Quantitative X-ray Diffraction Mineralogy of Los Angeles Basin Core Samples

James R. Hein[1], Brandie R. McIntyre[1], Brian D. Edwards[1], and Orion I. Lakota[1]

Open-File Report 2006-1036

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

[1] U.S. Geological Survey, 345 Middlefield Rd., MS999, Menlo Park, Ca 94025

U.S. Department of the Interior
Gale A. Norton, Secretary

U.S. Geological Survey
Pat Leahy, Acting Director

U.S. Geological Survey, Reston, Virginia 2006
Revised and reprinted: 2006

For product and ordering information:
World Wide Web: http://www.usgs.gov/pubprod
Telephone: 1-888-ASK-USGS

For more information on the USGS—the Federal source for science about the Earth,
its natural and living resources, natural hazards, and the environment:
World Wide Web: http://www.usgs.gov
Telephone: 1-888-ASK-USGS

Contents

Figures

Tables

Appendices

Quantitative X-ray Diffraction Mineralogy of Los Angeles Basin Core Samples

By James R. Hein, Brandie R. McIntyre, Brian D. Edwards, and Orion Lakota

Explanation

This report contains X-ray diffraction (XRD) analysis of mineralogy for 81 sediment samples (Appendix 1) from cores taken from three drill holes in the Los Angeles Basin in 2000-2001. We analyzed 26 samples from Pier F core, 29 from Pier C core, and 26 from the Webster core (Fig 1). These three sites provide an offshore-onshore record across the Southern California coastal zone. This report is designed to be a data repository; these data will be used in further studies, including geochemical modeling as part of the CABRILLO project. Summary tables quantify the major mineral groups (Table 1, 2, 3), whereas detailed mineralogy is presented in three appendices (Append. 2-4). The rationale, methodology, and techniques are described below.

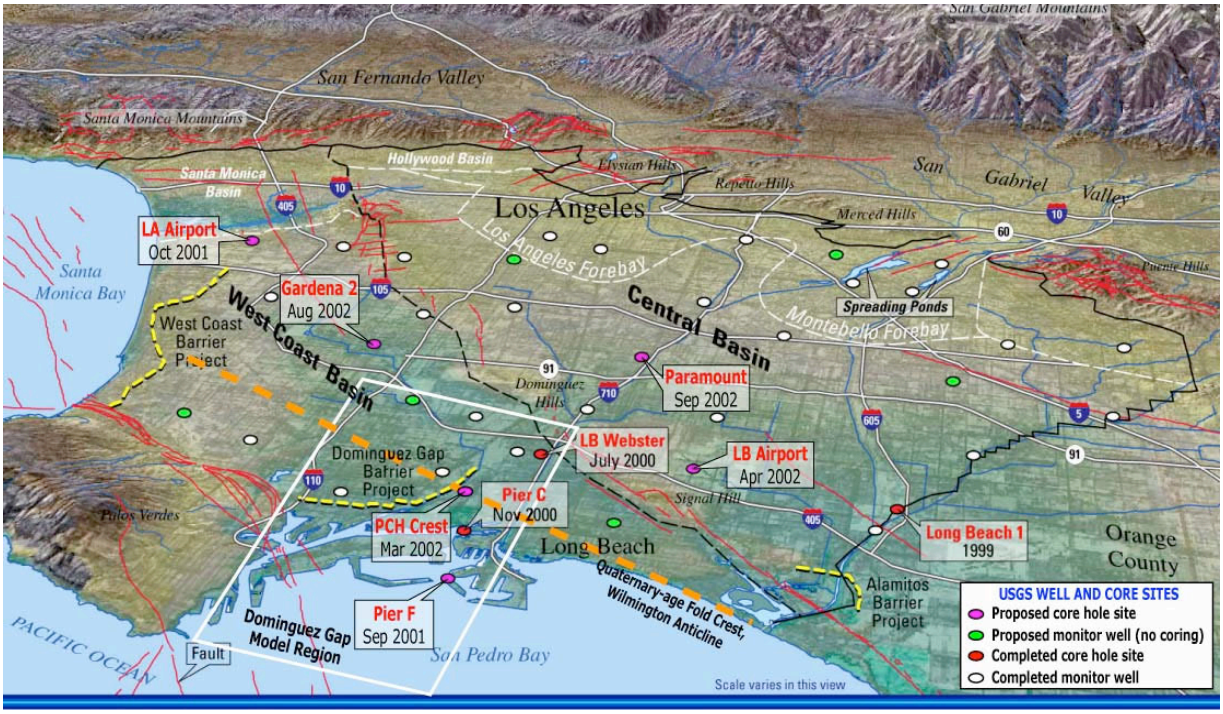

Figure 1. Location of drill sites for the USGS FOQUS-L.A. and CABRILLO Projects. Cores collected at sites Pier F, Pier C, and LB Webster, located within the white box, were analyzed here.

Rationale

U.S. Geological Survey (USGS) scientists are working in collaboration with other Federal and State agencies as well as regional, county, and local water managers to better understand the Quaternary stratigraphy of the Los Angeles Basin and to identify pathways of salt-water intrusion into fresh-water coastal aquifers in the Long Beach, California (Dominguez Gap) area. USGS efforts involve both the Water Resources and Geologic Disciplines. The latter includes the FOQUS-LA Project, a component of the USGS Earthquake Hazards Program, and Coastal Aquifers Stratigraphic Architecture (CASA), a component of the CABRILLO Project (Southern California Bight Regional Investigations-Life, Land, and Ocean) of the Coastal and Marine Geology Program.

We present the mineralogy of samples from three 425-m deep (1400 feet) continuous-recovery boreholes completed in 2000-2001 by the joint CASA/FOCUS-LA projects: Long Beach Pier F (LBPF), Long Beach Pier C (LBPC), and Long Beach Webster (LWEB). The boreholes

were sited and designed to: (1) provide 1-D stratigraphic and sedimentological data that would serve as detailed reference sections in building a 3-D model of the coastal Los Angeles Basin; (2) identify and classify depositional environments and sediment physical properties with respect to age (chronostratigraphy); (3) integrate interpretations of onshore borehole geophysical logs with offshore seismic-reflection data; and (4) model the chemistry of the pore fluids and integrate with the chemistry and mineralogy of the solid phases. Descriptions of the joint project and a preliminary report of the 3-D model can be found in Edwards and Evans (2002), Hillhouse et al. (2002), and Ponti et al. (2005). This report contains the quantitative XRD mineralogy that will be used for the modeling and to aid in interpreting the geological evolution of the Los Angeles Basin.

Samples for XRD analysis were taken from cores after the cores were split, photographed, and described (e.g., Powell and Ponti, 2001). The sediment samples were selected based on an even distribution through time periods, changes in sediment type, and proximity to intervals sampled for pore-waters. Sediment samples were taken at the top, middle, and bottom of age-dated stratigraphic units. Samples were also chosen to represent the range of textual types: sand, silt, and clay layers within each time period.

Methods

Quantitative mineralogy was determined by XRD for all samples. The samples were prepared for analysis according to the methods described by Eberl (2003) and summarized below. Three gram samples were mixed with 0.333g of pure ZnO and ground with a mortar and pestle until fine enough to pass through a 500 μm sieve. This mixture was then ground with 4.0 ml methanol for 5 min. in a McCrone micronizing mill. The ground mixture was then dried at 80°C. The resulting powder was ground once more with a mortar and pestle to 500 μm. The sample was then back-packed into an aluminum sample holder. Samples were analyzed using a Philips XRD

with a graphite monochromator. Step scans were run from 5º to 65º 2Θ with 0.02º steps, using Cu kα radiation, and a count time of 2 s/step. A typical XRD pattern is presented in Figure 2.

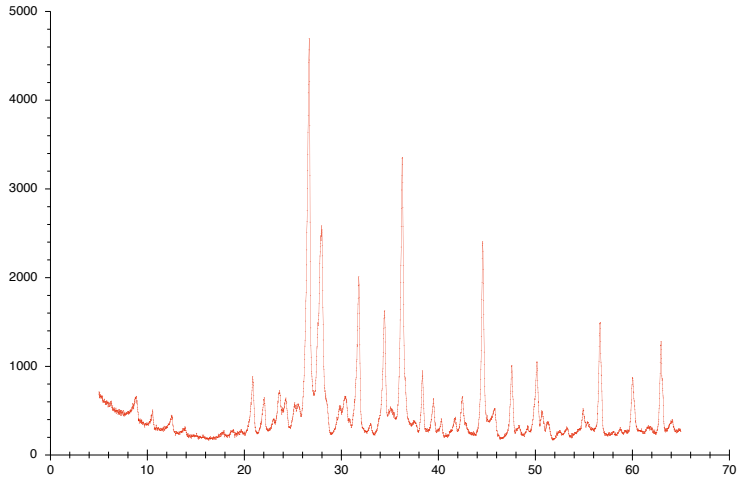

Figure 2. Example of X-ray diffractogram (sample XRD115, Long Beach Pier C)

XRD scan digital data were first input to Philips X-Pert High Score for initial qualitative peak analysis. A background level was calculated using a bending level of approximately one, and a peak search completed with a significance level of 0.30. The Search-Match command identified possible minerals contained in the sample. Minerals were selected from the Search-Match results based on their significance of fit score, their likely possibility of being contained in the sample based on the geology of the Los Angeles Basin, and a visual examination of diffraction patterns. Minerals that may not have been chosen by X-Pert HighScore, but which are present based on a visual examination of the diffraction pattern (mostly poorly crystalline phases) were manually added to the minerals list. Zincite (internal standard) and aluminum (sample holder material) were also added to the group of minerals. Minerals were chosen until all significant peaks were accounted for.

