Prepared in cooperation with the
U.S. DEPARTMENT OF ENERGY
DOE/ID-22205

Construction Diagrams, Geophysical Logs, and Lithologic Descriptions for Boreholes USGS 126a, 126b, 127, 128, 129, 130, 131, 132, 133, and 134, Idaho National Laboratory, Idaho

Data Series 350

U.S. Department of the Interior
U.S. Geological Survey

FRONT COVER— U.S. Geological Survey hydrologic technician (Mark Vance) describing basalt core for vertical direction and depth.

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DIRK KEMPTHORNE, Secretary

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Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
gallon (gal)	3.785	liter (L)
gallon (gal)	0.003785	cubic meter (m^3)
pound per square inch (lb/in^2)	6.895	kilopascal (kPa)
picocurie per liter (pCi/L)	0.037	becquerel per liter (Bq/L)
cubic feet per minute (ft^3/min)	0.000472	cubic meter per second (m^3/s)

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

$$°C=(°F-32)/1.8$$

Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD of 1929).

Horizontal coordinate information is referenced to the North American Datum of 1927 (NAD 27).

Altitude, as used in this report, refers to distance above the vertical datum.

Acronyms

bls	below land surface
CFA	Central Facilities Area
CSL	Core Storage Library
DOE	Department of Energy
HDR	Hydrologic Data Repository
INL	Idaho National Laboratory
INTEC	Idaho Nuclear Technology and Engineering Center
ISU	Idaho State University
NRF	Naval Reactors Facility
RTC	Reactor Technology Complex
RWMC	Radioactive Waste Management Complex
SRP	Snake River Plain
SRPA	Snake River Plain aquifer
TAN	Test Area North
USGS	U.S. Geological Survey
USCS	Unified Soil Classification System

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Abstract

This report summarizes construction, geophysical, and lithologic data collected from ten U.S. Geological Survey (USGS) boreholes completed between 1999 nd 2006 at the Idaho National Laboratory (INL): USGS 126a, 126b, 127, 128, 129, 130, 131, 132, 133, and 134. Nine boreholes were continuously cored; USGS 126b had 5 ft of core. Completion depths range from 472 to 1,238 ft. Geophysical data were collected for each borehole, and those data are summarized in this report. Cores were photographed and digitally logged using commercially available software. Digital core logs are in appendixes A through J. Borehole descriptions summarize location, completion date, and amount and type of core recovered. This report was prepared by the USGS in cooperation with the U.S. Department of Energy (DOE).

Introduction

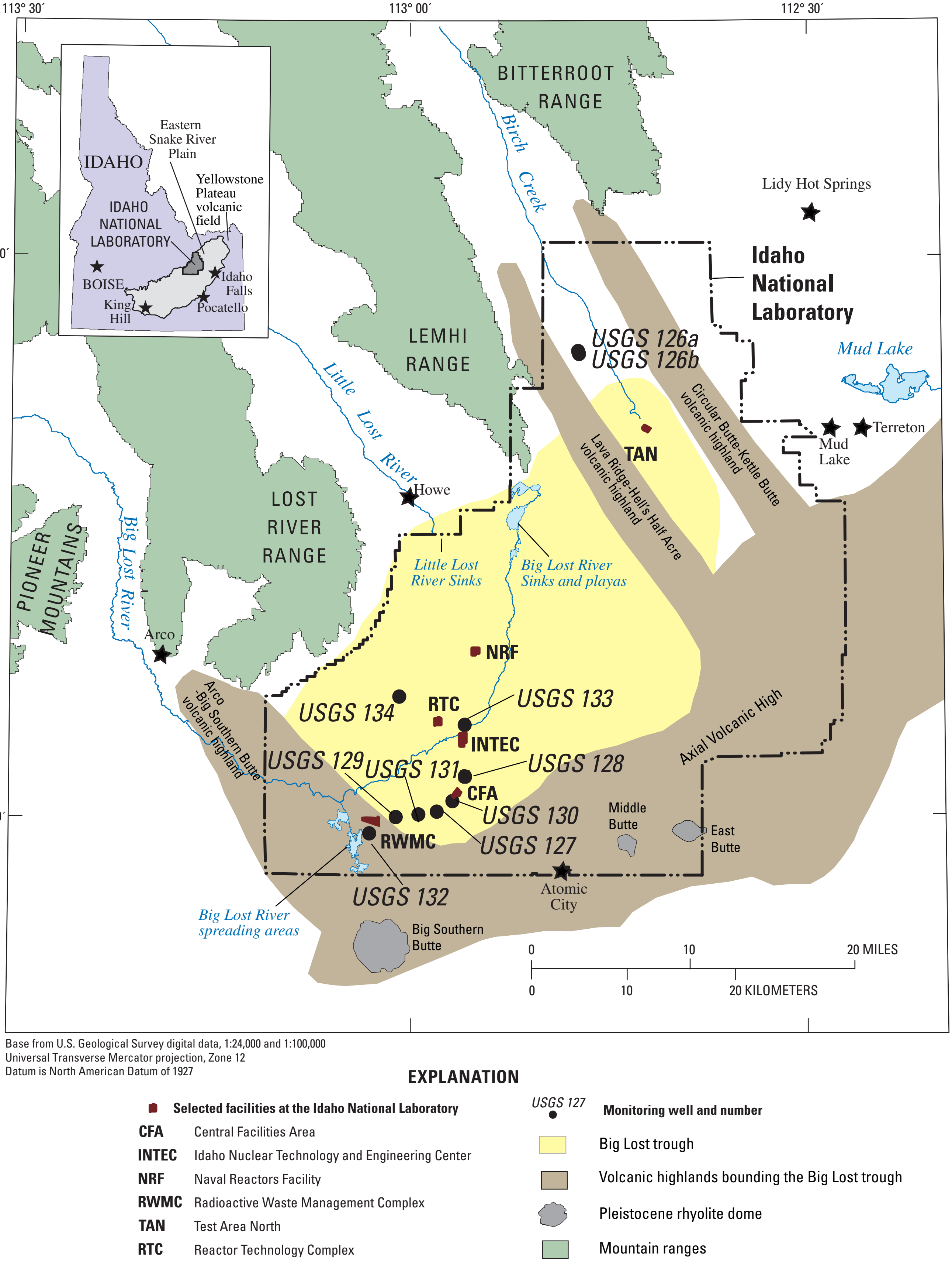
The Idaho National Laboratory (INL) is operated by the U.S. Department of Energy (DOE) and occupies approximately 890 mi^2 of the eastern Snake River Plain (SRP) in eastern Idaho (fig. 1). Facilities at the INL are used in the development of peacetime atomic-energy applications, nuclear safety research, defense programs, environmental research, and advanced energy concepts. Wastewater containing radionuclide and chemical wastes generated at these facilities was discharged to onsite infiltration ponds, evaporation ponds, and disposal wells from 1952 to 1983. Since 1983, most aqueous wastes have been discharged to infiltration ponds. Solid and liquid radioactive and chemical wastes have been buried in trenches and pits excavated in surficial sediment at the Radioactive Waste Management Complex (RWMC, fig. 1). Past disposal practices have resulted in detectable concentrations of selected radiochemical, inorganic, and organic waste constituents in water collected from INL monitoring wells completed in the Snake River Plain aquifer (SRPA) (Mann and Beasley, 1994; Cecil and others, 1998; Bartholomay and Tucker, 2000).

The U.S. Geological Survey (USGS) has conducted hydrologic, geologic, and geophysical research at the INL since 1949. Early work characterized water resources and geology in the INL area prior to construction of nuclear-reactor testing facilities. Since completion of those studies, the USGS has maintained ground-water quality and water-level monitoring networks at the INL to gather data for research on hydrologic trends, and to trace the movement of facility-related radiochemical and chemical contaminants in the SRPA.

Hundreds of monitoring wells at the INL penetrate the upper 200 ft of the SRPA where most ground-water movement probably occurs (Ackerman and others, 2006, p. 39). Additional boreholes were needed to study both the intermediate and deep parts of the SRPA because the deeper regional flow system is not well understood. Boreholes that extend several hundred feet into the SRPA provide data useful for constructing and evaluating conceptual, flow, and transport models.

Purpose and Scope

In 1997, the USGS, in cooperation with the DOE Idaho Operations Office, began a multi-year project to core ten boreholes with depths ranging from 472 to 1,238 ft below land surface (bls). Information collected during this project is being used to better define the three-dimensional geologic framework of the SRPA at the INL. This report summarizes the geologic setting of the SRPA, presents geophysical methods used to characterize the geologic and hydrologic setting, and includes information collected from each borehole. Of the ten boreholes, nine were continuously cored and one was partially cored. Wireline geophysical logs were run through drill stem and in open boreholes to better define stratigraphy and hydrologic properties of the SRPA. Cores were examined, described,



Base from U.S. Geological Survey digital data, 1:24,000 and 1:100,000
Universal Transverse Mercator projection, Zone 12
Datum is North American Datum of 1927

Figure 1. Index map showing location of some facilities and USGS boreholes, Idaho National Laboratory, Idaho. Mountain ranges shown in green.

and photographed. Digital core logs are presented in appendixes A through J.

Geologic Setting

The eastern SRP formed when the North American Plate moved southwestward across a fixed melting anomaly that severely disrupted the crust (Pierce and Morgan, 1992; Pierce and others, 2002; Morgan and McIntosh, 2005, p. 288). Thermal disruption caused a series of volcanic fields characterized by initial uplift, followed by bimodal magmatism (rhyolitic resurgent caldera eruptions followed and buried by basalt eruptions) and ongoing subsidence due to emplacement of a mafic midcrustal sill (Braile and others, 1982; Anders and Sleep, 1992, p. 15, 379; Peng and Humphries, 1998, p. 7,171; Rodgers and others, 2002; Shervais and others, 2006, p. 365). The resulting volcanic plain is 200 mi long from southwest to northeast, and roughly 50 mi wide from southeast to northwest. The eastern SRP rises from King Hill, Idaho (elevation 2,900 ft) to the edge of the Yellowstone Plateau volcanic field (elevation 7,874 ft), a difference of 4,974 ft.

Olivine tholeiitic basalt flows, erupted as tube-fed, inflated, pahoehoe, comprise more than 85 percent of the subsurface volume of the eastern SRP at the INL (Kuntz and others, 1992; Anderson and Liszewski, 1997). A typical eastern SRP basalt flow has vesicular zones and cooling fractures on the top and sides, with vesicle sheets, pipe vesicles, megavesicles in the interior, and a diktytaxitic to massive core (Self and others, 1998; fig. 2, modified from fig. 3 in Self and others, p. 90). Where flows succeed each other without significant intervals of time, flows may make molds of the underlying surface (“flow and mold structures” see appendixes A through J). Near-vent flows are thinner than distal flows, and accumulations of thin flows have a larger volume of high conductivity zones than the same volume of thick flows, thus spaces occupied by vents tend to have more fractured, high-conductivity volume than spaces distal to vents (Anderson and others, 1999). Distribution of basalt flows is controlled by previously existing topography, rate of effusion, and duration of eruption.

Eolian, fluvial, alluvial and lacustrine sediments are found in eastern SRP drill cores, and they are predominantly

