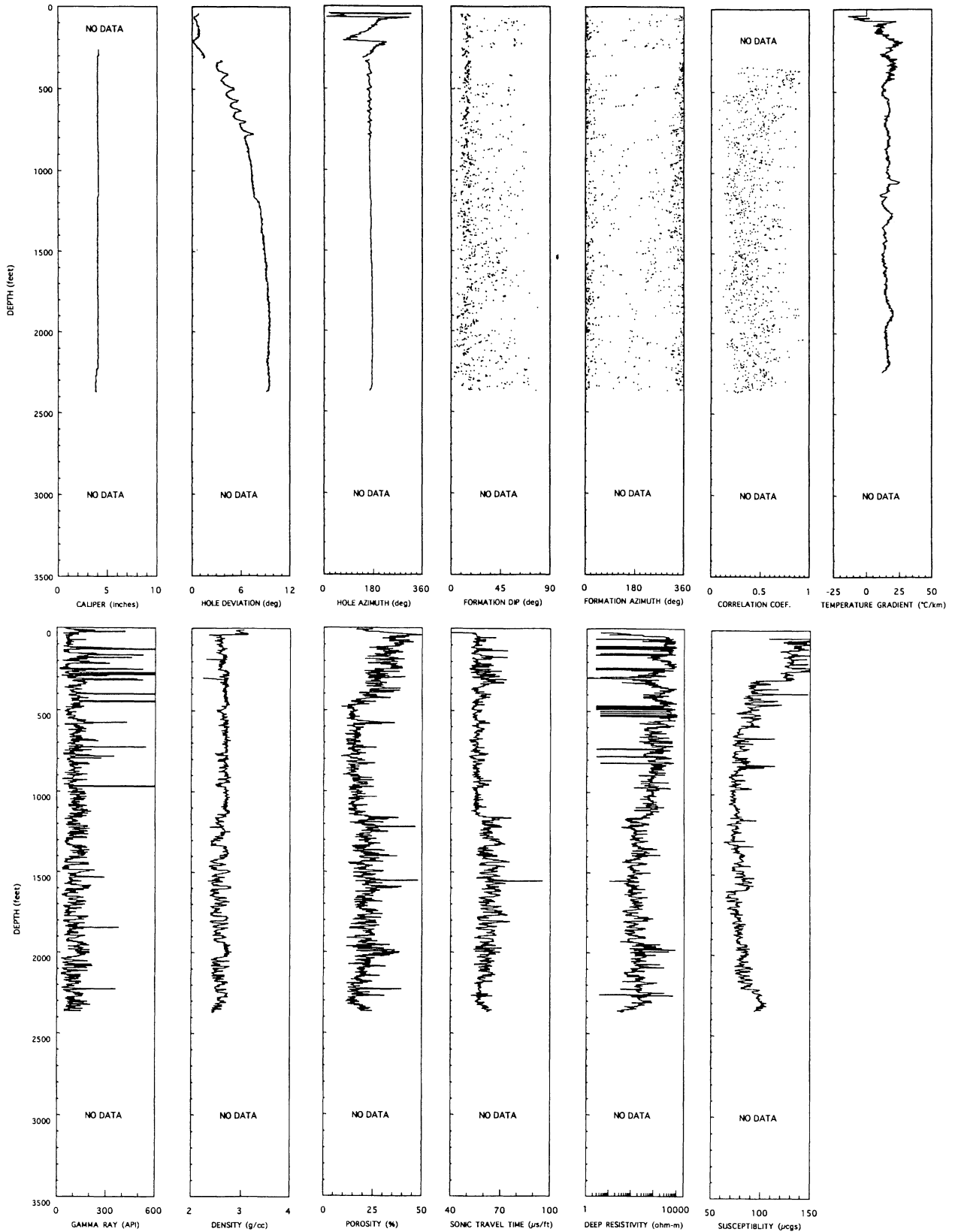


Fig. 9. Princeton. Upper panel: Geophysical logs of hole properties (*L to R*): Caliper (in), Hole deviation (deg), Hole azimuth (deg), Formation dip (deg), Formation azimuth (deg), Dipmeter correlation coefficient (increasing from 0.0 to 1.0), and Temperature gradient ($^{\circ}\text{C}/\text{km}$). The temperature gradient range for Titusville is expanded to show large variations. Lower panel: Geophysical logs of rock properties (*L to R*): Gamma ray (API), Bulk density (g/cc), Neutron porosity (%), Sonic travel time ($\mu\text{s}/\text{ft}$), Resistivity (Ωm), Magnetic susceptibility (μcgs). Susceptibility data are not corrected for temperature drift with time or for static calibration offsets. Data from hole #1 (cased above 300 ft) are replaced by data from hole #2 (open hole) where there is depth overlap. Log depth is referenced to the rig floor, like the core depth, and intervals where no data are available are annotated.

the sites, consistent with nearby continental provinces, and groundwater flows with a downward velocity of 1 cm/yr at the Martinsville site. At Titusville, large variations in temperature gradient were recorded below 500 ft depth, possibly due to deep groundwater flow. The mean gradient, however, is consistent with the other holes. Observing the variations in temperature gradient, groundwater was likely flowing through open fractures during logging, but its persistence over time cannot be determined without long-term instrumentation of the boreholes.

