Prepared in cooperation with the California Department of Water Resources

Geologic Logs of Geotechnical Cores From the Subsurface Sacramento-San Joaquin Delta, California

Open-File Report 2014–1127

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

COVER
Cores from the California Department of Water Resources geotechnical boreholes drilled in the Sacramento-San Joaquin Delta, California. Photograph by Katherine Maier, 2013.

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Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)

SI to Inch/Pound

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
	Area	
square kilometer (km^2)	0.3861	square mile (mi^2)

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Abstract

This report presents and summarizes descriptive geologic logs of geotechnical cores collected from 2009–12 in the Sacramento–San Joaquin Delta, California, by the California Department of Water Resources. Graphic logs are presented for 1,785.7 ft of retained cores from 56 borehole sites throughout the Sacramento-San Joaquin Delta. Most core sections are from a depth of ~100–200 feet. Cores primarily contain mud, silt, and sand lithologies. Tephra (volcanic ash and pumice), paleosols, and gravels are also documented in some core sections. Geologic observations contained in the core logs in this report provide stratigraphic context for subsequent sampling and data for future chronostratigraphic subsurface correlations.

Introduction

In this report, areas from south of Sacramento to Clifton Court Forebay are considered a part of the Sacramento–San Joaquin Delta (the delta) (fig. 1). Since 2009, the California Department of Water Resources (CDWR) has led an ongoing drilling and coring program in the delta, supported by the Delta Habitat Conservation and Conveyance Program (DHCCP), to inform the design and construction of planned water-conveyance systems. Cores were obtained during drilling and described onsite by CDWR geologists and their contractors for engineering purposes. In 2012, the U.S. Geological Survey (USGS) entered into a cooperative agreement with CDWR to examine the newly collected subsurface data as a way to provide an enhanced Quaternary stratigraphic framework for the subsurface delta.

The Sacramento–San Joaquin Delta includes the lower reaches of the Sacramento and San Joaquin Rivers and the confluence of these two rivers, upstream from San Francisco Bay. Much of California relies on the fresh water supply that travels through the delta. The delta also supports diverse and vulnerable ecosystems; as a result, it has become a site for numerous risk assessment, land management, water resource, infrastructure, and agriculture studies (for example, Ingebritsen and others, 2000). Agricultural modification in the Sacramento–San Joaquin Delta has led to compaction of peat soils and subsidence of the land surface below sea level over much of the delta (Deverel and Rojstaczer, 1996; Ingebritsen and others, 2000; Mount and Twiss, 2005; Coons and others, 2008). As a result, levees and a complex system of waterways have been constructed to keep seawater out of California's freshwater supplies and prevent destructive flooding of the islands within the delta (Jackson and Paterson, 1977; Ingebritsen and others, 2000; Burton and Cutter, 2008). The levees may be vulnerable to catastrophic failure by way of ground motion and liquefaction related to earthquakes on local faults and on faults in the adjacent, tectonically active San Francisco Bay area, which has experienced several large-magnitude (>*M*6.0) earthquakes in historical times (Unruh and Krug, 2007).

Given the environmental and water resources in the delta, there is increasing need for an improved understanding of the likelihood and potential impacts of natural hazards in the region. Geological context for the recently obtained geotechnical data is needed to inform future subsurface exploration by CDWR, to plan subsurface water-conveyance facilities, and to improve ongoing seismic and liquefaction hazards assessments in the delta.

A detailed understanding of subsurface Quaternary stratigraphy is essential to evaluating seismic and liquefaction hazards in the modern Sacramento–San Joaquin Delta. Geologic logs are a crucial first step toward establishing age, correlation, and potential tectonic deformation of the Quaternary deposits. Geologic logs are also necessary for interpreting depositional environments and the influence of these settings on liquefaction susceptibility and the engineering parameters that would determine infrastructure design and performance. Although a geologic context for the Quaternary in the Sacramento–San Joaquin Delta has been established from surface mapping in the region (for example, Atwater, 1982; Lettis, 1982; Unruh and others, 2009), detailed geologic data from subsurface Quaternary deposits older than the Holocene are lacking.