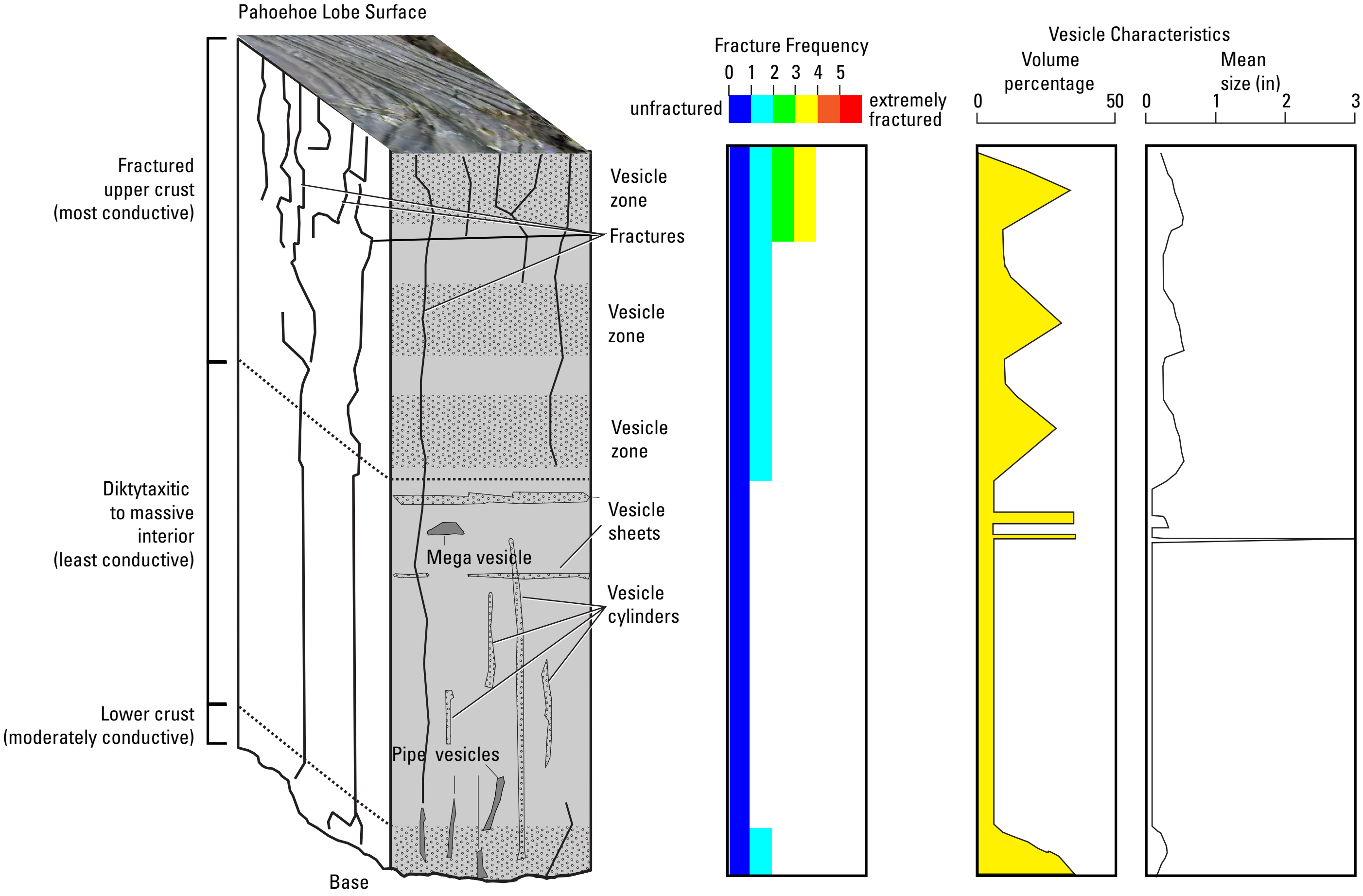


Figure 2. Cross section of typical olivine tholeiitic pahoehoe basalt flow that shows zones and structures as well as fracture frequency and vesicle characteristics (modified from figure 3 in Self and others, 1998, p. 90). Photograph of pahoehoe lobe surface courtesy of Scott Hughes at Idaho State University, Pocatello, Idaho.

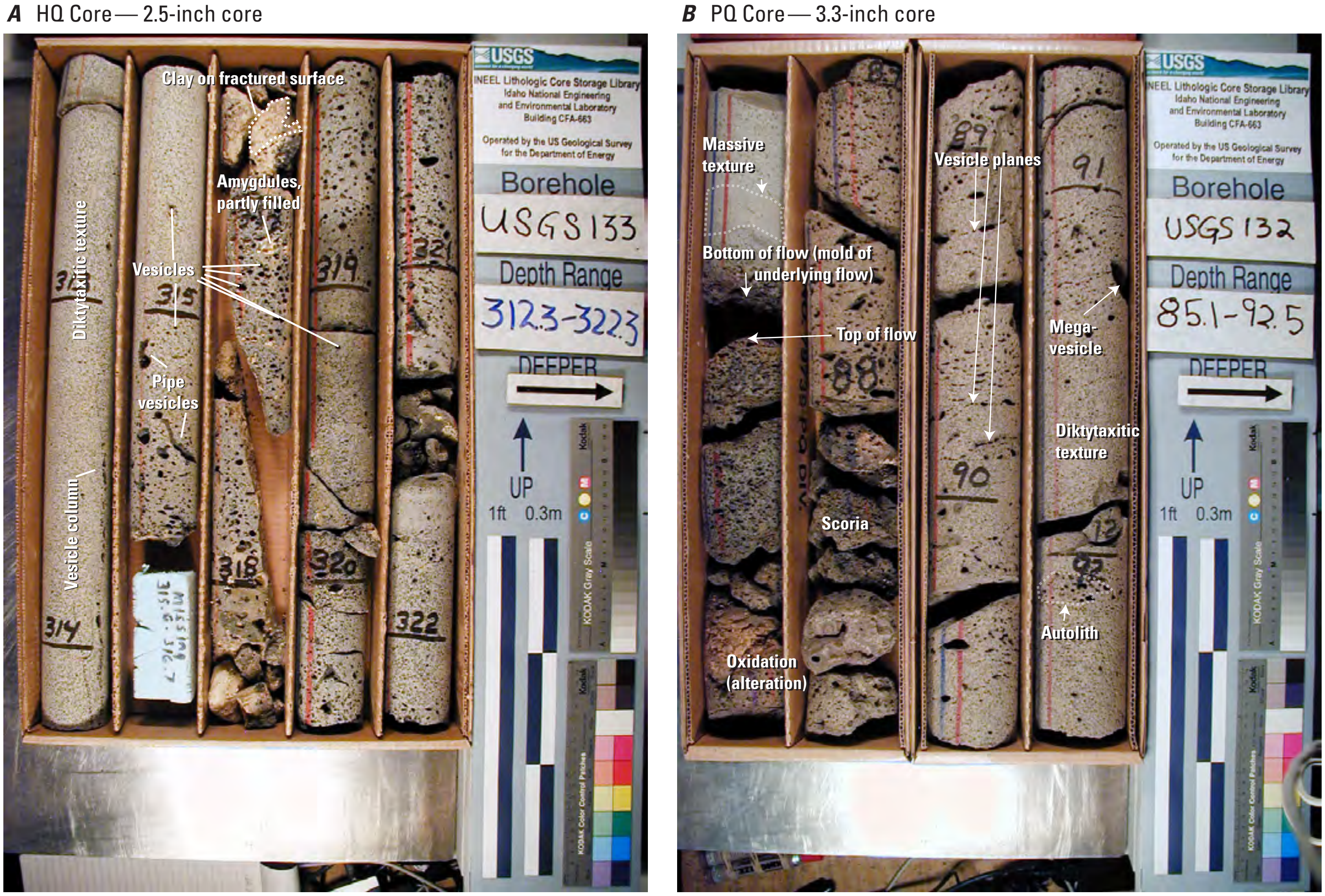
fine grained (Blair, 2002; Bestland and others, 2002), although difficulty in retrieving coarse-grained sediments in core may have biased the core record to some extent. Provenance and detrital-zircon studies indicate that the Big Lost River has been the main source of sediment since late Pliocene time on the part of the eastern SRP occupied by the INL. A depocenter known as the Big Lost trough is the result of the deposition from the Big Lost River in this area around the INL (Geslin and others, 2002).

Sediments penetrated by these boreholes range from 0 to 313 ft thick, and they are thickest in the northwestern part of the INL (Anderson and others, 1996; Welhan and others, 2007). Bounded on northwest by mountains and on the other three sides by informally named volcanic highlands (see fig. 1), boreholes in the Big Lost trough contain significantly greater amounts of sediment than do boreholes in other parts of the INL site (Welhan and others, 2007, p. 6; Anderson and others, 1999, fig. 9, table 2; Hughes and others, 2002).

Deposits of rhyolitic and other evolved-composition ashes are rare but important time markers. Such deposits are the result of eolian transport from distant sources, and preservation of such deposits depends on the simultaneous occurrence of an ash-producing eruption upwind of the eastern SRP and either a basaltic eruption or a sedimentary depositional environment that allows quick burial of the ash. None of the boreholes reported here penetrated to the depth of the caldera-related rhyolitic rocks that underlie the eastern SRP basalts.

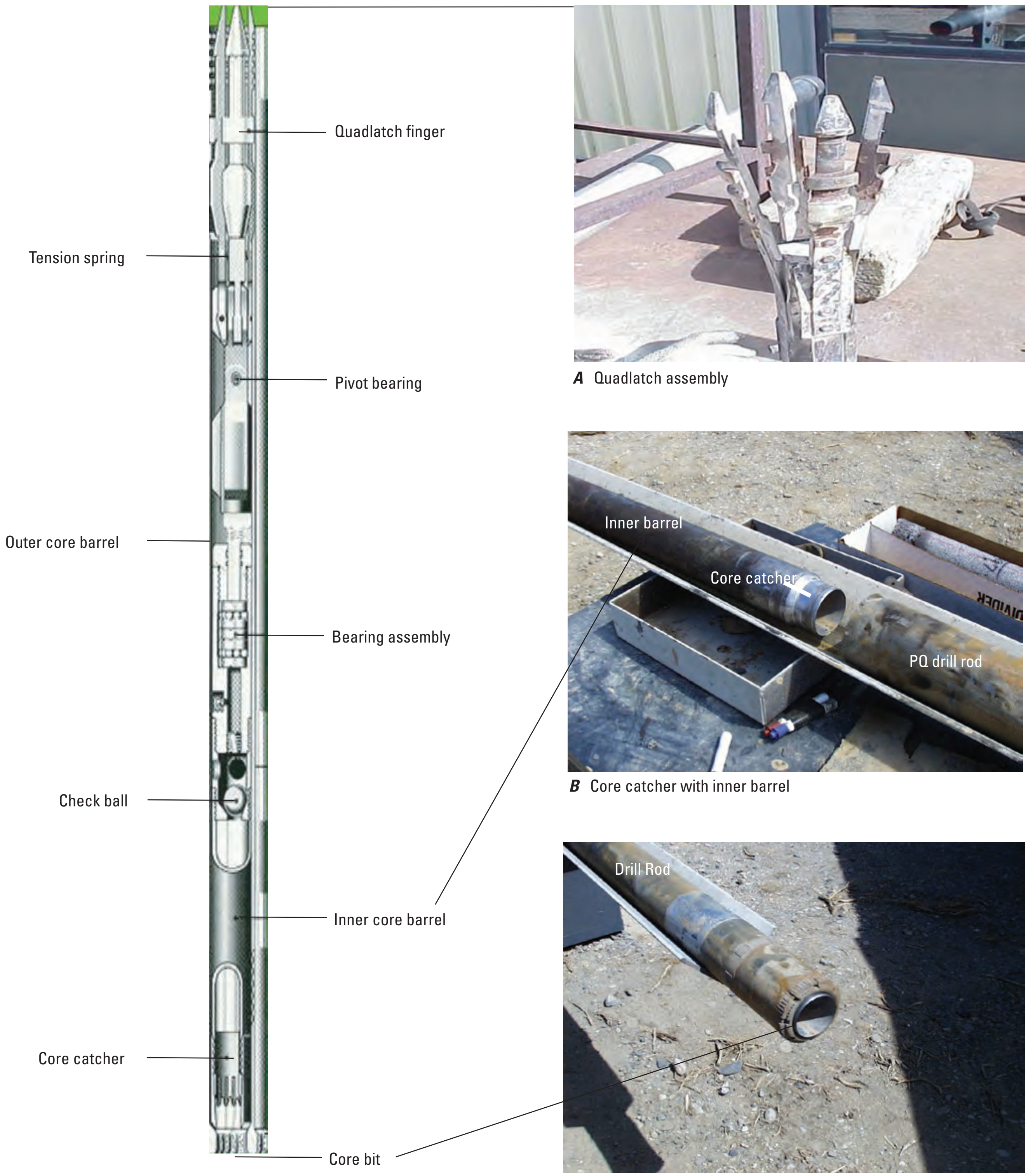
Borehole Construction

The USGS INL Drilling Program uses a truck-mounted wireline core rig, two coring systems, and support equipment for rotary coring in volcanic rock and sediment. This rig is capable of drilling depths that exceed 1,400 ft. The two primary coring systems are PQ and HQ, distinguished by their diameter. Typical PQ rotary coring produces a 4.8-in. borehole and a 3.3-in. diameter core (fig. 3*B*). The HQ rotary coring system produces a 3.8-in. borehole and a 2.5-in. diameter core (fig. 3*A*). Both PQ and HQ rotary core systems use similar diamond and carbide bits, core catchers, latch assemblies, and retrieval systems (fig. 4). Core was retrieved using a wireline latching mechanism (quadlatch) located at the top of the core barrel assembly. Support equipment includes a 350 lb/in^2,


A HQ Core — 2.5-inch core

B PQ Core — 3.3-inch core

Figure 3. Photographs showing examples of HQ and PQ core from USGS boreholes 133 and 132 at the Idaho National Laboratory, Idaho.



A Quadlatch assembly

B Core catcher with inner barrel

C Core bit

Modified from Christensen product brochure, 1997.

Figure 4. Illustration and photographs showing coring assembly and components used to drill and retrieve core. *A*, Quadlatch assembly; *B*, Core catcher with inner barrel; *C*, Core bit.

900 ft^3/min capacity diesel air compressor, pipe trailer, and a 3,000-gal water truck.

Prior to coring, casing was driven through surficial sediment. Once surface casing was placed, boreholes were continuously cored for several hundred feet. Drilling fluid used for coring included air or air mixed with water. Drilling fluid was used during coring to cool the bit face and circulate drill cuttings. Foam additives were used in certain circumstances to help stabilize the borehole and lift the cuttings to the surface.

Boreholes drilled on the eastern SRP mostly penetrate basalt with sediment layers that vary from less than a foot to tens of feet thick. In general, diktytaxitic to massive basalt cored well but flow tops and bottoms caused problems, especially where series of thin flows resulted in heavily fractured and unstable rock. Core recovery of fine sediment is typically more successful than recovery of coarse sand and gravel. Under saturated conditions, sediment recovery is difficult because wet, unconsolidated sediment falls out of the core barrel.

Most of the boreholes were completed for water-quality and / or water-level monitoring. One of the wells was constructed as a control well for geophysical logging calibration. Final construction details for each borehole are shown in figures 8 through 17.

