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Heavy-mineral data from samples collected in Willapa Bay and vicinity, Washington

By

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Summary

Samples described in this report were collected during a multidisiplinary geologic study of Willapa Bay, Washington (Figs. 1 and 2). The heavy-mineral analyses were made in the 3-4Ø fraction (0.125 - 0.062 mm) using standard separation and microscopic techniques.

Opaque minerals were not specifically identified, but probably include magnetite, ilmenite, and chrome spinel. Aggregates are defined as grains containing more than one mineral, e.g., an opaque mineral and a clinopyroxene.

The most common groups of minerals identified in the Willapa Bay sediments are orthopyroxene (mostly hypersthene with rare enstatite), clinopyroxene (mostly augite and titanaugite, with rare diopside), and hornblende (green, blue-green, brown and basaltic varieties). Aegerine-augite was sufficiently distinctive to permit positive identification. Various percentages of epidote (which includes rare clinozoisite and zoisite), garnet (mostly colorless and pink, with rare yellow varieties), kyanite and sphene occur in all samples. More than 50% of the samples contain zircon, rutile, apatite, and staurolite. Other minerals identified include tremolite/actinolite, sillimanite, chloritoid, topaz(?), tourmaline, and glaucophane.

Samples are grouped in tables according to the area in which they were collected (modern samples) or the terrace unit in which they occur (Pleistocene samples). Percentages of individual nonopaque minerals are percentages of the total nonopaque mineral group. Asterisks (*) indicate the mineral was seen but not encountered during the point count. Interpretation of these analyses are published elsewhere (Luepke and Clifton, in press).

Reference

Luepke, Gretchen and Clifton, H.E., Heavy-mineral distribution in modern and ancient bay deposits, Willapa Bay, Washington (in press).

