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Heavy Minerals from the Palos Verdes Margin, Southern California: Data and Factor Analysis

by

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INTRODUCTION

Heavy or high-density minerals in the 63-250-_m (micron) size fraction (very fine and fine sand) were analyzed from 36 beach and offshore sites (38 samples) of the Palos Verdes margin to determine the areal and temporal mineralogic distributions and the relation of those distributions to the deposit affected by material discharged from the Los Angeles County Sanitation District sewage system (Lee, 1994) (Figure 1). Data presented here were tabulated for a report to the Department of Justice (Wong, 1994). The results of the data analysis are discussed in Wong (in press).

The study of heavy minerals is a common method of determining sources (provenance) and distributions of sediments (e.g., Van Andel and Poole, 1960). The choice of grain size is governed by ease of sample preparation, examination by optical microscopy, and comparability to previous studies. How representative the 63-250-_m heavy minerals are of the whole sample can be approximated by the amount of sand in the sample. Lee and others (1994) mapped a pre-effluent, effluent-affected, and surface layer in the study area off Palos Verdes. The amount of sand in the top and pre-effluent layers ranges from about 20 to 80 percent; in the middle of the effluent body, sand is less than 20 percent (Figure 2; MacArthur and others, 1994). Qualitatively, the 63-250-_m heavy minerals are more representative of the top and pre-effluent layer, but these minerals will also provide useful information about the middle layer.

SAMPLE COLLECTION

Offshore Samples. Box cores (approximately 22 x 30 x 60 cm deep) were collected from shelf sites on two surveys, F5-92-SC and S1-93-SC, conducted by the USGS in 1992 and 1993. Several 8-cm diameter cylindrical subcores were extracted from each box core for various analyses. Subsamples of 5-10 cm^3 were taken from the subcores for textural and mineralogic analyses at selected depths in the subcore.

Of 27 shelf subsamples for this study, 25 come from 2-cm segments in the upper 11 cm of core. Two other samples come from deeper intervals at USGS station 556, one from box core 147 at 31-33 cm, and one from gravity core 179 at 79-81 cm (hereafter referred to as 147-30 and 179-80, respectively) (Figure 3, Table 1). These were samples identified from other sediment parameters as being part of effluent-affected and pre-effluent strata, respectively (Lee, 1994).

Beach Samples. Sediment samples were collected from 11 beaches between Hermosa Beach in the north and Cabrillo Beach (east of Point Fermin) in the south (Figure 3) in September 1992. Samples of 600-1000 cm^3 in volume were taken from the uppermost 10 cm of the wave-swept (swash) zone of each beach.

SAMPLE PREPARATION AND ANALYSIS

Bulk Sample Preparation. Four size fractions were separated by sieving: less than 63 _ m, 63 _m to 250 _m, 250 _m to 2 mm, and greater than 2 mm (Table 1). The 63-250 _m fraction was set aside for density separation; the other size fractions were stored. The sediment finer than 63 _m was not retained.

Density Separation and Sample Counts. Low- and high-density ("heavy") minerals were separated from the 63-250-_m fraction in tetrabromoethane (specific gravity of the heavy liquid used ranged from 2.91 to 2.94). Representative splits of the low- and high-density fractions were permanently mounted in piccolyte (refractive index = 1.52) on 27 by 45 mm glass slides. The high-density mineral slides were analyzed by point counting. The samples from the low-density fraction were not analyzed further.

Between 300 and 600 heavy grains were counted to insure that at least a statistically representative 200 nonopaque grains were included. Grains were counted along longitudinal traverses of the grain mount. Minerals were identified by standard optical properties and, in some samples, confirmed by powder X-ray diffraction. The abundance of each mineral was calculated as a percent of total counts (Table 2).

In addition to mineral count percentages, a factor analysis was determined for this data set using the program FACAN (M.A. Noble, USGS, 1985, last revision 1993, written communication). The factors for this study were determined using the Q-mode method. The data were first scaled using the maximum value for each mineral. The cosine-theta statistic was used as the measure of similarity. Factors were rotated using the varimax method (see Joreskog et al., 1976, for further discussion of this statistical method). The percentages of 25 heavy-mineral species for 38 beach and offshore samples (columns 1-25, Table 2) constitute the input data set. After several test iterations, the final number of factors requested was nine, which accounted for 89 percent of the total data. The number of factors requested is a compromise between maximizing the amount of the total data accounted for and minimizing the number of factors based on progressively smaller amounts of the data accounted for. Of the nine, each of factors 5, 7, 8, and 9 accounts for less than five percent of the data. Plots of the resulting factors show the spatial distribution of related samples (Wong, in press).

The factor calculations are relatively unaffected by modifications to the data by omission of a mineral (the opaque grains) or changes in the mineral abundance within the calculated error. The results of several factor calculations for samples 2b, 103, and 152 (representative of factors 4, 3, and 1, respectively) with these modifications in the input data for each run are listed in Table 4. The factor loadings changed little with these variations: (a) the opaque minerals were omitted because of their lack of information about mineral provenances; (b) a mineral (epidotes) with moderate abundance (15 percent in sample 152) was replaced first with a low (11 percent) and then with a high (19 percent) value; and (c) a mineral (barite) with a large abundance (61 percent in sample 103) was replaced with low (54 percent) and then high (66 percent) values.

MINERAL DISTRIBUTIONS

The nonopaque heavy minerals with the greatest mean abundance are hornblende (31 percent), augite (14 percent), epidotes (9 percent), and barite (9 percent) (Table 2). The distributions of these minerals as well as carbonate fragments and glaucophane are plotted in Figures 4 through 9 for all the samples in plan view and for station 556 in profile.

Hornblende is concentrated in the samples on the outer shelf and downcore at station 556 (Figure 4). Figure 4 is a plot of combined green, brown, and basaltic hornblende abundance and shows that high values of 50 percent or more are common.

Augite is concentrated in the area around Abalone Cove and Portuguese Bend and offshore to about 30 m depth (Figure 5), with a maximum value of 88 percent of the heavy-mineral sample at Abalone Cove. Augite is brown to reddish-brown and consists of as much as 1.6 percent TiO_2 as determined by microprobe analysis (Table 3).

The distribution of epidote group minerals is similar to that for hornblende. The minerals have characteristic bright-yellow to colorless pleochroism and anomalous or high birefringence and consist of as much as 20 percent of the heavy-mineral fraction (Figure 6).

Barite is concentrated west of Long Point and offshore at station 104, and occurs in moderate amounts at White's Point (Figure 7). The sample from Long Point is 80 percent barite. This mineral is a barium sulfate distinguished by its high density, good cleavage, low positive optic angle, and characteristic X-ray diffractogram.

Carbonate fragments are abundant at Lunada Bay and White's Point beaches (Figure 8). Carbonate fragments appearing in the heavy-mineral fraction are probably aragonite from disintegrating shell fragments.

Glaucophane occurs in minor amounts except at Point Fermin where it is fairly common (Figure 9). The mineral is a low-grade metamorphic amphibole characterized by pleochroism in shades of blue and violet.

The mineral abundances are different in each of the surface, middle, and pre-effluent samples at station 556 (Table 2). The pre-effluent sample (179-80) is similar to that of the surface sample (147-10) in abundance of hornblende and augite. The surface sample is richer in epidote and apatite. The mid-effluent sample (147-32) has less hornblende and augite and more micas and carbonate fragments than the pre-effluent or surface samples. The pre-effluent and mid-effluent samples have about the same amount of epidotes.

FACTOR ANALYSIS

The results of the factor analysis are provided in two tables, the rotated factor scores matrix (Table 4) and the rotated factor loadings matrix (Table 6). The rotated factor scores matrix (Table 4) lists the relative weight or contribution of each mineral species to each factor. The mineral scores with the greatest magnitudes, whether positive or negative, are the ones that are important in distinguishing one factor from another. The significance of a high-scoring mineral is negligible if the original mineral abundance is very small (less than 0.5 percent in this data set). Minerals with large abundances (such as hornblende) usually contribute to one or more factors; minerals with relatively small (0.5 to 5 percent) abundances can be important in a factor by virtue of their presence or absence. The rotated factor scores for each factor with magnitude greater than 0.2 are highlighted in Table 4.

The rotated factor loadings matrix lists the weight of each factor in each sample (Table 6). The square of a factor loading value in percent is the proportion of the sample data explained by that factor. The sum of the squared loadings approaches unity if the nine factors can explain all the data in a sample. The nine factors explain 73 to 99 percent of the data in the surface samples and sample 147-32 and about 60 percent of the subsurface sample 179-80. Factor loadings of 0.32 and greater are highlighted in Table 6. These values squared represent 10 percent or more of the sample data explained by a factor; at less than 10 percent, the areal distribution of the factors becomes irregular.

Table 7 compares the calculated factors to the sample data. The calculated factors scores are listed with the mineral composition of (a) an average of the samples that have a factor loading of 0.32 or greater and (b) the mineral composition of the sample that has the maximum factor loading for that factor, i.e., the one that is the "ideal" of that factor in this data set. For example, in factor 1, the minerals with high scores are green hornblende, epidotes, sphene, and apatite. The abundance of the average factor 1 sample shows that hornblende and epidotes are the two most abundant minerals. Sphene and apatite occur in amounts less than 5 percent, but the systematic appearance of these minerals in samples of this factor elevate their scores in the factor calculations. On the other hand, an average factor 1 sample contains 10 percent augite (Ti_aug in the table); but sample 152, with a loading of 0.97 for factor 1, has less than 1 percent augite. This scatter of data resulted in a low score for augite in this factor. Consistency of appearance in samples determines whether a mineral defines a factor; however, this consistency criterion does not apply for mineral abundances less than 0.5 percent (lined-out values in Table 7).

Further discussion of mineral provinces are presented in Wong (in press).

ACKNOWLEDGMENTS

Rob Kayen and Brian Edwards assisted in the collection of the beach samples. Valerie Coombs prepared the samples for petrographic examination. Jim Hein provided a helpful review of this manuscript.

REFERENCES CITED

Joreskog, K.G., Klovan, J.E., and Reyment, R.A., 1976, Geological factor analysis: Amsterdam, Elsevier Scientific Publishing Company, 178 p.

McArthur, W.G., Fong, G., and Drake, D.E., 1994, Results of Grain Size and Settling Analyses of Sediment on the Palos Verdes Margin, in Lee, H.J., editor, 1994, The Distribution and Character of Contaminated, Effluent-affected Sediment, Palos Verdes Margin, Southern California. Expert Report, Appendix D.

Van Andel, T.H., and Poole, D.M., 1960, Sources of Recent Sediments in the Northern Gulf of Mexico: Journal of Sedimentary Petrology, v. 30, no. 1, p. 91-122.

Wong, F.L., 1994, Heavy-mineral provinces of the Palos Verdes area, southern California, in Drake, D.E., Sherwood, C.R., and Wiberg, P., editors, The fate of contaminated sediments on the Palos Verdes shelf and slope: Appendix J, Menlo Park, California, U.S. Geological Survey.

Wong, F.L., in press, Heavy mineral provinces of the Palos Verdes margin, southern California: Continental Shelf Research, __ p.

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LIST OF FIGURES

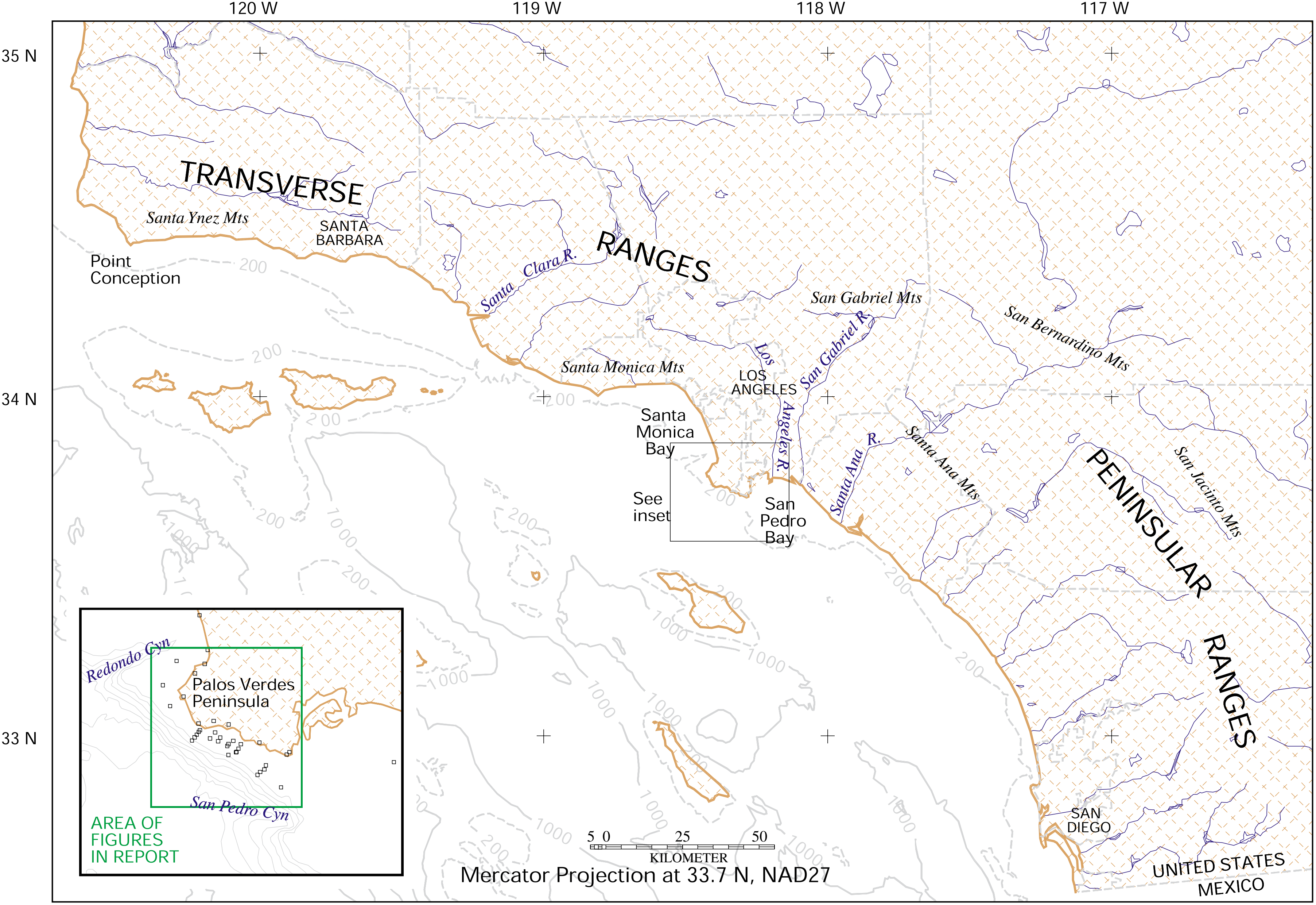

Figure 1. Regional map of coastal southern California from Point Conception to San Diego. From north to south, the major rivers (all ephemeral) are the Santa Clara, Los Angeles, San Gabriel, and Santa Ana. Inset shows location of Redondo Canyon and area of study.