Geophysical Logs

Borehole wireline geophysical data have been used extensively in hydrologic studies at the INL since 1952 to characterize stratigraphic units within the basalts and sediments of the SRPA, and to define hydrologic properties of the rocks that make up the SRPA. The USGS maintains an extensive archive of INL-related geophysical logs.

Borehole geophysical data used in this report to characterize and define stratigraphic units and hydrologic properties were derived primarily from caliper, gamma-gamma, natural gamma, and neutron logs. Borehole video logs were used to corroborate stratigraphic information where necessary. Examples of features that can be identified with geophysical logging techniques are shown in figure 5.

Borehole geophysical logs are on file in Log ASCII Standard (LAS) and LOG format (a proprietary binary format) and available to interested parties through the USGS INL Project Office or through the INL Hydrologic Data Repository (HDR). The following summary describes the four types of geophysical logs used primarily by USGS INL Project Office researchers for data acquisition at the INL.

Caliper Logs

The caliper tool provides an electronic wall trace of the drill-hole diameter by using three extendable spring-loaded arms, capable of detecting small changes in borehole diameter (> 0.15 inch). Changes in borehole diameter, detected by the amount of deflection of the caliper arms, are recorded as the caliper tool is brought up from the bottom of the borehole.

Caliper logs were run in open boreholes immediately after the drill string was removed. Borehole caving prevented a continuous caliper profile in some boreholes. As the drill string was being removed, multiple caliper logs were run, when necessary, to capture borehole diameter data above and below intervals prone to caving. Caliper data were used to identify fracture locations, areas of competent basalt, and cavernous zones (fig. 5). Caliper logs also were used when designing monitoring wells to determine location of casing, annular seal, and well screen.

Gamma-Gamma Logs

The gamma-gamma density log, also known as the induced gamma-density log, measures bulk density of the formation in the borehole's immediate vicinity. Two separately spaced detectors record induced gamma-radiation intensity from an encapsulated radioactive source after it is backscattered or absorbed in a drill hole, borehole fluid, or surrounding media (Chase and others, 1964). The induced gamma signal is attenuated in direct proportion to the bulk density of a formation. Very dense materials increase scatter and cause increased absorption of gamma radiation; the increased absorption of gamma radiation results in fewer particles returning to the detector. The opposite is true for fractured and low-density materials. Examples of density differences recorded by gamma-gamma logs are shown in figure 5.

Gamma-gamma logging requires one source and two separately spaced detectors, referred to as the short- and long-spaced detectors. The short-spaced detector has a smaller volume of investigation than the long-spaced detector. Although the resolution of the long-spaced detector is lower than the short-spaced detector, data from the long-spaced detector are less affected by well casing and near-borehole conditions than are data from the short-spaced detector (Glover and others, 2002). For this report, data collected from the long-spaced detector are shown in figures 8 through 17.

Natural Gamma Logs

Natural gamma logs record gamma radiation emitted by naturally occurring radioisotopes and are commonly used at the INL to identify sedimentary layers in boreholes and basalt sources that show distinguishable differences in Potassium-40. Some examples of naturally occurring radioisotopes in the eastern SRP are potassium-40, bismuth-214, lead-214, actinium-228, thorium-232, and uranium-238 (Barraclough and others, 1976). Fine-grained detrital sediments naturally contain greater concentrations of gamma-emitting isotopes; most basalts do not contain large amounts of naturally occurring gamma-emitting isotopes, and crystalline rock, such as basalt, is less likely to preferentially absorb gamma emitters. The gamma

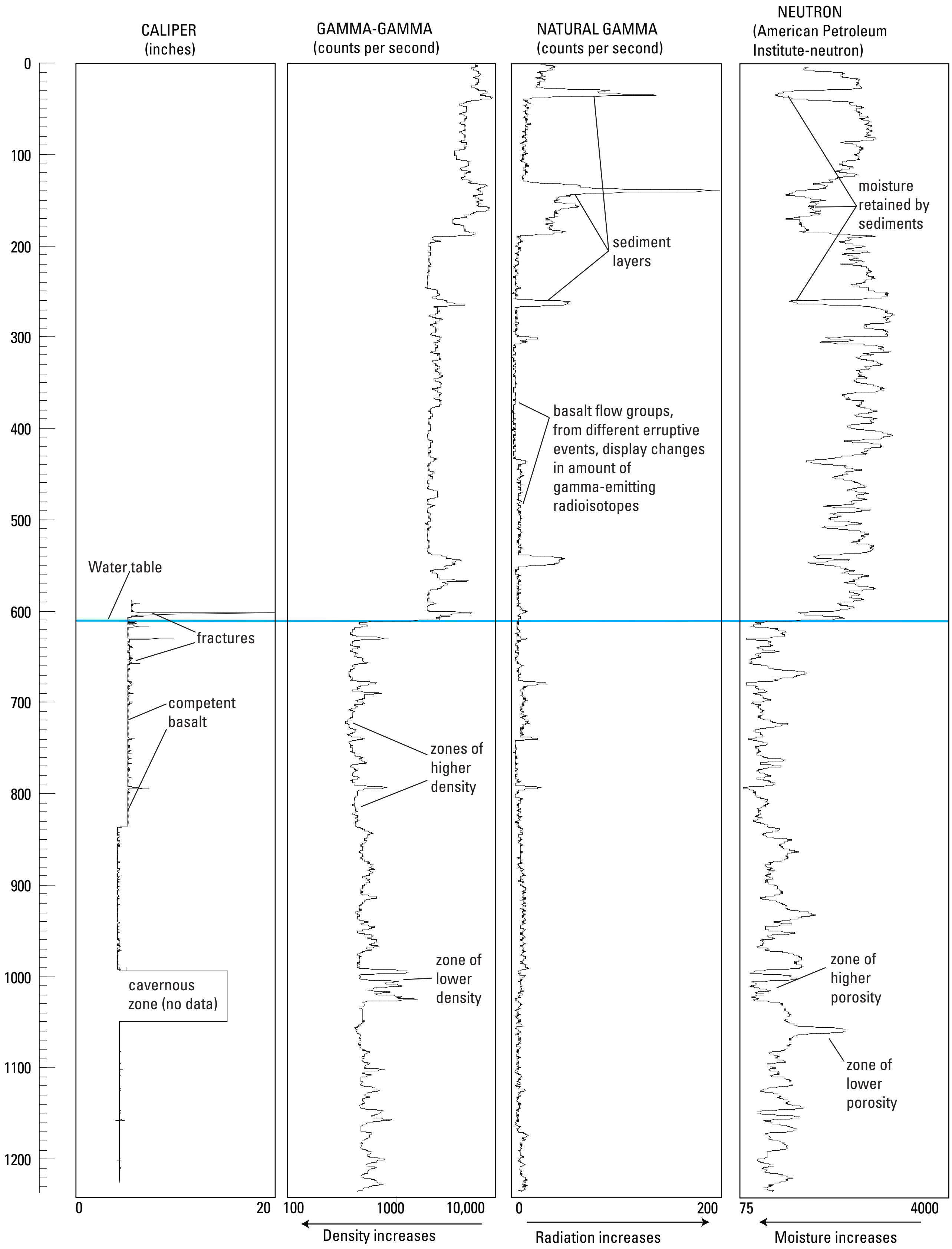


Figure 5. Graph showing typical hydrogeologic features that are discernible in caliper, gamma-gamma, natural gamma, and neutron logs in boreholes at the Idaho National Laboratory, Idaho.

detector measures total gamma radiation without distinguishing between individual contributions of the various isotopes.

The probe used for recording the natural gamma log contains a single pressure-housed sodium iodide scintillation detector. Naturally occurring gamma radiation hits the sodium iodide crystal and causes a visible light emission called scintillation. A photomultiplier tube detects scintillations and transforms them into pulses of electrical energy, which are recorded and digitally displayed in a log of gamma-radiation responses.

Natural gamma logs are used to distinguish between basalt and sediment layers and may also be used to differentiate between basalt flows of different flow groups if the flow groups contain measurable differences in naturally occurring radioisotopes. Examples of elevated natural gamma response due to the presence of sediment layers and changes in natural gamma signal resulting from different basalt groups are shown in figure 5.

Neutron Logs

The neutron log records the continuous measurement of the induced radiation produced by bombarding surrounding media (casing, formation, and fluid) with fast neutrons (energies greater than 10^5 eV) from a sealed neutron source, which collide with surrounding atomic nuclei until they are captured (Keys, 1990, p. 95). The neutron tool used by the USGS INL Project Office has an Americium / Beryllium neutron source, and a He^3 detector that counts slow (thermal) neutrons (those that have energies less than 0.025 eV).

Hydrogen nuclei have approximately the same mass as neutrons, so neutrons that collide with hydrogen nuclei are slowed, and are recorded at a lower rate than those that collide with nuclei other than hydrogen. Hydrogen content is inversely proportional to thermal neutron count at the detector, when the spacing between source and detector is greater than 11.8 in, as it is in the neutron tool used by the USGS INL Project Office (Keys, 1990, p.95–96). Because water is the most common hydrogen-bearing substance in eastern SRP boreholes, neutron logs are considered good indicators of saturated formation porosity. When combined with natural gamma logs to provide information about sediment location, neutron logs may also help identify perched water zones in the unsaturated zone (see fig. 5). Neutron response changes related to perched water and zones of higher and lower water-filled porosity are shown in figure 5.

Core Logs

Core logs are presented in appendixes A through J. The core logs were created using a standardized method to record lithologic logs with photographs of core (Johnson and others, 2005). Core was logged with commercial logging software, using a procedure developed by USGS INL Project Office for use at the Lithologic Core Storage Library. The method deliberately maximizes description and minimizes interpretation.

Data recorded are: depth below land surface; core photograph; igneous, soil, and sedimentary structures; a lithologic description; a numeric value for fracture frequency displayed as a histogram; a line graph of mean vesicle size for an interval; and a color curve of vesicle volume percentage.

Core Log Columns

The left-most column of every core log is depth, in feet bls (fig. 6). The second column contains a photograph of the core. The third column contains igneous, soil, or sedimentary symbols to call attention to structures of particular interest, see core log header in appendixes A through J for a key to the symbols. For basalt, structures of interest were vesicle zones, large vesicles, vesicle planes, mega vesicles, vesicle cylinders, pipe vesicles, pillows, vesicle sheets, flow and mold structures, and spatter features (agglomerated spatter). Sediment was classified by the Unified Soil Classification System (table 1) based on particle size (table 2) and soil texture (American Society for Testing and Materials, 1985). Sediment particle size was estimated by comparison to a chart based on the Wentworth scale (table 2) (Wentworth, 1922). Some intervals of sediment core were sampled for sediment property analysis before being logged.

The fourth column contains a colored lithology symbol (fig. 6). The fifth column is for miscellaneous text, such as notes about where samples were taken, by whom, and for what purpose. The sixth column is for written lithologic descriptions. Lithology was described in standard geological terms for color, texture, composition (minerals), magnetic attraction, xenoliths, alteration, and structures of interest.

The seventh column is a histogram representation for fracture frequency, a numeric value based on number of fractures per interval. Fracture frequency numeric values are 0 for intervals of unfractured core, 1 for very slightly fractured core (pieces averaged 3 to 5 ft), 2 for slightly fractured core (pieces averaged 1 to 3 ft), 3 for moderately fractured core (pieces averaged .33 to 1.0 ft), 4 for intensely fractured core (pieces averaged .0875 to 0.33 ft), 5 for extremely fractured core (pieces averaged less than .0875 ft).

The eighth column contains a line graph of estimated mean vesicle size in 0.1 inches, and yellow-filled curve that describes the estimated volume percent of vesicles per interval of basalt. Vesicle size and percentage were visually estimated using charts adapted from Compton, 1962.

Core Photographs

Photographs for logging are taken with a custom-built jig mounted on a rolling table (fig. 7). The jig controls depth of field, light intensity, angle, and position of core boxes assuring consistent photographs. Well name, depth intervals, and color charts are photographed with the core, to assist in photo processing. Core photographs were color corrected if necessary and stacked for presentation using commercially available

MAJOR DIVISIONS			GROUP SYMBOL	GROUP NAME
COARSE GRAINED SOILS (>50% retained on #200 sieve, aperture 75 µm)	**GRAVEL** (>50% of coarse fraction retained on #4 sieve, aperture 4.75 mm)	CLEAN GRAVELS (little or no fines)	GW	WELL-GRADED GRAVEL, FINE TO COARSE GRAVEL
			GP	POORLY-GRADED GRAVEL
		GRAVELS WITH FINES (appreciable amount of fines)	GM	SILTY GRAVEL
			GC	CLAYEY GRAVEL
	SAND (>50% of coarse fraction passes # 4 sieve, aperture 4.75 mm)	CLEAN SANDS (little or no fines)	SW	WELL-GRADED SAND, FINE TO COARSE SAND
			SP	POORLY-GRADED SAND
		SAND WITH FINES (appreciable amount of fines)	SM	SILTY SAND
			SC	CLAYEY SAND
FINE GRAINED SOILS (FINES) (>50% passes #200 sieve, aperture 75 µm)	**SILT AND CLAY**	INORGANIC	ML	SILT
			CL	CLAY
		ORGANIC	OL	ORGANIC SILT, ORGANIC CLAY
	SILT AND CLAY	INORGANIC	MH	SILT OF HIGH PLASTICITY, ELASTIC SILT
			CH	CLAY OF HIGH PLASTICITY, FAT CLAY
		ORGANIC	OH	ORGANIC CLAY, ORGANIC SILT
HIGHLY ORGANIC SOILS			PT	PEAT

Modified from American Society for Testing and Materials, 1985, D 2487-83, Classification of Soils for Engineering Purposes: Annual Book of ASTM Standards. Vol. 04.08, pp 395-408.

