Soil Chemistry and Mineralogy of the Santa Cruz Coastal Terraces

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1.0 Introduction

Marine terraces in the central coast of California provide an opportunity to study a soil chronosequence in which similar materials (beach deposits) have been weathered under similar slope, climatic, and vegetation conditions during the Quaternary. The terraces between Santa Cruz and An_o Nuevo, California have been studied for decades and are thought to be one of the best example of marine terraces in California {Lawson (1893), Wilson (1907); Branner and others (1909), Rode (1930) Page and Holmes (1945), Alexander (1953), Bradley (1956, 1957, 1958, and 1965), Bradley and Addicott (1968), Clark (1966 and 1970), Jahns and Hamilton (1971), Lajoie and others (1972), Bradley and Griggs (1976). Hanks and others (1986), Aniku (1986), Fine and others (1988), Anderson (1990 and 1994), and Rosenbloom and Anderson (1994).} Here we report morphological, chemical, physical and mineralogical data for the soils that were formed in deposits on the Santa Cruz marine terraces in order to examine soil characteristics as a function of increasing terrace age.

2.0 Geologic setting

The main characteristics of terrace formation include (1) deposition of sediment while the platform is still submerged (2) platforms, formed by wave energy, are cut into bedrock during sea-level high stands (3) as sea level drops beach sediment, colluvium, and local stream alluvium are deposited onto the newly exposed bedrock platform and (4) terraces are tectonically uplifted, deformed, eroded and incised (Bradley and Griggs 1976). In general, the terraces slope seaward at low angles and with a slight concavity. Although processes that form and deform the terraces are well understood, the time of deposition and stabilization of the terrace surface, and the exact rates of the tectonic uplift, are less well known (Bradley and Griggs 1976, Hanks and others 1986, Perg and others 1999). In general, however, terraces increase in age from the lowest terrace that forms the current ocean blufftop to the highest terrace that occurs ~4 km inland and ~500 m in elevation.

There are five discernable terraces between Santa Cruz and An_o Nuevo, California defined by Bradley and Griggs (1976), in order from oldest to youngest, as Quarry, Blackrock, Wilder, Western and Highway 1. Only the Highway 1 terrace is spatially continuous. Regional uplift rates appear to be more rapid toward the south, as a result, identification and correlation of specific terraces is problematic especially where fewer than five terraces are present (Anderson, 1990, 1994). Although we refer to our sites using the nomenclature of Bradley and Griggs, we caution that absolute ages and even the assignment of terrace names are tenuous until more dating information becomes available. Our identification of the top two terraces, Quarry terrace and Black Rock (Table 1) are particularly suspect. The two sites could conceivably be front and back edges of one terrace (Quarry) or indeed are two separate terraces.

The present climate is Mediterranean with cool, wet winters (9 to 10°C) and warm dry summers (16 to 17°C) with the influence of fog. The climate of the late Pleistocene, when the marine terraces were cut, was similar to present day with only moderately cooler, wetter conditions during glacial periods (Gorsline et al. 1976, Johnson, 1977, Sims et al., 1981). The vegetation at present, on the terraces is composed of annual grasses and oak with redwood trees found in the stream channels.

There are numerous faults traversing these terraces from the North American-Pacific plate boundary (Anderson, 1990, 1994). Tectonics associated with these faults is one of the major components in forming marine terraces. The uplift rates along the coast according to Bradley and Griggs (1976) vary from 0.16 to 0.48m kyr^{-1}, but may be as fast as 1.15m kyr^{-1} (Perg and others, 1999) Understanding rates of uplift aid in dating the terraces and soil profiles.

Underlying the terraces is Tertiary Santa Cruz mudstone and Santa Margarita sandstone. These are easily eroded by waves and streams, but remain intact in interfluves (Clark, 1981: Bradley and Griggs, 1976). The Santa Cruz Mudstone is a thin to medium-bedded, brown and gray to light-gray, buff, and light-yellow siliceous mudstone with nonsiliceous mudstone and siltstone and minor amounts of sandstone. The siliceous nature implies organic deposition in a quiescent, deep-water environment. The Santa Margarita sandstone is a thin, bioturbated light-gray to grayish-orange to white, friable, very fine-to very coarse-grained arkosic sandstone. Fine-grained sandstone commonly contains glauconite. A quartz and feldspar pebble conglomerate crops out locally at the base of the section. The Santa Margarita Sandstone represents a shallow marine deposit (Barnes and others 2000).

3.0 Field and laboratory procedures

Conventional methods were used to describe, sample and analyze soils from the Santa Cruz terraces. Briefly, soil profiles were sampled by genetic horizons from backhoe pits and drill cores. Physical, extractive chemical, and total chemical analyses are reported in appendices following the conventions of Harden and others (1986), USGS Bulletin series 1590. A detailed explanation of our field and analytical methods is included in Singer and Janitzky (1986). Methods for iron and clay mineralogy are described in J.R. Aniku (1986).

4.0 Data set descriptions

4.1 Table 1 Locations of Sample Sites

List UTM coordinates and elevation for all terrace sample sites.

4.2 Table 2 Field descriptions

Table 2a, Field description abbreviation explanations: This table describes the abbreviations used in the following table. This includes explanations for soil structure, texture, consistence, horizon boundaries, roots and pores, and clay films.

Table 2b, Field description: A “--" indicates that property was not described. This table list the properties described in the field for all soil horizons and consist of:

No.—A numeric sequence to quickly cross compare data from table to table

Sample—Descriptor of pit

Horizon—General description of the sampled horizon according to conventions of the Soil Survey Staff (1998)

Depth—Depth of upper and lower boundaries, in cm, of the horizon

Lower Boundary—Description of contact with lower boundary according to conventions of the Soil Survey Staff (1998)

Munsell Color—Moist and dry color according to the Munsell color chart.