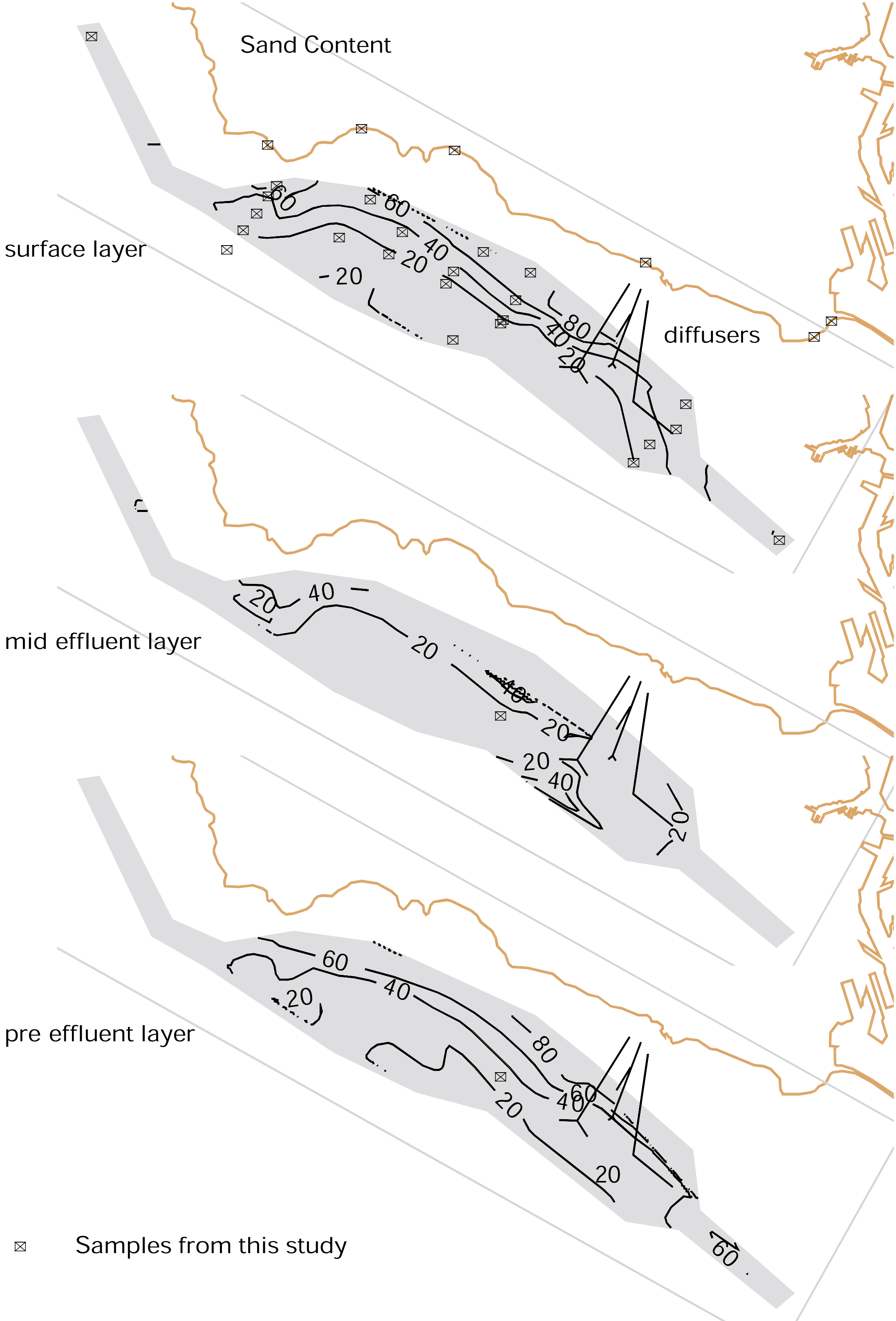

Figure 2. Abundance of sand (63-2000 *m) as percent of total sediment in the top and middle of the effluent affected deposit and in the pre-effluent on the Palos Verdes margin. Determined by disaggregated sediment method (Lee, 1994, Appendix D). Lines radiating from coast on the east are traces of LACSD sewage diffuser pipes.

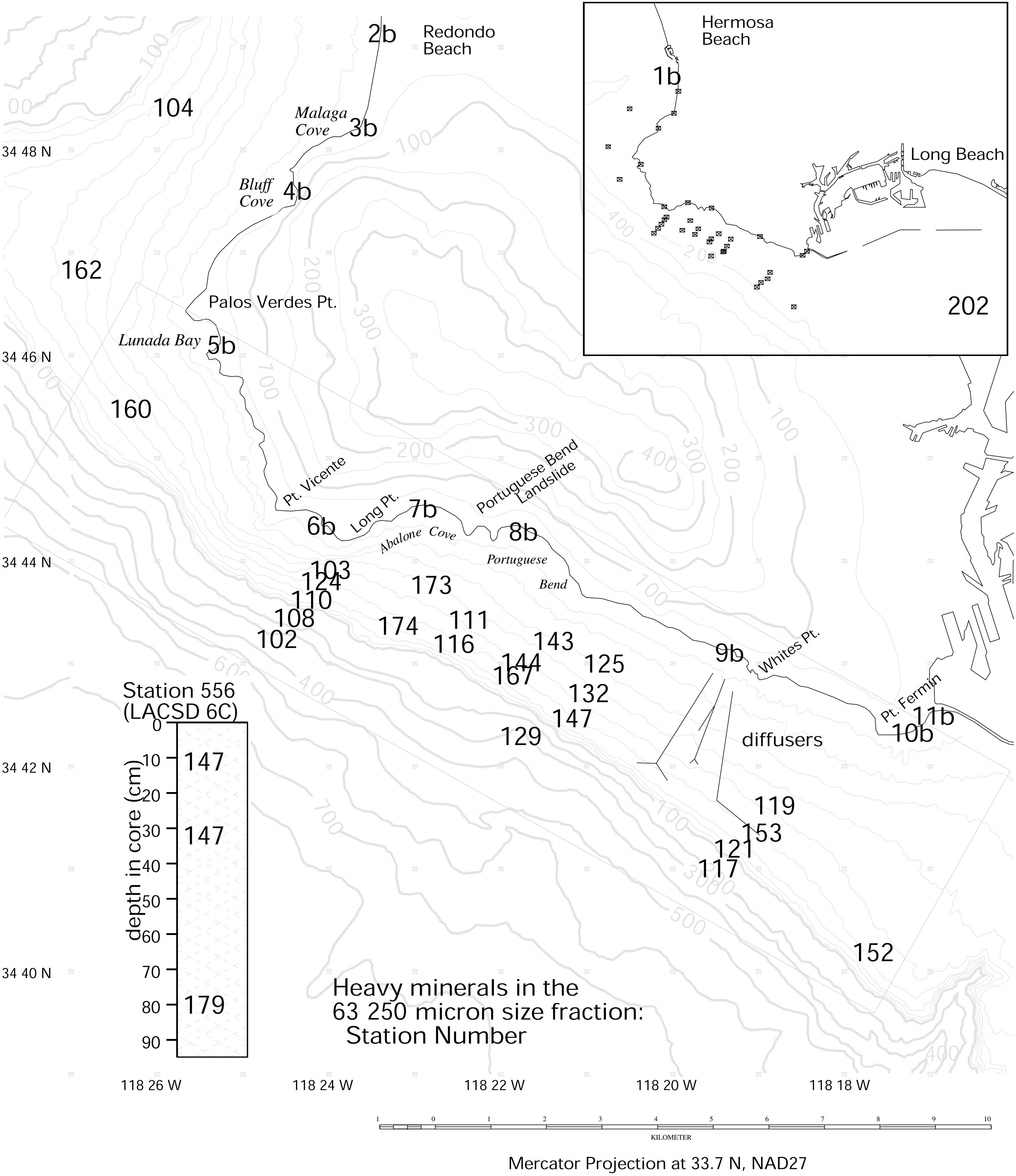

Figure 3. Map of heavy-mineral sample sites and location names in the Palos Verdes study area. The station numbers are centered on the sample location. The inset (upper right) is a regional map showing sample 1b at Hermosa Beach and sample 202 south of Long Beach. "Site 556" is a plot of the distribution of samples downcore at one location and includes two subsamples from box core 147 (at 9-11 and 31-33 cm depth) and one from gravity core 179 (79-81 cm depth). The lines radiating from Whites Point are the LACSD sewage diffuser pipers. The gray rectangular box encompasses the focal study area of the expert report (Lee, 1994).

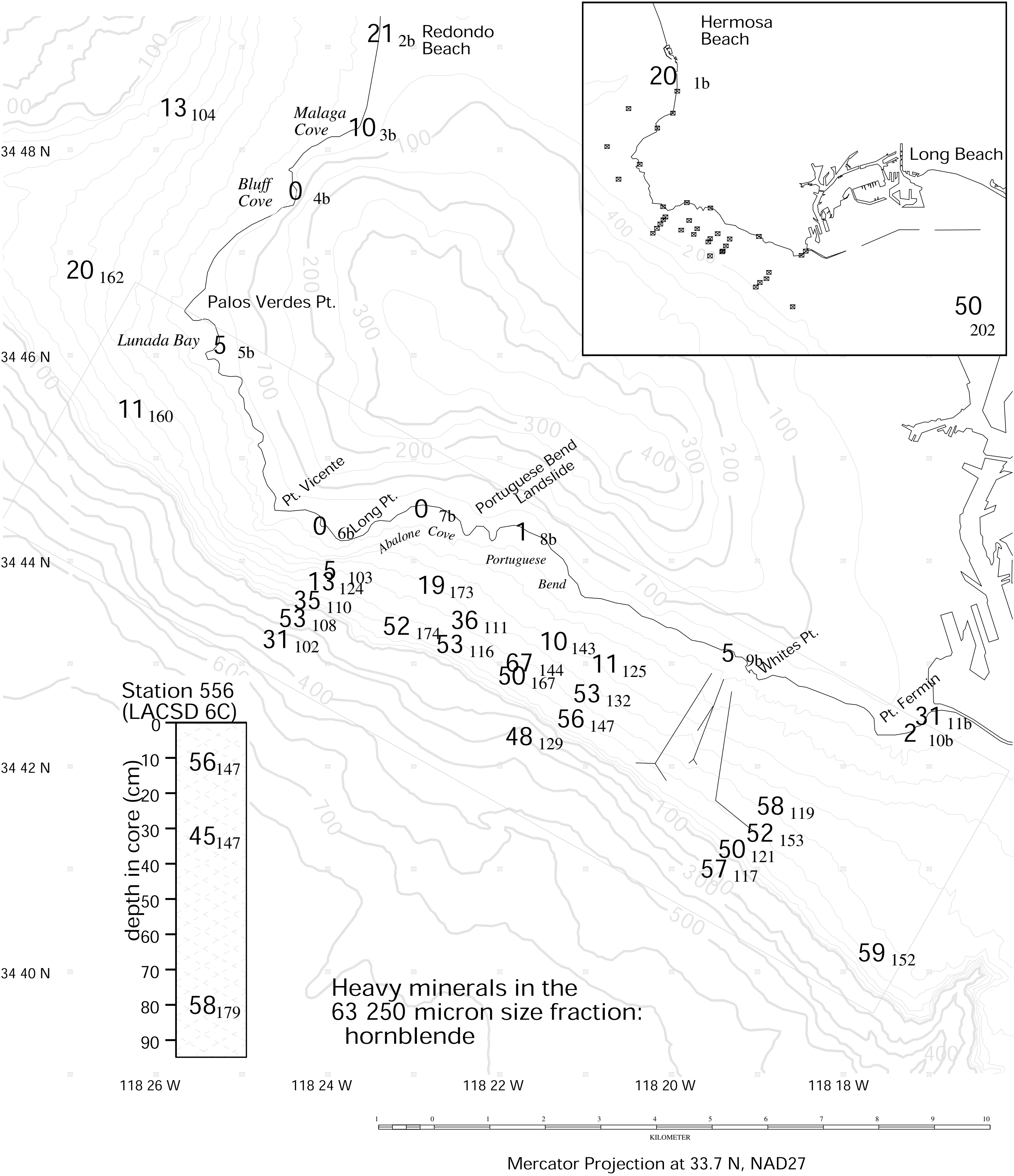

Figure 4. Plot of hornblende abundance in percent. Highest values occur in samples from greater than 40 m water depth; large values also appear in the subsurface samples at station 556. In this and Figures 7 through 11, mineral percent is centered on the sample site and core number is plotted to the lower