The recent drilling and sampling by CDWR, which extend to depths of >200 ft subsurface, provide significant new "exposures" of the sediments that underlie the young peat and rivers on the surface. Utilizing this new information requires a detailed examination and relogging of core samples that have been retained. The primary purpose of this logging is to identify attributes of the core deposits, including potential materials for dating, buried soils, and evidence of unconformities. In the future, these observations could be used for subsurface correlations, depositional environment interpretations, and insights into delta evolution.

This report details results of the relogging effort and includes descriptions of a total of 1,785.7 ft of core from 56 boreholes (fig. 1) collected from subsurface depths ranging from 6.5–228.1 ft (table 1). This initial core logging effort focuses on cores retained from ~100–200 ft drilled depths. Additional cores have been retained from shallower depths, primarily from boreholes near the Clifton Court Forebay in the southern delta (fig. 1), but detailed geologic logs for these additional shallow cores are not presented herein.

Methodology

Geotechnical Drilling and Retained Samples

From 2009–12, CDWR drilled more than 128 boreholes in the Sacramento–San Joaquin Delta, primarily along a roughly north-south trending line from south of Sacramento to Clifton Court Forebay (fig. 1). Geotechnical drilling generally involved continuous sampling using a hollow-stem auger in shallow, minimally consolidated sediments (on the order of several feet drilled depth), and mud rotary drilling in sediment as much as 200 ft below the surface. In the depth range of primary interest to CDWR (generally 100–200 ft), the sampling procedure involved 3.5-ft-long punch core samples alternated with 1.5-ft-long Standard Penetration Test (SPT) samples, occasionally interrupted by 2-ft-long Shelby Tube samples. Punch core samples were collected in unlined barrels, and they were extruded and described at the drill site. For limited depth ranges (~2–90 ft length within ~200-ft-deep boreholes; table 1), whole cores were placed in core boxes for storage. Cores that were not retained in boxes were subsampled over a small interval (~0.5 ft), and the remainder (minus the subsample) of the core was discarded at the drill site. Small punch core samples and SPT samples were stored in glass jars, and some of these have been removed by CDWR for laboratory analyses (for example, particle size or Atterberg limits). Some retained jar samples were examined by the authors and sampled for tephra or paleontological analyses, but jar samples are not described individually or documented here. Most Shelby Tube samples remain unextruded and were not used this study.

Retained punch core samples are stored in their original core boxes at room temperature, on open shelving, in a CDWR warehouse in West Sacramento, Calif. All of the core boxes are 2 ft in length, thus the longest continuous core segments are 2 ft long.

Geotechnical logging in the field by CDWR and their contractors classified large-scale (generally ft to tens of ft) sediment packages using the Unified Soil Classification System (American Society for Testing and Materials, 2007). Within these units, field logs documented plasticity, dilatancy, toughness, dry strength (Casagrande, 1932; Seed and others, 1966), color, grain-size distribution within sands, hardness, and moisture. In addition, geologic observations included the presence or absence of carbonate, mica, peat and organic material, volcanic ash, pumice, and smaller-scale lithologic and physical property variations.

Geologic Core Descriptions

To complement the CDWR core field descriptions, we examined the cores and identified attributes at a much finer scale (0.1 ft or less) to document subtle differences in geologic parameters that would assist in interpretations of depositional environment and diagenetic processes. Boxed punch core samples were stored whole (they were not split longitudinally for field description purposes) and were often coated in drilling mud. Prior to detailed logging, drilling mud and other disturbed material was scraped from one side of the core to reveal internal core color and structures. Core descriptions included color (primary color, and secondary colors if mottled or banded), core disturbance, grain size, lithology (following the classification scheme defined by Shepard [1954]), bedding thickness, bed contacts, sorting, roundness, and bioturbation intensity. Additional components, such as lithologic accessories (for example, laminae, dark minerals), physical structures (for example, sedimentary structures, loading), fossils, trace fossils, diagenetic features (for example, pedogenic carbonate), and fractures were also examined.

Geologic core descriptions were recorded using a custom logging software program developed by the USGS. Initially developed using Filemaker® software, the logging system is currently being rewritten as a Java-based front end to an open-source SQL database server (PostgreSQL). The custom Filemaker® software program was used for geologic logging of the cores in the CDWR warehouse. These data were subsequently imported into the PostgreSQL database at USGS. The software facilitates consistency in descriptions, quality-assurance checking, and stores all captured information in the PostgreSQL database for subsequent output and analysis.