Texture—Soil texture class following conventions of Soil Survey Staff (1998), a + indicates more clay

Structure—Soil structure strength, size and type according to conventions of Soil Survey Staff (1998)

Consistence—Consistence according to conventions of Soil Survey Staff (1998), described for dry, moist and wet consistence

Roots—Root abundance and size according to conventions of Soil Survey Staff, (1998)

Pores—Pore abundance and size according to conventions of Soil Survey Staff, (1998)

Clay films—Clay frequency, thickness and morphology according to conventions of Soil Survey Staff (1998)

pH—The pH of the sample as determined in the field

4.3 Table 3 Physical properties

This table yields data from particle size analysis delineated according to classification of Soil Survey Staff, (1998). The first three columns are the same as the Table 2. The other columns are as follows:

Basal depth—Lower depth of sample horizon in cm

Bulk Density—Grams soil per cubic centimeter on an oven-dry basis

Texture—Texture according to the particle size distribution and as defined by Soil Survey Staff (1998)

4.4 Table 4 Extractive chemical analyses

The first three columns are the same as the Table 2. Analyses performed on selected samples, <2 mm fraction, quantifying, organic carbon, cation exchange capacity, Fe, Al, pH, exchangeable Na, K, Ca, Mg, and N.

4.5 Table 5 Mineralogy

Analyses performed selected samples to determined presence of Kaolinite, Mica, Chlorite-Vermiculite, Gibbsite, expanding clays, Quartz and Feldspar.

4.6 Table 6 Total chemical analyses of the fine (<47 µm) fraction by X-ray fluorescence.

The first three columns are the same as the Table 2. Analyzed for Quartz (SiO_2), Alumium Oxide (Al_2O_3), Iron Oxide (Fe_2O_3), Magnesium Oxide (MgO), Calcium Oxide (CaO), Sodium Oxide (Na_2O), Potassium Oxide (K_2O), Titanium Dioxide

(TiO_2), Phosphorus Pentoxide (P_2O_5), Manganous Oxide (MnO), Zirconium Dioxide (ZrO_2).

4.7 Table 7 Total chemical analyses of the <2mm fraction by X-ray fluorescence.

The first three columns are the same as the Table 2. Analyzed for Quartz (SiO_2), Alumium Oxide (Al_2O_3), Iron Oxide (Fe_2O_3), Magnesium Oxide (MgO), Calcium Oxide (CaO), Sodium Oxide (Na_2O), Potassium Oxide (K_2O), Titanium Dioxide (TiO_2), Phosphorus Pentoxide (P_2O_5), Manganous Oxide (MnO), Zirconium Dioxide (ZrO_2).

5.0 References

Alexander,C.S., 1953, The marine and stream terraces of the Capitola-Watsonville area: California University Publications Geography, v. 10, p. 1-44.

Anderson, R.S., 1990, Evolution of the northern Santa Cruz Mountains by advection of crust past a San Andreas Fault bend.: Science, v. 249, p. 397-401.

———1994, Evolution of the Santa Cruz Mountains, California, through tectonic growth and geomophic decay.: Journal of Geophysical Research, v. 99, no. B10, p. 20161-20179.

Aniku, Jacob Robert Francis, 1986, Trends of pedogenic iron oxides in a marine terrace chronosequence. Davis, University of California, Ph.D. dissertation, 227 p.

Barnes, J. Roberts, S., and Mills, S., 2000, Description of map units for the geology of the Pescadero/Butano creek watershed, and the Half Moon Bay and Montara Mountain quadrangles, San Mateo County, California. USGS Open-File Report 00-127..

Bradley, W.C., 1956, Carbon-14 date for a marine terrace at Santa Cruz, California: Geological Society of America Bulletin, v. 67, p. 675-677

———1957, Origin of marine-terrace deposits in the Santa Cruz area, California: Geological Society of America Bulletin, v.67, p. 421-444.

———1958, Submarine abrasion and wave-cut platforms: California: Geological Society of America Bulletin, v.69, p. 967-974.

———1965, Marine Terraces on Ben Lomond Mountains, California, in Wahrhaftig, C., and others, eds., Internat. Assoc. Quaternary Research 7th Cong., field conf. I guidebook, Northern Great Basin and California: p148-150.

Bradley, W.C. and Addicott, W.O. 1968, Age of first marine terrace near Santa Cruz, California: California: Geological Society of America Bulletin, v. 79, p. 1203-1210.

Bradley, W.C. and Griggs, G.B. 1976, Form, genesis, and deformation of central California wave-cut platforms: California: Geological Society of America Bulletin, v. 87, p. 433-449.

Branner, J.C., Newsom, J.F., and Arnold, Ralph, 1909, Santa Cruz folio: U.S. Geol. Survey and Geol. Atlas, Folio 163, 11 p.

Bryant, R.B., N. Curi, C. B. Roth, and Franzmeir, D.P., 1983. Use of internal standard with differential X-ray diffraction analysis for iron oxides. Soil Sci Soc. Amer. J. 47: 168-173.

Clark, J.C., 1966, Terriary stratigraphy of the Felton-Santa Cruz area, Santa Cruz Mountains, California: Stanford, Calif., Stanford University, Ph.D. dissertation, 184 p.

Fine, P., Singer,M.J. 1989, Contribution of ferrimagnetic minerals to oxalate extractable and dithionite extractable iron.: Soil Science Society of America Journal, v. 53, no. 1, p. 191-196

Gorsline, D.S., Pao, G.A., Prensky, S. E., and Mulhern, M., 1976, High resolution studies of paleo-climatic and paleo-oceanographic history in California Contental Borderland basin sediments, AAPG Bull., 60, 675.