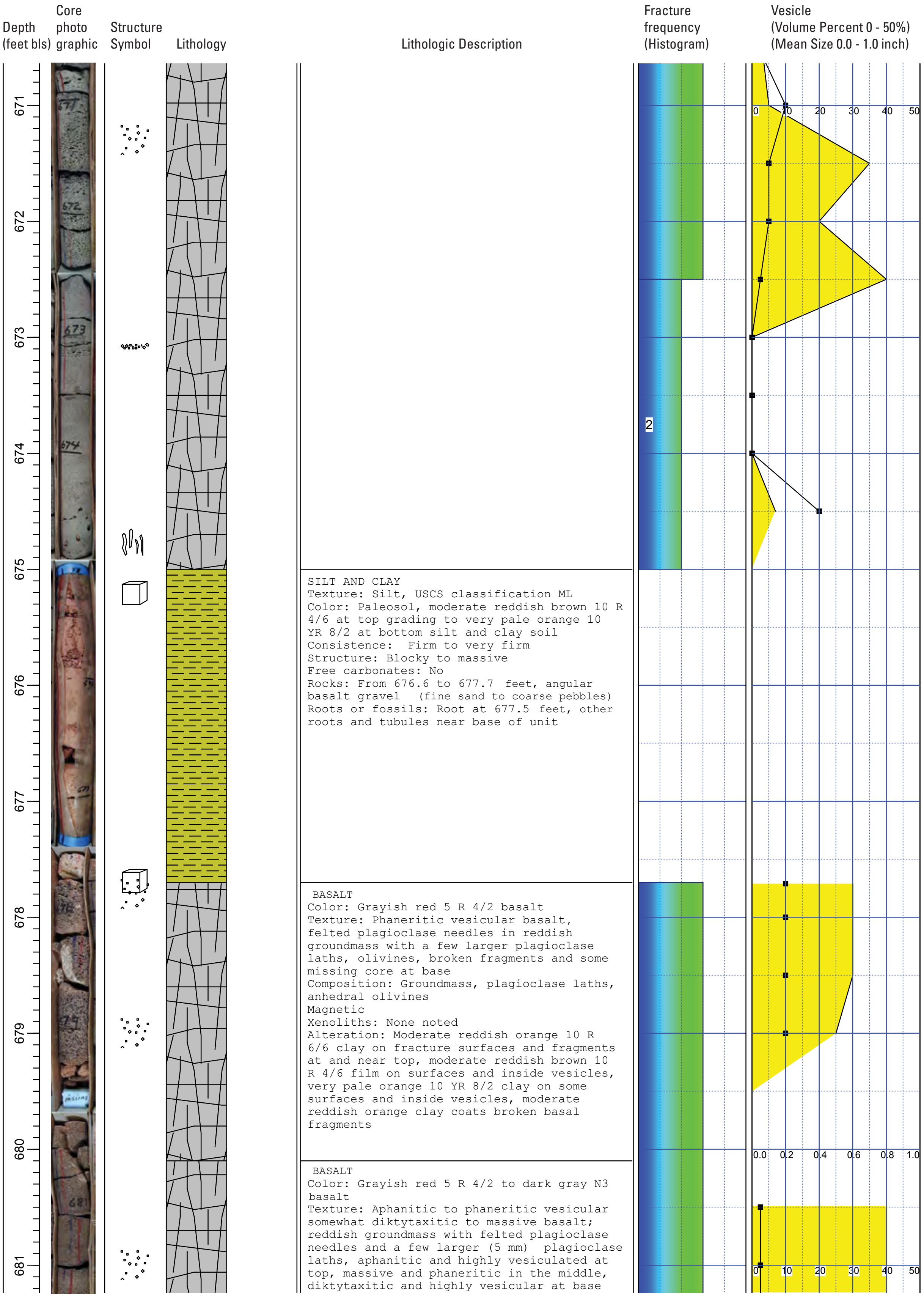
Table 1. ASTM unified soil classification system used in core logs (American Society for Testing and Materials, 1985).

Table 2. Wentworth scale of particle sizes used in core logs (modified from Wentworth, 1922).

Wentworth Grain-size scale

Millimeters (mm)	Wentworth size class
4096	Boulder
256	Cobble
64	Pebble
4	Granule
2	Very coarse sand
1	Coarse sand
0.5	Medium sand
0.25	Fine sand
0.125	Very fine sand
0.0625	Coarse silt
0.031	Medium silt
0.0078	Fine silt
0.0039	Very fine silt
0.00006	Clay

Modified from Wentworth, 1922



SILT AND CLAY
Texture: Silt, USCS classification ML
Color: Paleosol, moderate reddish brown 10 R 4/6 at top grading to very pale orange 10 YR 8/2 at bottom silt and clay soil
Consistence: Firm to very firm
Structure: Blocky to massive
Free carbonates: No
Rocks: From 676.6 to 677.7 feet, angular basalt gravel (fine sand to coarse pebbles)
Roots or fossils: Root at 677.5 feet, other roots and tubules near base of unit

BASALT
Color: Grayish red 5 R 4/2 basalt
Texture: Phaneritic vesicular basalt, felted plagioclase needles in reddish groundmass with a few larger plagioclase laths, olivines, broken fragments and some missing core at base
Composition: Groundmass, plagioclase laths, anhedral olivines
Magnetic
Xenoliths: None noted
Alteration: Moderate reddish orange 10 R 6/6 clay on fracture surfaces and fragments at and near top, moderate reddish brown 10 R 4/6 film on surfaces and inside vesicles, very pale orange 10 YR 8/2 clay on some surfaces and inside vesicles, moderate reddish orange clay coats broken basal fragments

BASALT
Color: Grayish red 5 R 4/2 to dark gray N3 basalt
Texture: Aphanitic to phaneritic vesicular somewhat diktytaxitic to massive basalt; reddish groundmass with felted plagioclase needles and a few larger (5 mm) plagioclase laths, aphanitic and highly vesiculated at top, massive and phaneritic in the middle, diktytaxitic and highly vesicular at base

Figure 6. Illustration showing example of a lithologic log for USGS 132, Idaho National Laboratory, Idaho. Structure symbols and all abbreviations used in lithologic descriptions are explained in appendixes A through J.

software, and inserted into core logs. An example of a log with a core photograph for USGS 132 is shown in figure 6.

Core Descriptions

Lithologic descriptions were constructed from examination of cores and supplemented with geophysical data. After the core was drilled and extracted, it was marked in the field for vertical direction and depth. Examination of core was done at the Lithologic CSL located at the INL Central Facilities Area (CFA). Geophysical data were used during the examination to identify areas of missing or lost core and to check accuracy of depths marked on core.

Most of the core from drilling on the eastern SRP is olivine tholeiite basalt from flows that vary in thickness. Individual basalt flows could be distinguished from one another by locating vesicular and fractured flow tops, diktytaxitic to massive interiors, and vesicular flow bottoms. Basalt color, composition, and texture were described using a standardized format. Xenoliths and alteration were noted where present.

Sediment layers were the other main core component, and they vary in both composition and thickness. Most sediment layers are generally fine-grained, and they include large amounts of silt, clay, fine sand as well as limited amounts of coarse sand and gravel. Coarse-grained sediments may be underrepresented owing to difficulty in recovering coarse-grained unconsolidated sediment, especially in the saturated zone. Fine-grained sediment is the result of eolian, fluvial, and lacustrine deposition (Blair, 2002). Some sediment tops were oxidized or baked (yellowish red to red in color) when they were heated by overlying basalt.

A very small amount of rhyolite ash was observed. It is fine-grained, pinkish-gray, and contains less than 1 percent mafic minerals; this unit is unaltered and poorly consolidated.

Borehole Descriptions

Borehole descriptions include: location, completion date, core size, core depth, core recovery footage, and a general description of recovered core (appendices A through J). Nine boreholes were continuously cored and one was partially cored. Additional information includes sediment layer and basalt flow thickness and the approximate number of individual basalt flows. Thickness and number of basalt flows for each borehole were approximated based on identification of vesicular flow tops and bottoms taken from core and geophysical data. The number of basalt flows can only be approximated because most eastern SRP olivine tholeiite basalts are so similar that they cannot be distinguished from one another except by geochemical analysis, paleomagnetic inclination, or other sophisticated methods. A summary of borehole data is presented in table 3.

Figure 7. Setup used to photograph core.

USGS 126a and USGS 126b

USGS 126a and USGS 126b, northwest of Test Area North (TAN) (fig. 1), were completed in 2000 as a pair of wells 50 ft apart. USGS 126a was HQ rotary cored from 5.6 to 543.9 ft, then reamed and cased before PQ rotary coring from 543.9 to 647.9 ft. Combined recovery for basalt and sediment in USGS 126a was about 94 percent, excluding surficial sediment. Basalt recovery was 566.8 of 596.3 ft and sediment recovery was 40.0 of 46.0 ft (table 3). USGS 126b was cored from 467.0 to 472.0 ft with 5.0 ft of basalt recovered and no sediment recovered in the part of borehole cored (table 1). The final borehole construction diagram, general lithology, and geophysical logs (caliper, gamma-gamma density, natural gamma, and neutron) for USGS 126a and USGS 126b are shown in figures 8 and 9. Core logs for USGS 126a and USGS 126b are presented in appendixes A and B.

Over 92 percent of the total borehole lithology penetrated in boreholes USGS 126a and USGS 126b consists of basalt. Surficial sediment is 5.6 ft thick in USGS 126a and primarily consists of fine-grained sand and loess. In USGS 126a, sediment layers range from about 1 to 37 ft thick and make up about 11 percent of the unsaturated zone;

Table 3. Summary data for cored boreholes USGS 126a, 126b, 127, 128, 129, 130, 131, 132, 133, and 134.

[Summary of borehole core information approximated from lithologic core logs and/or geophysical data. Surficial sediment thickness was taken from driller's log. Number of basalt and sediment layers and basalt flow and sediment thickness was approximated from lithologic core logs and/or geophysical information where core was not collected. Depth to water table was referenced to land-surface datum. Abbreviations: ft, feet; mo-yr, month-year; —, no data].

Data type	Borehole Designation									
	USGS 126a	USGS 126b	USGS 127	USGS 128	USGS 129	USGS 130	USGS 131	USGS 132	USGS 133	USGS 134
Borehole depth, in ft	647.9	472.0	598.1	767.4	779.1	723.0	808.5	1238.0	812.0	949.0
Core recovered, in ft	606.4	5.0	537.1	647.4	734.1	637.0	713.6	1187.0	698.2	912.3
Surficial sediment thickness, in ft	5.6	8.0[†]	15.5	23.0	9.2	10.3	10.1	9.0	27.5	10.5
Basalt thickness, in ft	596.3	419.0[†]	512.1	666.4	717.9	622.2	696.0	1139.6	690.0	904.6
Basalt core recovered, in ft	566.8	5.0	505.1	616.4	708.4	613.7	681.7	1123.4	661.5	895.9
Number of basalt flows (approximate)	28[‡]	18[†,‡]	35[‡]	40[‡]	50[‡]	30[‡]	50[‡]	85[‡]	48[‡]	50[‡]
Average basalt flow thickness, in ft	21[‡]	21[†,‡]	15[‡]	17[‡]	14[‡]	21[‡]	14[‡]	13[‡]	14[‡]	18[‡]
Rhyolite thickness, in ft	0.0	—	0.0	0.0	2.0	0.0	2.0	0.0	0.0	0.0
Total rhyolite recovered, in ft	0.0	—	0.0	0.0	0.5	0.0	1.5	0.0	0.0	0.0
Sediment thickness[*], in ft	46.0	45.0[†]	70.5	78.0	50.0	90.5	100.4	89.4	94.5	33.9
Sediment core recovered, in ft	40.0	—	31.5	31.0	25.0	23.0	29.8	63.6	36.7	15.9
Number of sediment layers[*]	2	2[†]	7	7	12	9	7	10	6	9
Depth to water table, in ft	411.4	412.0	506.0	481.0	601.0	481.0	545.0	606.0	431.7	513.0
Water level date (mo-yr)	Nov-00	Nov-00	Nov-00	Oct-02	May-02	Nov-03	Jan-04	Jun-06	Jun-05	Aug-06

[*] Excludes thickness of surficial sediment.

[†] Lithologic interpretation based on geophysical data and correlation to USGS 126a lithologic log.

[‡] Basalt flow location based on identification of vesiculated flow tops and bottoms in lithologic core logs and geophysical log data.

no sediment layers were encountered in the saturated zone. Recovered sediment ranges in particle size from clay and silt to sand.

Basalt in USGS 126a and USGS 126b is olivine tholeiite. It is medium light- to dark-gray in color and is vesicular to dense in texture. There are about 28 individual basalt flows that were described in USGS 126a, and these flows range from 3 to 60 ft thick. Basalt flow thickness averaged 21 ft (table 3).