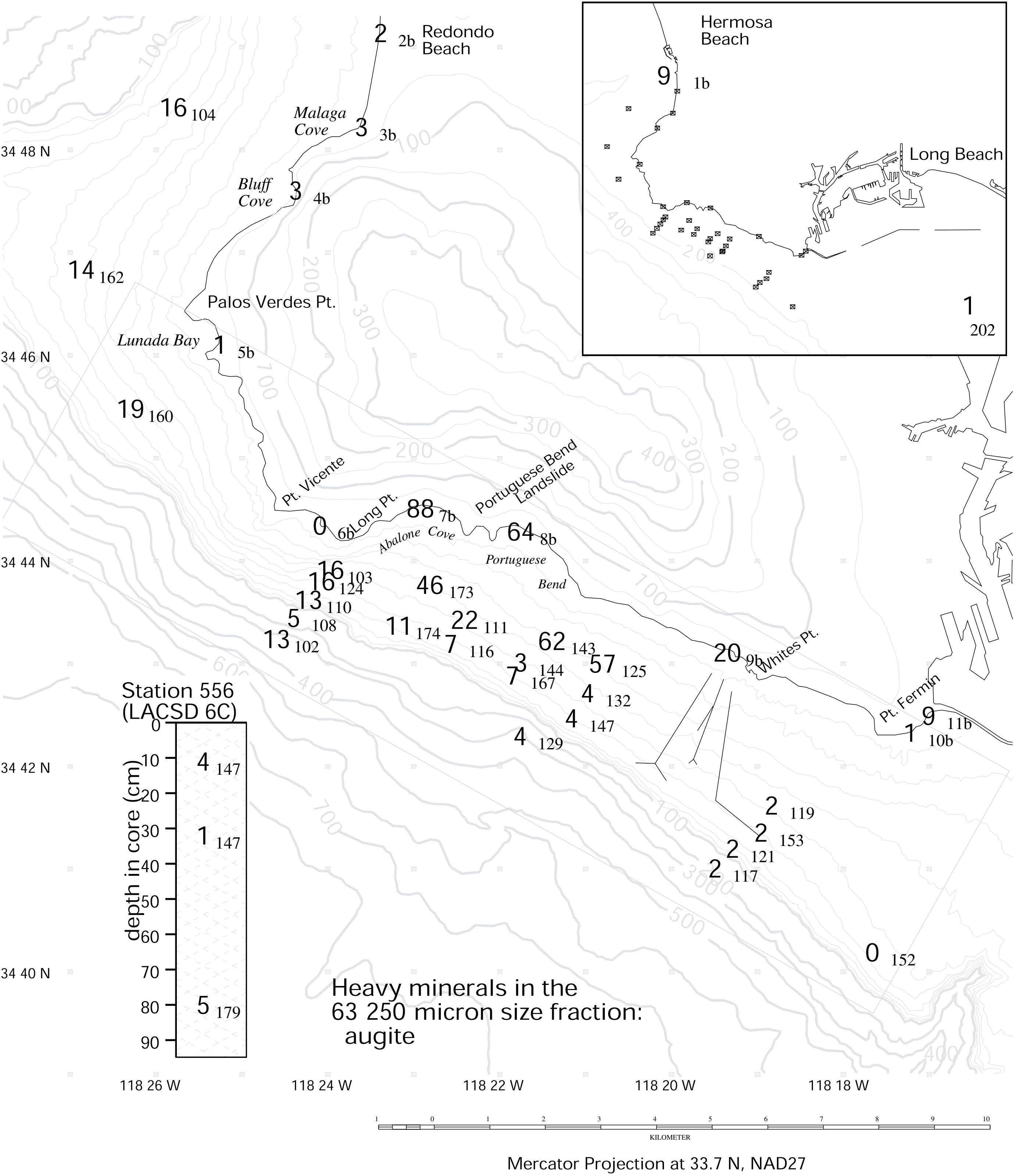

Figure 5. Plot of augite abundance in percent. Augite is concentrated in the coastal and shallow shelf area off Abalone Cove and Portuguese Bend.

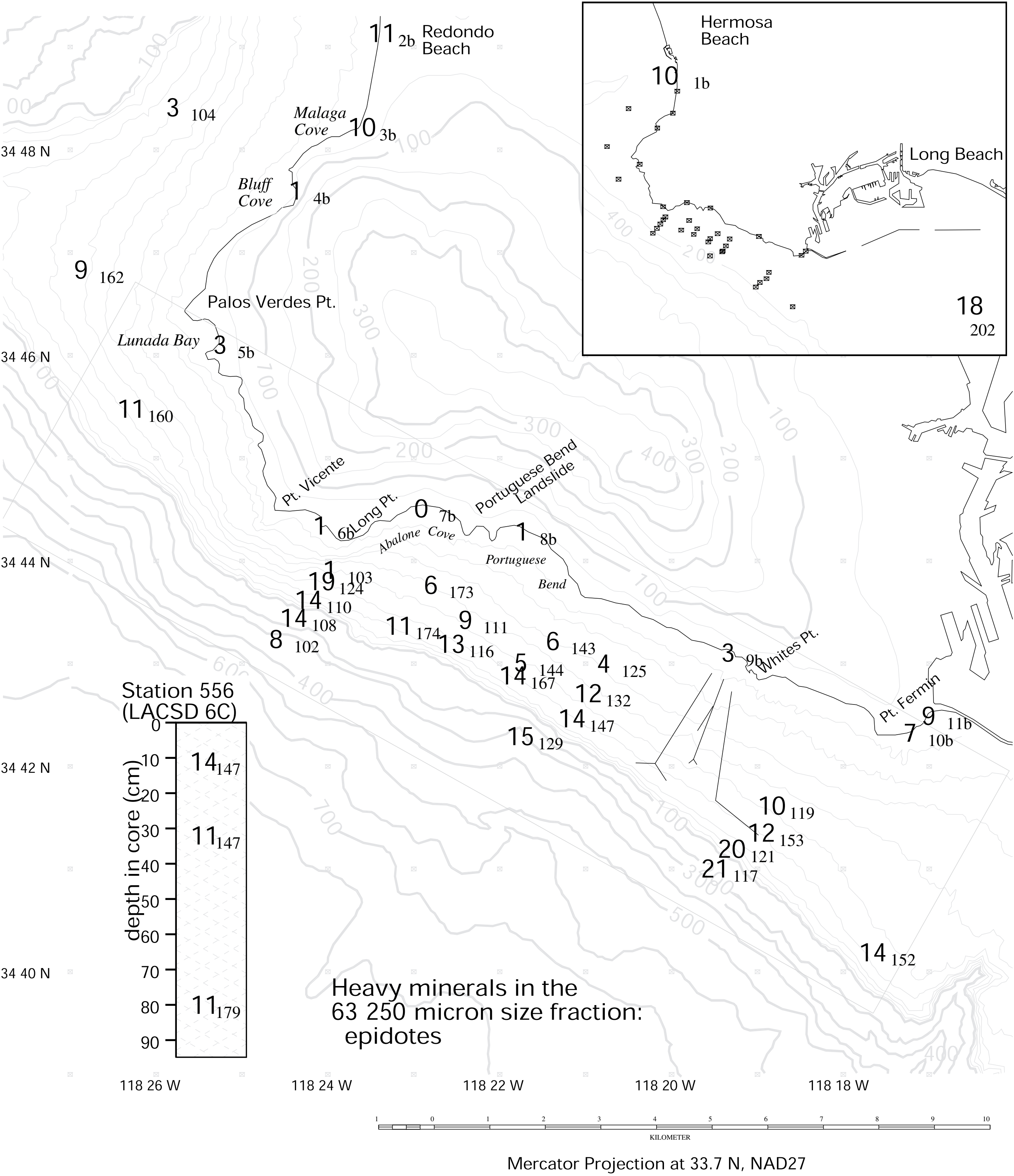

Figure 6. Plot of abundance of epidote group minerals in percent. Larger values occur in the shelf area deeper than 40 m and in the subsurface samples from station 556.

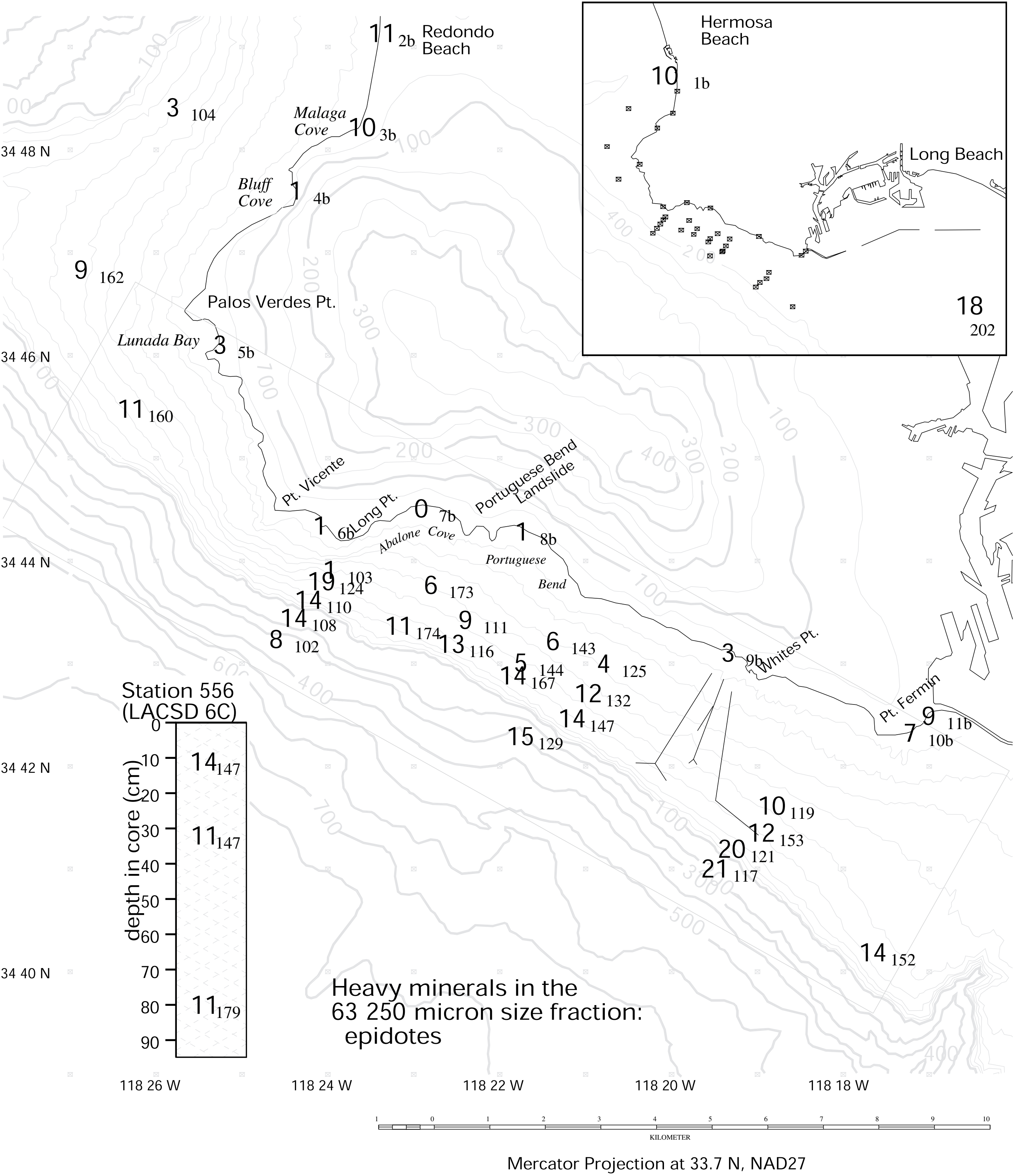

Figure 6. Plot of abundance of epidote group minerals in percent. Larger values occur in the shelf area deeper than 40 m and in the subsurface samples from station 556.