Using the software, each core was entered separately into the database with a distinct name linked to the borehole site. The top of each core was entered as the drilled depth recorded on the CDWR core boxes, and the core length was measured from core remaining in the box. For measured core lengths less than the cored interval, the top of the core was "hung" by default at the top of the cored interval, unless samples were removed or other information indicated that the core needed to be relocated. If a measured core length exceeded the cored interval, the bottom of the core was constrained to the bottom of the cored interval. Log descriptions were recorded with their depths relative to the top of the core, and the software automatically handled any adjustments to ensure that computed depths were located correctly within the cored interval.

The software also allowed independent logging of each attribute for maximum flexibility. For example, color intervals did not need to match lithology intervals, and accessories attributes could have independent and overlapping ranges within each core. Quality-assurance checks within the software ensure that the recorded core data does not contain internal contradictions.

Initial conditions were recorded for each core, including hydrocarbon shows (any visual evidence for natural petroleum products), core disturbance, and colors. None of the Sacramento–San Joaquin Delta cores in this report contained hydrocarbon shows, so this attribute is not included on the graphic logs. Core disturbance was the most prominent disturbance for each interval in a core. Munsell colors were recorded, but all colors documented in this report represent dry colors that include effects of alteration during 1–4 years of exposure.

Primary and secondary lithologies were recorded along with estimated median grain size for each layer within a core. Bedding was generally indicated as massive*,* laminated (bed thickness <1 mm), thinly-bedded (bed thickness <1 cm), medium-bedded (bed thickness >1 cm and <10 cm), or thickly bedded (bed thickness >10 cm). Bedding was recorded as massive if the core was intact and no bedding was observed. If the core was disturbed such that any bedding that may have been present could no longer be observed, a note of "bedding not observed" was recorded. The basal contact for each lithologic unit was indicated as the lithologic transition occurring over <1 cm (sharp), ~1–2 cm (clear), many centimeters (diffuse), >10 cm (gradational), uncertain, or unknown. Core units that ended at the base of a core box were recorded as having unknown basal contacts. Breaks in the core that occurred owing to sample removal during the geotechnical logging were indicated as uncertain basal contacts.

Additional characteristics, including sorting, grain roundness, and bioturbation intensity were recorded. Relative sorting terms were assigned based on the number of grain sizes present. For example, a bed containing only silt (with visual inspection) was well-sorted, and a bed with a mixture of clay, very fine sand, and medium sand was moderately sorted. Roundness was only recorded for grain sizes above very fine sand, and most grains in delta cores were subangular to subrounded. Percent bioturbation was visually estimated. Units characterized by fine-scale sedimentary structures with no visible bioturbation were labeled as such; however, lacking evidence of fine-scale sedimentary structures, units with no bioturbation present in hand sample were labeled as rare bioturbation (<10 percent).

The logging software provided numerous possible accessory inputs defined over intervals of the core samples, and several types occurred frequently in the delta cores included in this report. Commonly observed lithologic accessories included dark mineral concentrations, dark mineral banding, the presence of mica, inferred paleosols, pebbles and (or) granules, coal laminae, and silt, sand, and clay laminae. Dark mineral concentrations were recorded where dark mineral grains occurred throughout a layer, typically a sand-rich unit. Dark mineral banding was recorded where laminations were defined by dark minerals. A layer was reported as micaceous if mica flakes were visible. A unit was interpreted as a paleosol where pedogenic carbonate or a leached zone above a layer with pedogenic carbonate was present. Paleosol and pedogenic carbonate were noted as possibilities in the core logs; more definitive soil interpretations from cores alone were hindered by the segmented retention of core samples. Pebbles and (or) granules were reported as an accessory if grains larger than very coarse sand were present within a layer, but not abundant enough to classify the layer as gravel or gravelly in the lithology input. Coal laminae were recorded where laminations were defined by concentrated organic material. Other sedimentary structures were recorded as physical structures and include cross-bedding, ripple laminations, chaotic or deformed bedding, and grading. Fossils included leaves and other undifferentiated plant material. Trace fossils included rootlets and undifferentiated burrows. Frequently observed diagenetic accessories included clay films recording translocated clays, mottles of texture, oxidation, and reduction, and pedogenic carbonates of various stages (Birkeland and others, 1990), including carbonate nodules, carbonate veinlets, and soft carbonate masses. A blue internal core color revealed after scraping of the core was recorded as mottles*,* reduced.