These qualitative results from X-Pert High Score were then used as a basis for quantitative analysis in another software program, RockJock 2 (Eberl, 2003). The program compares integrated X-ray intensities for minerals present in a sample with that of an internal standard (zincite) and weight percents are calculated from previously measured mineral intensity factors (Eberl 2004). The RockJock program is freely available from the USGS at ftp://brrcrftp.cr.usgs.gov/pub/ddeberl/.

Each sample scan was analyzed using RockJock's Solver function and the auto background setting, from 20° to 65° 2-theta, omitting 37.9°-39° and 44°-45° to remove peaks created by the aluminum sample holder. Samples were first analyzed using the minerals matched in X-Pert High Score. If the sample contained chlorite, illite, mica, or smectite, all entries for each mineral were selected, and a second iteration was preformed, accepting minerals with results of 1.0% or greater. If the total percentage did not fall between 90% and 110%, the sample was run again, refining the likely suite of minerals present. Only one sample (XRD208) falls outside (128%) the range 90-110%, for which we could not find an explanation.

The cumulative error (≤10%) and cumulative accuracy translates into individual mineral errors of usually less than 2% (Eberl, 2004). The RockJock procedure has been checked for accuracy using artificial mixtures and generally gives results that are within 1 or 2 weight % of actual values (Eberl, 2003). A sum for an analysis that is close to 100% is a further check because weight percents for each mineral are calculated independently with respect to the zincite internal standard. The analysis is limited by the mineral suite available in RockJock compared to the suite in Philips HighScore. Therefore, some minerals are indicated to be present in the tables and appendices, but are not quantified.

Acknowledgements

D.D. Eberl provided advice on using the RockJock Program. Robert Rosenbauer and D.D. Eberl provided helpful reviews of this paper.

Literature Cited

Eberl, D.D., 2003. User's Guide to Rockjock – A program for determining quantitative mineralogy from powder X-ray diffraction data. U.S. Geological Survey Open-File Report 03-78, 46 pp.

Eberl, D.D., 2004. Quantitative mineralogy of the Yukon River system: Changes with reach and season, and determining sediment provenance. American Mineralogist, v 89. p 1784-1794.

Edwards, B.D. and Evans, K.R., 2002. Saltwater intrusion in Los Angeles area coastal aquifers - the marine connection. U.S. Geological Survey Fact Sheet 030-02, 2 pp (*http://geopubs.wr.usgs.gov/fact-sheet/fs030-02*).

Hillhouse, J.W., Reichard, E.G., and Ponti, D.J., 2002. Probing the Los Angeles basin - insights into ground-water resources and earthquake hazards. U.S. Geological Survey Fact Sheet 086-02 2 pp (*http://geopubs.wr.usgs.gov/fact-sheet/fs086-02*).

Ponti, D.J., Ehman, K.D., Edwards, B.D., Tinsley, J.C., Hildenbrand, T., Hillhouse, J.W., Hanson, R.T., McDougall, K., Powell, C.L. II, Wan, E., Land, M., Mahan, S., and Sarna-Wojcicki, A.M., 2005. A 3-dimensional model of water-bearing sequences in the Dominguez Gap region, Long Beach, California. U.S. Geological Survey Administrative Report to Los Angeles area water managers, 18 manuscript pages, 1 table, 15 figures.

Powell, C. II, and Ponti, D. (eds.), 2001. Research coring in the Los Angeles Region: data and initial report of the Long Beach Daniel Webster core site (LWEB) and monitoring well, Long Beach, California (unpublished, compiled data).

Key Search Words: Mineralogy, RockJock, X-ray diffraction, Los Angeles Basin

Table 1. Quantitative mineralogy for mineral groups for core-sediment samples from Long Beach Pier F (See Appendix 2 for detailed mineralogy)

XRD No.	XRD 148	XRD 149	XRD 150	XRD 151	XRD 152	XRD 153	XRD 154	XRD 155
Core	LBPF	LBPF	LBPF	LBPF	LBPF	LBPF	LBPF	LBPF
Section	4	8	8	13	26	36	47	52
Starting cm	93.5	115.5	8.0	114.3	9.2	20.0	31.0	29.3
Ending cm	95.5	117.5	11.0	117.0	11.6	24.0	34.5	31.5
Quartz	18.0	21.7	12.5	18.9	16.8	12.0	9.4	23.4
K-Feldspar	28.2	20.8	39.1	33.8	41.4	37.1	15.3	29.7
Plagioclase	29.8	50.3	9.0	27.9	11.6	9.6	22.6	39.8
Calcite	--	--	--	--	--	--	--	--
Kaolinite	--	--	--	--	--	--	--	--
Smectite	--	--	--	--	--	--	--	--
Illite	6.0	--	11.5	--	5.0	9.3	34.9	--
Mica	14.6	5.1	16.1	15.9	14.3	14.7	2.6	8.8
Chlorite	--	3.4	8.3	--	5.8	12.2	12.2	2.2
Amphibole	1.6	x	2.7	4.9	2.0	3.0	1.4	x
Pyroxene	x	1.8	0.5	0.6	0.2	x	x	2.6
Gypsum	--	--	--	--	--	--	--	--
Vermiculite	--	--	--	--	--	--	--	--
Total	98.2	103.1	99.7	102.0	97.1	97.9	98.4	106.5

XRD No.	XRD 156	XRD 157	XRD 158	XRD 159	XRD 160	XRD 161	XRD 162	XRD 163
Core	LBPF	LBPF	LBPF	LBPF	LBPF	LBPF	LBPF	LBPF
Section	65	80	88	102	109	128	134	137
Starting cm	8.1	91.4	20.9	32.6	63.7	52.4	38.2	28.4
Ending cm	10.8	94.2	23.4	35.3	35.4	54.5	40.7	31.1
Quartz	20.0	17.7	17.5	15.0	20.5	14.2	9.1	10.1
K-Feldspar	35.8	21.1	0.0	23.6	40.3	41.7	12.8	37.7
Plagioclase	33.9	34.7	38.2	28.1	26.7	12.3	16.2	8.9
Calcite	--	--	--	--	--	--	--	--
Kaolinite	--	--	--	--	--	--	--	3.3
Smectite	--	--	--	--	--	--	--	--
Illite	--	4.4	12.3	--	--	8.8	24.8	16.4
Mica	7.9	15.0	14.7	15.2	9.1	16.8	19.7	18.6
Chlorite	3.7	3.4	9.2	5.3	3.6	8.4	6.9	5.6
Amphibole	0.6	1.9	1.9	3.0	1.8	3.4	0.4	x
Pyroxene	1.0	2.6	2.7	1.8	x	0.4	1.2	x
Gypsum	--	--	--	--	--	--	--	--
Vermiculite	--	--	--	--	--	--	--	--
Total	102.9	100.8	96.5	92.0	102.0	106.0	91.1	100.5

Table1 continued

XRD No.	XRD 164	XRD 165	XRD 166	XRD 167	XRD 168	XRD 169	XRD 170	XRD 171
Core	LBPF	LBPF	LBPF	LBPF	LBPF	LBPF	LBPF	LBPF
Section	152	159	170	184	184	197	203	220
Starting cm	63.5	70.5	49.5	102.8	22.5	123.0	58.4	35.5
Ending cm	66.0	73.2	51.2	104.5	25.5	125.4	61.0	38.3
Quartz	18.0	10.6	10.7	10.9	24.4	17.8	18.5	12.4
K-Feldspar	42.1	53.3	--	17.8	18.7	35.3	16.7	18.3
Plagioclase	22.5	4.8	24.1	24.5	46.9	9.8	37.7	29.6
Calcite	--	--	--	--	--	--	--	--
Kaolinite	--	--	--	--	--	--	--	--
Smectite	--	--	--	--	--	14.5	--	--
Illite	--	--	25.3	--	--	--	--	--
Mica	12.4	19.5	16.8	16.3	12.5	15.6	7.2	16.6
Chlorite	6.9	7.2	11.7	17.0	3.2	0.9	9.8	12.7
Amphibole	3.4	3.8	0.2	2.2	1.0	2.2	4.1	2.9
Pyroxene	0.6	x	2.4	2.6	1.9	0.4	1.3	2.1
Gypsum	--	--	--	--	0.8	--	--	--
Vermiculite	--	--	--	--	--	--	--	--
Total	105.9	99.2	91.2	91.3	109.4	96.5	95.4	94.6

XRD No.	XRD 172	XRD 173
Core	LBPF	LBPF
Section	233	238
Starting cm	46.1	62.3
Ending cm	48.3	64.7
Quartz	8.8	13.8
K-Feldspar	15.8	20.3
Plagioclase	19.9	26.8
Calcite	--	x
Kaolinite	3.7	--
Smectite	11.6	--
Illite	8.8	9.0
Mica	16.4	8.5
Chlorite	8.0	15.4
Amphibole	2.6	2.0
Pyroxene	--	1.4
Gypsum	--	x
Vermiculite	--	+
Total	95.6	94.4