USGS 127

USGS 127, southwest of CFA (fig. 1), was completed in 1999. USGS 127 was PQ rotary cored from 15.5 to 93.0 ft and from 128.0 to 598.1 ft. The borehole was HQ rotary cored from 93.0 to 128.0 ft. Combined core recovery for both basalt and sediment was about 92 percent, excluding surficial sediment. Basalt recovery was 505.1 of 512.1 ft and sediment recovery was 31.5 of 70.5 ft (table 3). The final borehole construction diagram, general lithology, and geophysical logs (caliper, gamma-gamma density, natural gamma, and neutron) for USGS 127 are shown in figure 10. A core log for USGS 127 is presented in appendix C.

Basalt makes up over 85 percent of the stratigraphic column in USGS 127. Surficial sediment is 15.5 ft of loess. Sediment layers ranged from about 1 to 54 ft thick and make up about 14 percent of the unsaturated zone; no sediment was encountered in the saturated zone. Recovered sediment ranges in particle size from silt with clay to gravel.

Basalt in USGS 127 is olivine tholeiite. It is medium- to dark-gray in color and vesicular to dense in texture. Approximately 35 individual basalt flows were described in USGS 127 that ranged from 1 to 50 ft thick. Basalt flow thickness averaged 15 ft in USGS 127 (table 3).

USGS 128

USGS 128, north of CFA (fig. 1), was completed in 2002. USGS 128 was PQ rotary cored from 23.0 to 533.0 ft and HQ rotary cored from 533.0 to 767.4 ft. Combined core recovery for basalt and sediment was about 87 percent, excluding surficial sediment. Basalt recovery was 616.4 of 666.4 ft and sediment recovery was 31.0 of 78.0 ft (table 3). The final borehole construction diagram, general lithology, and geophysical logs (caliper, gamma-gamma density, natural gamma, and neutron) for USGS 128 are shown in figure 11. A core log for USGS 128 is presented in appendix D.

The stratigraphic column for USGS 128 consists mostly of basalt. Basalt makes up about 87 percent of total borehole lithology. Surficial sediment is 23.0 ft of loess and fine sand. Sediment layers range from about 4 to 38 ft thick, and that make up about 13 percent of the unsaturated zone and about 14 percent of the saturated zone. Recovered sediments are predominately silty sand that alternate with sequences of clayey silt, and silty gravel.

Basalt in USGS 128 is olivine tholeiite. It is light- to dark-gray in color and vesicular to dense in texture. There are about 40 individual basalt flows described in USGS 128 that range from 2 to 50 ft in thickness. Basalt flow thickness averaged 17 ft (table 3).

USGS 129

USGS 129, east of the RWMC (fig. 1), was completed in 2002. USGS 129 was PQ rotary cored from 9.2 to 779.1 ft. Combined recovery for basalt, rhyolite, and sediment was about 95 percent, excluding surficial sediment. Basalt recovery was 708.4 of 717.9 ft, rhyolite ash recovery was 0.5 of 2.0 ft, and sediment recovery was 25.0 of 50.0 ft (table 3). The final borehole construction diagram, general lithology, and geophysical logs (caliper, gamma-gamma, natural gamma, and neutron) for USGS 129 are shown in figure 12. A core log for USGS 129 is presented in appendix E.

Basalt makes up most of the stratigraphic column for USGS 129, and it represents about 92 percent of the total borehole lithology. Surficial sediment was 9.2 ft of loess. Sediment layers range from approximately 1 to 16 ft thick and represent about 8 percent of the unsaturated zone and about 4 percent of the saturated zone. Particle size of recovered sediments ranges from silt with clay to gravel.

Basalt in USGS 129 is olivine tholeiite. It is medium- to dark-gray in color and vesicular to dense in texture. About 50 basalt flows that range from 2- to 50-ft thick were described in USGS 129. Basalt flow thickness averages 14 ft (table 3).

Rhyolite ash was described from 752.0 to 754.0 ft. The rhyolite ash is pinkish-gray in color and fine-grained in texture.

USGS 130

USGS 130, located along the southern corner of CFA (fig. 1), was completed in 2003. USGS 130 was PQ rotary cored from 10.3 to 679.0 ft and HQ rotary cored from 679.0 to 723.0 ft. Combined core recovery for basalt and sediment was about 89 percent, excluding surficial sediment. Basalt recovery was 613.7 of 622.2 ft and sediment recovery was 23.0 of 90.5 ft (table 3). The final borehole construction diagram, general lithology, and geophysical logs (caliper, gamma-gamma density, natural gamma, and neutron) for USGS 130 are shown in figure 13. A core log for USGS 130 is presented in appendix F.

Basalt makes up about 86 percent of the stratigraphic column at USGS 130. Surficial sediment is 10.3 ft of loess. Cored sediment layers range from approximately 1 to 34 ft thick and represent about 8 percent of the unsaturated zone and about 24 percent of the saturated zone. Recovered sediments range in particle size from clayey to fine-grained sand.

Basalt in USGS 130 is olivine tholeiite. It is light brownish-gray to dark-gray in color and vesicular to dense in texture. Approximately 30 basalt flows were described that range from 2 to 75 ft thick. Basalt flow thickness averages 21 ft (table 3).

USGS 131

USGS 131, located east of RWMC (fig. 1), was completed in 2003. USGS 131 was PQ rotary cored from 10.1 to 619.0 ft and HQ rotary cored from 619.0 to 808.5 ft. Combined core recovery for basalt, rhyolite, and sediment was about 89 percent, excluding surficial sediment. Basalt recovery was 681.7 of 696.0 ft, lithic quartzite sand with reworked rhyolite ash recovery was 1.5 of 2.0 ft, and sediment recovery was 29.8 of 100.4 ft (table 3). The final borehole construction diagram, general lithology, and geophysical logs (caliper, gamma-gamma density, natural gamma, and neutron) for USGS 131 are shown in figure 14. A core log for USGS 131 is presented in appendix G.

Basalt makes up about 86 percent of the stratigraphic column for USGS 131. Surficial sediment is 10.1 ft of loess. Cored sediment layers range from 1 to 38 ft thick and make up about 18 percent of the unsaturated zone and about 4 percent of the saturated zone. Sediments range in particle size from clay to gravel. Rhyolite ash mixed with sediment was described at 277 ft, and pinkish-gray to pale orange reworked rhyolitic ash mixed with basalt and quartzitic lithic sand was described at 566 ft.

Basalt in USGS 131 is olivine tholeiite. It is medium-gray to blackish-red in color and vesicular to dense in texture. Approximately 50 basalt flows were described in USGS 131 that ranged from 2 to 35 ft thick. Basalt flow thickness averaged 14 ft (table 3).

USGS 132

USGS 132, located 1 mile south of the RWMC (fig. 1), was completed in 2004. USGS 132 was PQ rotary cored from 9.0 to 833.0 ft, and HQ rotary cored from 833.0 to 1,238.0 ft. Combined core recovery for basalt and sediment was approximately 97 percent, excluding surficial sediment. Basalt recovery was 1,123.4 of 1,139.6 ft and sediment recovery was 63.6 of 89.4 ft (table 3). The final borehole construction diagram, general lithology, and geophysical logs (caliper, gamma-gamma, natural gamma, and neutron) for USGS 132 are shown in figure 15. A core log for USGS 132 is presented in appendix H.

About 92 percent of the stratigraphic column at USGS 132 is basalt. Surficial sediment is 9.0 ft of loess. Cored sediment layers range from 2 to 58 ft thick and make up about 18 percent of the unsaturated zone and about 2 percent of the saturated zone. Recovered sediments range from clay to gravel in particle size.

Basalt recovered at USGS 132 is olivine tholeiite. It is light- to dark-gray in color and vesicular to dense in texture. Approximately 85 individual basalt flows that ranged from 2- to over 50-ft thick were described in USGS 132. Basalt flow thickness averages 13 ft (table 3).

USGS 133

USGS 133, located north of Idaho Nuclear Technology and Engineering Center (INTEC) (fig. 1), was completed in 2005. USGS 133 was PQ rotary cored from 27.5 to 253.0 ft and from 438.2 to 643.0 ft. USGS 133 was HQ rotary cored from 253.0 to 438.2 ft and from 643.0 to 812.0 ft. The well was reamed and cased in sections. Combined core recovery for basalt and sediment was about 89 percent, excluding surficial sediment. Basalt recovery was 661.5 of 690.0 ft and sediment recovery was 36.7 of 94.5 ft (table 3). The final borehole construction diagram, general lithology, and geophysical logs (caliper, gamma-gamma, natural gamma, and neutron) for USGS 133 are shown in figure 16. A core log for USGS 133 is presented in appendix I.

About 85 percent of the stratigraphic column at USGS 133 is basalt. Surficial sediment is 27.5 ft of loess and fine sand. Cored sediment layers range from 3- to over 30-ft thick and make up about 14 percent of the unsaturated zone and about 19 percent of the saturated zone. Recovered sediments range in size from silt to gravel. A majority of the sediments recovered were fine sand.

Basalt at USGS 133 is olivine tholeiite. It is light-gray to blackish-red in color and vesicular to dense in texture. Approximately 48 individual basalt flows were described that range from 2- to 58-ft thick. Basalt flow thickness averages 14 ft (table 3).

USGS 134

USGS 134, located 2 miles northwest of the Reactor Technology Complex (RTC) (fig.1), was completed in 2005. USGS 134 was PQ rotary cored from 10.5 to 544.0 ft and HQ rotary cored from 544.0 to 949.0 ft. Combined core recovery for basalt and sediment was about 97 percent, excluding surficial sediment. Basalt recovery was 895.9 of 904.6 ft and sediment recovery was 15.9 of 33.9 ft (table 3). The final borehole construction diagram, general lithology, and geophysical logs (caliper, gamma-gamma, natural gamma, and neutron) for USGS 134 are shown in figure 17. A core log for USGS 134 is presented in appendix J.

About 95 percent of the stratigraphic column at USGS 134 is basalt. Surficial sediment is 10.5 ft of loess. Cored sediment layers range from less than 1-ft to 9-ft thick. Cored sediment layers make up about 7 percent of the unsaturated zone and about 5 percent of the saturated zone. Recovered sediments are silt, fine sand, and coarse sand.

Basalt in USGS 134 is olivine tholeiite. It is medium-gray to blackish-red in color and vesicular to dense in texture. Approximately 50 individual basalt flows were described that ranged from 2- to 60-ft thick. Basalt flow thickness averaged 18 ft (table 3).

Summary

Ten cored boreholes, with depths ranging from 472 to 1,238 ft, were drilled between 1999 and 2006. Just over 6,650 ft of core was recovered from the ten boreholes. Cores were photographed, described, and archived at the USGS Lithologic Core Storage Library located at Central Facilities Area.

Excluding USGS 126b, which was only partially cored, core recovery varied from about 87 to 97 percent. Olivine tholeiite basalt comprised most of the stratigraphic column with individual flows ranging from 1 to 75 ft thick. A two foot layer of rhyolite ash was recovered at USGS 129 and small amounts of reworked rhyolite ash mixed with sand in USGS 131. Sediment layers ranged from less than 1 foot to 58 ft thick, grain size ranged from clay to gravel.

Drilling through rock and sediment was achieved using a truck-mounted core rig. Wireline PQ and HQ core systems were used for recovery of rock and sediment. Support equipment included a compressor, pipe trailer, and water truck.

This report summarizes the construction, geophysical, and lithologic data collected from ten USGS boreholes completed between 1999 and 2006: USGS 126a, 126b, 127, 128 129 130, 131, 132, 133, and 134. Core logs are found in the appendixes A through J. Construction diagrams, general lithology, and geophysical data are presented in figures 8 through 17.