All accessories were recorded with an abundance representing the visually estimated percent of the cored interval that contained the accessory. Abundance categories for accessories included pervasive (>60 percent), abundant (30–60 percent), common (10–30 percent), few-moderate (5–10 percent), and rare (<5 percent). For example, a pervasive micaceous accessory was noted where mica occurs in >60 percent of the interval, not where a sand layer was >60 percent mica.

Other descriptive information or comments were documented as remarks, displayed within intervals related to the comment. These remarks were used to provide a summary of the core layers and record additional information not covered in the custom program menus.

Sampling

Samples from geotechnical cores were obtained during and after geologic core descriptions. Sample locations are indicated in the core logs in this report, and sample types are described in table 2. Sampling included bulk core samples for tephra, smear slides, diatoms, clay chemistry, and organic material, as well as whole core samples for paleomagnetics.

Graphic Logs

Prior to the generation of core graphic logs, descriptions initially recorded in the Filemaker® version of the software were transferred to the PostgreSQL database. Customized views of the final core log information were then exported from the database into Strater® software. Graphic logs were plotted with Strater® software using a standard template for each borehole, and an explanation of the symbology is provided in figure 2. The depths of each cored interval were cross-checked with geotechnical logs provided by CDWR.

Discussion

This report is intended to serve as a record of geologic core log descriptions from retained geotechnical cores collected for the CDWR DHCCP program in the Sacramento–San Joaquin Delta. This report does not present additional interpretations, sample descriptions, or analytical results. Retained geotechnical cores are not evenly distributed throughout the Sacramento-San Joaquin Delta. Most of the available cores are from boreholes drilled along a roughly north-south trending line from south of Sacramento to Clifton Court Forebay, with many fewer cores available to the east and west (fig. 1). Of the retained cores, few are from ~100–200 ft subsurface depth in the southern delta. Even in the northern delta where coring was more extensive (fig. 1), cores were retained from only small intervals of select boreholes (table 1). In fact, none of the boreholes drilled for the DHCCP program have retained-box cores for the entire drilled interval.

Despite the data gaps, these new core logs are significant because they reveal detailed structures, composition, and other geologic variability within subsurface geotechnical units. In future studies, the logs could be used to refine interpretations of intervals that were not cored or where cores were not retained. Additionally, the logs provide a detailed stratigraphic and depositional context in which subsamples and future analyses can be located. We advocate the continued retention of geotechnical core material from drilling in the Sacramento–San Joaquin Delta and the subsequent detailed geologic description of all core samples.