Dash means not present; x means present based on visual examinations of diffraction pattern, but RockJock would not quantify; + means present based on X-Pert HighScore, but mineral not in the RockJock database

Table 2. Quantitative mineralogy for mineral groups for core-sediment samples from Long Beach Pier C (See Appendix 3 for detailed mineralogy)

XRD No.	XRD 115	XRD 116	XRD 117	XRD 118	XRD 119	XRD 120	XRD 121	XRD 122
Core	LBPC	LBPC	LBPC	LBPC	LBPC	LBPC	LBPC	LBPC
Section	2	5	5	8	11	14	36	39
Starting cm	27.5	18.6	79.7	53.5	8.0	13.5	30.8	30.6
Ending cm	29.4	21.6	83.5	56.4	10.0	16.0	35.1	33.4
Quartz	14.8	19.2	6.6	3.6	12.7	10.6	19.5	19.4
K-Feldspar	20.7	22.2	21.8	24.0	14.1	16.7	23.6	41.3
Plagioclase	34.0	43.2	11.3	3.1	30.9	28.4	49.4	26.6
Calcite	--	--	2.2	2.2	8.2	3.4	--	--
Kaolinite	--	--	--	--	--	2.4	--	--
Smectite	--	--	24.7	24.2	--	--	--	--
Illite	--	--	3.2	7.4	--	--	--	--
Mica	16.2	12.2	15.6	15.2	14.7	15.3	8.0	13.5
Chlorite	2.7	2.8	3.2	8.7	8.1	12.4	3.5	3.4
Amphibole	2.1	2.9	1.4	x	4.3	2.7	0.4	2.9
Pyroxene	2.0	1.2	1.2	x	1.2	1.2	1.2	0.4
Vermiculite	--	--	+	+	--	--	--	--
Total	92.5	103.7	91.1	88.4	94.2	92.8	105.6	107.5

XRD No.	XRD 123	XRD 124	XRD 125	XRD 126	XRD 127	XRD 128	XRD 129	XRD 130
Core	LBPC	LBPC	LBPC	LBPC	LBPC	LBPC	LBPC	LBPC
Section	45	46	52	54	74	84	96	97
Starting cm	35.4	46.6	46.0	8.2	6.6	52.4	135.0	50.2
Ending cm	38.0	48.7	48.4	10.5	9.3	54.4	137.5	52.5
Quartz	15.3	20.6	23.5	11.5	7.4	18.0	16.9	14.1
K-Feldspar	--	25.8	52.5	15.0	12.9	37.9	19.8	48.5
Plagioclase	--	41.4	15.5	26.0	19.8	23.4	38.1	17.6
Calcite	0.9	--	--	x	0.8	--	--	--
Kaolinite	--	--	--	--	--	--	--	--
Smectite	--	--	--	--	13.7	--	--	--
Illite	--	--	--	--	15.2	--	--	7.4
Mica	--	16.2	13.1	16.9	21.5	11.5	14.5	17.8
Chlorite	--	0.8	0.5	21.8	6.6	13.8	10.5	11.2
Amphibole	1.7	2.9	x	1.7	--	3.3	2.4	2
Pyroxene	0.7	x	x	2.3	2	1.3	1.8	x
Vermiculite	--	--	--	--	+	--	--	--
Total	103.6	107.7	105.1	95.2	99.7	109.2	104.0	118.7

Table 2 continued

XRD No.	XRD 132	XRD 133	XRD 134	XRD 136	XRD 137	XRD 138	XRD 139	XRD 140
Core	LBPC	LBPC	LBPC	LBPC	LBPC	LBPC	LBPC	LBPC
Section	120	127	145	154	163	177	182	192
Starting cm	11.5	23.5	7.4	8.2	33.7	37.3	17.8	83.3
Ending cm	14.3	26.2	9.8	11.3	36.4	39.6	20.2	86.4
Quartz	14.6	27.5	18.8	20.9	23.4	16.1	9.7	12.8
K-Feldspar	22.1	36.0	23.6	34.9	8.0	44.9	33.9	17.4
Plagioclase	29.4	28.4	32.7	34.0	51.0	21.5	9.3	36.2
Calcite	--	--	--	--	--	--	--	--
Kaolinite	3.4	2.0	--	--	--	--	--	--
Smectite	--	--	--	--	4.4	--	--	--
Illite	--	--	--	--	--	--	25.5	10.0
Mica	17.0	7.0	15.9	3.8	14.3	17.7	26.3	15.9
Chlorite	11.0	--	6.9	9.8	--	6.5	--	8.1
Amphibole	2.4	0.5	1.7	2.7	3.2	2.4	x	x
Pyroxene	2.0	0.7	1.5	x	1.6	x	0.7	1.2
Vermiculite	--	--	--	--	+	--	--	--
Total	101.9	102.1	101.1	106.1	105.9	109.1	105.3	103.7

XRD No.	XRD 141	XRD 143	XRD 144	XRD 145	XRD 146
Core	LBPC	LBPC	LBPC	LBPC	LBPC
Section	207	222	226	226	234
Starting cm	63.0	129.5	30.2	5.6	141.9
Ending cm	65.6	133.0	33.2	8.0	143.0
Quartz	13.9	26.9	17.0	23.3	26.6
K-Feldspar	38.0	45.9	36.4	21.5	43.3
Plagioclase	16.0	20.7	25.6	45.4	13.9
Calcite	--	--	--	--	--
Kaolinite	--	--	--	--	--
Smectite	--	--	--	--	--
Illite	--	--	--	--	1.7
Mica	17.4	7.3	12.8	11.5	14.4
Chlorite	6.9	--	2.0	--	--
Amphibole	2.6	x	3.4	1.5	0.2
Pyroxene	x	2.2	0.6	3.1	x
Vermiculite	--	--	--	--	--
Total	94.7	103.0	97.8	106.3	100.1

Dash means not present; x means present based on visual examinations of diffraction pattern, but RockJock would not quantify the mineral; + means present based on X-Pert HighScore, but mineral not in the RockJock database

Table 3. Quantitative mineralogy for mineral groups for core-sediment samples from Long Beach Webster (See Appendix 4 for detailed mineralogy)

XRD No.	XRD 184	XRD 185	XRD 186	XRD 187	XRD 188	XRD 189	XRD 190	XRD 191
Core	LWEB	LWEB	LWEB	LWEB	LWEB	LWEB	LWEB	LWEB
Section	1	7	8	16	22	40	47	58
Starting cm	21.0	24.9	24.0	42.5	13	26.6	24.5	21.0
Ending cm	23.0	27.2	26.5	45.0	14.5	29.0	28.0	23.0
Quartz	11.4	18.6	3.4	24.0	16.1	22.7	10.6	36.0
K-Feldspar	38.8	20.3	12.7	11.3	38.6	20.0	13.0	22.3
Plagioclase	9.5	41.3	20.6	60.0	10.6	48.6	22.2	33.5
Calcite	--	--	x	--	--	--	--	--
Kaolinite	--	--	8.7	--	--	2.9	--	--
Smectite	--	--	--	--	--	--	7.6	--
Illite	8.1	--	24.2	--	--	1.6	10.9	--
Mica	18.0	13.3	17.8	--	12.1	8.6	20.9	8.0
Chlorite	2.2	1.0	--	3.4	15.1	--	6.8	4.4
Amphibole	3.4	2.7	x	4.3	2.5	1.7	1.7	x
Pyroxene	x	1.4	--	2.4	x	--	x	1.7
Gypsum	--	--	--	--	--	--	--	--
Alunite	--	--	--	--	--	--	0.5	--
Clinoptilolite	--	--	--	--	--	--	0.5	--
Magnetite	--	--	--	--	--	--	--	--
Total	91.4	98.6	87.5	108.4	95.0	106.0	91.7	105.9

XRD No.	XRD 192	XRD 193	XRD 194	XRD 195	XRD 196	XRD 197	XRD 198	XRD 199
Core	LWEB	LWEB	LWEB	LWEB	LWEB	LWEB	LWEB	LWEB
Section	66	72	85	101	110	129	134	146
Starting cm	28.5	25.0	12.6	31.5	31.0	16.6	25.0	74.5
Ending cm	31.0	27.0	14.7	34.5	33.0	19.0	27.0	77.0
Quartz	18.6	15.4	29.0	18.2	22.9	11.5	8.2	36.0
K-Feldspar	44.3	34.6	24.7	25.1	28.1	42.8	7.2	20.5
Plagioclase	10.5	9.9	38.1	50.5	44.4	--	17.2	2.2
Calcite	--	--	--	--	--	--	1.2	--
Kaolinite	1.0	--	--	--	--	3.0	7.1	--
Smectite	--	--	--	--	--	--	2.0	--
Illite	1.5	4.8	--	--	--	11.4	0.4	--
Mica	11.1	15.0	11.4	7.1	10.7	14.2	0.5	8.0
Chlorite	10.2	6.9	--	--	--	13.5	33.5	--
Amphibole	3.2	3.8	0.8	x	x	7.3	7.4	28.8
Pyroxene	x	x	1.6	1.2	1.3	x	3.4	1.7
Gypsum	--	--	--	--	--	--	0.4	--
Alunite	--	--	--	--	--	--	--	--
Clinoptilolite	--	--	--	--	--	--	--	--
Magnetite	--	--	--	--	--	--	1.8	--
Total	100.4	90.4	105.6	102.1	107.4	103.7	90.4	97.2