Hanks, T.C., Bucknam, R.C., Lajoie, K.R., Wallace, R.E., 1984, Modification of Wave-Cut and Faulting-Controlled Landforms: Journal of Geophysical Research, v. 89, no. B7, p. 5771-5790.

Harden, J.W., 1986, Soils developed in granitic alluvium near Merced, California, in Harden, J. W., (ed): A series of soil chronosequences in the western United States U.S. Geological Survey Bulletin 1590A, 35p

Johnson, D.L., The late Quaternary climate of coastal California: Evidence for an ice age refugium, Quat. Res., 8, 154-179, 1977

Lajoie, K.R., Weber, G.E., and Tinsley, J.C., 1972, Marine terraces deformation: San Mateo and Santa Cruz Counties, *in* Progress report on USGS Quaternary studies in San Francisco Bay area, an informal collection of preliminary papers, Friends of Pleistocene guidebook: p.100-113.

Lawson, A.C., 1893, The post-Pliocene diastrophism of the coast of southern California: California University Department of Geological Science Bulletin, v1, p.115- 160.

Page, B.M. and Holmes, C.N., 1945, Geology of the bituminous sandstone deposits near Santa Cruz, Santa Cruz County, California: U.S. Geological Survey Oil and Gas Inv. Prelim. Map 27.

Perg, L.A., Anderson, R.S., and Finkel, R.C., 1999, 10Be and 26Al dating of the Santa Cruz Marine Terraces, California.: EOS transactions, AGU Supplement, v. 80, no. 46, p. F443.

Rode, Karl, 1930, Geomophogenie des Ben Lomond (Kaliforien), eine Studie über Terrassenbildung durch marine Abrasion: Zeitschr. Geomorphologie, v. 5, p.16-78.

Rosenbloom, N.A. and Anderson, R.S. 1994, Hillslope and channel evolution in a marine terraced landscape, Santa Cruz, California.: Journal of Geophysical Research, v. 99, no B7, p. 14013-14029.

Schulze, D.G. 1981. Identification of iron oxide minerals by differential X-ray diffaction. Soil Sci. Soc. Am. J. 45: 437-440.

Sims, J.D. Adam, D.P., and Rymer, M.J., Late Pleistocene stratigraphy and palynology of Clear Lake, in Research in Ceysers-Clear Lake Geothermal Area, Northern California, U.S. Geological Survey Prof. Pap. 1141, edited by R.J. McLaughlin and J.M. Donnelly-Nolan, 219-230, 1981.

Singer, M.J and Janitzky, P, Editors Field and Laboratory Procedures Used in a Soil Chronosequence Study, U.S. Geological Survey Bulletin 1648.

Soil Survey Staff, 1998. Keys to Soil Taxonomy. U.S. Dept. Agric., 8th ed, 326 p. Washington D.C.

Wilson, M.E., 1907, Shore topography near Davenport, Santa Cruz County: California Physical Geography Club Bulletin, v. 1, p. 1-14.

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Table 1. Locations of Sample Sites Terraces names based on Bradley and Griggs (1976)		
Sample Site	UTM Coordinates	Elevation
Highway 1 (Davenport) Terrace Site SC2	10s 0586434e 4090149n	14m
Western Terrace	Not Sampled	Not Sampled
Wilder Terrace Site SC3 (upper site) Site SC4 (lower site) Site SC5 (lower site)	10s 0584467e 4093212n 10s 0584486e 4092971n 10s 0584486e 4092971n	126m 116m 116m
Black Rock Terrace Site SC1 Site SC7 Site SC9	10s 0583143e 4093268n 10s 0583143e 4093268n	138m 138m
Quarry/ Black Rock Terrace Site SC 6 Site SC8	10s 0582905e 4093610n	159m

Table 2

Field description abbreviation explanations

SOIL STRUCTURE

Grade	Size	Type
m; massive	vf; very fine (v thin)	gr; granular
sg; single grained	f; fine (thin)	pl; platey
1; week	m; medium	pr; prismatic
2; moderate	c; course (thick)	cpr; columnar
3; strong	vc; very coarse (v thick)	abk; angular blocky
		sbk; subangular blocky

*If two structures-listed as primary and secondary

SOIL TEXTURE

Size	Texture	Texture
co; coarse	S; sand	SCL; sandy-clay loam
f; fine	LS; loamy sand	CL; clay loam
vf; very fine	SL; sandy loam	SiCL; silty-clay loam
	L; Loam	SC; sandy clay
	SiL; silt loam	C; clay
	Si; silt	SiC; silty clay

SOIL CONSISTENCE

Dry	Moist	Wet	Wet
lo; loose	lo; loose	so; nonsticky	po; nonplastic
so; soft	vfr; very friable	ss; slightly sticky	ps; slightly plastic
sh; slightly hard	fr; friable	s; sticky	p; plastic
h; hard	fi; firm	vs; very sticky	vp; very plastic
vh; very hard	vf; very firm		
eh; extremely hard	efi; extremely firm		

HORIZON BOUNDARIES

Distinctness	Topography
va; very abrupt	s; smooth
a; abrupt	w; wavy
c; clear	i; irregular
g; gradual	b; broken
d; diffuse	

ROOTS AND PORES

Size	Abundance	Pore Shape
vf; very	1; few	tub; tubular
f; fine	2; common	ir; irregular
m; medium	3; many	v; vesicular
co; coarse		