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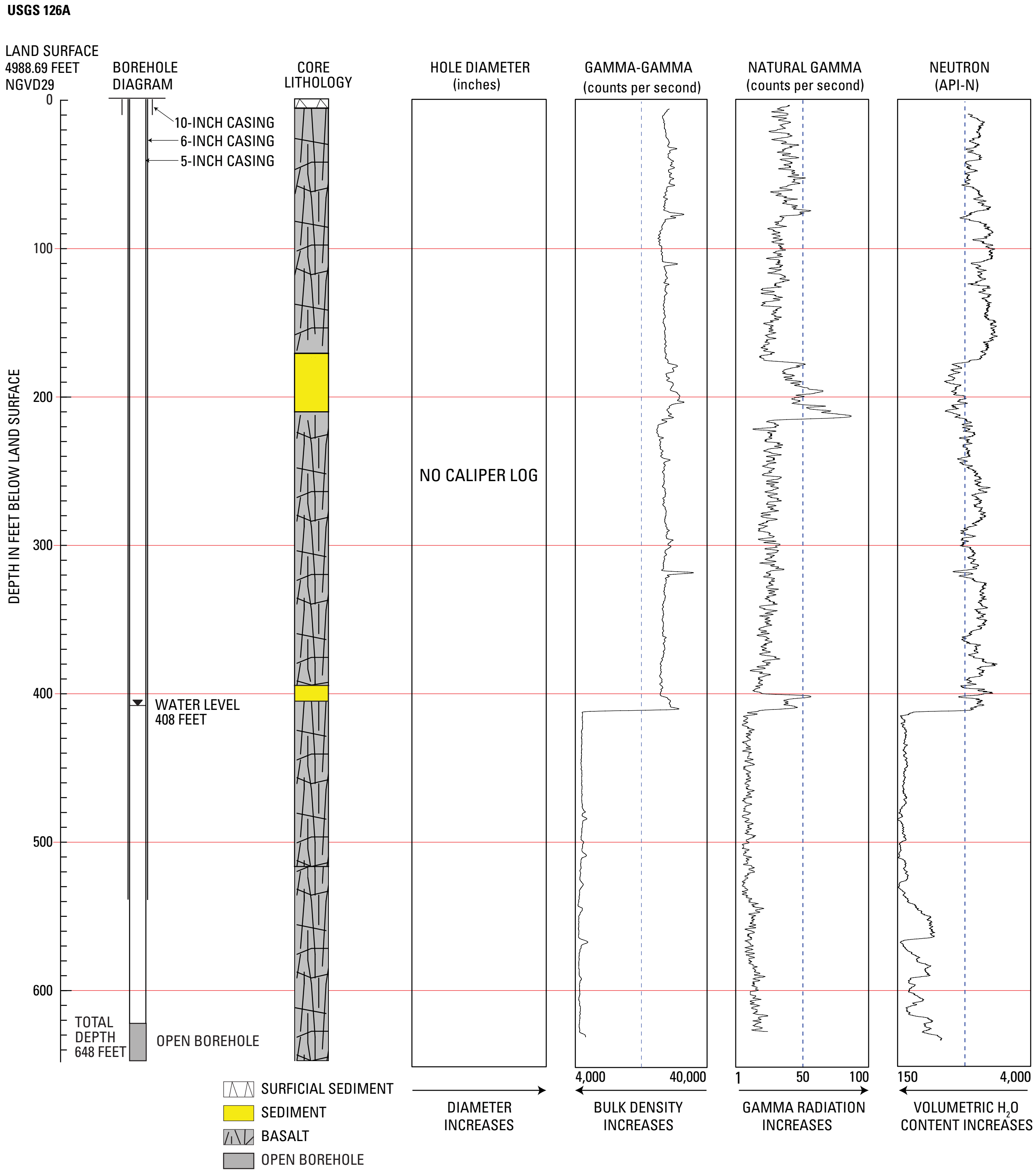

Figure 8. Borehole construction diagram, simplified lithologic log, and geophysical logs (caliper, gamma-gamma, natural gamma, and neutron) for USGS 126a, Idaho National Laboratory, Idaho.

USGS 126B

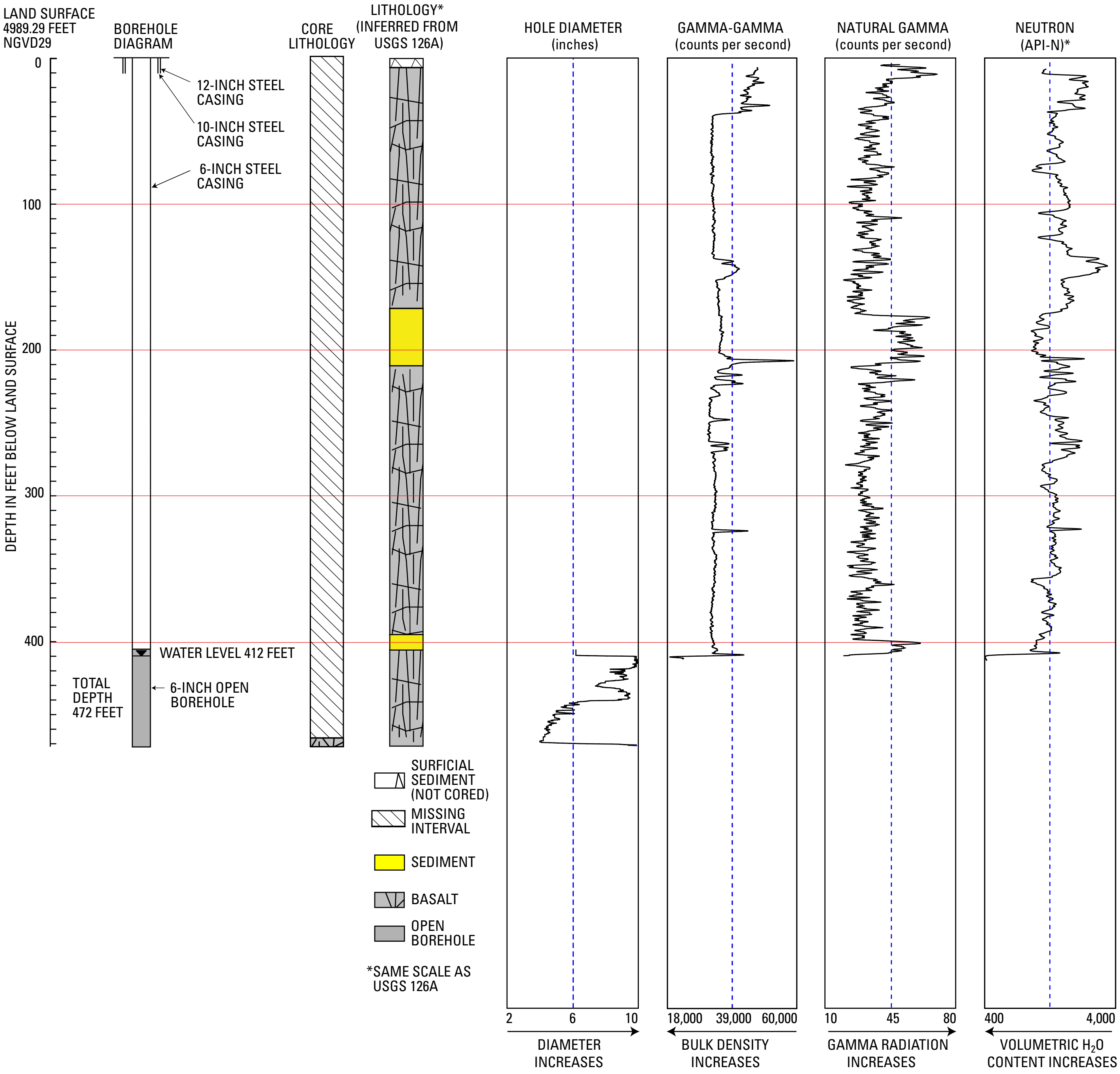

Figure 9. Borehole construction diagram, simplified lithologic log, and geophysical logs (caliper, gamma-gamma, natural gamma, and neutron) for USGS 126b, Idaho National Laboratory, Idaho.

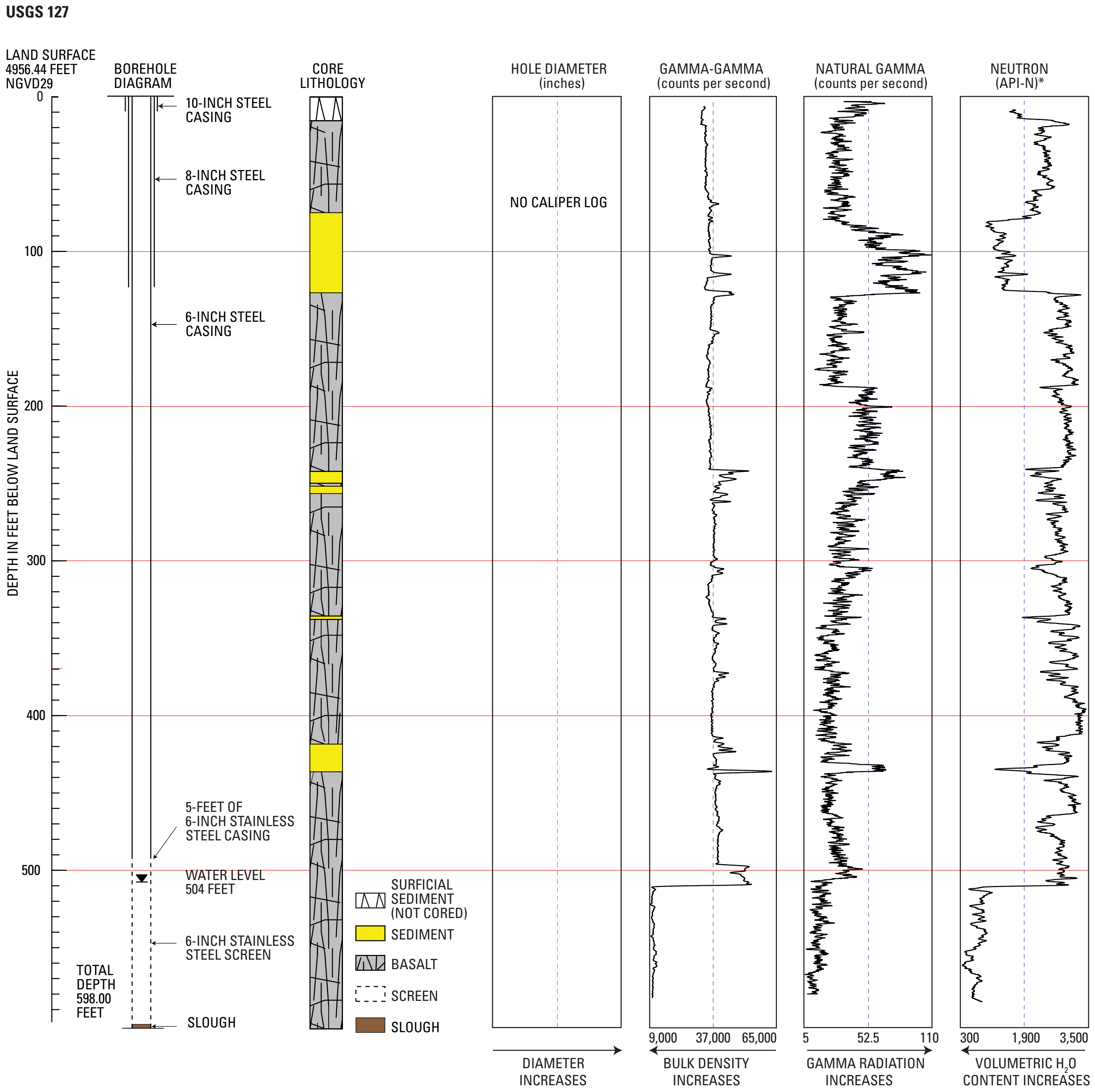

Figure 10. Borehole construction diagram, simplified lithologic log, and geophysical logs (caliper, gamma-gamma, natural gamma, and neutron) for USGS 127, Idaho National Laboratory, Idaho.

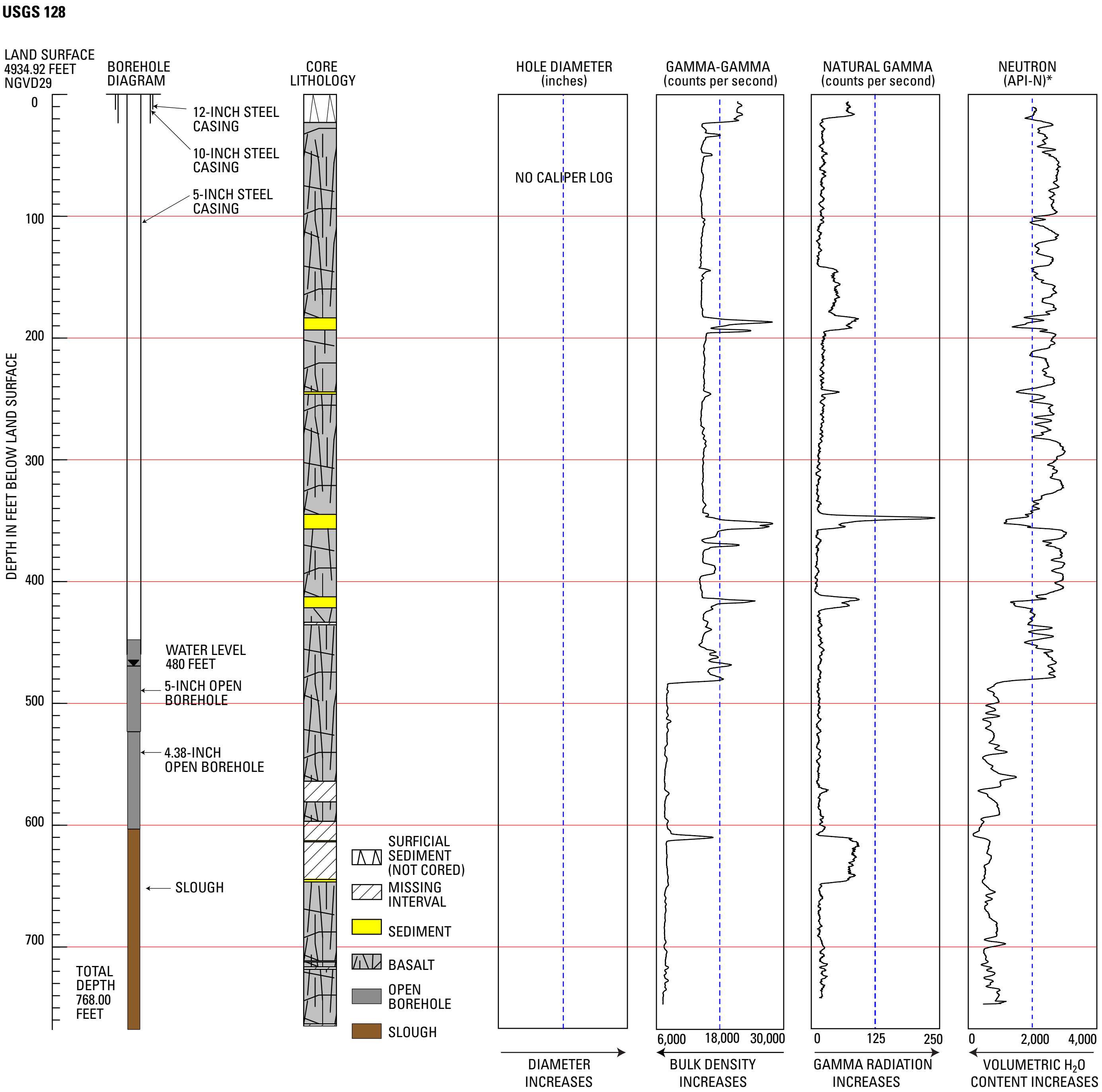

Figure 11. Borehole construction diagram, simplified lithologic log, and geophysical logs (caliper, gamma-gamma, natural gamma, and neutron) for USGS 128, Idaho National Laboratory, Idaho.