Table 3 continued

XRD No.	XRD 200	XRD 201	XRD 202	XRD 203	XRD 204	XRD 205	XRD 206	XRD 207
Core	LWEB	LWEB	LWEB	LWEB	LWEB	LWEB	LWEB	LWEB
Section	160	160	189	200	235	241	244	245
Starting cm	21.0	86.5	24.0	49.5	46.0	105.5	21.5	14.0
Ending cm	22.5	88.0	33.0	53.0	49.0	108.0	23.0	17.0
Quartz	10.4	16.2	32.2	23.1	36.0	29.5	15.0	18.8
K-Feldspar	13.0	33.9	--	54.8	48.3	--	23.9	40.5
Plagioclase	25.2	2.9	61.6	8.3	22.2	63.5	29.0	20.1
Calcite	--	--	--	--	--	--	--	--
Kaolinite	--	4.0	--	--	--	--	--	--
Smectite	--	--	--	--	--	--	--	--
Illite	--	16.9	--	--	--	--	--	--
Mica	13.2	17.8	5.8	10.1	--	3.1	16.5	12.1
Chlorite	21.5	9.0	2.0	1.9	--	3.9	6.6	3.2
Amphibole	4.9	1.0	x	x	x	x	0.6	1.5
Pyroxene	3.0	x	4.5	x	x	3.8	0.5	x
Gypsum	--	--	--	--	--	--	--	--
Alunite	--	--	--	--	--	--	--	--
Clinoptilolite	--	--	--	--	--	--	--	--
Magnetite	--	--	--	--	--	--	--	--
Total	91.4	101.7	106.1	98.2	106.6	103.8	92.1	96.2

XRD No.	XRD 208	XRD 209
Core	LWEB	LWEB
Section	247	249
Starting cm	28.5	36.5
Ending cm	31.0	38.0
Quartz	27.0	18.9
K-Feldspar	24.6	51.7
Plagioclase	35.7	4.2
Calcite	1.2	--
Kaolinite	--	1.5
Smectite	--	--
Illite	6.5	--
Mica	10.6	15.4
Chlorite	18.1	5.1
Amphibole	3.5	3.5
Pyroxene	0.7	x
Gypsum	--	--
Alunite	--	--
Clinoptilolite	--	--
Magnetite	--	--
Total	127.8	100.3

Dash means not present; x means present based on visual examinations of diffraction pattern, but RockJock would not quantify; + means present based on X-Pert HighScore, but mineral not in the RockJock database

Appendix 1. Sample Descriptions and ages of Long Beach Pier F, Pier C, and Webster drill cores

Long Beach Pier F Core			
Sample No./lab No.	Age	Unit Description	Sample Description
LBPF-4-C1/XRD-93.5-95.5	l Pleistocene, Holocene (<15 ka)	Silty sand	Silty sand
LBPF-8-C1/XRD-115.5-117.5	m,l Pleistocene (300-50 ka)	Silty clay	Silty clay
LBPF-8-C1/XRD-8-11	m,l Pleistocene (300-50 ka)	Clayey silt	Sticky clay
LBPF-13-C1/XRD-114.3-117	m,l Pleistocene (300-50 ka)	Sandy silt	Dark mineral band
LBPF-26-C1/XRD-9.2-11.6	m,l Pleistocene (300-50 ka)	Silt	Silt with shell fragments
LBPF-36-C1/XRD-20-24	m,l Pleistocene (300-50 ka)	Mud	Mud
LBPF-47-C1/XRD-31-34.5	m,l Pleistocene (300-50 ka)	Silty clay	Silty clay
LBPF-52-C1/XRD-29.3-31.5	m,l Pleistocene (500-300 ka)	Sand	Sand
LBPC-65-C1/XRD-8.1-10.8	m,l Pleistocene (500-300 ka)	Sand	Sand
LBPF-80-C1/XRD-91.4-94.2	m,l Pleistocene (500-300 ka)	Silty sand	Silty sand
LBPF-88-C1/XRD-20.9-23.4	m,l Pleistocene (500-300 ka)	Silty clay	Silty clay
LBPF-102-C1/XRD-32.6-35.3	m,l Pleistocene (500-300 ka)	Sandy silt	Sandy silt
LBPF-109-C1/XRD-63.7-65.4	m,l Pleistocene (500-300 ka)	Sand	Sand
LBPF-128-C1/XRD-52.4-54.5	m Pleistocene (<780-300 ka)	Silt	Silt
LBPF-134-C1/XRD-38.2-40.7	m Pleistocene (<780-300 ka)	Compact clay	Mudstone at 713.5 ft
LBPF-137-C1/XRD-28.4-31.1	m Pleistocene (<780-300 ka)	Clay	Clay-rich layer
LBPF-152-C1/XRD-63.5-66	m Pleistocene (<780-300 ka)	Silt	Silt
LBPF-159-C1/XRD-70.5-73.2	m Pleistocene (<780-300 ka)	Clay-rich layer	Clay-rich layer
LBPF-170-C1/XRD-49.5-51.2	m Pleistocene (<780-300 ka)	Clay-rich layer	Clay-rich layer
LBPF-184-C1/XRD-102.8-104.5	m Pleistocene (<780-300 ka)	Clay	Clay
LBPF-184-C1/XRD-22.5-25.5	m Pleistocene (<780-300 ka)	Sand	Sand
LBPF-197-C1/XRD-123-125.4	m Pleistocene (<780-300 ka)	Silt	Silt
LBPF-203-C1/XRD-58.4-61.0	Pliocene (<2.0-1.8 Ma)	Silt clay	Silt clay
LBPF-220-C1/XRD-35.5-38.3	Pliocene (<2.0-1.8 Ma)	Clay	Very compact clay
LBPF-233-C1/XRD-46.1-48.3	Pliocene (<2.0-1.8 Ma)	Clay	Clay
LBPF-238-C1/XRD-62.3-64.7	Pliocene (<2.0-1.8 Ma)	Silt clay	Silt clay

Appendix 1 continued

Long Beach Pier C Core			
Sample No./lab No.	Age	Unit Description	Sample Description
LBPC-2-C1/XRD-27.5-29.4	l Pleistocene, Holocene (<15 ka)	Sandy silt	Sandy silt
LBPC-5-C1/XRD-18.6-21.6	l Pleistocene, Holocene (<15 ka)	Sand	Sand
LBPC-5-C1/XRD-79.7-83.5	l Pleistocene, Holocene (<15 ka)	Mud	Mud
LBPC-8-C1/XRD-53.5-56.4	l Pleistocene, Holocene (<15 ka)	Clay	Lens organic-rich clay laminae
LBPC-11-C1/XRD-8-10	l Pleistocene, Holocene (<15 ka)	Silty sand	Silt surrounding carbonate rock fragment
LBPC-14-C1/XRD-13.5-16	l Pleistocene, Holocene (<15 ka)	Silty clay	Silty clay
LBPC-36-C1/XRD-30.8-35.1	l Pleistocene, Holocene (<15 ka)	Pebbly sand	Sand
LBPC-39-C1/XRD-30.6-33.4	m,l Pleistocene (300-50 ka)	Silty sand	Dark mineral sand
LBPC-45-C1/XRD-35.4-38	m,l Pleistocene (300-50 ka)	Silt	Silt surrounding small carbonate mass
LBPC-46-C1/XRD-46.6-48.7	m,l Pleistocene (300-50 ka)	Sand	Sand
LBPC-52-C1/XRD-46-48.4	m,l Pleistocene (300-50 ka)	Sand	Sand
LBPC-54-C1/XRD-8.2-10.5	m Pleistocene (<780-300 ka)	Clayey silt	Clayey silt
LBPC-74-C1/XRD-6.6-9.3	m Pleistocene (<780-300 ka)	Mud	Sticky laminated mud
LBPC-84-C1/XRD-52.4-54.4	m Pleistocene (<780-300 ka)	Silt	Silt
LBPC-96-C1/XRD-135-137.5	m Pleistocene (<780-300 ka)	Silt	Silt
LBPC-97-C1/XRD-50.2-52.5	m Pleistocene (<780-300 ka)	Clay	Clayey silt
LBPC-120-C1/XRD-11.5-14.3	m Pleistocene (<780-300 ka)	Clayey silt	Clayey silt
LBPC-127-C1/XRD-23.5-26.2	m Pleistocene (<780-300 ka)	Sand	Clayey silt to sand
LBPC-145-C1/XRD-7.4-9.8	m Pleistocene (<780-300 ka)	Silty clay	Silty clay
LBPC-154-C1/XRD-8.2-11.3	m Pleistocene (<780-300 ka)	Silt	Silt
LBPC-163-C1/XRD-33.7-36.4	m Pleistocene (<780-300 ka)	Silty sand	Silty sand
LBPC-177-C1/XRD-37.3-39.6	m Pleistocene (<780-300 ka)	Silty sand	Silty sand
LBPC-182-C1/XRD-17.8-20.2	Pliocene (<2.0-1.8 Ma)	Clayey silt	Clayey silt
LBPC-192-C1/XRD-83.3-86.4	Pliocene (<2.0-1.8 Ma)	Clayey silt	Clayey silt
LBPC-207-C1/XRD-63-65.6	Pliocene (<2.0-1.8 Ma)	Silty clay	Silty clay
LBPC-222-C1/XRD-15.3-19.4	Pliocene (<2.0-1.8 Ma)	Clayey silt	Bentonite (?)
LBPC-226-C1/XRD-30.2-33.2	Pliocene (<2.0-1.8 Ma)	Sand	Dark mineral sand
LBPC-226-C1/XRD-5.6-8.0	Pliocene (<2.0-1.8 Ma)	Sand	Sand
LBPC-234-C2/XRD-141.9-143	Pliocene (<2.0-1.8 Ma)	Sand-silt-clay	Sand-silt-clay