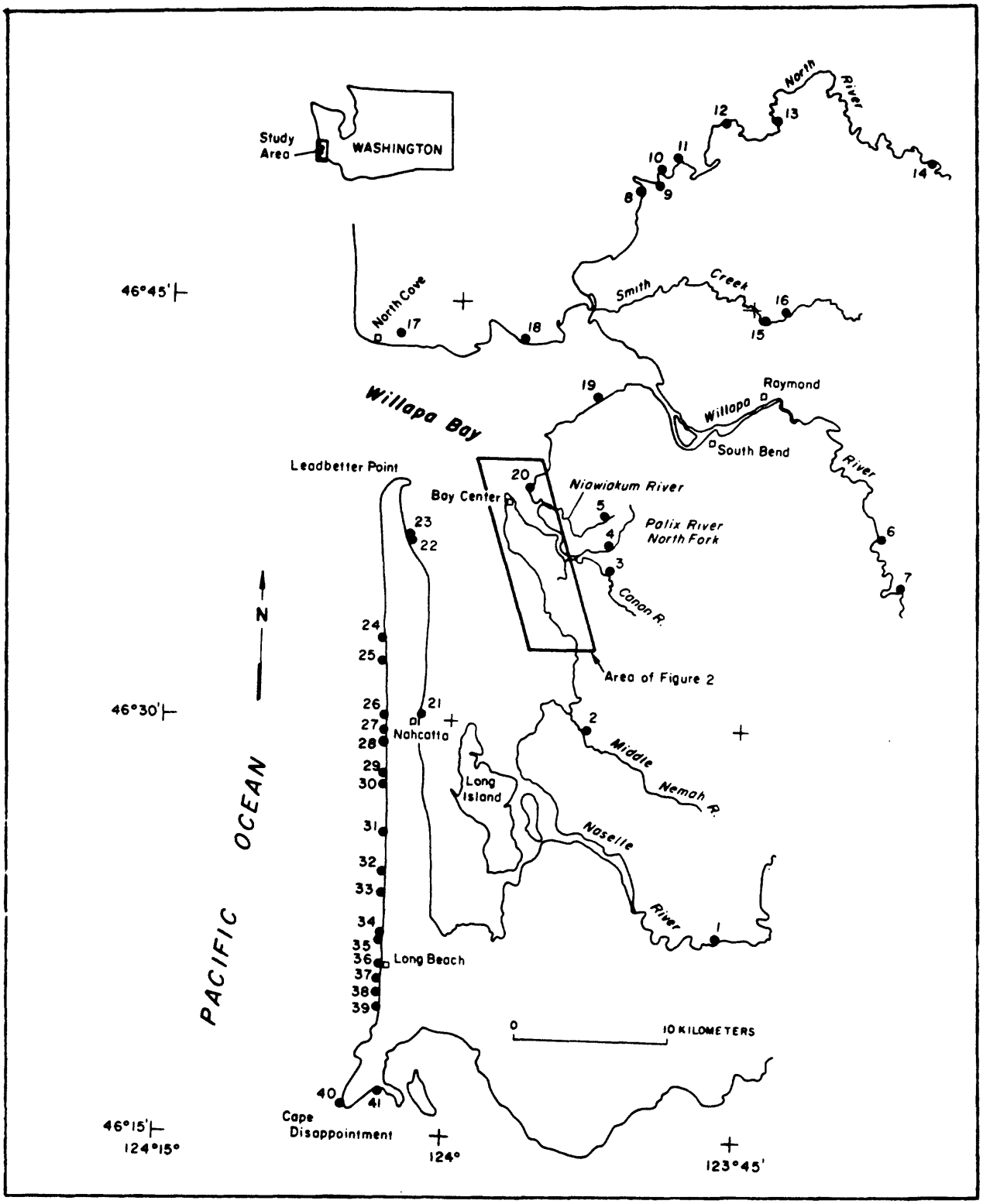

Figure 1. Sample location map with index map of study area. Key to sample locations on Page 3.

Key to Sample Locations in Figure 1.

1. 74Na - 1, 2, 3, 4
2. 74Nem - 1, 2, 3, 4
3. 77C - 1, 2
4. 77NP - 1
5. 74P - 1
6. 74Wi - 1, 2
7. 74Wi - 3, 4
8. 74No - 3
9. 74No - 4
10. 77No - 3, 3a, 3b
11. 74No - 2
12. 74No - 1; 77No - 2
13. 77No - 1
14. 77No - 4a, 4b
15. 77S - 1
16. 77S - 2
17. 77WGL - 80, 81, 82, 83, 84, 85, 86, 87, 88
18. 74WGL - 15
19. 74WGL - 45
20. 0823-1
21. 74WGL - 51; 77WGL - 53
22. 77WGL - 55
23. 77WGL - 54
24. 74WGL - 52; 77WGL - 56
25. 77WGL - 57
26. 74WGL - 53; 77WGL - 58
27. 77WGL - 59
28. 74WGL - 54; 77WGL - 60
29. 77WGL - 61
30. 74WGL - 55
31. 77WGL - 62
32. 77WGL - 63
33. 77WGL - 64
34. 74WGL - 56; 77WGL - 65
35. 77WGL - 66
36. 77WGL - 67
37. 74WGL - 57, 58
38. 77WGL - 69
39. 77WGL - 68
40. 77TF - 2
41. 77TF - 1