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Figures

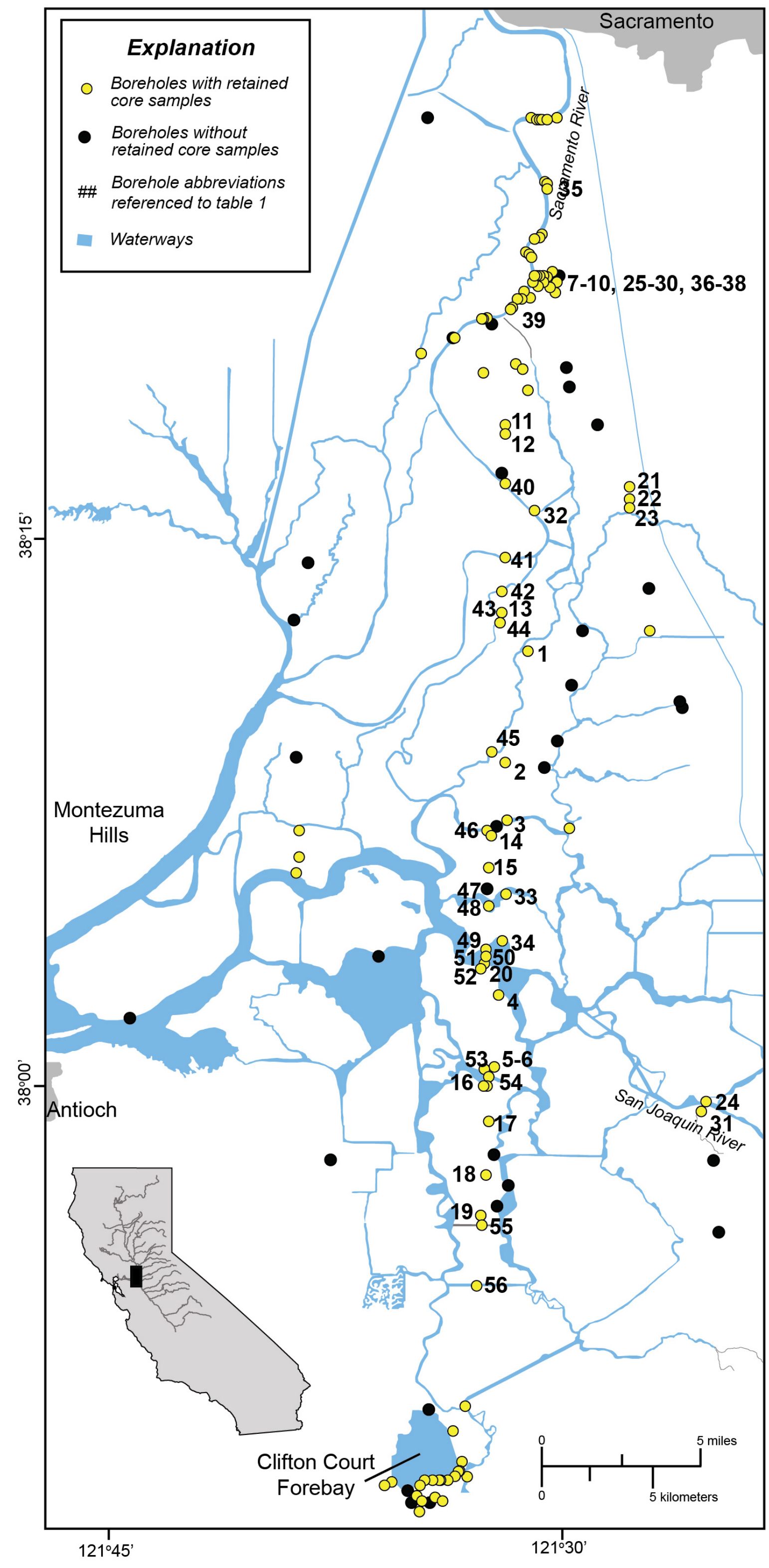

Figure 1. Map of borehole locations. Inset shows location within California.