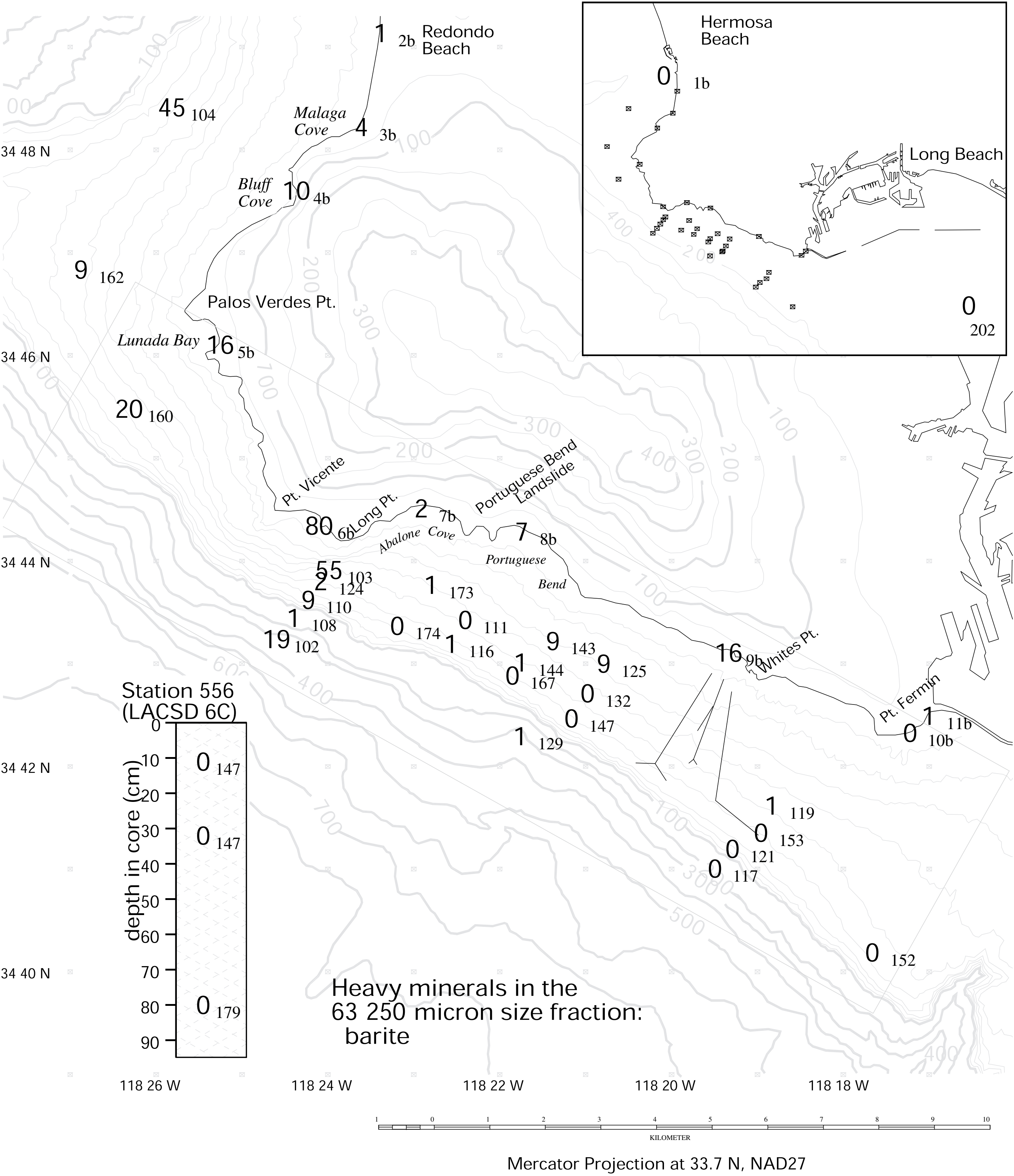

Figure 7. Plot of abundance of barite in percent. Main concentration is at and offshore of Long Point.

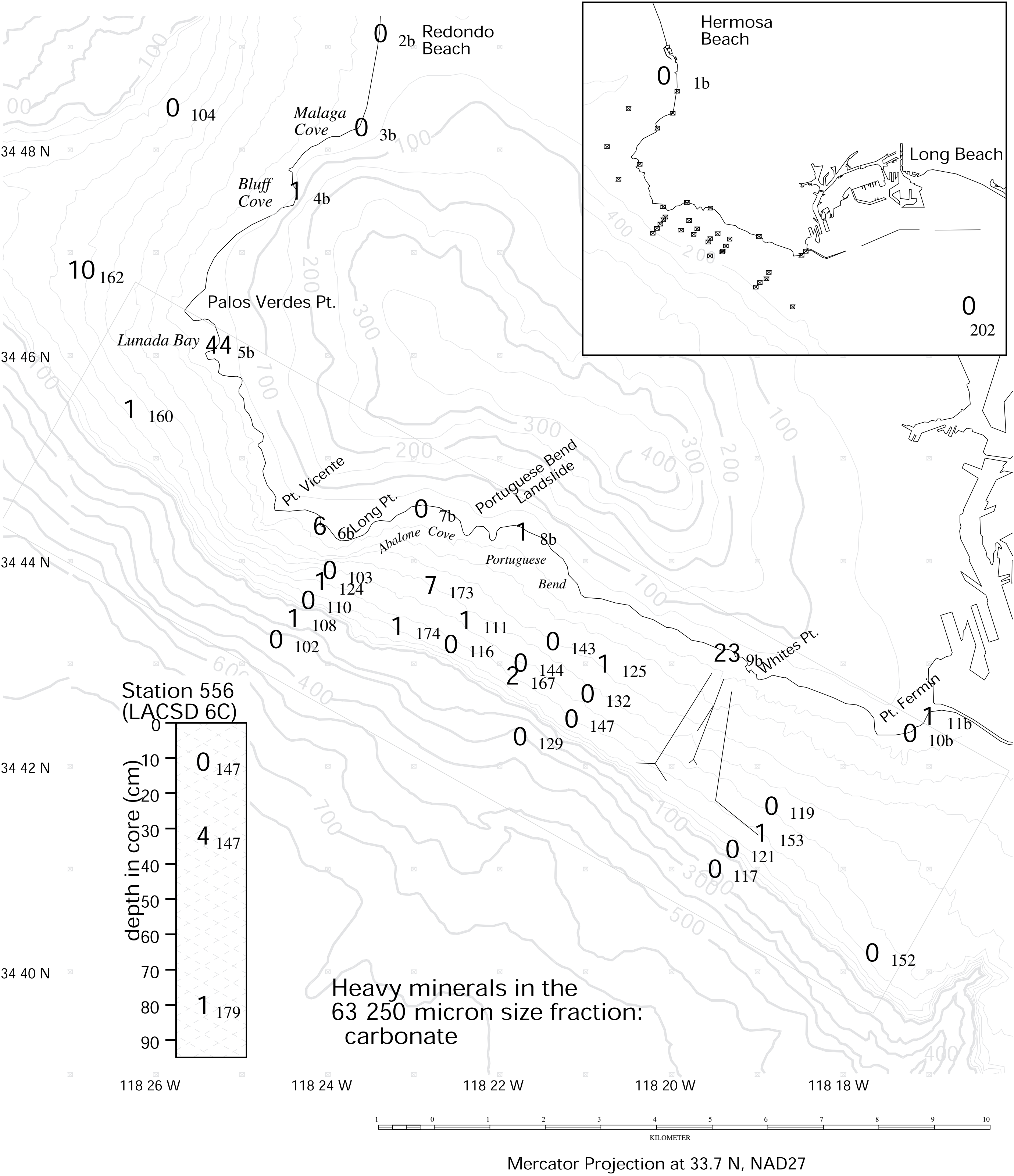

Figure 8. Plot of abundance of carbonate fragments in percent. Two separate maxima are at Lunada Bay and west of Whites Point.

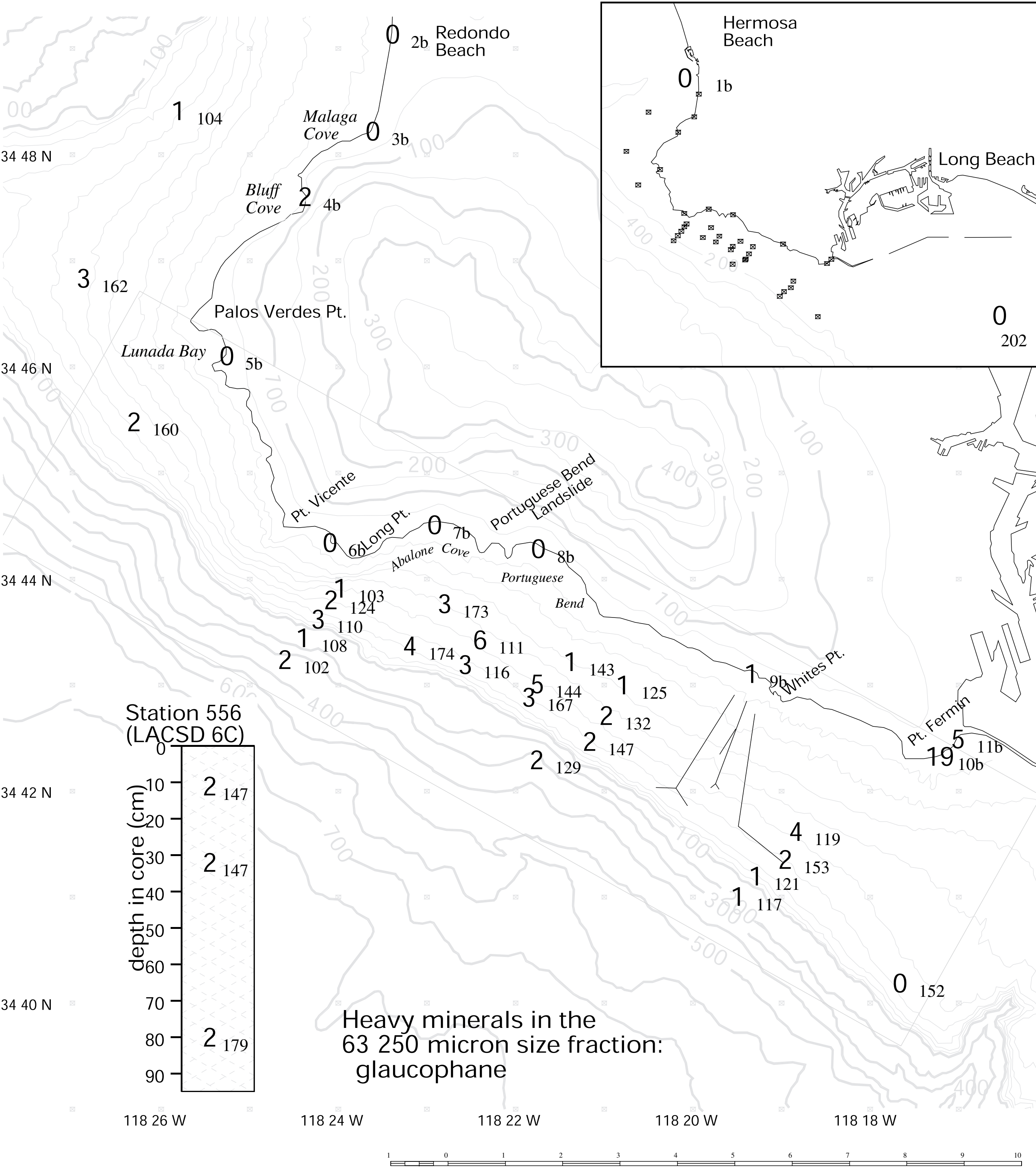

Figure 9. Plot of abundance of glaucophane in percent. Trace amounts occur in most of the samples but the highest concentration of this mineral is at Point Fermin where a glaucophane schist bearing sedimentary layer occurs in the cliffs.