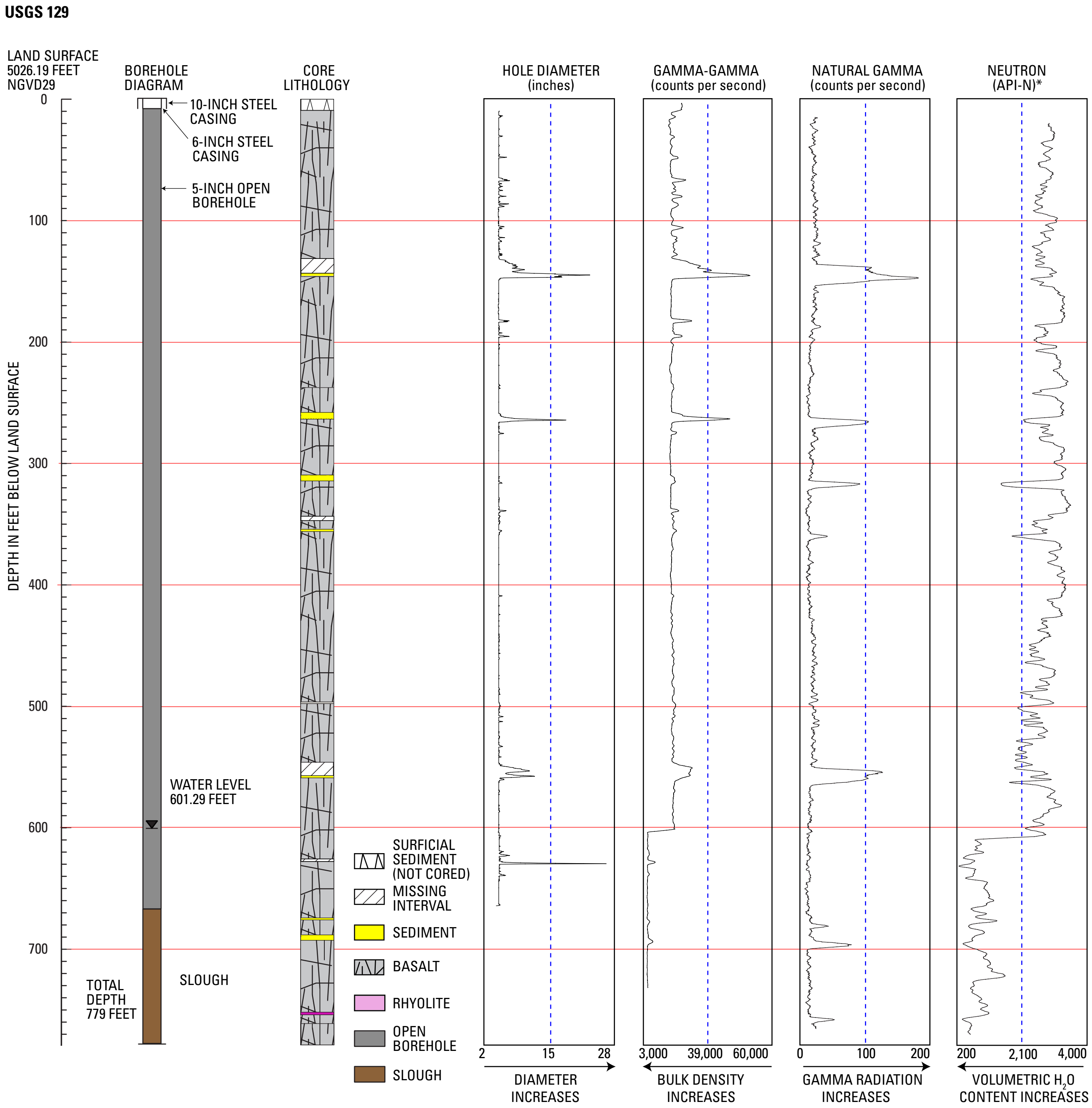

Figure 12. Borehole construction diagram, simplified lithologic log, and geophysical logs (caliper, gamma-gamma, natural gamma, and neutron) for USGS 129, Idaho National Laboratory, Idaho.

USGS 130

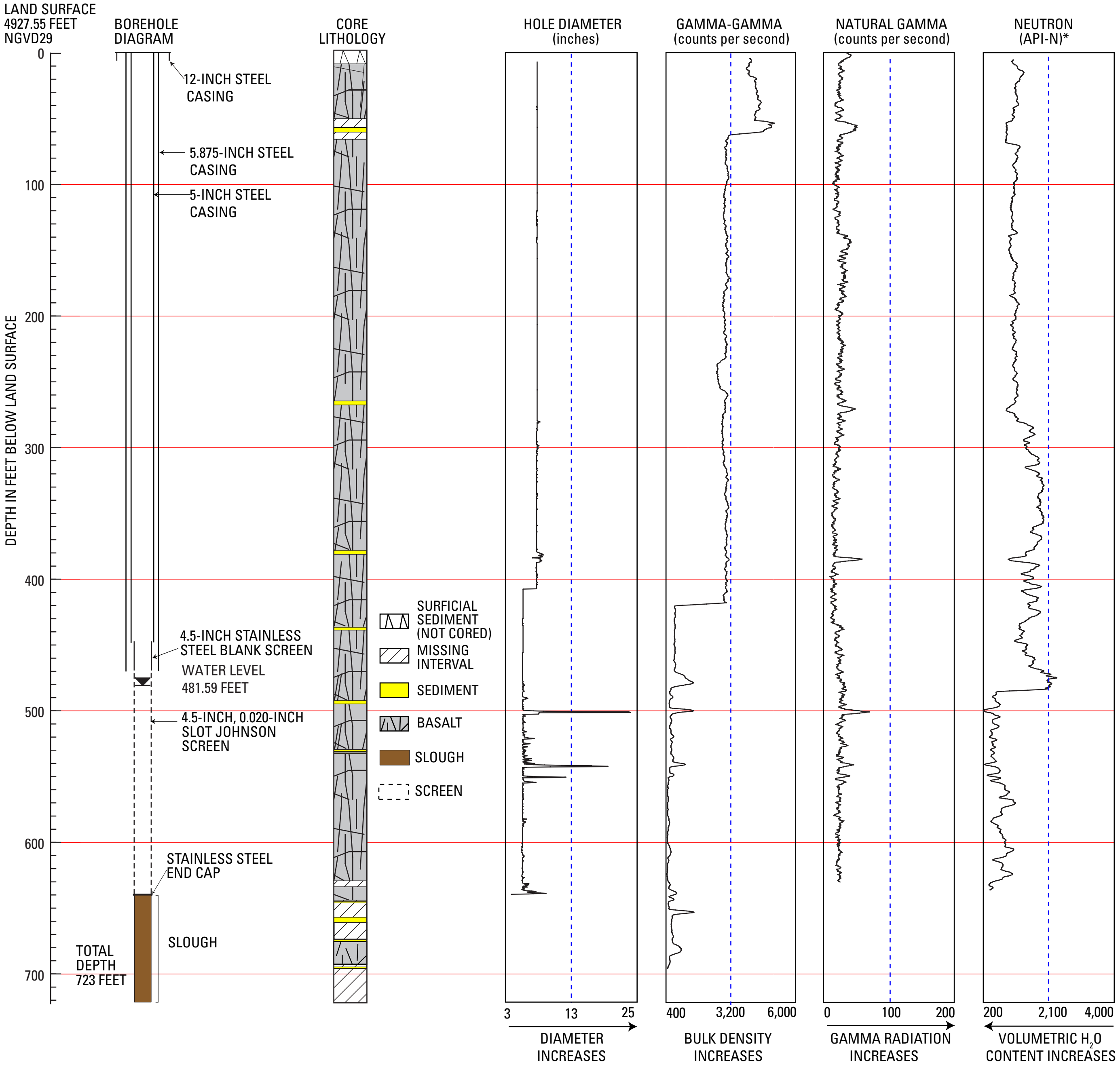

Figure 13. Borehole construction diagram, simplified lithologic log, and geophysical logs (caliper, gamma-gamma, natural gamma, and neutron) for USGS 130, Idaho National Laboratory, Idaho.

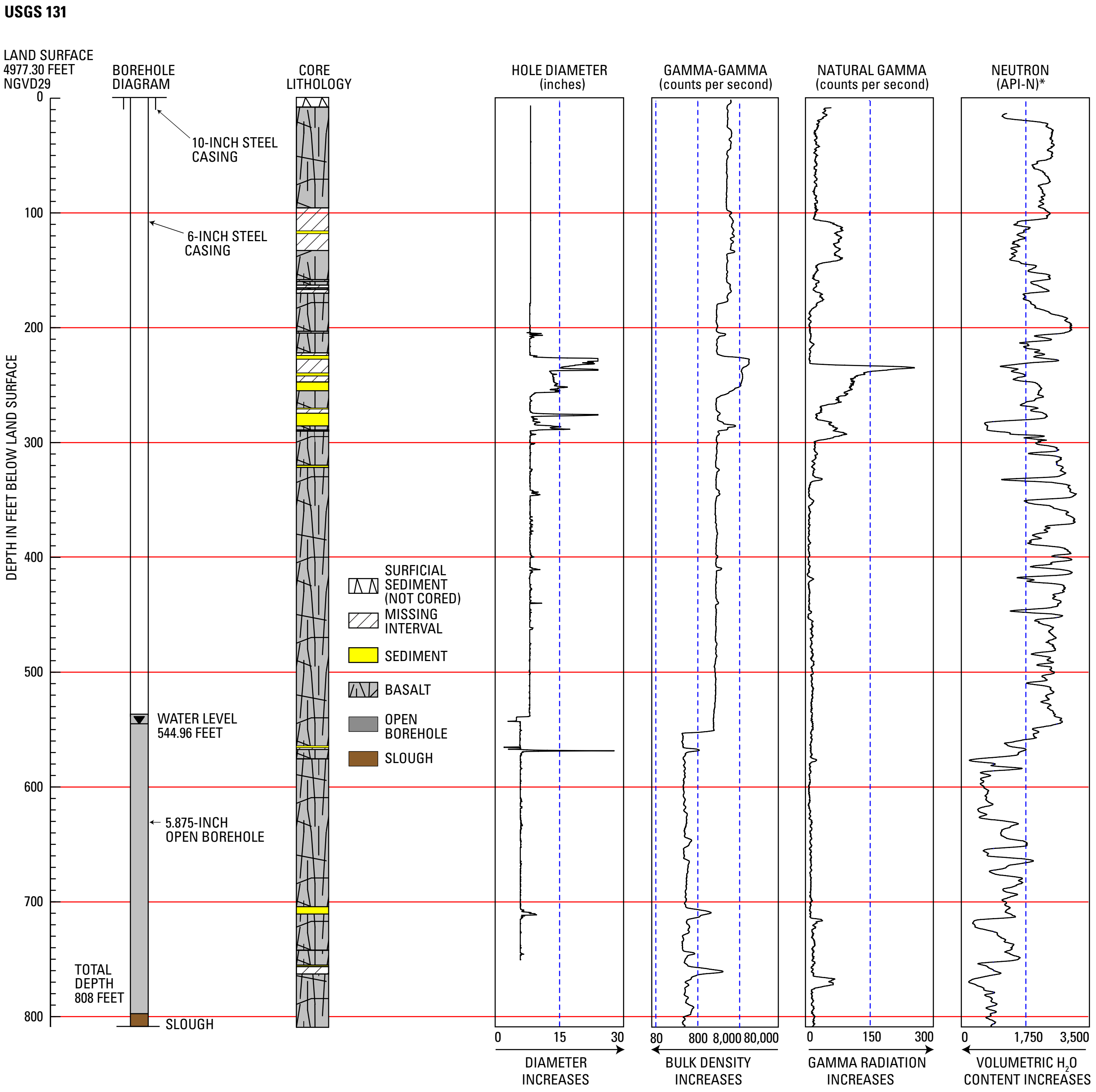

Figure 14. Borehole construction diagram, simplified lithologic log, and geophysical logs (caliper, gamma-gamma, natural gamma, and neutron) for USGS 131, Idaho National Laboratory, Idaho.