CLAY FILMS

Frequency	Thickness	Morphology
v1; very few	n; thin	of; ped face coatings
1; few	mk; moderately thick	br; bridging grains
2; common	k; thick	po; pore linings
3; many		(w; occours as waves or lamellae)
4; continuous		co; coats on clasts

Table 3. Physical properties

No.	Sample	Horizon	Basal Depth (cm)	Bulk Density (g/cm^3)	Texture	Total sand (%)	Very coarse sand (%)	Coarse sand (%)	Medium sand (%)	Fine, very fine sand (%)	Silt (%)	<2-mm clay (%)	<1-mm clay (%)
					Alluvium of Davenport terrace								
1	SC2	A1	29	1.57	sandy loam	69.03	0.94	3.77	8.80	55.52	21.71	9.26	7.78
2	SC2	A2	50	1.70	sandy loam	70.08	0.10	2.48	6.83	60.66	20.26	9.66	4.46
3	SC2	B1	90	1.76	sandy clay loam	68.33	0.62	3.85	8.84	55.02	17.05	14.62	13.56
4	SC2	B2	106	1.96	sandy clay loam	66.80	0.10	2.47	7.73	56.49	16.30	16.90	13.93
5	SC2	B3	170	1.65	sandy clay loam	83.67	0.00	1.12	12.30	70.25	3.02	13.31	12.24
6	SC2	C1ox	200	1.66	sand	96.36	0.00	3.13	20.61	72.62	1.74	1.90	1.68
7	SC2	IIC2	457	--	sand	97.47	0.20	0.91	5.99	90.36	1.60	0.93	0.89
8	SC2	IICn	518	--	sand	97.47	0.00	1.32	5.36	90.79	1.24	1.29	1.18
					Alluvium of Wilder terrace								
9	SC3	A11	8	1.32	clay loam	45.10	1.13	8.76	11.68	23.54	32.90	22.00	15.20
10	SC3	A12	23	1.51	clay loam	43.92	2.04	9.56	10.96	21.36	33.94	22.14	15.19
11	SC3	A3	87	1.50	clay loam	41.03	1.49	7.93	10.60	21.01	35.26	23.71	15.94
12	SC3	IIB21t	126	1.57	clay loam	41.75	1.99	8.85	10.64	20.28	31.53	26.72	20.83
13	SC3	IIB22t	190	1.82	clay loam	52.09	3.28	11.43	13.92	23.46	23.93	23.98	19.56
14	SC3	IIIB23t	240	1.77	clay	51.94	2.87	14.91	15.46	18.70	21.06	27.00	22.04
15	SC3	IIIB31	325	1.90	sandy clay	55.68	1.84	15.15	18.12	20.57	19.45	24.87	19.81
16	SC3	IIIB32	390	1.88	sandy clay	65.10	1.22	15.82	21.63	26.43	10.58	24.32	20.12
28	SC5	All	2.5	--	sandy clay loam	57.99	0.11	10.79	17.67	29.42	24.71	17.30	13.63
29	SC5	A12	25	1.69	sandy clay loam	53.26	1.05	11.45	15.02	25.74	24.98	21.76	16.85
30	SC5	B1	60	1.56	clay	48.96	1.03	11.57	14.05	22.31	21.54	29.50	25.25
31	SC5	B21t	85	1.66	clay	48.46	1.29	12.59	15.46	19.13	12.49	39.05	35.00
32	SC5	B22t	111	1.75	clay	41.32	1.16	9.99	13.46	16.72	10.48	48.20	45.26
33	SC5	B31t	158	1.66	clay	52.79	1.14	12.19	17.15	22.31	14.90	32.31	30.83
34	SC5	B32	220	1.60	clay	57.32	1.26	10.33	18.23	27.50	13.26	29.42	27.95
35	SC5	B33	270	1.67	sandy clay	58.64	0.86	9.18	19.01	29.59	12.63	28.73	25.96
36	SC5	B34	325	1.65	sandy clay	59.31	0.43	5.30	15.48	38.10	11.38	29.31	26.71
37	SC5	B35	415	1.51	sandy clay loam	65.38	0.48	4.22	9.65	51.02	13.29	21.33	18.96
38	SC5	Cox	480	1.51	sandy clay loam	72.08	4.65	17.58	20.58	29.27	9.02	18.90	16.84
39	SC5 core	Cox	640	--	loamy sand	82.56	0.10	0.71	3.65	78.10	11.68	5.76	3.08