Wong, F.L., 2001, USGS OFR 01-153

Table 1. Data generated during preparation of heavy mineral separates

			0*	1	2	3	3	3	4	5	6	7	7	8	9	9
Station	Cruise	Core	Interval cm	Prep Date	Raw Wt g	>2mm g	0.25-2 mm g	63-250um (2-4p) g	2-4p/raw %	2-4p/>63 %	specific gravity	light g	heavy g	wt%hvy (2-4p) %	magnt g	magnt (2-4p) %
1	PV0992	B	0-10	Jan-93	nd	nd	729.77	112.54	nd	13.4	2.9162	4.71	1.29	21.5	0.06	1
2	PV0992	B	0-10	Jan-93	nd	nd	199.24	19.92	nd	9.1	2.9162	4	0.91	18.5	0.05	1
3	PV0992	B	0-10	Jan-93	nd	nd	93.84	103.07	nd	52.3	2.9162	3.85	1.55	28.7	0.23	4.3
4	PV0992	B	0-10	Dec-92	nd	47.03	1088.57	13.75	nd	1.2	2.9241	3.04	0.31	9.3	0.02	0.6
5	PV0992	B1	0-10	Dec-92	nd	937.13	189.1	5.55	nd	0.5	2.9241	5.42	0.12	2.2	0.01	0.2
6	PV0992	B	0-10	Dec-92	nd	170.78	1143	0.48	nd	0	2.9209	0.27	0.23	46	nd	nd
7	PV0992	B	0-10	Dec-92	nd	4.1	493.6	267.8	nd	35	2.9268	2.66	1.38	34.2	nd	nd
8	PV0992	B3	0-10	Dec-92	nd	90.3	835	46.4	nd	4.8	2.9268	3.82	1.61	29.7	0.02	0.4
9	PV0992	B	0-10	Dec-92	nd	106.46	1117.33	0.62	nd	0.1	2.9241	0.51	0.08	13.6	nd	nd
10	PV0992	B	0-10	Dec-92	nd	626.94	101.53	1.99	nd	0.3	2.9203	1.76	0.22	11.1	nd	nd
11	PV0992	B	0-10	Dec-92	nd	nd	15.47	58.38	nd	79.1	2.9241	3.61	0.38	9.5	0.04	1
102	F5-92-SC	B1	?	May-93	nd	nd	1.42	1.97	nd	58.1	2.9243	1.94	0.03	1.5	0.002	0.1
103	F5-92-SC	B1	10	Apr-93	3.14	nd	0.23	1.16	36.9	83.5	2.9268	1.15	0.01	0.9	nd	nd
104	F5-92-SC	B1	10	May-93	nd	nd	0.02	2.54	nd	99.2	2.9237	2.46	0.07	2.8	0.001	0.1
108	F5-92-SC	B2	8	May-93	nd	nd	0.12	2.3	nd	95	2.9243	2.25	0.04	1.7	0.003	0.1
110	F5-92-SC	B1	10	May-93	nd	nd	0.08	1.01	nd	92.7	2.9237	0.98	0.02	2	0.002	0.2
111	F5-92-SC	B1	10	Nov-93	15.64	nd	0.01	3.58	22.9	99.7	2.9239	3.5	0.06	1.7	0.001	0
116	F5-92-SC	B1	10	Nov-93	10.02	nd	0.01	0.71	7.1	98.6	2.9239	0.71	0.02	2.7	nd	nd
117	F5-92-SC	B4	10	May-93	nd	nd	0.11	1.15	nd	91.3	2.9243	1.11	0.03	2.6	0.002	0.2
119	F5-92-SC	B2	10	May-93	nd	nd	0.03	4.49	nd	99.3	2.9237	4.27	0.22	4.9	0.005	0.1
121	F5-92-SC	B1	10	May-93	nd	nd	0.03	0.58	nd	95.1	2.9243	0.59	0.01	1.7	0.004	0.7
124	F5-92-SC	B1	10	May-93	nd	nd	0.54	4.86	nd	90	2.9237	4.78	0.02	0.4	0.004	0.1
125	F5-92-SC	B2	10	Apr-93	8.26	nd	4.26	1.1	13.3	20.5	2.9268	1.03	0.04	3.7	0.004	0.3
129	F5-92-SC	B2	10	May-93	nd	nd	0.02	0.56	nd	96.6	2.9243	0.64	0.01	1.5	0.005	0.7
132	F5-92-SC	B1	10	May-93	nd	nd	0.03	6.31	nd	99.5	2.9237	6	0.3	4.8	0.006	0.1
143	F5-92-SC	B1	10	Nov-93	14.64	nd	7.18	0.75	5.1	9.5	2.9239	0.73	0.07	8.8	nd	nd
144	F5-92-SC	B1	10	Nov-93	22.22	nd	0.02	5.29	23.8	99.6	2.9239	5.12	0.17	3.2	nd	nd
147	F5-92-SC	B3	10	May-93	nd	nd	0.02	1.25	nd	98.4	2.9237	1.22	0.02	1.6	nd	nd
147	F5-92-SC	B3	31-33	Nov-93	28.43	nd	0.03	1.39	4.9	97.9	2.9239	1.38	0.01	0.7	nd	nd
152	F5-92-SC	B2	0-2	Apr-93	3.93	nd	0.05	2.51	63.9	98	2.9268	2.31	0.21	8.3	0.005	0.2
153	F5-92-SC	B1	10	Apr-93	12.6	nd	3.1	3.4	27	52.3	2.9268	3.13	0.02	0.6	0.002	0.1
153	F5-92-SC	B1r	10	Apr-93	9.69	nd	2.41	3.1	32	56.3	2.9268	1.71	0.03	1.7	0.001	0.1
160	F5-92-SC	B1	10	May-93	11.15	nd	0.01	2.75	24.7	99.6	2.9243	2.74	0.01	0.4	nd	nd
162	F5-92-SC	B1	10	May-93	27.76	nd	0.07	9.64	34.7	99.3	2.9243	9.53	0.1	1	0.003	0
167	F5-92-SC	W1	10	Nov-93	10.28	nd	0.02	1.29	12.5	98.5	2.9239	1.24	0.02	1.6	nd	nd
173	F5-92-SC	B1	10	Nov-93	12.82	nd	0.05	4.64	36.2	98.9	2.9239	4.53	0.05	1.1	nd	nd
174	F5-92-SC	B1	10	Nov-93	15.98	nd	0.01	1.74	10.9	99.4	2.9239	1.47	0.03	2	nd	nd
179	F5-92-SC	G1	61-63	Nov-93	43.89	nd	0.04	15.24	34.7	99.7	2.9239	15.01	0.65	4.2	nd	nd
202	S1-93-SC	B1	9-11	May-93	47.64	nd	2.65	24.45	51.3	90.2	2.9429	22.35	2.31	9.4	nd	nd

* Notes:

0. 102: label obscured; assuming 10cm.
   179: corrected to 79-81cm for plots
1. Sample preparation date.
2. Raw, wet sample weight.
3. Weight of each size class. 63-250um = 2-4phi.
4. 63-250um size class as percent of raw weight.
   In beach samples, same as "2-4p/>63"
5. 63-250um size class as percent of weight of >63um class.
6. Specific gravity of tetrabromoethane.
7. Weight of light and heavy mineral separates.
8. Heavy minerals as weight percent of 63-250um size class.
9. Weight of extracted magnetic grains; as percent of 63-250um size class.

nd = no data; rounding automated by software

					1	2	3	4	5	6
station	cruise	sample	increm	totpts	hb_grn	hb_brn	hb_bas	amp_bg	trem	glcph
1b	PV0992	1b	0-10	344	19.48	0.00	0.29	0.00	0.29	0.29
2b	PV0992	2b	0-10	439	20.50	0.68	0.00	0.00	0.00	0.23
		2b'		435	21.15	1.15	0.00	0.23	0.00	0.00
3b	PV0992	3b	0-10	536	9.70	0.37	0.37	0.00	0.00	0.37
4b	PV0992	4b	0-10	538	0.37	0.00	0.00	0.19	0.00	2.23
5b	PV0992	5b	0-10	370	5.41	0.00	0.00	0.00	0.00	0.27
6b	PV0992	6b	0-10	311	0.32	0.00	0.00	0.00	0.00	0.00
7b	PV0992	7b	0-10	307	0.33	0.00	0.00	0.00	0.00	0.00
8b	PV0992	8b	0-10	336	0.89	0.00	0.00	0.00	0.00	0.30
9b	PV0992	9b	0-10	357	5.04	0.00	0.00	0.00	0.00	1.12
10b	PV0992	10b	0-10	579	1.55	0.17	0.00	0.00	0.00	19.00
11b	PV0992	11b	0-10	339	30.09	0.88	0.29	0.00	0.00	5.01
102	F5-92-SC	102-B1	9-11	312	31.41	0.00	0.00	0.00	0.00	2.24
103	F5-92-SC	103-B1	9-11	377	3.71	0.27	0.00	0.00	0.00	1.06
		103-B1'		370	5.41	0.00	0.00	0.00	0.00	0.81
104	F5-92-SC	104-B1	9-11	355	10.99	1.41	0.28	0.00	0.00	1.41
108	F5-92-SC	108-B2	7-9	331	52.57	0.00	0.00	0.00	0.00	0.91
110	F5-92-SC	110-B1	9-11	378	34.66	0.79	0.00	0.00	0.00	2.65
111	F5-92-SC	111-B1	9-11	402	32.84	0.25	0.25	0.00	0.00	7.46
		111-B1'		361	35.73	0.55	0.00	0.00	0.00	5.54
116	F5-92-SC	116-B1	9-11	343	52.19	0.58	0.00	0.29	0.58	3.21
117	F5-92-SC	117-B4	9-11	327	55.35	0.92	0.31	0.00	0.00	0.92
119	F5-92-SC	119-B2	9-11	356	57.02	1.40	0.00	0.00	0.00	3.93
121	F5-92-SC	121-B1	9-11	333	49.25	0.90	0.00	0.00	0.00	0.90
124	F5-92-SC	124-B1	9-11	343	11.95	1.17	0.00	0.00	0.00	2.04
125	F5-92-SC	125-B2	9-11	361	11.36	0.00	0.00	0.00	0.00	1.11
		125-B2'		339	13.86	0.00	0.00	0.88	0.00	2.36
129	F5-92-SC	129-B2	9-11	332	47.89	0.00	0.00	0.00	0.00	2.11
132	F5-92-SC	132-B1	9-11	380	51.84	0.79	0.00	0.00	0.00	2.37
143	F5-92-SC	143-B1	9-11	339	10.03	0.00	0.00	0.00	0.00	1.47
144	F5-92-SC	144-B1	9-11	351	66.95	0.28	0.00	0.00	1.42	5.41
147-10	F5-92-SC	147-B3	9-11	348	54.60	0.29	0.86	0.00	0.00	2.01
147-32	F5-92-SC	147-B3	31-33	366	45.08	0.00	0.00	0.00	0.27	2.19
152	F5-92-SC	152-B2	0-2	339	55.75	0.88	0.29	0.00	0.00	0.29
		152-B2'		417	54.44	4.80	0.00	0.00	0.00	0.24
153	F5-92-SC	153-B1	9-11	437	46.22	1.37	0.23	0.00	0.00	0.69
		153-B1'		394	46.45	2.28	0.51	0.00	0.00	0.51
153	F5-92-SC	153-B1r	9-11	401	50.62	1.25	0.25	0.00	0.00	2.00
160	F5-92-SC	160-B1	9-11	334	11.08	0.00	0.00	0.00	0.00	1.80
162	F5-92-SC	162-B1	9-11	332	18.07	1.51	0.00	0.00	0.00	2.71
167	F5-92-SC	167-W1	9-11	379	49.60	0.00	0.00	0.00	0.00	3.17
173	F5-92-SC	173-B1	9-11	377	18.57	0.00	0.00	0.00	0.27	2.92
174	F5-92-SC	174-B1	9-11	395	52.15	0.00	0.00	0.00	0.25	3.54
179-80	F5-92-SC	179-G1	79-81	353	57.79	0.28	0.00	0.00	0.00	1.70
202	S1-93-SC	202-B1	9-11	338	47.93	2.37	0.00	0.00	0.00	0.30
min					0.3	0.0	0.0	0.0	0.0	0.0
max					67.0	4.8	0.9	0.9	1.4	19.0
mean					30.2	0.6	0.1	0.0	0.1	2.2
std					21.2	0.9	0.2	0.1	0.2	3.0