Appendix 1 continued

Long Beach Webster Core			
Sample No./lab No.	Age	Unit Description	Sample Description
LWEB-1-C1/XRD-21-23	l Pleistocene, Holocene (<15 ka)	Silty sand	Silty sand
LWEB-7-C1/XRD-24.9-27.2	l Pleistocene, Holocene (<15 ka)	Sand	Sand
LWEB-8-C1/XRD-24-26.5	l Pleistocene, Holocene (<15 ka)	Sand	Sand
LWEB-16-C1/XRD-42.5-45	l Pleistocene, Holocene (<15 ka)	Gravelly sand	Gravelly sand
LWEB-22-C1/XRD-13-14.5	m,l Pleistocene (300-50 ka)	Silt	Silt
LWEB-40-C1/XRD-26.6-29	m,l Pleistocene (300-50 ka)	Sand	Dark mineral concentration
LWEB-47-C1/XRD-24.5-28	m,l Pleistocene (300-50 ka)	Clay	Clay
LWEB-58-C1/XRD-21-23	m,l Pleistocene (300-50 ka)	Silt	Silt
LWEB-66-C1/XRD-28.5-31	m,l Pleistocene (300-50 ka)	Sandy silt	Sandy silt
LWEB-72-C1/XRD-25-27	m,l Pleistocene (300-50 ka)	Silt	Silt
LWEB-85-C1/XRD-12.6-14.7	m,l Pleistocene (300-50 ka)	Silty sand	Silty sand w/ drilling mud(?)
LWEB-101-1C/XRD-31.5-34.5	m,l Pleistocene (300-50 ka)	Sand	Sand
LWEB-110-C1/XRD-31-33	m,l Pleistocene (500-300 ka)	Sand	Sand
LWEB-129-C1/XRD-16.6-19	m,l Pleistocene (500-300 ka)	Silty clay	Cross-burrowed silty/clay
LWEB-134-C1/XRD-25-27	m,l Pleistocene (500-300 ka)	Clay	Silty clay
LWEB-146-C1/XRD-74.5-77	m,l Pleistocene (500-300 ka)	Silt	Clay-rich layer w/ abundant dark mineral banding
LWEB-160C1/XRD-21-22.5	m,l Pleistocene (500-300 ka)	Silty clay	Silty clay
LWEB-160-C1/XRD-86.5-88	m,l Pleistocene (500-300 ka)	Clayey silt	Green clay w/ shell fragments
LWEB-189-C1/XRD-24-33	m,l Pleistocene (500-300 ka)	Sand	Yellow-stained sand
LWEB-200-C1/XRD-49.5-53	m Pleistocene (<780-300 ka)	Pebbly sand	Pebbly sand
LWEB-235-C1/XRD-46-49	m Pleistocene (<780-300 ka)	Sand	Sand
LWEB-241-C1/XRD-105.5-108	m Pleistocene (<780-300 ka)	Sand	Sand
LWEB-244-C1/XRD-21.5-23	m Pleistocene (<780-300 ka)	Silty sand	Silty sand
LWEB-245-C1/XRD-14-17	Pliocene (<2.0-1.8 Ma)	Silty sand	Clay-rich lamina in sandy silt
LWEB-247-C1/XRD-28.5-31	Pliocene (<2.0-1.8 Ma)	Clayey silt	Clayey silt
LWEB-249-C1/XRD-36.5-38	Pliocene (<2.0-1.8 Ma)	Silty sand	Dark mineral lens

l=late; m=middle; m,l=middle and late; ka=thousand years; Ma=million years

Appendix 2. Quantitative mineralogy of core-sediment samples from Long Beach Pier F

XRD #	XRD 148	XRD 149	XRD 150	XRD 151	XRD 152	XRD 153	XRD 154	XRD 155
Core	LBPF	LBPF	LBPF	LBPF	LBPF	LBPF	LBPF	LBPF
Section	4	8	8	13	26	36	47	52
Starting cm	93.5	115.5	8.0	114.3	9.2	20.0	31.0	29.3
Ending cm	95.5	117.5	11.0	117.0	11.6	24.0	34.5	31.5
Quartz	18.0	21.7	12.5	18.9	16.8	12.0	9.4	23.4
Microcline - combined	12.2	16.4	7.6	10.3	13.1	11.4	15.3	29.7
Sanidine	--	4.4	--	--	--	--	--	--
Orthoclase	7.4	--	2.4	5.5	--	--	--	--
Anorthoclase	8.6	--	29.1	18.0	28.3	25.7	--	--
Albite	15.1	33.1	8.9	27.9	11.6	9.6	12.6	39.8
Oligoclase	7.8	--	--	--	--	--	--	--
Labradorite	6.9	17.2	0.1	--	--	--	10.0	--
Bytownite	--	--	--	--	--	--	--	--
Anorthite	--	--	--	--	--	--	--	--
Calcite	--	--	--	--	--	--	--	--
Ord. Kaolinite	--	--	--	--	--	--	--	--
Dickite	--	--	--	--	--	--	--	--
Smectite - combined	--	--	--	--	--	--	--	--
1Md Illite (+mica)	6.0	--	11.5	--	5.0	9.3	34.9	--
IM Illite (R>1; 70-80%I)	--	--	--	--	--	--	--	--
IM Illite (RM30)	--	--	--	--	--	--	--	--
Biotite (1M)	--	4.3	--	--	--	--	--	--
Biotite (2M1)	--	--	--	--	--	--	--	8.8
Phlogopite (2M1)	14.6	0.8	16.1	15.9	14.3	14.7	2.6	--
Chlorite CCa-1	--	--	--	--	1.9	4.6	4.1	--
Chlorite CCa-3	--	--	--	--	--	--	--	--
Chlorite Tusc	--	3.4	8.3	--	2.8	4.3	8.1	--
Mg-Chlorite (A)	--	--	--	--	1.1	1.8	--	2.2
Clinochlore	--	--	--	--	--	1.5	--	--
Amphibole	1.6	x	2.7	4.9	2.0	3.0	1.4	x
Pyroxene	x	1.8	0.5	0.6	0.2	x	x	2.6
Gypsum	--	--	--	--	--	--	--	--
Vermiculite	--	--	--	--	--	--	--	--
Total	98.2	103.1	99.7	102.0	97.1	97.9	98.4	106.5

Appendix 2 continued

XRD #	XRD 156	XRD 157	XRD 158	XRD 159	XRD 160	XRD 161	XRD 162	XRD 163
Core	LBPF	LBPF	LBPF	LBPF	LBPF	LBPF	LBPF	LBPF
Section	65	80	88	102	109	128	134	137
Starting cm	8.1	91.4	20.9	32.6	63.7	52.4	38.2	28.4
Ending cm	10.8	94.2	23.4	35.3	65.4	54.5	40.7	31.1
Quartz	20.0	17.7	17.5	15.0	20.5	14.2	9.1	10.1
Microcline - combined	13.7	21.1	--	23.6	14.4	10.5	12.8	11.1
Sanidine	--	--	--	--	--	--	--	--
Orthoclase	7.2	--	--	--	--	--	--	--
Anorthoclase	14.9	--	--	--	25.9	31.2	--	26.6
Albite	33.9	22.7	27.1	28.1	26.7	12.3	16.2	5.8
Oligoclase	--	--	--	--	--	--	--	--
Labradorite	--	12.0	11.1	--	--	--	--	--
Bytownite	--	--	--	--	--	--	--	3.1
Anorthite	--	--	--	--	--	--	--	--
Calcite	--	--	--	--	--	--	--	--
Ord. Kaolinite	--	--	--	--	--	--	--	--
Dickite	--	--	--	--	--	--	--	3.3
Smectite - combined	--	--	--	--	--	--	--	--
1Md Illite (+mica)	--	4.4	12.3	--	--	8.8	24.8	12.3
IM Illite (R>1; 70-80%I)	--	--	--	--	--	--	--	--
IM Illite (RM30)	--	--	--	--	--	--	--	4.1
Biotite (1M)	1.9	--	--	0.5	--	--	--	--
Biotite (2M1)	6.0	--	--	14.7	9.1	1.1	2.8	--
Phlogopite (2M1)	--	15.0	14.7	--	--	15.7	16.9	18.6
Chlorite CCa-1	--	3.1	1.0	4.0	--	1.0	1.7	--
Chlorite CCa-3	--	x	--	--	x	--	--	--
Chlorite Tusc	3.7	0.3	4.8	0.5	--	4.2	3.8	--
Mg-Chlorite (A)	--	--	3.4	0.8	3.6	3.2	1.4	5.6
Clinochlore	--	--	--	--	--	--	--	--
Amphibole	0.6	1.9	1.9	3.0	1.8	3.4	0.4	x
Pyroxene	1.0	2.6	2.7	1.8	x	0.4	1.2	x
Gypsum	--	--	--	--	--	--	--	--
Vermiculite	--	--	--	--	--	--	--	--
Total	102.9	100.8	96.5	92.0	102.0	106.0	91.1	100.5