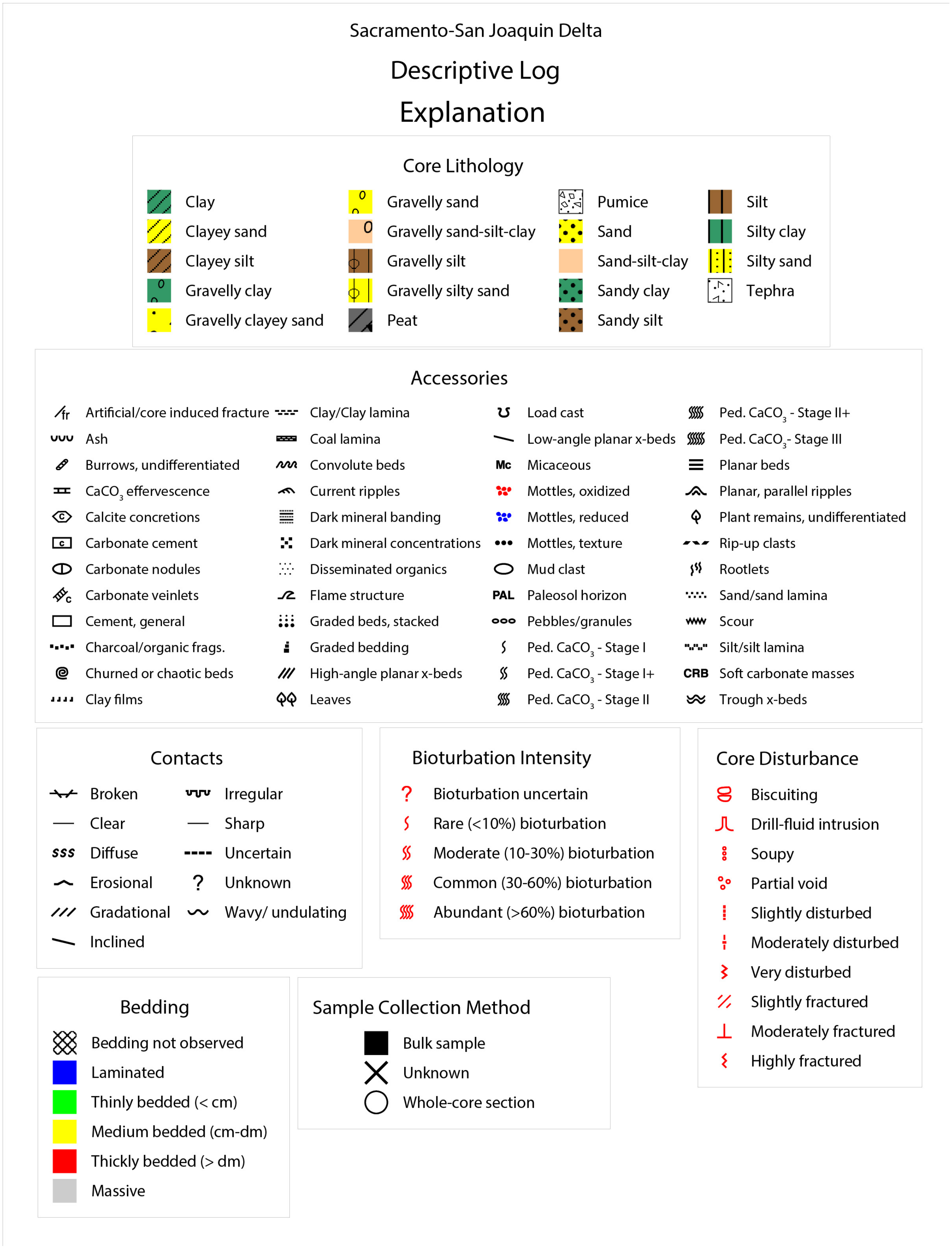

Figure 2. Explanation for graphic core logs. Bedding is categorized as centimeter (cm) to decimeter (dm) scale.

Tables

Table 1. Geotechnical borehole and core data in this report.