Notes: see last page of table

station	7 hypers	8 ensta	9 Ti_aug	10 oth_cpx	11 epids	12 laws	13 pumpel	14 zirc	15 sphene	16 garnet
1b	7.27	0.00	9.01	8.14	10.17	0.00	0.00	0.87	8.14	2.62
2b	2.96	0.00	2.05	4.56	10.71	0.00	0.00	2.51	3.42	5.92
	3.68	0.00	1.15	4.14	7.13	0.00	0.00	2.53	3.68	6.44
3b	1.68	0.00	3.17	0.75	10.45	0.00	0.00	3.92	3.36	3.36
4b	0.19	0.00	3.35	17.10	1.30	0.00	0.00	0.00	0.37	0.37
5b	0.00	0.00	0.81	0.27	2.70	0.00	0.00	0.00	0.54	0.27
6b	0.00	0.00	0.00	0.00	0.64	0.00	0.00	0.00	0.00	0.00
7b	0.33	0.00	88.27	0.98	0.00	0.00	0.00	0.00	0.00	0.33
8b	0.00	0.00	63.99	1.19	1.49	0.00	0.00	0.00	0.00	0.00
9b	0.00	0.00	19.61	1.12	2.80	0.00	0.00	0.00	0.28	0.28
10b	0.00	0.00	1.04	0.00	7.08	6.04	1.04	0.35	1.73	0.35
11b	0.88	0.00	9.44	2.36	9.14	0.29	0.00	0.59	3.54	0.59
102	0.32	0.00	12.82	2.56	8.33	0.00	0.00	0.00	1.60	0.00
103	0.00	0.00	13.26	0.00	5.04	0.00	0.00	0.53	2.65	0.00
	0.27	0.00	15.68	1.08	1.08	0.00	0.00	0.27	1.89	0.00
104	0.00	0.85	16.06	3.38	2.54	0.85	0.00	0.56	1.41	0.28
108	0.00	0.00	5.44	1.51	14.20	0.00	0.00	0.30	5.74	1.21
110	0.26	0.00	12.96	2.38	14.02	0.26	0.00	0.00	2.91	0.79
111	0.50	0.00	23.38	5.97	6.22	1.00	0.00	0.25	3.23	0.00
	0.00	0.00	21.61	1.66	8.86	0.00	0.00	0.00	5.54	0.28
116	0.00	0.00	7.29	1.46	13.12	0.00	0.00	0.87	4.08	0.87
117	0.31	0.00	2.14	1.83	20.80	0.31	0.00	0.00	2.75	0.61
119	0.00	0.00	1.69	3.09	9.83	0.00	0.00	0.28	4.21	1.40
121	0.30	0.00	1.80	0.60	19.82	0.00	0.00	0.30	5.71	0.60
124	0.58	0.00	16.03	4.96	18.66	0.00	0.00	0.58	4.96	1.46
125	0.00	0.00	57.34	0.28	4.43	0.00	0.00	0.28	1.66	0.00
	0.00	0.00	59.00	0.59	1.77	0.00	0.00	0.29	0.29	0.29
129	0.00	0.60	3.92	5.12	14.76	0.00	0.00	0.00	4.82	0.60
132	0.26	0.00	4.47	3.42	11.84	0.53	0.00	0.00	2.11	0.26
143	0.00	0.00	61.95	2.36	5.90	0.00	0.00	0.00	1.18	0.00
144	0.28	0.00	3.13	1.14	5.41	0.00	0.00	0.00	0.85	0.28
147-10	0.29	0.00	4.31	0.86	14.37	0.00	0.00	0.00	5.46	0.29
147-32	0.27	0.00	0.82	0.82	11.20	0.55	0.00	0.27	3.83	0.55
152	0.00	0.00	0.88	0.88	15.34	0.00	0.00	0.00	5.90	0.88
	0.48	0.00	0.00	1.44	14.15	0.00	0.00	0.24	3.36	0.96
153	1.37	0.00	0.69	1.14	14.87	0.00	0.00	0.23	7.55	1.14
	0.25	0.00	1.27	2.28	10.41	0.00	0.00	1.78	3.55	2.03
153	0.25	0.00	2.24	1.00	12.22	0.25	0.00	0.25	4.24	1.25
160	0.60	0.00	18.56	3.59	10.78	0.00	0.00	0.00	2.40	0.90
162	2.71	0.00	14.46	4.22	9.34	0.60	0.00	0.00	2.41	0.60
167	0.00	0.00	6.60	1.06	13.72	0.79	0.00	0.00	6.33	1.06
173	0.00	0.00	46.42	0.80	5.57	0.27	0.00	0.00	0.80	0.53
174	0.00	0.00	10.89	1.01	11.39	0.00	0.00	0.00	3.04	1.27
179-80	0.00	0.00	4.82	1.98	11.33	0.28	0.00	0.28	2.55	0.00
202	0.89	0.00	0.89	0.30	18.05	0.00	0.00	0.30	3.85	1.18
min	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
max	7.3	0.9	88.3	17.1	20.8	6.0	1.0	3.9	8.1	6.4
mean	0.6	0.0	14.5	2.3	9.4	0.3	0.0	0.4	3.1	0.9
std	1.3	0.2	20.7	2.9	5.5	0.9	0.2	0.8	2.1	1.3

	17	18	19	20	21	22	23	24	25	26
station	tourmal	micas	corund	rutile	barite	apat	CO3	rf_alt	rf_met	opqs
1b	0.00	0.58	0.00	0.00	0.00	1.74	0.00	6.10	0.00	21.51
2b	0.00	0.23	0.00	0.23	0.91	0.68	0.00	7.97	0.00	35.08
	0.00	0.23	0.00	0.00	0.69	0.23	0.00	8.05	2.07	35.40
3b	0.00	0.19	0.00	0.19	3.73	1.12	0.19	6.72	1.31	46.64
4b	0.19	0.19	0.00	0.00	10.41	0.00	1.12	12.08	0.00	50.19
5b	0.27	0.54	0.00	0.00	16.49	0.00	43.51	9.46	0.00	8.11
6b	0.00	0.32	0.00	0.00	79.74	0.00	6.43	2.25	0.00	9.32
7b	0.00	0.00	0.00	0.00	2.28	0.00	0.33	2.28	0.00	4.23
8b	0.00	0.00	0.00	0.00	7.14	0.00	0.60	3.87	0.00	19.35
9b	0.00	0.00	0.00	0.00	15.69	0.00	22.69	11.48	0.00	14.85
10b	0.00	1.04	0.17	0.00	0.00	1.38	0.17	33.51	2.07	22.11
11b	0.00	1.77	0.00	0.00	0.59	1.77	0.88	20.65	0.00	9.73
102	0.00	0.64	0.00	0.00	19.23	1.60	0.00	11.22	0.00	6.73
103	0.00	0.53	0.00	0.00	61.01	0.00	0.80	3.71	0.00	6.63
	0.00	0.81	0.00	0.00	55.41	0.54	0.27	4.59	0.00	8.11
104	0.00	0.28	0.00	0.00	45.35	0.56	0.28	5.63	0.00	4.79
108	0.00	1.51	0.00	0.00	1.21	2.72	0.91	6.65	0.00	3.32
110	0.00	0.26	0.00	0.00	8.73	1.85	0.00	7.94	0.00	6.35
111	0.00	0.25	0.00	0.00	0.00	2.24	0.50	8.71	0.00	3.98
	0.00	1.11	1.11	0.00	0.00	0.00	0.55	10.25	0.00	5.26
116	0.00	1.46	0.00	0.00	1.46	0.87	0.00	4.37	0.00	4.96
117	0.00	2.75	0.00	0.00	0.00	0.92	0.00	3.67	0.00	2.45
119	0.00	2.25	0.00	0.00	1.40	1.40	0.28	6.74	0.00	2.53
121	0.00	0.60	0.00	0.00	0.00	4.80	0.00	6.61	0.30	5.11
124	0.00	0.87	0.00	0.00	2.04	2.62	0.87	9.04	0.00	18.66
125	0.00	0.83	0.00	0.00	9.14	1.66	0.55	4.43	0.00	6.37
	0.00	0.29	0.00	0.00	8.85	0.29	0.29	3.54	0.00	5.60
129	0.00	0.30	0.00	0.00	0.90	3.92	0.00	8.13	0.00	3.31
132	0.00	0.79	0.26	0.00	0.00	2.37	0.26	12.37	0.00	2.63
143	0.00	0.29	0.00	0.00	8.85	0.29	0.29	2.06	0.00	3.54
144	0.00	3.70	0.00	0.00	0.57	0.85	0.28	5.41	0.00	2.85
147-10	0.00	0.57	0.00	0.00	0.00	2.30	0.00	8.33	0.29	2.87
147-32	0.00	16.94	0.27	0.00	0.00	0.82	3.83	6.28	0.00	4.37
152	0.00	0.88	0.00	0.00	0.00	4.72	0.29	5.90	0.00	5.31
	0.00	0.96	0.00	0.00	0.48	4.56	0.24	3.84	0.24	7.19
153	0.00	0.69	0.00	0.00	0.23	2.75	0.23	6.41	0.00	10.07
	0.00	1.78	0.00	0.00	0.00	3.81	0.00	8.63	0.00	10.41
153	0.00	0.50	0.00	0.00	0.25	1.75	1.25	7.98	0.00	9.23
160	0.00	0.30	0.00	0.00	20.36	0.00	0.60	11.08	0.00	15.27
162	0.00	1.81	0.00	0.00	9.04	0.60	10.24	10.84	0.00	6.93
167	0.00	4.75	0.00	0.00	0.00	0.26	1.85	6.07	0.00	2.90
173	0.00	2.65	0.00	0.00	0.80	0.53	7.43	4.51	0.00	5.57
174	0.00	2.28	0.00	0.00	0.00	0.25	0.51	7.34	0.00	4.05
179-80	0.00	1.98	1.98	0.00	0.00	0.85	1.42	7.37	0.00	3.97
202	0.00	4.14	0.00	0.00	0.30	1.48	0.00	11.83	0.00	4.14
min	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	0.0	2.5
max	0.3	16.9	2.0	0.2	79.7	4.8	43.5	33.5	2.1	50.2
mean	0.0	1.4	0.1	0.0	8.7	1.4	2.4	7.9	0.1	10.5
std	0.0	2.6	0.3	0.0	17.6	1.4	7.3	5.2	0.5	11.3

station	27 unkn	6.1 glph	6.2 b-g glph	11.1 epidote	11.2 clzois	18.1 mica	18.2 biot	25.1 met_rf	25.2 grn_sch	26.1 opq
1b	3.49	0.29	0.00	7.27	2.91	0.58	0.00	0.00	0.00	21.51
2b	1.37	0.23	0.00	7.29	3.42	0.23	0.00	0.00	0.00	34.62
	2.07	0.00	0.00	4.60	2.53	0.23	0.00	0.00	2.07	35.40
3b	2.43	0.37	0.00	7.84	2.61	0.19	0.00	1.31	0.00	46.64
4b	0.37	2.23	0.00	0.93	0.37	0.19	0.00	0.00	0.00	50.19
5b	11.35	0.27	0.00	2.70	0.00	0.54	0.00	0.00	0.00	8.11
6b	0.96	0.00	0.00	0.64	0.00	0.32	0.00	0.00	0.00	9.32
7b	0.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.23
8b	1.19	0.30	0.00	1.49	0.00	0.00	0.00	0.00	0.00	19.35
9b	5.04	1.12	0.00	2.80	0.00	0.00	0.00	0.00	0.00	14.85
10b	1.21	19.00	0.00	5.18	1.90	1.04	0.00	2.07	0.00	22.11
11b	1.47	5.01	0.00	7.08	2.06	1.77	0.00	0.00	0.00	9.73
102	1.28	2.24	0.00	1.60	6.73	0.64	0.00	0.00	0.00	6.73
103	0.80	1.06	0.00	3.45	1.59	0.53	0.00	0.00	0.00	6.63
	3.78	0.27	0.54	0.54	0.54	0.54	0.27	0.00	0.00	8.11
104	3.10	0.85	0.56	1.13	1.41	0.28	0.00	0.00	0.00	4.79
108	1.81	0.91	0.00	8.76	5.44	1.51	0.00	0.00	0.00	3.32
110	3.17	2.65	0.00	5.29	8.73	0.26	0.00	0.00	0.00	6.35
111	2.99	7.46	0.00	4.48	1.74	0.00	0.25	0.00	0.00	3.98
	1.94	5.54	0.00	4.99	3.88	1.11	0.00	0.00	0.00	5.26
116	2.33	3.21	0.00	6.71	6.41	1.17	0.29	0.00	0.00	4.96
117	3.98	0.92	0.00	5.20	15.60	2.75	0.00	0.00	0.00	2.45
119	2.53	3.09	0.84	4.78	5.06	2.25	0.00	0.00	0.00	2.53
121	2.40	0.90	0.00	10.51	9.31	0.60	0.00	0.00	0.30	5.11
124	3.50	2.04	0.00	10.50	8.16	0.87	0.00	0.00	0.00	18.66
125	0.55	1.11	0.00	4.16	0.28	0.83	0.00	0.00	0.00	6.09
	1.77	2.06	0.29	0.29	1.47	0.29	0.00	0.00	0.00	5.60
129	3.61	2.11	0.00	2.71	12.05	0.30	0.00	0.00	0.00	3.31
132	3.42	2.37	0.00	8.95	2.89	0.79	0.00	0.00	0.00	2.63
143	1.77	1.47	0.00	3.83	2.06	0.29	0.00	0.00	0.00	3.54
144	1.14	5.41	0.00	1.99	3.42	3.70	0.00	0.00	0.00	2.85
147-10	2.30	2.01	0.00	10.92	3.45	0.57	0.00	0.00	0.29	2.87
147-32	1.64	2.19	0.00	5.46	5.74	16.94	0.00	0.00	0.00	4.37
152	1.77	0.29	0.00	9.73	5.60	0.88	0.00	0.00	0.00	5.31
	2.40	0.24	0.00	4.80	9.35	0.96	0.00	0.00	0.24	7.19
153	4.12	0.69	0.00	13.50	1.37	0.69	0.00	0.00	0.00	10.07
	4.06	0.51	0.00	2.54	7.87	1.78	0.00	0.00	0.00	10.41
153	3.24	2.00	0.00	8.48	3.74	0.50	0.00	0.00	0.00	9.23
160	2.69	1.80	0.00	8.98	1.80	0.30	0.00	0.00	0.00	15.27
162	3.92	2.71	0.00	9.04	0.30	1.81	0.00	0.00	0.00	6.93
167	1.85	3.17	0.00	4.49	9.23	4.75	0.00	0.00	0.00	2.90
173	2.39	2.92	0.00	3.71	1.86	2.65	0.00	0.00	0.00	5.57
174	2.03	3.54	0.00	6.08	5.32	2.28	0.00	0.00	0.00	4.05
179-80	1.42	1.70	0.00	5.38	5.95	1.98	0.00	0.00	0.00	3.97
202	2.07	0.30	0.00	11.83	6.21	4.14	0.00	0.00	0.00	4.14
min	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5
max	11.4	19.0	0.8	13.5	15.6	16.9	0.3	2.1	2.1	50.2
mean	2.5	2.2	0.0	5.4	4.0	1.4	0.0	0.1	0.1	10.5
std	1.7	3.0	0.2	3.4	3.6	2.6	0.1	0.4	0.3	11.3

station	26.2 cr spinel	27.1 unkn	27.2 brn_is?	27.3 fib_mic?
1b	0.00	3.49	0.00	0.00
2b	0.46	1.37	0.00	0.00
	0.00	2.07	0.00	0.00
3b	0.00	2.43	0.00	0.00
4b	0.00	0.37	0.00	0.00
5b	0.00	1.08	10.27	0.00
6b	0.00	0.96	0.00	0.00
7b	0.00	0.65	0.00	0.00
8b	0.00	1.19	0.00	0.00
9b	0.00	2.80	0.00	2.24
10b	0.00	1.21	0.00	0.00
11b	0.00	1.47	0.00	0.00
102	0.00	1.28	0.00	0.00
103	0.00	0.80	0.00	0.00
	0.00	3.78	0.00	0.00
104	0.00	3.10	0.00	0.00
108	0.00	1.81	0.00	0.00
110	0.00	3.17	0.00	0.00
111	0.00	2.99	0.00	0.00
	0.00	1.94	0.00	0.00
116	0.00	2.33	0.00	0.00
117	0.00	3.98	0.00	0.00
119	0.00	2.53	0.00	0.00
121	0.00	2.40	0.00	0.00
124	0.00	3.50	0.00	0.00
125	0.28	0.55	0.00	0.00
	0.00	1.77	0.00	0.00
129	0.00	3.61	0.00	0.00
132	0.00	3.42	0.00	0.00
143	0.00	1.77	0.00	0.00
144	0.00	1.14	0.00	0.00
147-10	0.00	2.30	0.00	0.00
147-32	0.00	1.64	0.00	0.00
152	0.00	1.77	0.00	0.00
	0.00	2.40	0.00	0.00
153	0.00	4.12	0.00	0.00
	0.00	4.06	0.00	0.00
153	0.00	3.24	0.00	0.00
160	0.00	2.69	0.00	0.00
162	0.00	3.92	0.00	0.00
167	0.00	1.85	0.00	0.00
173	0.00	2.39	0.00	0.00
174	0.00	2.03	0.00	0.00
179-80	0.00	1.42	0.00	0.00
202	0.00	2.07	0.00	0.00
min	0.0	0.4	0.0	0.0
max	0.5	4.1	10.3	2.2
mean	0.0	2.2	0.2	0.0
std	0.1	1.0	1.5	0.3