Appendix 2 continued

XRD #	XRD 164	XRD 165	XRD 166	XRD 167	XRD 168	XRD 169	XRD 170	XRD 171	XRD 172	XRD 173
Core	LBPF	LBPF	LBPF	LBPF	LBPF	LBPF	LBPF	LBPF	LBPF	LBPF
Section	152	159	170	184	184	197	203	220	233	238
Starting cm	63.5	70.5	49.5	102.8	22.5	123.0	58.4	35.5	46.1	62.3
Ending cm	66.0	73.2	51.2	104.5	25.5	125.4	61.0	38.3	48.3	64.7
Quartz	18.0	10.6	10.7	10.9	24.4	17.8	18.5	12.4	8.8	13.8
Microcline - combined	18.1	--	--	17.8	18.7	--	16.7	18.3	9.2	9.9
Sanidine	--	--	--	--	--	--	--	--	--	2.8
Orthoclase	--	--	--	--	--	--	--	--	6.6	7.6
Anorthoclase	24.0	53.3	--	--	--	35.3	--	--	--	--
Albite	8.3	4.8	14.5	--	46.9	9.8	8.0	6.6	9.4	8.4
Oligoclase	--	--	--	--	--	--	7.5	7.9	--	--
Andesine	--	--	--	--	--	--	9.7	--	--	7.7
Labradorite	14.2	--	9.6	24.5	--	x	12.5	13.1	10.5	10.7
Bytownite	--	--	--	--	--	--	--	2.0	--	--
Anorthite	--	--	--	--	--	--	--	--	--	--
Calcite	--	--	--	--	--	--	--	--	--	x
Ord. Kaolinite	--	--	--	--	--	--	--	--	3.7	--
Dickite	--	--	--	--	--	--	--	--	--	--
Smectite - combined	--	--	--	--	--	14.5	--	--	11.6	--
1Md Illite (+mica)	--	--	25.3	--	--	--	--	--	8.8	--
IM Illite (R>1; 70-80%I)	--	--	--	--	--	--	--	--	--	--
IM Illite (RM30)	--	--	--	--	--	--	--	--	--	9.0
Biotite (1M)	--	3.6	--	--	--	--	--	x	--	--
Biotite (2M1)	12.4	15.9	--	--	--	x	--	x	--	8.5
Phlogopite (2M1)	--	--	16.8	16.3	12.5	15.6	7.2	16.6	16.4	--
Chlorite CCa-1	--	6.0	--	2.2	1.9	0.9	--	--	--	--
Chlorite CCa-3	--	--	--	5.4	--	--	--	--	--	--
Chlorite Tusc	5.4	1.2	10.1	9.3	1.3	--	6.1	9.1	8.0	8.5
Mg-Chlorite (A)	1.5	--	1.6	0.1	--	--	3.7	3.6	--	6.9
Clinochlore	--	--	--	--	--	--	--	--	--	--
Amphibole	3.4	3.8	0.2	2.2	1.0	2.2	4.1	2.9	2.6	2.0
Pyroxene	0.6	x	2.4	2.6	1.9	0.4	1.3	2.1	--	1.4
Gypsum	--	--	--	--	0.8	--	--	--	--	x
Vermiculite	--	--	--	--	--	--	--	--	--	+
Total	105.9	99.2	91.2	91.3	109.4	96.5	95.4	94.6	95.6	94.4

Dash means not present; x means present based on visual examinations of diffraction pattern, but RockJock would not quantify; + means present based on X-Pert HighScore, but mineral not in the RockJock database; See Appendix 4 for explanation of clay minerals and mica minerals

Appendix 3. Quantitative mineralogy of core-sediment samples from Long Beach Pier C

XRD #	XRD 115	XRD 116	XRD 117	XRD 118	XRD 119	XRD 120	XRD 121	XRD 122	XRD 123
Core	LBPC	LBPC	LBPC	LBPC	LBPC	LBPC	LBPC	LBPC	LBPC
Section	2	5	5	8	11	14	36	39	45
Starting cm	27.5	18.6	79.7	53.5	8.0	13.5	30.8	30.6	35.4
Ending cm	29.4	21.6	83.5	56.4	10.0	16.0	35.1	33.4	38.0
Quartz	14.8	19.2	6.6	3.6	12.7	10.6	19.5	19.4	15.3
Microcline - combined	20.7	22.2	7.8	6.2	9.2	8.8	18.9	10.8	13.0
Sanidine	--	--	--	--	4.9	--	--	--	--
Orthoclase	--	--	--	--	--	7.9	4.7	4.7	--
Anorthoclase	--	--	14.0	17.8	--	--	--	25.8	24.6
Albite	34.0	43.2	5.8	3.1	12.3	12.1	13.2	17.0	9.0
Oligoclase	--	--	--	--	--	5.7	12.8	1.3	--
Andesine	--	--	--	--	--	2.8	12.3	--	--
Labradorite	--	--	5.5	--	18.6	7.8	11.1	8.3	4.4
Bytownite	--	--	--	--	--	--	--	--	3.6
Anorthite	--	--	--	--	--	--	--	--	--
Calcite	--	--	2.2	2.2	8.2	3.4	--	--	0.9
Kaolinite (Dry Branch)	--	--	--	--	--	--	--	--	--
Dickite	--	--	--	--	--	2.4	--	--	--
Smectite - combined	--	--	24.7	17.0	--	--	--	--	--
Saponite	--	--	--	7.2	--	--	--	--	--
IM Illite (R>2; 88%I)	--	--	--	--	--	--	--	--	--
IM Illite (RM30)	--	--	3.2	--	--	--	--	--	--
2M1 Illite (SG4)	--	--	--	--	--	--	--	--	--
1Md Illite (+mica)	--	--	--	7.4	--	--	--	--	6.3
Biotite (1M)	--	--	--	--	--	--	--	--	--
Biotite (2M1)	--	1.1	3.2	--	--	--	--	--	--
Phlogopite (2M1)	16.2	11.1	12.4	15.2	14.7	15.3	8.0	13.5	15.8
Chlorite CCa-1	2.2	--	--	--	0.7	--	--	--	--
Chlorite CCa-3	0.5	--	3.2	--	--	--	--	--	--
Chlorite CCM	--	--	--	--	--	--	--	--	--
Chlorite Tusc	--	0.2	--	6.5	7.4	9.2	2.8	--	4.6
Mg-Chlorite (A)	--	2.6	--	2.2	--	3.2	0.7	3.4	3.8
Clinochlore	--	--	--	--	--	--	--	--	--
Amphibole	2.1	2.9	1.4	x	4.3	2.7	0.4	2.9	1.7
Pyroxene	2.0	1.2	1.2	x	1.2	1.2	1.2	0.4	0.7
Gypsum	--	--	--	--	--	--	--	--	--
Vermiculite	--	--	+	+	--	--	--	--	--
Total	92.5	103.7	91.1	88.4	94.2	92.8	105.6	107.5	103.6

Appendix 3 continued.