No.	Sample	Horizon	Basal Depth (cm)	Bulk Density (g/cm³)	Texture	Total sand (%)	Very coarse sand (%)	Coarse sand (%)	Medium sand (%)	Fine, very fine sand (%)	Silt (%)	<2-mm clay (%)	<1-mm clay (%)
40	SC5 core	Cox	762	--	loamy sand	84.64	0.63	1.04	3.24	79.73	9.09	6.27	3.89
41	SC5 core	Cox	823	--	loamy sand	85.14	0.21	8.88	3.41	72.65	10.28	4.58	2.02
42	SC5 core	Cox	1128	--	sandy loam	65.40	1.65	3.40	2.06	58.29	23.52	11.08	6.88
					Alluvium of Black Rock terrace								
43	SC1	A11	3	--	sandy clay loam	56.00	2.04	10.41	19.23	24.32	26.35	17.65	14.71
44	SC1	A12	50	1.52	clay loam	52.19	1.55	9.59	17.33	23.72	27.61	20.20	17.87
45	SC1	B11	65	1.67	sandy clay loam	56.23	1.99	10.74	18.37	25.13	22.37	21.63	20.68
46	SC1	B12	84	1.65	clay loam	52.26	1.21	9.36	19.13	22.56	22.60	25.14	23.00
47	SC1	B21t	128	1.70	clay	49.43	1.15	10.35	20.59	17.35	11.27	39.30	36.61
48	SC1	B22t	195	1.68	sandy clay	62.11	1.24	12.11	24.53	24.22	11.97	25.92	23.64
49	SC1	B31	270	1.71	sandy clay loam	69.49	2.82	15.51	30.72	20.44	9.71	20.80	18.50
50	SC1	IIB32	390	1.74	sandy clay	69.31	2.73	14.09	30.19	22.30	7.39	23.30	19.49
52	SC9	A11	4	--	clay loam	54.20	0.33	12.94	26.22	14.71	22.13	23.67	20.69
53	SC9	A12	53	1.55	clay	50.85	0.21	10.55	23.99	16.10	19.94	29.21	26.54
54	SC9	IIB2	122	1.65	sandy clay	70.24	0.00	22.16	38.61	9.47	5.29	24.47	22.79
55	SC9	IIIC1	191	1.22	sandy clay loam	60.11	0.22	8.35	22.75	28.79	26.22	13.67	9.89
56	SC9	IVC2	280	1.66	clay	54.03	9.13	12.54	12.83	19.53	16.43	29.54	24.68
57	SC9	VC3	420	1.64	sandy clay loam	75.84	2.93	27.41	26.76	18.74	11.38	12.78	8.99
59	SC7	A12	46	--	sandy clay loam	54.86	1.96	9.40	19.63	23.87	29.35	15.79	13.12
61	SC7	B12	93	--	clay loam	52.64	2.49	9.15	18.91	22.09	27.02	20.34	18.01
62	SC7	B13	107	--	clay loam	51.10	2.09	8.69	18.74	21.57	24.90	24.00	23.25
					Alluvium of quarry terrace								
65	SC6	A11	2	--	clay	0.00	0.00	0.00	0.00	0.00	0.00	19.06	14.80
66	SC6	A12	16	1.53	clay loam	51.55	3.27	10.75	12.86	24.67	27.12	21.33	17.60
67	SC6	A2	24	1.49	sandy clay loam	47.79	3.17	10.13	12.08	22.41	27.62	24.59	--
68	SC6	B21	43	1.48	clay	45.63	2.69	9.31	11.38	22.25	27.23	27.14	25.52
69	SC6	IIB22	74	1.61	clay	38.39	2.44	8.47	10.44	17.05	12.89	48.72	45.35
70	SC6	IIB23	96	1.63	clay	37.64	2.41	8.49	10.33	16.41	5.89	56.47	52.00
71	SC6	IIIB31	185	1.68	sandy clay	60.48	5.29	13.50	14.69	27.00	13.53	26.00	19.78
72	SC6	IIIB32	264	1.56	sandy clay loam	63.28	0.97	4.86	8.96	48.49	17.11	19.61	13.87
73	SC6	IIIB33	314	1.63	sandy clay loam	77.53	0.77	14.87	23.13	38.77	10.75	11.72	9.21

No.	Sample	Horizon	Basal Depth (cm)	Bulk Density (g/cm^3)	Texture	Total sand (%)	Very coarse sand (%)	Coarse sand (%)	Medium sand (%)	Fine, very fine sand (%)	Silt (%)	<2-mm clay (%)	<1-mm clay (%)
74	SC6	IVC1ox	474	1.55	sand	93.35	0.64	25.51	39.65	27.54	4.38	2.27	1.97
75	SC8	A11	9	--	clay loam	42.12	0.21	7.87	15.76	18.28	37.88	20.00	16.49
76	SC8	A12	27	1.44	loam	42.47	0.54	8.71	15.16	18.06	33.86	23.67	0.00
77	SC8	A2	50	1.68	clay loam	41.97	0.43	7.92	14.86	18.98	32.65	25.38	21.26
78	SC8	IIB2t	110	1.64	clay	34.87	0.10	7.43	14.03	13.30	13.90	51.23	49.21
79	SC8	IIIB31	191	1.66	sandy clay	69.95	0.00	9.44	38.78	21.73	6.94	23.11	20.81
80	SC8	IIIB32	259	1.72	sandy clay	61.61	0.10	2.95	17.72	40.84	16.03	22.36	19.65
81	SC8	IVC1	328	1.94	clay	41.34	0.30	5.47	15.40	20.16	27.29	31.37	27.25
82	SC8	VC2	360	1.77	clay	55.20	0.82	7.45	23.47	23.47	13.86	30.94	27.76
83	SC8	VIC3	413	1.74	sandy clay	64.22	1.07	10.12	24.28	28.75	10.86	24.92	23.43
84	SC8	VIC4	480	1.61	sand	88.66	5.77	42.61	31.48	8.80	5.39	5.95	--