NOTES

station	sample identification used in this rep	
cruise	PV0992 is designation for beach sam	
core	label for 102 obscured; assumed 9-11	
	depth of 179 corrected from 61-63cr	
sample	' indicates replicate count;	
	r indicates replicate sample	
increm	depth of sample	
totpts	number of points counted	
1	hornblende, green	
2	hornblende, brown	
3	hornblende, basaltic	
4	amphibole, blue-green	
5	tremolite	
6	glaucophane	sum of colur
7	hypersthene	
8	enstatite	
9	titanaugite	
10	clinopyroxene, other	
11	epidotes	sum of colur
12	lawsonite	
13	pumpellyite	
14	zircon	
15	sphene	
16	garnet	
17	tourmaline	
18	micas	sum of colur
19	corundum	
20	rutile	
21	barite	
22	apatite	
23	carbonate	
24	rock fragments, altered	
25	rock fragments, metamorphic	sum of colur
26	opaques	sum of colur
27	unknown	sum of colur
6.1	glaucophane	
6.2	blue-green glaucophane	
11.1	epidote	
11.2	zoisite/clinozoisite	
18.1	mica	
18.2	biotite	
24.1	rock fragments, metamorphic	
24.2	greenschist	
26.1	opaques	
26.2	Cr spinel	
27.1	unknown	
27.2	brown isotropic?	
27.3	fibrous mica?	

station	
1b	
2b	port
	ples
3b	1 as others
4b	m
5b	
6b	
7b	
8b	
9b	
10b	
11b	
102	
103	
	mns 6.1, 6.2
104	
108	
110	
111	
	mns 11.1, 11.2
116	
117	
119	
121	
124	
125	
	mns 18.1, 18.2
129	
132	
143	
144	
147-10	
147-32	
152	mns 25.1, 25.2
	mns 26.1, 26.2
153	mns 27.1-27.3
153	
160	
162	
167	
173	
174	
179-80	
202	
min	
max	
mean	
std	

Table 3. Microprobe analyses of augite grains from sample PV0992 8B3 from the beach at the toe of the Portuguese Bend Landslide.

No.	1	2	3	4	5	6	7	8	9	10	12
SiO2	51.064	50.128	50.711	49.312	50.399	51.376	50.674	50.025	50.261	51.341	52.605
Al2O3	3.537	3.382	3.691	4.939	3.679	3.186	3.825	4.163	4.154	2.971	1.900
TiO2	1.072	1.559	1.392	1.590	1.441	1.105	1.264	1.735	1.471	1.159	0.657
Cr2O3	0.388	0.080	0.279	0.237	0.192	0.172	0.189	0.408	0.066	0.156	0.326
FeO	6.917	9.193	7.900	5.980	8.303	7.361	6.223	7.684	6.780	6.753	6.404
MgO	14.799	14.146	15.240	13.984	14.652	14.827	15.118	13.941	14.360	15.124	16.191
CaO	21.150	20.517	20.476	21.819	20.349	21.029	21.106	20.750	21.834	21.143	20.392
MnO	0.183	0.225	0.181	0.167	0.267	0.219	0.164	0.202	0.175	0.207	0.205
Na2O	0.314	0.410	0.423	0.367	0.386	0.420	0.365	0.414	0.375	0.363	0.253
Total	99.424	99.64	100.293	98.395	99.668	99.695	98.928	99.322	99.476	99.217	98.933
Si	1.898	1.880	1.876	1.852	1.880	1.907	1.888	1.870	1.871	1.911	1.952
Al	0.155	0.150	0.161	0.219	0.162	0.139	0.168	0.183	0.182	0.130	0.083
Ti	0.030	0.044	0.039	0.045	0.040	0.031	0.035	0.049	0.041	0.032	0.018
Cr	0.011	0.002	0.008	0.007	0.006	0.005	0.006	0.012	0.002	0.005	0.010
Fe	0.215	0.288	0.244	0.188	0.259	0.229	0.194	0.240	0.211	0.210	0.199
Mg	0.820	0.791	0.840	0.783	0.815	0.820	0.839	0.777	0.797	0.839	0.896
Ca	0.842	0.824	0.812	0.878	0.813	0.836	0.842	0.831	0.871	0.843	0.811
Mn	0.006	0.007	0.006	0.005	0.008	0.007	0.005	0.006	0.006	0.007	0.007
Na	0.023	0.030	0.030	0.027	0.028	0.030	0.026	0.030	0.027	0.026	0.018
Total	4.000	4.016	4.016	4.004	4.010	4.005	4.004	3.999	4.009	4.003	3.993
Ca%	44.9	43.3	42.8	47.5	43.1	44.4	44.9	45.0	46.4	44.6	42.6
Mg%	43.7	41.5	44.3	42.3	43.2	43.5	44.8	42.0	42.4	44.3	47.0
Fe%	11.5	15.1	12.9	10.2	13.7	12.1	10.3	13.0	11.2	11.1	10.4

Table 4. Factor Loadings Calculated with Modified Abundances for Sensitivity Test.

Sample 2b

	a	b	c	d	e	f		
	*	Nonopaque calculations						
Factor	w/opq		54% BA	66% BA	11% EP	19% EP	mean	stdev
1	0.305	0.320	0.318	0.320	0.313	0.324	0.317	0.007
2o	0.086	0.052	0.052	0.052	0.052	0.052	0.058	0.014
3	0.051	0.032	0.032	0.031	0.032	0.031	0.035	0.008
4o	0.865	0.863	0.863	0.864	0.863	0.864	0.864	0.001
5	0.061	0.051	0.051	0.051	0.048	0.054	0.053	0.005
6	0.127	0.138	0.138	0.137	0.142	0.135	0.136	0.005
7	0.011	-0.015	0.014	-0.016	-0.013	-0.017	-0.006	0.015
8	0.075	0.063	0.063	0.063	0.064	0.062	0.065	0.005
9	0.108	0.130	0.130	0.130	0.137	-0.064	0.095	0.078

Sample 103

	a	b	c	d	e	f		
	*	Nonopaque calculations						
Factor	w/opq	61% BA	54% BA	66% BA	11% EP	19% EP	mean	stdev
1	0.274	0.271	0.299	0.253	0.264	0.275	0.273	0.015
2o	0.222	0.214	0.230	0.204	0.214	0.214	0.216	0.009
3	0.876	0.881	0.858	0.893	0.882	0.880	0.878	0.011
4o	0.186	0.174	0.193	0.162	0.177	0.172	0.177	0.011
5	0.096	0.104	0.108	0.101	0.104	0.104	0.103	0.004
6	0.056	0.064	0.070	0.060	0.075	0.058	0.064	0.007
7	0.007	-0.001	0.000	-0.002	-0.001	-0.001	0.000	0.003
8	-0.031	0.003	0.000	0.005	0.002	0.004	-0.003	0.014
9	0.109	0.094	0.098	0.091	0.089	0.097	0.096	0.007

Sample 152

	a	b	c	d	e	f		
	*	Nonopaque calculations						
Factor	w/opq	15% EP	54% BA	66% BA	11% EP	19% EP	mean	stdev
1	0.966	0.967	0.966	0.967	0.958	0.969	0.966	0.004
2o	0.073	0.068	0.069	0.068	0.060	0.074	0.069	0.005
3	0.040	0.039	0.039	0.038	0.032	0.044	0.039	0.004
4o	0.113	0.108	0.109	0.107	0.092	0.117	0.108	0.009
5	0.006	0.006	0.007	0.006	-0.003	0.015	0.006	0.006
6	0.052	0.078	0.080	0.077	0.076	0.077	0.073	0.010
7	0.012	0.018	0.019	0.018	0.023	0.013	0.017	0.004
8	0.020	-0.013	-0.013	-0.014	-0.007	-0.019	-0.008	0.014
9	0.037	0.034	0.035	0.034	0.030	0.033	0.034	0.002

Notes: a: Loading on factors calculated with opaque minerals.
b-f: Loadings on factors calculated without opaque minerals.
b: unmodified abundances; barite = 16%, epidotes = 15%
c, d: barite = 54% and 66%, respectively
e, f: epidotes = 11% and 19%, respectively
2o, 4o: factors for which opaque minerals have a significant contribution in the first factor calculation.

Table 5. Rotated Factor Scores Matrix for 9 Factors.

Factor	1	2	3	4	5	6	7	8	9	Total
% information explained (38 samples)	39.96	12.88	6.35	6.80	4.88	7.75	3.36	3.47	3.56	89.01
hornblende_green	**0.45**	0.00	-0.02	-0.15	-0.03	**0.59**	-0.05	-0.03	-0.02	
hornblende_brown	0.16	-0.07	-0.06	0.04	0.02	-0.06	-0.08	-0.11	**0.90**	
hornblende_basaltic	0.15	-0.02	0.02	0.09	-0.10	-0.19	0.12	0.04	-0.03	
amphibole_blue-green	-0.06	-0.02	-0.01	0.01	-0.09	0.18	-0.08	**0.53**	0.03	
tremolite	-0.11	0.02	-0.01	0.01	-0.09	**0.48**	0.01	0.09	0.01	
glaucophane	0.02	0.05	0.00	-0.05	-0.02	0.16	**0.47**	0.10	0.03	
hypersthene	0.01	0.01	-0.04	**0.32**	0.03	-0.07	-0.06	0.08	0.07	
enstatite	0.04	-0.01	0.14	-0.12	-0.19	-0.09	0.06	0.14	**0.30**	
titan-augite	-0.07	**0.98**	-0.04	-0.01	-0.02	-0.02	-0.04	-0.03	0.05	
clinopyroxene_other	0.07	0.08	-0.02	0.06	-0.01	-0.04	0.00	**0.66**	0.08	
epidotes	**0.47**	0.09	0.08	0.18	0.13	0.12	-0.08	-0.09	0.02	
lawsonite	-0.01	-0.01	-0.01	-0.02	-0.03	0.04	**0.41**	-0.01	0.07	
pumpellyite	-0.03	-0.02	-0.01	0.01	-0.02	0.01	**0.37**	-0.02	0.00	
zircon	-0.06	0.00	0.06	**0.47**	-0.08	0.02	0.07	-0.01	0.00	
sphene	**0.44**	0.01	0.13	**0.25**	-0.03	-0.06	-0.10	0.04	-0.20	
garnet	-0.01	0.01	-0.03	**0.49**	0.05	0.08	-0.08	0.00	0.02	
tourmaline	0.00	-0.06	-0.08	-0.03	**0.41**	-0.05	-0.10	**0.40**	-0.06	
micas	-0.01	0.00	0.00	0.02	0.06	**0.36**	-0.01	-0.11	0.00	
corundum	0.01	-0.02	-0.01	-0.05	0.01	0.15	0.05	-0.04	-0.01	
rutile	-0.10	-0.01	-0.01	**0.49**	-0.02	0.04	0.02	-0.05	-0.02	
barite	-0.06	0.02	**0.97**	-0.04	0.05	0.00	-0.02	0.03	0.03	
apatite	**0.52**	0.05	-0.05	-0.13	-0.08	**-0.36**	0.12	0.02	-0.15	
carbonate	-0.03	0.01	-0.01	-0.02	**0.79**	-0.01	-0.02	-0.11	0.01	
rock_fragments_altered	0.11	0.08	0.05	0.04	**0.31**	0.03	**0.46**	0.12	0.10	
rock_fragments_metamorphic	-0.04	-0.02	0.00	0.17	-0.04	-0.02	**0.42**	-0.06	-0.05	

Bold-face values are scores with magnitudes > 0.2 and identify the minerals that are characteristic of a factor.