USGS 132

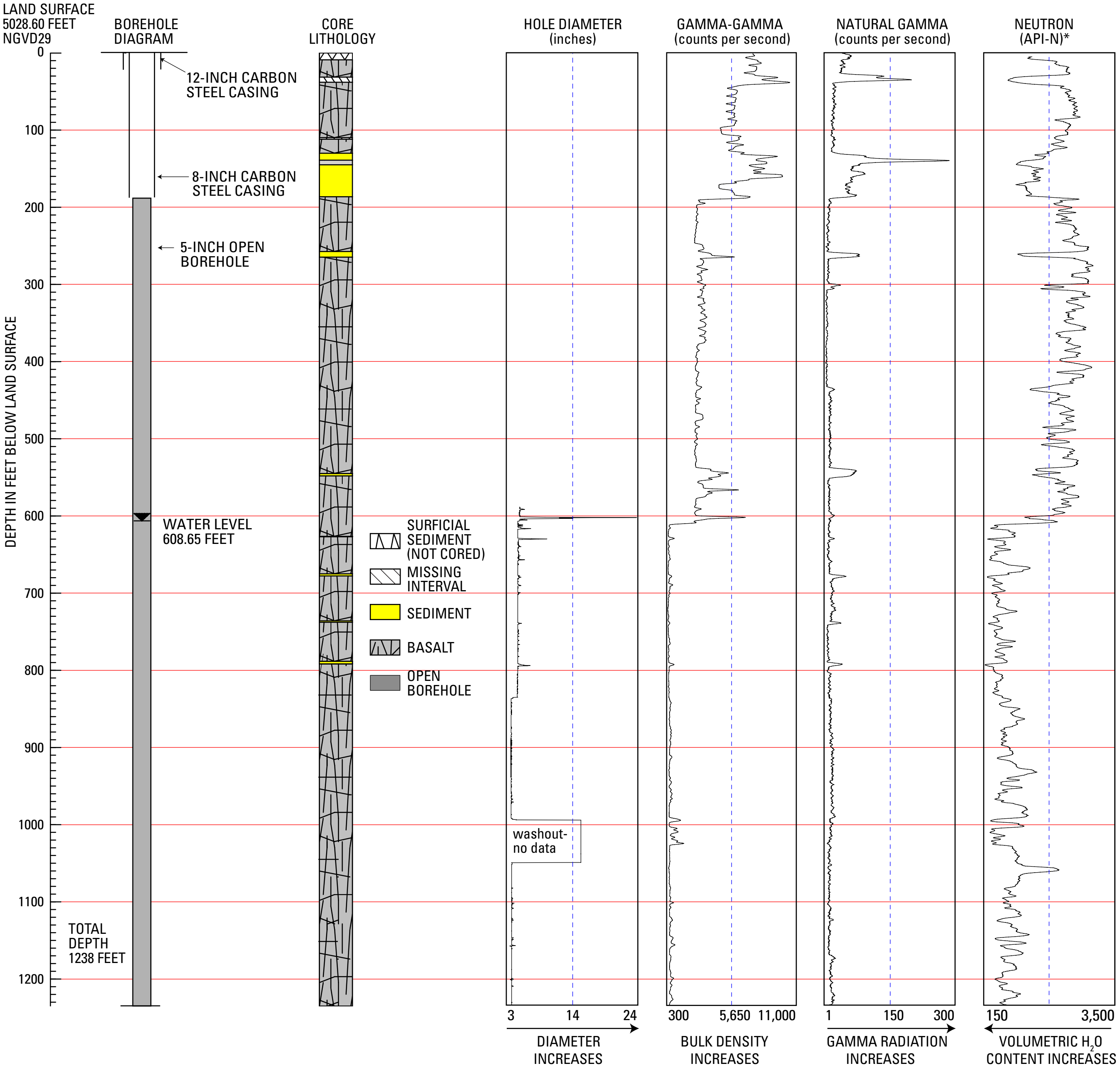

Figure 15. Borehole construction diagram, simplified lithologic log, and geophysical logs (caliper, gamma-gamma, natural gamma, and neutron) for USGS 132, Idaho National Laboratory, Idaho.

USGS 133

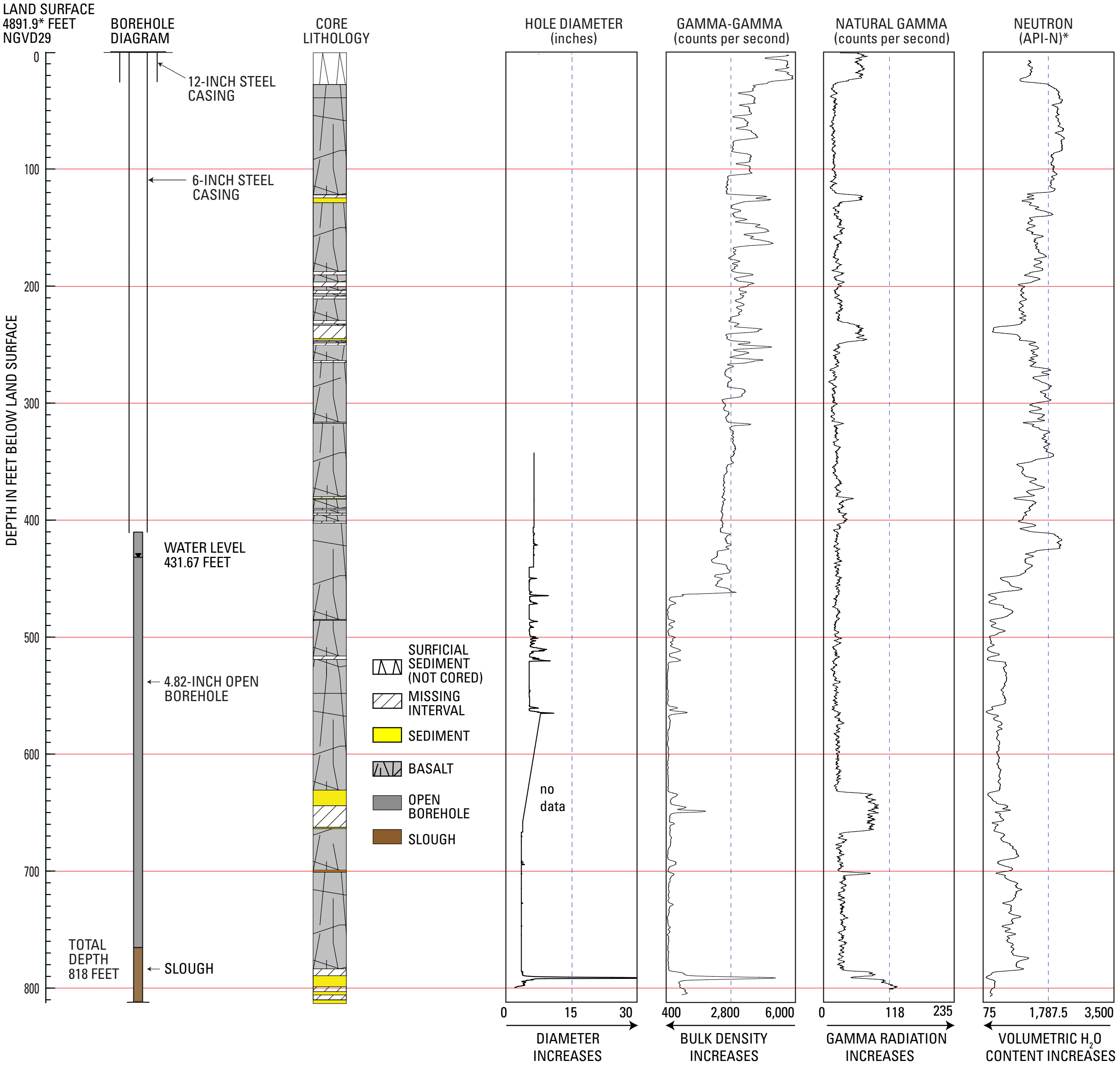

Figure 16. Borehole construction diagram, simplified lithologic log, and geophysical logs (caliper, gamma-gamma, natural gamma, and neutron) for USGS 133, Idaho National Laboratory, Idaho.

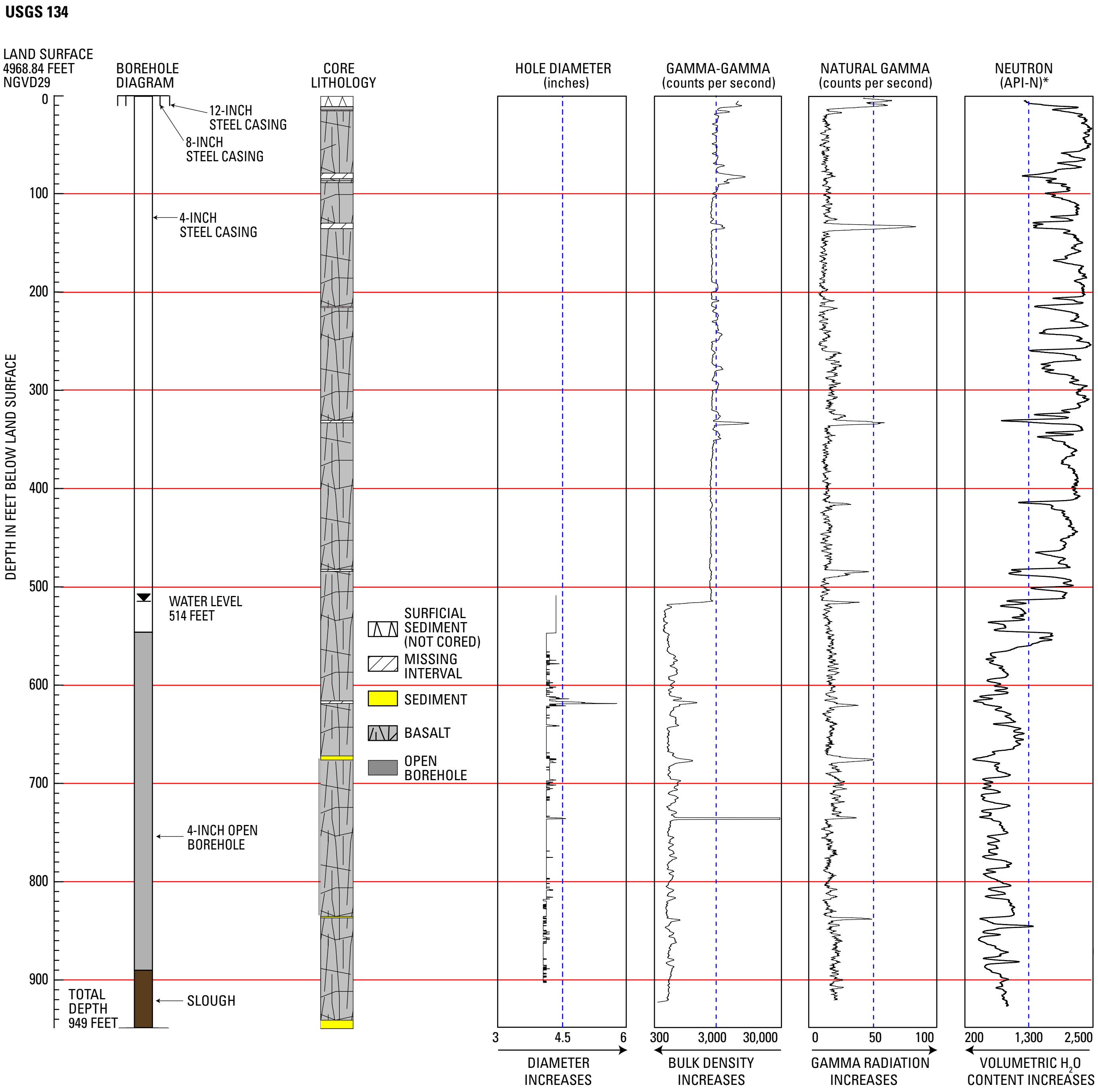

Figure 17. Borehole construction diagram, simplified lithologic log, and geophysical logs (caliper, gamma-gamma, natural gamma, and neutron) for USGS 134, Idaho National Laboratory, Idaho.

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Glossary

Ash (volcanic)—Fine pyroclastic material (under 2.0 mm diameter; under 0.063 mm diameter for fine ash).

Caliche (Syn. of calcrete)—A reddish-brown to buff or white calcareous material of secondary accumulation

Eolian (e-o'-li-an)—wind-derived

Flow/mold—Basalt structure in which an overlying flow makes a mold of an underlying basalt surface.

Free carbonate—The presence of calcium carbonate observed as effervescence on application of hydrochloric acid.

Lithics—Sand-sized rock fragments in a sedimentary rock or soil

Loess—Eolian sediment

Paleosol—fossil soil

Rhizolith—Calcified rootlets of plants

Soil structure (structureless-single-grained, structureless-massive, platy, granular, blocky, prismatic, columnar)—Soil structure refers to units composed of primary particles. See *http://soils.usda.gov/technical/manual/contents/chapter3g.html*

Twining and others—**Construction Diagrams, Geophysical Logs, and Lithologic Descriptions for Boreholes USGS 126a, 126b, 127, 128, 129, 130, 131, 132, 133, and 134, Idaho National Laboratory, Idaho**—Data Series 350