Extractive chemical analyses

All analyses in mg/100 g soil

No.	Sample	Horizon	Depth (cm)	Organic Carbon	Exchange Na	Exchange K	Exchange Ca	Exchange Mg	Exchange N	Cation exchange capacity	Fe	Al	pH
					Alluvium of Davenport terrace								
1	SC2	A1	29	1.07	0.24	0.13	6.62	0.89	--	5.29	0.48	0.09	6.81
2	SC2	A2	50	0.29	0.29	0.07	3.56	0.53	--	5.38	0.36	0.05	7.22
3	SC2	B1	90	0.12	0.29	0.07	4.61	1.25	--	7.20	0.50	0.06	7.25
4	SC2	B2	106	0.18	0.56	0.10	5.16	3.14	--	9.84	0.54	0.07	7.41
5	SC2	B3	170	0.03	0.84	0.10	3.78	8.05	--	12.85	0.72	0.09	7.42
6	SC2	C1ox	200	0.07	0.29	0.07	1.47	3.14	--	5.01	0.60	0.05	7.34
7	SC2	IIC2	457	0.08	0.40	0.09	3.01	2.68	--	6.38	0.49	0.04	7.14
8	SC2	IICn	518	0.07	0.34	0.07	1.80	3.86	--	6.11	0.51	0.05	7.52
					Alluvium of Wilder terrace								
9	SC3	A11	8	2.36	0.14	0.75	10.43	3.86	--	17.78	1.50	0.17	6.64
10	SC3	A12	23	1.84	0.04	0.35	10.54	1.25	--	17.69	1.62	0.20	6.48
11	SC3	A3	87	0.81	0.14	0.13	7.86	1.07	--	13.31	1.73	0.26	6.87
12	SC3	IIB21t	126	0.44	0.24	0.10	6.96	0.62	--	12.13	1.76	0.29	7.04
13	SC3	IIB22t	190	0.19	0.14	0.09	3.66	0.98	--	9.57	1.89	0.28	7.05
14	SC3	IIIB23t	240	0.18	0.14	0.09	3.06	2.96	--	10.21	0.16	0.26	6.50
15	SC3	IIIB31	325	0.17	0.24	0.09	2.73	3.22	--	8.84	1.77	0.24	6.88
16	SC3	IIIB32	390	0.17	0.19	0.09	2.45	2.86	--	7.38	1.43	0.20	6.68
28	SC5	All	2.5	4.12	0.24	0.86	9.21	1.47	--	16.59	1.04	0.17	6.10
29	SC5	A12	25	1.63	0.00	0.28	8.23	0.66	--	13.31	1.41	0.24	6.37
30	SC5	B1	60	0.77	0.08	0.20	6.43	0.44	--	11.49	1.95	0.38	6.45
31	SC5	B21t	85	0.45	0.30	0.14	6.35	1.03	--	12.22	2.34	0.48	6.53
32	SC5	B22t	111	0.40	0.30	0.12	6.05	2.86	--	14.77	2.82	0.45	6.56
33	SC5	B31t	158	0.27	0.24	0.07	2.27	2.64	--	9.94	2.41	0.38	5.44
34	SC5	B32	220	0.25	0.19	0.07	1.37	2.35	--	8.39	2.09	0.27	5.27
35	SC5	B33	270	0.20	0.24	0.09	1.29	2.49	--	7.75	1.77	0.27	5.21
36	SC5	B34	325	0.19	0.00	0.10	1.82	3.60	--	9.75	2.05	0.27	5.15
37	SC5	B35	415	0.18	0.24	0.14	2.65	4.47	--	11.12	1.70	0.24	5.49
38	SC5	Cox	480	0.10	0.30	0.13	2.20	3.45	--	7.93	0.75	0.11	5.62
39	SC5core	Cox	640	--	0.19	0.20	3.64	3.96	--	8.93	0.79	0.12	6.26

Table 4

No.	Sample	Horizon	Depth (cm)	Organic Carbon	Exchange Na	Exchange K	Exchange Ca	Exchange Mg	Exchange N	Cation exchange capacity	Fe	Al	pH
					Alluvium of Davenport terrace								
40	SC5core	Cox	762	--	0.35	0.25	5.14	6.38	--	13.95	0.91	0.12	6.19
41	SC5core	Cox	823	--	0.19	0.14	2.27	2.06	--	5.01	0.30	0.08	6.20
42	SC5core	Cox	1128	0.17	0.19	0.20	10.41	1.10	--	12.40	1.57	0.08	7.55
					Alluvium of Black Rock terrace								
43	SC1	A11	3	4.86	0.56	0.63	6.57	1.70	--	18.14	1.27	0.24	5.53
44	SC1	A12	50	0.75	0.19	0.13	2.24	0.98	--	9.94	1.38	0.29	5.71
45	SC1	B11	65	0.54	0.19	0.12	1.96	1.25	--	7.93	1.62	0.32	6.00
46	SC1	B12	84	0.49	0.19	0.10	2.07	1.87	--	8.44	1.53	0.20	5.90
47	SC1	B21t	128	0.25	0.40	0.12	4.39	5.31	--	14.13	3.24	0.47	6.00
48	SC1	B22t	195	0.22	0.40	0.10	2.89	3.14	--	10.21	4.18	0.45	6.03
49	SC1	B31	270	0.16	0.45	0.12	2.95	2.96	--	9.39	2.09	0.35	6.34
50	SC1	IIB32	390	0.16	0.50	0.13	3.06	3.04	--	10.21	2.00	0.12	6.35
52	SC9	A11	4	5.42	0.82	1.17	13.84	1.54	--	23.25	1.64	0.26	5.59
53	SC9	A12	53	2.32	0.64	0.48	12.13	0.69	--	17.32	2.14	0.35	6.09
54	SC9	IIB2	122	0.12	0.82	0.10	1.17	1.15	--	7.93	2.31	0.30	4.43
55	SC9	IIIC1	191	0.05	0.70	0.10	0.81	1.39	--	4.56	0.89	0.12	4.57
56	SC9	IVC2	280	0.04	1.18	0.10	2.71	5.29	--	14.31	2.12	0.15	4.48
57	SC9	VC3	420	0.05	0.76	0.08	1.27	2.24	--	5.92	0.59	0.08	4.83
59	SC7	A12	46	1.82	0.53	0.34	3.27	0.38	--	10.30	1.36	0.26	5.68
60	SC7	B11	76	0.76	0.59	0.20	1.94	0.61	--	7.75	1.54	0.32	5.65
61	SC7	B12	93	0.41	0.53	0.15	2.24	1.00	--	7.11	1.74	0.35	5.90
62	SC7	B13	107	4.00	0.59	0.15	2.55	1.54	--	8.11	2.15	0.44	5.99
					Alluvium of quarry terrace								
65	SC6	A11	2	2.32	0.24	0.62	6.20	1.54	--	17.60	1.31	0.23	5.50
66	SC6	A12	16	1.54	0.19	0.23	3.26	0.95	--	12.03	1.81	0.31	5.26
67	SC6	A2	24	1.37	0.08	0.25	2.43	1.03	--	11.94	2.07	0.37	5.09
68	SC6	B21	43	0.62	0.14	0.22	2.20	0.88	--	11.12	2.17	0.40	5.08
69	SC6	IIB22	74	0.29	0.41	0.23	1.82	2.72	--	14.95	3.73	0.61	5.10
70	SC6	IIB23	96	0.47	0.30	0.14	1.21	2.42	--	15.77	4.34	0.62	4.89
71	SC6	IIIB31	185	0.28	0.30	0.10	0.53	1.98	--	10.67	1.73	0.29	4.84
72	SC6	IIIB32	264	0.31	0.24	0.10	1.06	2.93	--	13.13	2.12	0.31	4.83
73	SC6	IIIB33	314	0.25	0.41	0.10	1.29	2.93	--	10.76	1.56	0.23	4.97
74	SC6	IVC1ox	474	0.25	0.64	0.23	1.43	2.01	--	6.11	0.33	0.12	5.49