Borehole Information					Retained Cores[3]	
Borehole[1]	Borehole Name	Year Drilled	Elevation[2] (ft)	Drilled Depth (ft)	Total (ft)	Depth Range (ft)
1	DCA-DH-003	2009	-4.4	200.0	51.5	61.5–199.7
2	DCA-DH-004	2009	-7.2	201.5	52.0	61.5–198.1
3	DCA-DH-005	2009	-13.0	202.0	61.2	60.0–197.7
4	DCA-DH-007	2012	-15.0	191.5	22.6	101.5–167.5
5	DCA-DH-008	2012	-17.9	109.5	2.0	104.5–106.5
6	DCA-DH-008A	2012	-17.5	200.5	20.5	105.5–172.2
7	DCA-DH-013	2011	10.6	204.5	31.1	89.5–146.9
8	DCA-DH-014	2011	8.8	199.5	33.3	90.0–146.8
9	DCA-DH-015	2011	8.2	210.0	23.3	81.5–153.5
10	DCA-DH-024	2011	11.2	201.5	31.9	81.5–179.5
11	DCA-DH-030	2011	-8.6	201.5	31.1	91.5–147.7
12	DCA-DH-031	2011	-4.2	199.3	25.5	84.5–156.7
13	DCA-DH-037	2011	2.7	201.5	26.7	91.5–147.3
14	DCA-DH-047	2012	-16.5	200.0	25.2	101.5–175
15	DCA-DH-048	2012	-13.0	217.0	18.5	103.5–181.7
16	DCA-DH-050	2012	-11.0	199.5	23.0	100.2–170
17	DCA-DH-051	2012	-15.6	200.0	27.5	101.5–167.5
18	DCA-DH-053	2012	-15.2	201.5	17.4	101.5–162.2
19	DCA-DH-054	2012	-9.7	199.5	26.8	99.5–170.7
20	DCB-DH-002	2012	-9.9	201.5	23.0	101.5–168.3
21	DCE-DH-003	2009	5.2	202.0	35.8	88.5–170.0
22	DCE-DH-004	2009	4.3	201.0	41.2	91.5–170.8
23	DCE-DH-005	2009	3.9	200.0	32.2	91.5–170.0
24	DCE-DH-010	2009	3.6	201.5	50.6	60.0–201.5
25	DCIF-DH-013	2012	9.0	189.0	72.3	6.5–187.5
26	DCIF-DH-014	2012	9.8	199.5	42.0	79.5–166.4
27	DCIF-DH-015	2012	8.5	200.0	38.3	79.5–170.2
28	DCN4-DH-028	2012	9.6	143.5	3.8	127.2–140.8
29	DCN4-DH-034	2012	11.8	143.0	8.0	133.5–142.0
30	DCN4-DH-036	2012	12.9	148.0	11.0	133.7–145.5
31	DCR-DH-010	2009	4.2	206.5	69.6	52.0–205.0
32	DCR-DH-011	2009	3.8	226.5	34.6	106.5–222.5
33	DCR-DH-015	2009	13.0	216.5	77.0	61.5–215.0
34	DCR-DH-016	2009	4.0	215.0	90.9	71.5–215.0
35	DCR3-DH-013	2012	10.8	180.0	2.1	131.5–133.6
36	DCR4-DH-013	2012	9.4	173.0	4.6	134.5–141.7
37	DCR4-DH-014	2012	9.7	173.0	5.9	135.0–142.1
38	DCR4-DH-015	2012	10.0	174.5	2.0	133.8–135.8
39	DCR5-DH-013	2012	9.2	164.3	7.8	134.5–151.6
40	DCRA-DH-001	2010	8.8	231.5	36.5	121.5–228.1
41	DCRA-DH-002	2010	10.0	221.5	36.9	126.5–217.3
42	DCRA-DH-003	2012	5.1	216.5	38.3	107.0–198.5
43	DCRA-DH-004	2012	5.6	221.5	38.0	103.0–198.8
44	DCRA-DH-005	2012	5.6	221.5	52.2	101.5–199.6
45	DCRA-DH-006	2010	7.8	223.0	36.1	120.8–210.5
46	DCRA-DH-007	2012	4.1	216.5	44.6	101.5–193.2
47	DCRA-DH-009	2012	6.2	225.0	43.8	121.5–225.0
48	DCRA-DH-010	2010	6.0	229.0	13.4	124.0–197.5
49	DCRA-DH-011	2010	5.5	236.5	19.1	124.5–198.0

Borehole Information					Retained Cores[3]	
Borehole[1]	Borehole Name	Year Drilled	Elevation[2] (ft)	Drilled Depth (ft)	Total (ft)	Depth Range (ft)
50	DCRA-DH-012	2010	6.4	212.5	32.7	114.0–190.0
51	DCRA-DH-013	2012	4.6	221.5	41.7	101.5–197.6
52	DCRA-DH-014	2010	4.7	222.9	23.1	123.5–197.0
53	DCRA-DH-015	2012	4.8	236.0	44.5	116.5–215.2
54	DCRA-DH-016	2012	5.7	220.0	33.8	132.0–217.4
55	DCRA-DH-017	2010	6.2	211.0	21.5	101.7–181.5
56	DCRA-DH-022	2010	5.2	212.5	25.7	104.0–169.0
			TOTALS	11,277.5	1,785.7	

[1]See Figure 1 for borehole locations.

[2]Elevation based on ground survey.

[3]Retained cores presented in this report.

Table 2. Sample abbreviations in core logs.

Sample Type	Abbreviation	Description
Tephra	TEP	Bulk samples for volcanic ash glass shards geochemical analyses
Smear slide	SM	Bulk samples to evaluate presence of volcanic glass shards
Micropaleontology	MP	Bulk samples for identification of diatoms
X-ray analyses	XRD	Bulk samples for clay chemistry and mineralogy
Paleobotany	PB	Bulk samples of organic material
Paleomagnetics	PM	Whole core samples for paleomagnetic analyses
To be determined	TBD	Bulk samples for potential future analyses