Table 6. Rotated Factor Loadings Matrix for 9 Factors

Factor / Sample	1	2	3	4	5	6	7	8	9	% Data % Data Explained
1b	**0.60**	0.13	0.05	**0.54**	0.01	0.02	-0.04	0.25	-0.06	73
2b	**0.32**	0.05	0.03	**0.86**	0.05	0.14	-0.02	0.06	0.13	89
3b	0.31	0.04	0.08	**0.85**	-0.02	0.01	0.21	-0.02	0.02	87
4b	0.08	0.07	0.04	0.07	0.25	0.05	0.05	**0.93**	0.07	95
5b	0.08	0.00	0.10	0.00	**0.90**	0.01	-0.01	0.22	-0.02	87
6b	-0.04	0.03	**0.96**	-0.03	0.19	0.01	0.00	0.01	0.04	95
7b	-0.06	**0.99**	-0.01	0.04	0.02	-0.01	-0.02	0.02	0.07	98
8b	0.00	**0.99**	0.09	0.01	0.06	0.01	0.03	0.04	0.08	99
9b	0.15	**0.38**	0.29	0.05	**0.75**	0.10	0.20	0.02	0.08	87
10b	0.21	0.05	0.03	0.13	0.10	0.08	**0.92**	0.04	0.06	92
11b	**0.79**	0.17	0.06	0.24	0.14	0.14	0.30	0.10	0.23	90
102	**0.78**	0.28	0.31	0.03	0.13	0.26	0.18	0.13	-0.02	92
103	0.27	0.21	**0.88**	0.17	0.10	0.06	0.00	0.00	0.09	95
104	0.30	0.13	**0.48**	0.03	-0.10	-0.07	0.13	0.17	**0.60**	74
108	**0.91**	0.13	0.08	0.18	0.06	0.25	0.00	0.02	-0.13	96
110	**0.88**	0.22	0.13	0.16	0.10	0.22	0.07	0.04	0.21	96
111	**0.78**	**0.33**	0.03	0.10	0.01	0.12	**0.32**	0.24	0.03	90
116	**0.55**	0.09	0.05	0.19	-0.04	**0.53**	-0.05	**0.34**	0.10	77
117	**0.83**	0.08	0.05	0.16	0.06	**0.34**	-0.03	-0.04	0.19	87
119	**0.82**	0.06	0.04	0.17	0.06	**0.36**	0.02	0.03	**0.32**	93
121	**0.95**	0.09	0.05	0.14	0.03	0.09	0.04	-0.04	0.05	94
124	**0.81**	0.22	0.07	**0.33**	0.11	0.00	0.02	0.08	0.23	90
125	**0.48**	**0.83**	0.14	0.05	0.04	0.01	0.07	0.00	-0.05	95
129	**0.86**	0.12	0.11	0.03	-0.05	0.09	0.09	0.18	0.02	81
132	**0.87**	0.12	0.02	0.04	0.10	0.30	0.15	0.07	0.19	94
143	0.31	**0.91**	0.14	0.07	0.05	0.12	-0.01	0.07	0.03	97
144	**0.43**	0.08	0.00	-0.03	-0.03	**0.76**	0.09	0.06	0.06	78
147-10	**0.84**	0.08	0.07	0.16	-0.01	0.11	0.13	0.02	-0.06	76
147-32	**0.57**	0.07	0.06	0.14	0.13	**0.60**	0.05	-0.06	-0.05	74
152	**0.97**	0.07	0.04	0.11	0.01	0.08	0.02	-0.01	0.03	96
153	**0.92**	0.05	0.06	0.26	0.03	0.11	-0.03	-0.01	0.18	96
160	**0.57**	**0.37**	**0.38**	0.31	0.22	0.20	0.10	0.18	0.04	83
162	**0.60**	0.20	0.10	0.27	0.31	0.14	0.08	0.09	**0.54**	91
167	**0.77**	0.13	0.10	0.22	0.10	**0.45**	0.03	-0.01	-0.09	87
173	**0.40**	**0.75**	0.02	0.07	0.23	**0.42**	0.12	0.00	0.03	96
174	**0.72**	0.19	0.06	0.16	0.09	**0.60**	0.05	0.02	-0.04	95
179-80	**0.61**	0.08	0.04	0.02	0.08	**0.46**	0.07	-0.02	0.03	60
202	**0.77**	0.04	0.03	0.22	0.12	0.26	-0.03	-0.09	**0.49**	96
min	-0.06	0.00	-0.01	-0.03	-0.10	-0.07	-0.05	-0.09	-0.13	60
max	0.97	0.99	0.96	0.86	0.90	0.76	0.92	0.93	0.60	99

Figures in bold-face type are factor loadings >= 0.32 indicating that the factor explains about 10% of the data in the sample.
"% Data Explained" = sum of the squared loadings for each sample which is the amount of a sample explained by the 9 factors.

Table 7. Comparison of Factor Loading with Average and Maximum Mineral Abundance

factor	1			2			3			4			5			6			7			8			9		
% expl	39.96			12.88			6.35			6.80			4.88			7.75			3.36			3.47			3.56		
# spls		27			8			4			4			2			9			2			2			4	
max load			**0.97**			**0.99**			**0.96**			**0.86**			**0.90**			**0.76**			**0.92**			**0.93**			**0.60**
	score	mean	152	score	mean	7b	score	mean	6b	score	mean	2b	score	mean	5b	score	mean	144	score	mean	10b	score	mean	4b	score	mean	104
hb_grn	**0.45**	40.08	55.75	0.00	11.27	0.33	-0.02	6.53	0.32	-0.15	15.41	20.50	-0.03	5.23	5.41	**0.59**	50.52	66.95	-0.05	17.20	1.55	-0.03	26.28	0.37	-0.02	33.50	10.99
hb_brn	0.16	0.57	0.88	-0.07	0.03	0.00	-0.06	0.42	0.00	0.04	0.56	0.68	0.02	0.00	0.00	-0.06	0.38	0.28	-0.08	0.21	0.17	-0.11	0.29	0.00	**0.90**	1.67	1.41
hb_bas	0.15	0.09	0.29	-0.02	0.03	0.00	0.02	0.07	0.00	0.09	0.17	0.00	-0.10	0.00	0.00	-0.19	0.03	0.00	0.12	0.13	0.00	0.04	0.00	0.00	-0.03	0.07	0.28
amp_bg	-0.06	0.01	0.00	-0.02	0.00	0.00	-0.01	0.00	0.00	0.01	0.00	0.00	-0.09	0.00	0.00	0.18	0.03	0.00	-0.08	0.00	0.00	~~0.53~~	0.24	0.19	0.03	0.00	0.00
trem	-0.11	0.11	0.00	0.02	0.03	0.00	-0.01	0.00	0.00	0.01	0.07	0.00	-0.09	0.00	0.00	~~0.48~~	0.31	1.42	0.01	0.00	0.00	0.09	0.29	0.00	0.01	0.00	0.00
glcph	0.02	2.30	0.29	0.05	2.02	0.00	0.00	1.07	0.00	-0.05	0.73	0.23	-0.02	0.70	0.27	0.16	3.00	5.41	**0.47**	13.23	19.00	0.10	2.72	2.23	0.03	2.09	1.41
hypers	0.01	0.74	0.00	0.01	0.18	0.33	-0.04	0.15	0.00	**0.32**	3.12	2.96	0.03	0.00	0.00	-0.07	0.10	0.28	-0.06	0.25	0.00	0.08	0.10	0.19	0.07	0.90	0.00
ensta	0.04	0.02	0.00	-0.01	0.00	0.00	0.14	0.21	0.00	-0.12	0.00	0.00	-0.19	0.00	0.00	-0.09	0.00	0.00	0.06	0.00	0.00	0.14	0.00	0.00	~~0.30~~	0.21	0.85
Ti_aug	-0.07	10.45	0.88	**0.98**	47.44	88.27	-0.04	11.97	0.00	-0.01	7.57	2.05	-0.02	10.21	0.81	-0.02	9.31	3.13	-0.04	12.21	1.04	-0.03	5.32	3.35	0.05	8.28	16.06
oth_cpx	0.07	2.45	0.88	0.08	2.04	0.98	-0.02	1.74	0.00	0.06	4.60	4.56	-0.01	0.70	0.27	-0.04	1.47	1.14	0.00	2.99	0.00	**0.66**	9.28	17.10	0.08	2.75	3.38
epids	**0.47**	12.13	15.34	0.09	4.65	0.00	0.08	4.75	0.64	0.18	12.50	10.71	0.13	2.75	2.70	0.12	11.37	5.41	-0.08	6.65	7.08	-0.09	7.21	1.30	0.02	9.94	2.54
laws	-0.01	0.18	0.00	-0.01	0.16	0.00	-0.01	0.21	0.00	-0.02	0.00	0.00	-0.03	0.00	0.00	0.04	0.24	0.00	**0.41**	3.52	6.04	-0.01	0.00	0.00	0.07	0.36	0.85
pumpel	-0.03	0.00	0.00	-0.02	0.00	0.00	-0.01	0.00	0.00	0.01	0.00	0.00	-0.02	0.00	0.00	0.01	0.00	0.00	**0.37**	0.52	1.04	-0.02	0.00	0.00	0.00	0.00	0.00
zirc	-0.06	0.29	0.00	0.00	0.07	0.00	0.06	0.27	0.00	**0.47**	1.97	2.51	-0.08	0.00	0.00	0.02	0.19	0.00	0.07	0.30	0.35	-0.01	0.44	0.00	0.00	0.29	0.56
sphene	**0.44**	3.85	5.90	0.01	1.19	0.00	0.13	1.62	0.00	**0.25**	4.97	3.42	-0.03	0.41	0.54	-0.06	3.16	0.85	-0.10	2.48	1.73	0.04	2.23	0.37	-0.20	2.97	1.41
garnet	-0.01	0.95	0.88	0.01	0.26	0.33	-0.03	0.30	0.00	**0.49**	3.34	5.92	0.05	0.28	0.27	0.08	0.73	0.28	-0.08	0.18	0.35	0.00	0.62	0.37	0.02	0.87	0.28
tourmal	0.00	0.00	0.00	-0.06	0.00	0.00	-0.08	0.00	0.00	-0.03	0.00	0.00	~~0.41~~	0.14	0.27	-0.05	0.00	0.00	-0.10	0.00	0.00	~~0.40~~	0.10	0.19	-0.06	0.00	0.00
micas	-0.01	2.07	0.88	0.00	0.54	0.00	0.00	0.36	0.32	0.02	0.47	0.23	0.06	0.27	0.54	**0.36**	4.31	3.70	-0.01	0.65	1.04	-0.11	0.83	0.19	0.00	2.12	0.28
corund	0.01	0.09	0.00	-0.02	0.00	0.00	-0.01	0.00	0.00	-0.05	0.00	0.00	0.01	0.00	0.00	0.15	0.25	0.00	0.05	0.09	0.17	-0.04	0.00	0.00	-0.01	0.00	0.00
rutile	-0.10	0.01	0.00	-0.01	0.00	0.00	-0.01	0.00	0.00	~~0.49~~	0.11	0.23	-0.02	0.00	0.00	0.04	0.00	0.00	0.02	0.00	0.00	-0.05	0.00	0.00	-0.02	0.00	0.00
barite	-0.06	2.85	0.00	0.02	8.03	2.28	**0.97**	51.62	79.74	-0.04	1.67	0.91	0.05	16.09	16.49	0.00	0.47	0.57	-0.02	0.00	0.00	0.03	5.94	10.41	0.03	14.02	45.35
apat	**0.52**	1.72	4.72	0.05	0.59	0.00	-0.05	0.14	0.00	-0.13	1.54	0.68	-0.08	0.00	0.00	**-0.36**	0.75	0.85	0.12	1.81	1.38	0.02	0.44	0.00	-0.15	1.01	0.56
CO3	-0.03	1.15	0.29	0.01	4.12	0.33	-0.01	2.03	6.43	-0.02	0.27	0.00	**0.79**	33.10	43.51	-0.01	1.73	0.28	-0.02	0.34	0.17	-0.11	0.56	1.12	0.01	2.70	0.28
rf_alt	0.11	8.00	5.90	0.08	6.05	2.28	0.05	5.67	2.25	0.04	7.46	7.97	**0.31**	10.47	9.46	0.03	5.75	5.41	**0.46**	21.11	33.51	0.12	8.23	12.08	0.10	8.76	5.63
rf_met	-0.04	0.02	0.00	-0.02	0.00	0.00	0.00	0.00	0.00	0.17	0.33	0.00	-0.04	0.00	0.00	-0.02	0.00	0.00	**0.42**	1.04	2.07	-0.06	0.00	0.00	-0.05	0.00	0.00

Notes
factor = factor number
%expl = amount of whole data set explained by factor
spls = number of samples with rotated factor loading >= 0.32; from Table 4.
max load = maximum loading for this factor
score = rotated factor score from Table 2; strikeouts are high scores with very small mineral abundance.
mean = mean mineral abundance calculated for "# spls"
152, 7b, 6b, 2b, 5b, 144, 10b, 4b, and 104 are the samples with the maximum loadings for each of factors 1 to 9, respectively.