Table 4

No.	Sample	Horizon	Depth (cm)	Organic Carbon	Exchange Na	Exchange K	Exchange Ca	Exchange Mg	Exchange N	Cation exchange capacity	Fe	Al	pH
Alluvium of Davenport terrace													
75	SC8	A11	9	2.50	0.59	1.21	9.69	1.00	--	19.14	1.29	0.19	5.48
76	SC8	A12	27	2.56	0.53	0.73	8.47	0.54	--	15.77	1.27	0.19	5.69
77	SC8	A2	50	0.94	0.47	0.37	4.36	0.38	--	10.67	1.74	0.36	5.61
78	SC8	IIB2t	110	0.30	0.59	0.21	2.45	2.86	--	14.86	3.13	0.32	4.59
79	SC8	IIIB31	191	0.04	0.64	0.11	1.38	2.47	--	10.39	0.64	0.12	4.85
80	SC8	IIIB32	259	0.07	0.94	0.15	1.94	3.25	--	9.12	1.31	0.16	5.07
81	SC8	IVC1	328	0.07	1.18	0.18	4.46	8.31	--	18.14	1.65	0.22	4.85
82	SC8	VC2	360	0.04	1.31	0.18	4.30	7.99	--	17.50	0.56	0.10	4.89
83	SC8	VIC3	413	0.04	1.18	0.18	4.20	7.43	--	17.32	0.43	0.12	5.10
84	SC8	VIC4	480	0.07	0.70	0.11	1.53	2.31	--	5.74	0.06	0.04	5.44

Mineralogy
Analysts: Jacob Aniku, University of California, Davis

+++,dominant; ++,moderate; +,trace; 0,not detected; --,not analyzed; XX,dominant; X,present.

Sample	Horizon	Depth (cm)	Kaolinite	Mica	Interstratified Chlorite-Vermuculite	Gibbsite	Expanding Clays	Quartz	Feldspar
Alluvium of Davenport terrace									
SC2	E	50	+++	+	++	+	+	XX	X
	Bt1	106	+++	+	++	+	+	XX	X
	C1	200	+	+	+	+	+	X	X
Alluvium of lower Wilder terrace									
SC5	A2	25	+++	+	++	+	0	XX	X
	Bt2	111	+++	+	++	+	+	XX	X
	BC1	220	+++	+	+	+	+	XX	X
Alluvium of Black Rock terrace									
SC1	A2	50	+++	+	++	+	0	XX	X
	Bt2	195	+++	+	++	+	+	XX	X
	2CB	390	+	0	+	0	0	XX	X
Alluvium of quarry terrace									
SC6	A2	16	+++	+	++	+	+	XX	X
	2Bt2	74	+++	+	++	+	0	XX	X
	2Bt3	96	+++	+	++	+	+	XX	X
	3CB	314	+++	+	+	+	0	XX	X

Total chemical analyses of the fine (<47µm) fraction by X-ray fluorescence
Analysts: A.J. Bartel, K.Stewart, and J. Taggart and R. Johnson and K. Dennen under J.R. Lindsay