The gamma ray logs in the clay-rich lithologies drilled in the NBCP were repeatable and are used to register depths between logging runs. Gamma ray values were measured up to 1000-API units in thin layers, but have a mean and standard deviation in most intervals of about 150 and 50 API units, respectively. The highest values (>300 API) occur mostly in the lower part of the stratigraphic sequence in the black shales of the Lockatong Fm, encountered through the bottom of Titusville, Nursery Road, and the upper part of Princeton. In the upper 300-ft interval of Somerset, and from about 600-ft to 1200-ft in Martinsville, the gamma ray mean and standard deviation are half that of other intervals, about 75 and 25 API units respectively. This is a result of the tool response through the casing at Somerset and in the Orange Mt. Basalt at Martinsville. The latter interval is obviously anomalous in all of the log responses.

With the exception of anomalous intervals in the Orange Mt. Basalt and in the lower part of Princeton, densities vary in each hole mostly between 2.60 and 2.80 g/cc. Values as high as 2.90 g/cc are reached in the lower Passaic formation (Titusville), possibly due to a greater concentration of secondary calcite and barite in the formation. Greater variability in bulk density is observed in the Stockton arkose through lower part of Princeton, associated with thin bedding in this interval. Large excursions in the density log below 2.60 g/cc occur at depths coincident with excursions in other logs and probably indicate fracturing. Bulk densities observed in the Orange Mt. Basalt increase with depth to greater than 3.05 g/cc near 800 ft depth in Martinsville and again towards its lower contact near 1200 ft, suggesting a decrease in porosity at the base of basalt flow units.

The neutron porosity logs exhibit systematically higher porosity than measured on core samples [C. Williams pers. comm., 1991], likely due to neutron absorption by clay in the formation. Average uncorrected porosity values, as high as 45% porosity in Somerset and as low as 10% in the Orange Mt. Basalt, reflect only relative variations. Porosities generally decrease with depth in the upper 500 to 1000 ft of each hole. Cyclical variations in porosity with depth are observed in Nursery as well as in other intervals. In the basalt, porosity increases significantly towards the top of the flow units in Martinsville, but is typically less variable than in the overlying and underlying sediments.

Sonic travel time logs correlate directly with porosity in the sediments and in the basalt and show similar decreases with depth. The sonic travel times range between 55 and 65 $\mu\text{s}/\text{ft}$, corresponding with formation compressional velocities of 4.7 km/s and 5.5 km/s. Travel times in the basalt average about 49 $\mu\text{s}/\text{ft}$, a velocity of 6.2 km/s.

The resistivity logs show considerable variation even as presented on a four-decade logarithmic scale. A general correlation with depth between resistivity and porosity is observed, however resistivity does not correlate with density, sonic, or gamma ray logs. In general, average resistivity values are about 20 Ωm in the upper part of the sequence (Martinsville, Weston Canal, Somerset, and Rutgers holes) and between 200 Ωm to 2000 Ωm in the older rocks (Titusville, Nursery Road, and Princeton holes). In this deeper sequence, gamma ray is high and variable and sharp decreases in resistivity are frequent, even though the highest average log values occur. Resistivities in the Orange Mt. Basalt are high, but variable, ranging from 500 Ωm to 5000 Ωm . Although the magnetic susceptibility logs presented here have not been corrected for temperature drift with time, they exhibit some fine-scale correlation with resistivity and generally show low values (20 to 40 μcgs) in sediments and extremely high values (>6000 μcgs) in basalt. The overall range of resistivities and magnetic susceptibilities recorded through this sequence in the Newark Rift Basin span three orders of magnitude.

Concluding remarks

The wireline logging data presented here from the Newark Rift Basin Coring Project were acquired during late 1990 and early 1991 and in early 1993. High-quality logs were acquired at seven sites and include: 3-arm dipmeter, borehole deviation, natural gamma radiation, focused resistivity, 3-channel sonic velocity, neutron porosity, bulk density, magnetic susceptibility, temperature, caliper and borehole televiewer. The extremely high percentage of core recovered presents a unique opportunity for studying these log data in conjunction with core collected over the same intervals. The log data and cores from the Newark Rift Basin Coring Project are archived at LDEO.

Based on these results, *in situ* physical properties can be studied through the entire Newark rift basin sedimentary sequence and in the Orange Mt. Basalt. The clay-rich sediments appear to be fractured and permeable, particularly at shallow depths, and exhibit relatively consistent physical property readings through significant portions of the Newark basin sequence. The Orange Mt. Basalt, and flow units within it, are delineated by anomalous physical properties observed in the logs. Anomalies in temperature gradient suggest active hydrologic flow in the upper intervals of all seven holes. The log data are potentially useful as indicators of fluid flow, the regional stress regime, and lithologic cycles in the Newark rift basin.

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