XRD #	XRD 124	XRD 125	XRD 126	XRD 127	XRD 128	XRD 129	XRD 130	XRD 132	XRD 133
Core	LBPC	LBPC	LBPC	LBPC	LBPC	LBPC	LBPC	LBPC	LBPC
Section	46	52	54	74	84	96	97	120	127
Starting cm	46.6	46.0	8.2	6.6	52.4	135.0	50.2	11.5	23.5
Ending cm	48.7	48.4	10.5	9.3	54.4	137.5	52.5	14.3	26.2
Quartz	20.6	23.5	11.5	7.4	18.0	16.9	14.1	14.6	27.5
Microcline - combined	14.5	15.0	9.4	10.5	14.6	15.7	13.1	14.0	18.8
Sanidine	--	--	--	--	--	4.1	--	--	2.2
Orthoclase	11.3	--	5.6	2.4	--	--	--	8.1	--
Anorthoclase	--	37.5	--	--	23.3	--	35.4	--	15.0
Albite	32.3	12.0	--	12.3	9.6	14.5	10.8	8.3	18.4
Oligoclase	4.8	3.5	--	--	--	6.3	--	5.6	--
Andesine	--	--	--	--	--	--	--	5.8	--
Labradorite	--	--	20.1	4.8	13.8	17.3	--	9.7	10.0
Bytownite	4.3	--	--	2.7	--	--	6.8	--	--
Anorthite	--	--	5.9	--	--	--	--	--	--
Calcite	--	--	x	0.8	--	--	--	--	--
Kaolinite (Dry Branch)	--	--	--	--	--	--	--	--	2.0
Dickite	--	--	--	--	--	--	--	3.4	--
Smectite - combined	--	--	--	13.7	--	--	--	--	--
Saponite	--	--	--	--	--	--	--	--	--
IM Illite (R>2; 88%I)	--	--	--	--	--	--	--	--	--
IM Illite (RM30)	--	--	--	--	--	--	7.4	--	--
2M1 Illite (SG4)	--	--	--	--	--	--	--	--	--
1Md Illite (+mica)	--	--	--	15.2	--	--	--	--	--
Biotite (1M)	--	--	x	--	1.7	--	--	--	1.0
Biotite (2M1)	--	--	--	0.4	9.8	4.6	--	--	6.0
Phlogopite (2M1)	16.2	13.1	16.9	21.1	--	9.9	17.8	17.0	--
Chlorite CCa-1	--	--	--	1.6	--	--	--	4.2	--
Chlorite CCa-3	--	--	--	--	13.8	--	--	--	--
Chlorite CCM	--	--	--	--	--	--	--	--	--
Chlorite Tusc	0.8	0.5	--	5.0	--	8.3	11.2	4.7	--
Mg-Chlorite (A)	--	--	x	--	--	2.2	--	2.1	--
Clinochlore	--	--	21.8	--	--	--	--	--	--
Amphibole	2.9	x	1.7	--	3.3	2.4	2.0	2.4	0.5
Pyroxene	x	x	2.3	2.0	1.3	1.8	x	2.0	0.7
Gypsum	--	--	--	--	--	--	--	--	--
Vermiculite	--	--	--	+	--	--	--	--	--
Total	107.7	105.1	95.2	99.7	109.2	104.0	118.7	101.9	102.1

Appendix 3 continued.

XRD #	XRD 134	XRD 136	XRD 137	XRD 138	XRD 139	XRD 140	XRD 141	XRD 143
Core	LBPC	LBPC	LBPC	LBPC	LBPC	LBPC	LBPC	LBPC
Section	145	154	163	177	182	192	207	222
Starting cm	7.4	8.2	33.7	37.3	17.8	83.3	63.0	129.5
Ending cm	9.8	11.3	36.4	39.6	20.2	86.4	65.6	133.0
Quartz	18.8	20.9	23.4	16.1	9.7	12.8	13.9	26.9
Microcline - combined	18.1	14.3	--	15.2	8.4	17.4	10.6	17.0
Sanidine	--	4.3	8.0	--	--	--	4.0	2.9
Orthoclase	5.5	--	--	--	--	--	--	--
Anorthoclase	--	16.3	--	29.7	25.5	--	23.4	26.0
Albite	11.5	16.9	34.3	10.0	5.1	10.0	7.8	20.7
Oligoclase	6.9	--	--	--	--	4.9	--	--
Andesine	--	--	--	--	--	9.1	--	--
Labradorite	14.3	13.0	16.7	11.5	--	7.4	8.2	--
Bytownite	--	--	--	--	4.2	4.8	--	--
Anorthite	--	4.1	--	--	--	--	--	--
Calcite	--	--	--	--	--	--	--	--
Kaolinite (Dry Branch)	--	--	--	--	--	--	--	--
Dickite	--	--	--	--	--	--	--	--
Smectite - combined	--	--	4.4	--	--	--	--	--
Saponite	--	--	--	--	--	--	--	--
IM Illite (R>2; 88%I)	--	--	--	--	--	--	--	--
IM Illite (RM30)	--	--	--	--	--	4.7	--	--
2M1 Illite (SG4)	--	--	--	--	--	5.3	--	--
1Md Illite (+mica)	--	--	--	--	25.5	--	--	--
Biotite (1M)	--	--	--	--	--	--	--	--
Biotite (2M1)	--	3.8	--	2.7	5.3	--	x	7.3
Phlogopite (2M1)	15.9	--	14.3	15.0	21.0	15.9	17.4	--
Chlorite CCa-1	--	--	--	--	--	3.2	--	--
Chlorite CCa-3	--	--	--	--	--	--	--	--
Chlorite CCM	--	--	--	--	--	--	--	--
Chlorite Tusc	5.3	6.4	--	5.4	--	4.9	--	--
Mg-Chlorite (A)	1.6	3.4	--	1.1	--	--	6.9	--
Clinochlore	--	--	--	--	--	--	--	--
Amphibole	1.7	2.7	3.2	2.4	x	x	2.6	x
Pyroxene	1.5	x	1.6	x	0.7	1.2	x	2.2
Gypsum	--	--	--	--	--	--	--	--
Vermiculite	--	--	+	--	--	--	--	--
Total	101.1	106.1	105.9	109.1	105.3	103.7	94.7	103.0

Appendix 3 continued

XRD #	XRD 144	XRD 145	XRD 146
Core	LBPC	LBPC	LBPC
Section	226	226	234
Starting cm	30.2	5.6	141.9
Ending cm	33.2	8.0	143.0
Quartz	17.0	23.3	26.6
Microcline - combined	13.4	21.5	--
Sanidine	--	--	--
Orthoclase	--	--	--
Anorthoclase	23.0	--	43.3
Albite	13.4	31.3	13.9
Oligoclase	--	--	--
Andesine	--	--	--
Labradorite	12.2	14.1	--
Bytownite	--	--	--
Anorthite	--	--	--
Calcite	--	--	--
Kaolinite (Dry Branch)	--	--	--
Dickite	--	--	--
Smectite - combined	--	--	--
Saponite	--	--	--
IM Illite (R>2; 88%I)	--	--	--
IM Illite (RM30)	--	--	--
2M1 Illite (SG4)	--	--	--
1Md Illite (+mica)	--	--	1.7
Biotite (1M)	--	--	--
Biotite (2M1)	--	--	--
Phlogopite (2M1)	12.8	11.5	14.4
Chlorite CCa-1	--	--	--
Chlorite CCa-3	--	--	--
Chlorite CCM	--	--	--
Chlorite Tusc	--	--	--
Mg-Chlorite (A)	2.0	--	--
Clinochlore	--	--	--
Amphibole	3.4	1.5	0.2
Pyroxene	0.6	3.1	x
Gypsum	--	--	--
Vermiculite	--	--	--
Total	97.8	106.3	100.1

Dash means not present; x means present based on visual examinations of diffraction pattern, but RockJock would not quantify; + means present based on X-Pert HighScore, but mineral not in the RockJock database; See Appendix 4 for explanation of clay minerals and mica minerals

Appendix 4. Quantitative mineralogy of core-sediment samples from Long Beach Webster

XRD #	XRD 184	XRD 185	XRD 186	XRD 187	XRD 188	XRD 189	XRD 190
Core	LWEB	LWEB	LWEB	LWEB	LWEB	LWEB	LWEB
Section	1	7	8	16	22	40	47
Starting cm	21.0	24.9	24.0	42.5	13.0	25.6	24.5
Ending cm	23.0	27.2	26.5	45.0	14.5	29.0	28.0
Quartz	11.4	18.6	3.4	24.0	16.1	22.7	10.6
Microcline - combined	7.8	20.3	6.8	--	--	--	--
Sanidine	--	--	--	11.3	--	--	--
Orthoclase	--	--	5.9	--	--	20.0	13.0
Anorthoclase	31.0	--	--	--	38.6	--	--
Albite	9.5	24.6	--	41.1	10.6	43.7	22.2
Oligoclase	--	--	10.3	--	--	--	--
Andesine	--	--	--	--	--	--	--
Labradorite	--	16.7	10.3	18.9	--	4.9	--
Bytownite	--	--	--	--	--	--	--
Anorthite	--	--	--	--	--	--	--
Calcite	--	--	x	--	--	--	--
Kaolinite - combined	--	--	8.0	--	--	2.9	--
Dickite	--	--	0.7	--	--	--	--
Smectite - combined	--	--	--	--	--	--	7.6
1Md Illite (+mica)	--	--	16.4	--	--	--	1.4
IM Illite (R>2; 88%I)	8.1	--	--	--	--	--	--
IM Illite (R>1; 70-80%I)	--	--	--	--	--	--	--
IM Illite (RM30)	--	--	7.8	--	--	--	--
2M1 Illite (SG4)	--	--	--	--	--	1.6	9.5
Biotite (1M)	--	--	--	--	1.6	3.5	--
Biotite (2M1)	--	--	--	--	10.5	5.1	4.3
Phlogopite (2M1)	18.0	13.3	17.8	--	--	--	16.6
Chlorite CCa-1	--	1.0	--	--	--	--	1.2
Chlorite CCa-3	--	--	--	--	--	--	--
Chlorite CCM	--	--	--	--	--	--	--
Chlorite CO	--	--	--	--	--	--	--
Chlorite Tusc	--	--	--	--	7.2	--	5.6
Mg-Chlorite (A)	2.2	--	--	3.4	x	--	--
Clinochlore	--	--	x	--	7.9	--	--
Amphibole	3.4	2.7	x	4.3	2.5	1.7	1.7
Pyroxene	x	1.4	--	2.4	x	--	x
Gypsum	--	--	--	--	--	--	--
Alunite	--	--	--	--	--	--	0.5
Clinoptilolite	--	--	--	--	--	--	0.5
Magnetite	--	--	--	--	--	--	--
Total	91.4	98.6	87.5	108.4	95.0	106.0	91.7