All analyses in weight percent

No.	Sample	Horizon	Basal Depth (cm)	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	MnO	ZrO_2
			Alluvium of Davenport terrace											
1	SC2	A1	29	71.00	13.70	3.15	0.51	1.33	2.32	1.69	0.76	0.12	0.05	0.04
4	SC2	B2	106	61.60	17.40	5.94	0.86	1.28	1.92	1.26	0.85	0.05	0.03	0.03
8	SC2	IICn	518	50.60	16.00	12.40	3.54	2.54	1.82	1.28	0.80	0.17	0.13	0.02
			Alluvium of Wilder terrace											
29	SC5	A12	25	92.50	3.55	0.76	0.10	0.25	0.51	1.58	0.31	0.05	0.02	0.02
32	SC5	B22t	111	47.30	25.00	8.77	0.60	0.28	0.26	0.79	0.88	0.11	0.02	0.07
38	SC5	Cox	480	49.90	26.30	6.67	0.91	0.39	1.05	1.21	0.62	0.07	0.02	0.02
			Alluvium of Black Rock terrace											
44	SC1	A12	50	80.80	8.15	2.94	0.23	0.24	0.45	0.83	0.69	0.06	0.02	0.03
48	SC1	B22t	195	48.20	22.40	12.90	0.64	0.25	0.61	0.97	0.97	0.06	0.02	0.02
50	SC1	IIB32	390	86.60	5.81	2.09	0.24	0.51	1.17	1.88	0.76	0.05	0.03	0.06
			Alluvium of quarry terrace											
65	SC6	A11	2	69.30	12.40	4.11	0.32	0.36	0.79	1.96	1.03	0.13	0.02	0.05
66	SC6	A12	16	64.40	16.70	5.62	0.50	0.30	0.73	1.77	1.09	0.14	0.03	0.05
67	SC6	A2	24	61.30	18.80	6.53	0.52	0.25	0.66	1.57	1.08	0.14	0.03	0.05
68	SC6	B21	43	60.00	19.10	6.56	0.52	0.25	0.69	1.52	1.05	0.14	0.03	0.04
69	SC6	IIB22	74	46.70	26.10	9.42	0.57	0.09	0.29	0.77	0.96	0.09	0.02	0.03
70	SC6	IIB23	96	44.70	26.70	10.10	0.60	0.07	0.26	0.64	0.97	0.09	0.02	0.03
71	SC6	IIIB31	185	49.80	24.60	8.38	0.77	0.05	0.34	1.39	0.98	0.07	0.02	0.03
72	SC6	IIIB32	264	49.10	23.60	10.20	0.99	0.12	0.63	0.98	0.99	0.07	0.02	0.02
73	SC6	IIIB33	314	47.00	26.00	8.57	0.86	0.18	0.74	1.17	0.74	0.09	0.02	0.02
74	SC6	IVC1ox	474	47.80	29.30	4.17	0.64	0.51	1.14	1.54	0.50	0.05	0.02	0.02
76	SC8	A12	27	67.70	15.10	5.01	0.38	0.33	0.82	1.67	0.99	0.10	0.02	0.05
80	SC8	IIIB32	259	58.10	19.20	7.15	0.63	0.37	1.28	1.02	0.74	0.05	0.02	0.03
84	SC8	VIC4	480	54.00	24.20	4.46	0.89	0.93	1.65	1.16	0.71	0.05	0.02	0.04

Table 7

Total chemical analyses of <2 mm fraction by X-ray fluorescence
Analysts: A.J. Bartel, K.Stewart, and J. Taggart and R. Johnson and K. Dennen under J.R. Lindsay
All analyses in weight percent

No.	Sample	Horizon	Basal Depth (cm)	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	MnO	ZrO_2
			Alluvium of Davenport terrace											
2	SC2	A2	50	79.80	9.69	1.83	0.41	1.27	1.93	1.78	0.52	0.05	0.03	0.03
4	SC2	B2	106	66.90	14.80	4.65	0.80	1.65	2.24	1.46	0.86	0.05	0.04	0.05
			Alluvium of Wilder terrace											
29	SC5	A12	25	69.50	12.10	3.84	0.38	0.64	0.68	1.85	0.81	0.17	0.09	0.04
32	SC5	B22t	111	59.00	19.40	6.83	0.44	0.25	0.20	0.97	0.75	0.09	0.02	0.02
38	SC5	Cox	480	63.40	18.40	4.03	0.50	0.36	1.07	1.92	0.40	0.05	0.04	0.01
			Alluvium of Black Rock terrace											
44	SC1	A12	50	72.30	11.90	4.08	0.31	0.34	0.70	1.67	0.96	0.08	0.02	0.07
48	SC1	B22t	195	63.40	16.00	6.31	0.45	0.26	0.63	1.16	0.94	0.05	0.02	0.05
50	SC1	IIB32	390	61.90	19.10	4.85	0.64	0.99	1.63	1.64	0.57	0.07	0.02	0.02
			Alluvium of quarry terrace											
65	SC6	A11	2	67.00	10.50	3.59	0.37	0.44	0.51	1.59	0.88	0.12	0.04	0.05
66	SC6	A12	16	68.00	13.20	4.41	0.37	0.31	0.56	1.66	0.95	0.12	0.04	0.05
67	SC6	A2	24	67.20	14.40	5.03	0.42	0.25	0.40	1.56	1.00	0.12	0.03	0.05
68	SC6	B21	43	65.90	15.20	5.19	0.42	0.24	0.47	1.51	0.96	0.11	0.03	0.05
69	SC6	IIB22	74	54.90	20.80	8.20	0.42	0.08	0.17	0.87	0.87	0.08	0.02	0.03
70	SC6	IIB23	96	60.70	17.50	7.77	0.35	0.05	0.15	0.68	0.82	0.06	0.02	0.03
71	SC6	IIIB31	185	64.70	16.60	5.98	0.56	0.05	0.28	1.37	0.83	0.05	0.02	0.04
72	SC6	IIIB32	264	59.90	17.90	7.41	0.78	0.20	0.72	1.13	1.12	0.05	0.02	0.04
73	SC6	IIIB33	314	61.20	18.90	5.67	0.56	0.26	0.80	1.86	0.66	0.06	0.02	0.03
74	SC6	IVC1ox	474	75.70	13.20	1.27	0.22	0.45	1.12	2.77	0.18	0.05	0.02	0.01
76	SC8	A12	27	72.80	9.65	3.46	0.28	0.51	0.61	1.25	0.84	0.10	0.02	0.04
80	SC8	IIIB32	259	67.60	14.30	6.02	0.33	0.12	0.34	0.46	0.57	0.05	0.02	0.02
84	SC8	VIC4	480	74.10	14.30	1.33	0.29	1.49	2.45	1.81	0.25	0.05	0.02	0.10