Appendix 4 continued

XRD #	XRD 191	XRD 192	XRD 193	XRD 194	XRD 195	XRD 196	XRD 197	XRD 198	XRD 199
Core	LWEB	LWEB	LWEB	LWEB	LWEB	LWEB	LWEB	LWEB	LWEB
Section	58	66	72	85	101	110	129	134	146
Starting cm	21.0	28.5	25.0	12.6	31.5	31.0	16.6	25.0	74.5
Ending cm	23.0	32.0	27.0	14.7	34.5	33.0	19.0	27.0	77.0
Quartz	36.0	18.6	15.4	28.7	29.0	18.2	11.5	8.2	36.0
Microcline - combined	--	15.6	--	--	24.7	25.1	--	--	--
Sanidine	--	--	4.6	--	--	--	--	--	20.5
Orthoclase	22.3	--	--	--	--	--	--	6.8	--
Anorthoclase	--	28.7	30.0	57.7	--	--	42.8	0.4	--
Albite	33.5	10.5	9.9	7.6	7.3	14.3	x	17.2	2.2
Oligoclase	--	--	--	--	14.8	9.3	--	--	--
Andesine	--	--	--	--	--	14.2	--	--	--
Labradorite	--	--	--	--	16.0	12.7	--	--	--
Bytownite	--	--	--	--	--	--	--	--	--
Anorthite	--	--	--	--	--	--	--	--	--
Calcite	--	--	--	--	--	--	--	1.2	--
Kaolinite - combined	--	1.0	--	--	--	--	--	7.1	--
Dickite	--	--	--	--	--	--	3.0	--	--
Smectite - combined	--	--	--	--	--	--	--	2.0	--
1Md Illite (+mica)	--	--	--	--	--	--	--	0.4	--
IM Illite (R>2; 88%I)	--	--	--	--	--	--	1.9	--	--
IM Illite (R>1; 70-80%I)	--	0.8	--	--	--	--	--	--	--
IM Illite (RM30)	--	0.7	--	--	--	--	9.5	--	--
2M1 Illite (SG4)	--	--	4.8	--	--	--	--	--	--
Biotite (1M)	--	--	--	--	--	7.1	--	0.5	--
Biotite (2M1)	8.0	--	--	9.5	x	--	6.2	--	8.0
Phlogopite (2M1)	--	11.1	15.0	--	11.4	--	8.0	--	--
Chlorite CCa-1	x	--	0.7	2.2	--	--	1.2	--	--
Chlorite CCa-3	--	--	--	--	--	--	--	1.7	--
Chlorite CCM	--	--	--	--	--	--	--	0.4	--
Chlorite CO	--	--	--	--	--	--	--	1.0	--
Chlorite Tusc	4.4	--	6.2	--	--	--	12.3	1.6	--
Mg-Chlorite (A)	--	--		--	--	--	--	27.6	--
Clinochlore	--	10.2	--	--	--	--	--	1.2	--
Amphibole	x	3.2	3.8	x	0.8	x	7.3	7.4	28.8
Pyroxene	1.7	x	x	x	1.6	1.2	x	3.4	1.7
Gypsum	--	--	--	--	--	--	--	0.4	--
Alunite	--	--	--	--	--	--	--	--	--
Clinoptilolite	--	--	--	--	--	--	--	--	--
Magnetite	--	--	--	--	--	--	--	1.8	--
Total	105.9	100.4	90.4	105.7	105.6	102.1	103.7	90.4	97.2

Appendix 4 continued

XRD #	XRD 200	XRD 201	XRD 202	XRD 203	XRD 204	XRD 205	XRD 206	XRD 207	XRD 208	XRD 209
Core	LWEB	LWEB	LWEB	LWEB	LWEB	LWEB	LWEB	LWEB	LWEB	LWEB
Section	160	160	189	200	235	241	244	245	247	249
Starting cm	21.0	86.5	24.0	49.5	46.0	105.5	21.5	14.0		36.5
Ending cm	22.5	88.0	33.0	53.0	49.0	108.0	23.0	17.0		38.0
Quartz	10.4	16.2	32.2	23.1	36.0	29.5	15.0	18.8	27.0	18.9
Microcline - combined	11.8	--	--	--	27.3	--	23.9	18.4	--	--
Sanidine	1.2	--	--	--	--	--	--	--	--	--
Orthoclase	--	8.7	--	--	--	--	--	--	24.6	--
Anorthoclase	--	25.2	--	54.8	21.0	--	--	22.1	--	51.7
Albite	12.7	--	--	8.3	22.2	63.5	9.2	x	35.7	4.2
Oligoclase	3.5	--	--	--	--	--	19.8	20.1	--	--
Andesine	2.3	--	--	--	--	--	--	--	--	--
Labradorite	6.7	2.9	61.6	--	--	--	--	--	--	--
Bytownite	--	--	--	--	--	--	--	--	--	--
Anorthite	--	--	--	--	--	--	--	--	--	--
Calcite	--	--	--	--	--	--	--	--	1.2	--
Kaolinite - combined	--	4.0	--	--	--	--	--	--	--	--
Dickite	--	--	--	--	--	--	--	--	--	1.5
1Md Illite (+mica)	--	--	--	--	x	--	--	--	--	--
IM Illite (R>2; 88%I)	--	x	--	--	x	--	--	--	--	--
IM Illite (R>1; 70-80%I)	--	7.4	--	--	x	--	--	--	--	--
IM Illite (RM30)	--	1.6	--	--	x	--	--	--	2.5	--
2M1 Illite (SG4)	--	7.9	--	--	x	--	--	--	4.0	--
Biotite (1M)	--	x	--	--	x	3.1	--	--	10.6	--
Biotite (2M1)	--	17.8	5.8	--	x	--	x	12.1	--	--
Phlogopite (2M1)	13.2	--	--	10.1	--	--	16.5	--	--	15.4
Chlorite CCa-1	2.8	--	2.0	--	x	--	--	3.2	--	--
Chlorite CCa-3	7.5	0.4	--	x	--	--	--	--	--	--
Chlorite CCM	--	--	--	--	--	--	--	--	--	--
Chlorite CO	--	--	--	--	--	--	--	--	--	--
Chlorite Tusc	11.2	8.6	--	--	--	3.9	4.9	--	9.5	5.0
Mg-Chlorite (A)	--	--	--	1.9	--	--	1.7	--	8.6	0.1
Clinochlore	--	--	--	--	--	--	--	--	--	--
Amphibole	4.9	1.0	x	x	x	x	0.6	1.5	3.5	3.5
Pyroxene	3.0	x	4.5	x	x	3.8	0.5	x	0.7	x
Total	91.4	101.7	106.1	98.2	106.6	103.8	92.1	96.2	127.8	100.3

Dash means not present; x means present based on visual examinations of diffraction pattern, but RockJock would not quantify; + means present based on X-Pert HighScore, but mineral not in the RockJock database; See Appendix 4 for explanation of clay minerals and mica minerals

Appendix 5. Explanation of clay and mica minerals in Appendices 2-4

Mineral	Explanation
1Md Illite (+mica)	1Md = Illite polytype characterized by disordered, metastable one-layer monoclinic structural arrangement
2M1 Illite (SG4)	2M1 = Illite polytype characterized by a metastable two-layer monoclinic structural arrangement
Biotite (1M)	1M = Biotite polytype characterized by a metastable one-layer monoclinic structural arrangement
Biotite (2M1)	2M1 = Biotite polytype characterized by a metastable two-layer monoclinic structural arrangement
Ca-Smectite	Calcium-rich smectite/montmorillonite
Chlorite CCa-1	USGS Denver Spectroscopy Laboratory standard
Chlorite CCa-3	USGS Denver Spectroscopy Laboratory standard
Chlorite CCM	Chlorite standard
Chlorite Tusc	Chlorite standard
Disord. Kaolinite	Disordered refers to the distribution of different atoms/ions among crystallographic structure sites is purely random
Fe-Smectite	Iron-rich smectite
IM Illite (R>1; 70-80%I)	1M = Illite polytype characterized by metastable one-layer monoclinic structural arrangement of 70-80% illite layers; R>1 refers to
IM Illite (R>2; 88%I)	1M = Illite polytype characterized by metastable one-layer monoclinic structural arrangement of 88% illite layers; R>2 refers to
IM Illite (RM30)	1M = Illite polytype characterized by metastable one-layer monoclinic structural arrangement of layers; RM30 refers to
Int. Microcline	Intermediate refers to an intermediate range of order or disorder of atoms that can share the same crystallographic structure site within a mineral
Kaolinite (Dry Branch)	Kaolinite standard
Mg-Chlorite (A)	Magnesium-rich chlorite
Na-Smectite	Sodium-rich smectite/montmorillonite
Ord. Kaolinite	Ordered is the total preference of a particular type of atom for a particular type of site
Ord. Microcline	Ordered is the total preference of a particular type of atom for a particular type of site
Phlogopite (2M1)	2M1 = Phlogopite polytype characterized by a metastable two-layer monoclinic structural arrangement