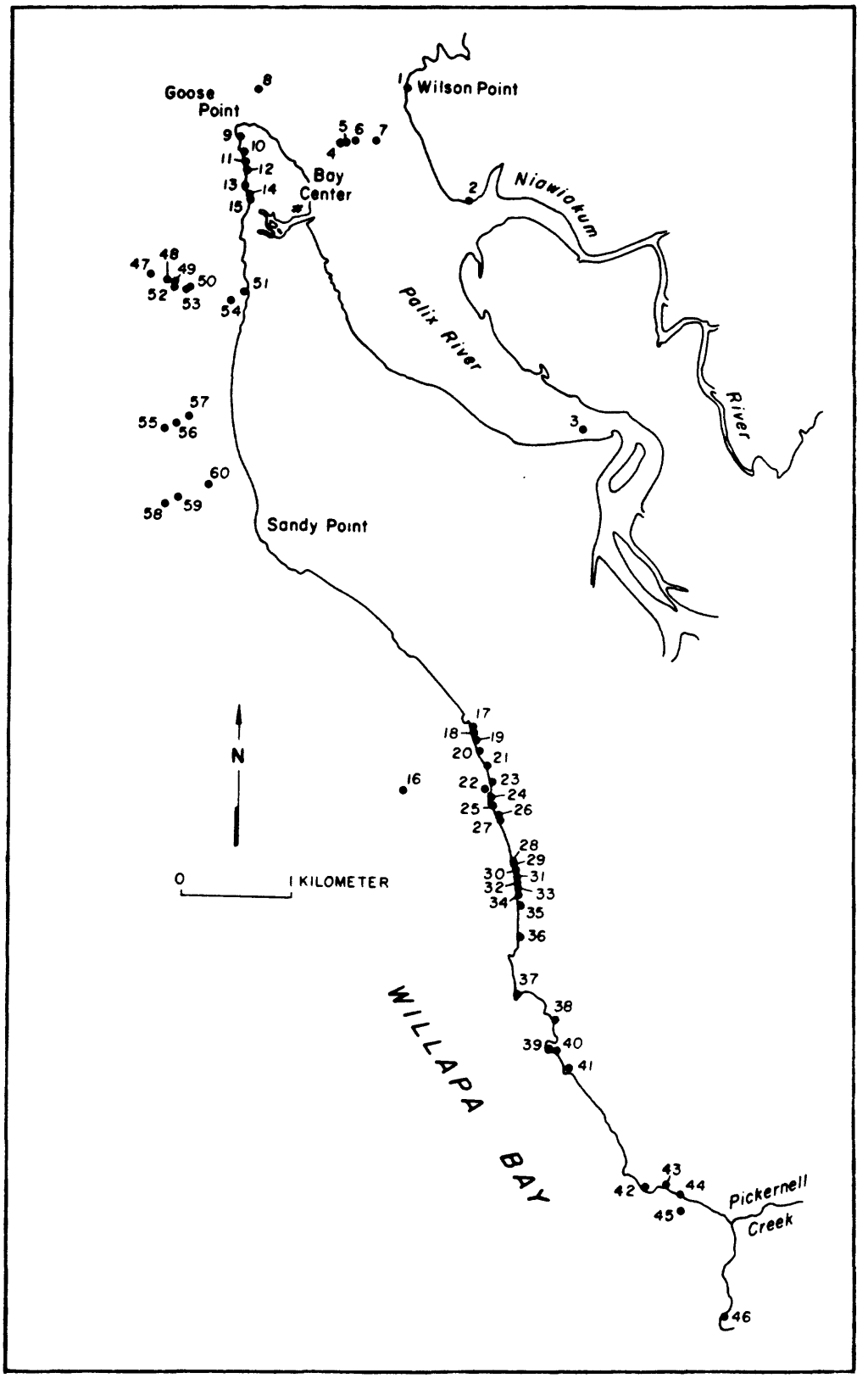

Figure 2. Enlarged area of Figure 1, showing sample locations on tidal flats and terraces from Goose Point to Pickernell Creek. Key to sample locations on Page 5.

Key to Sample Locations in Figure 2.

1. R902-6
2. U827-6
3. Q820-13b
4. Q823-12b
5. Q823-18
6. Q824-10
7. Q824-6
8. S711-2
9. S828-1
10. 77WGL - 75, 76, 77, 78, 79
11. P114-4
12. 77WGL - 73, 74
13. 77WGL - 70, 71
14. 77WGL - 72
15. P114-1, 2, 3
16. S801-3
17. 77WGL - 15, 16
18. 77WGL - 17, 18
19. 77WGL - 19, 20
20. 77WGL - 21, 22
21. 77WGL - 23, 24, 25, 26
22. S801-1
23. P113-1, 2, 3, 4, 5
24. 77WGL - 52
25. 77WGL - 50, 51; P113-6, 7, 8
26. 77WGL - 44, 45, 46, 47, 48, 49
27. 77WGL - 43
28. 77WGL - 40, 41, 42
29. 77WGL - 10, 13, 14, 37, 38
30. 77WGL - 8, 9, 39
31. 77WGL - 11, 12
32. 77WGL - 5, 6, 7
33. 77WGL - 34, 35, 36
34. 77WGL - 3, 4
35. 77WGL - 1, 2
36. 77WGL - 27, 28, 29; P113-12
37. P113-9, 10, 11; R901-1, 4; U822-2, 3, 5, 6
38. R901-6
39. S825-2
40. S825-1
41. S825-3
42. R901-8, 9
43. R902-1
44. R902-3
45. S805-3
46. U824-4
47. 74T1-9
48. 74T1-8
49. 74T1-7
50. 74T1-6
51. 74T1-1
52. 74T2-6
53. 74T2-5
54. 74T2-2
55. 74T3-5
56. 74T3-4
57. 74T3-3
58. 74T4-7
59. 74T4-6
60. 74T4-4

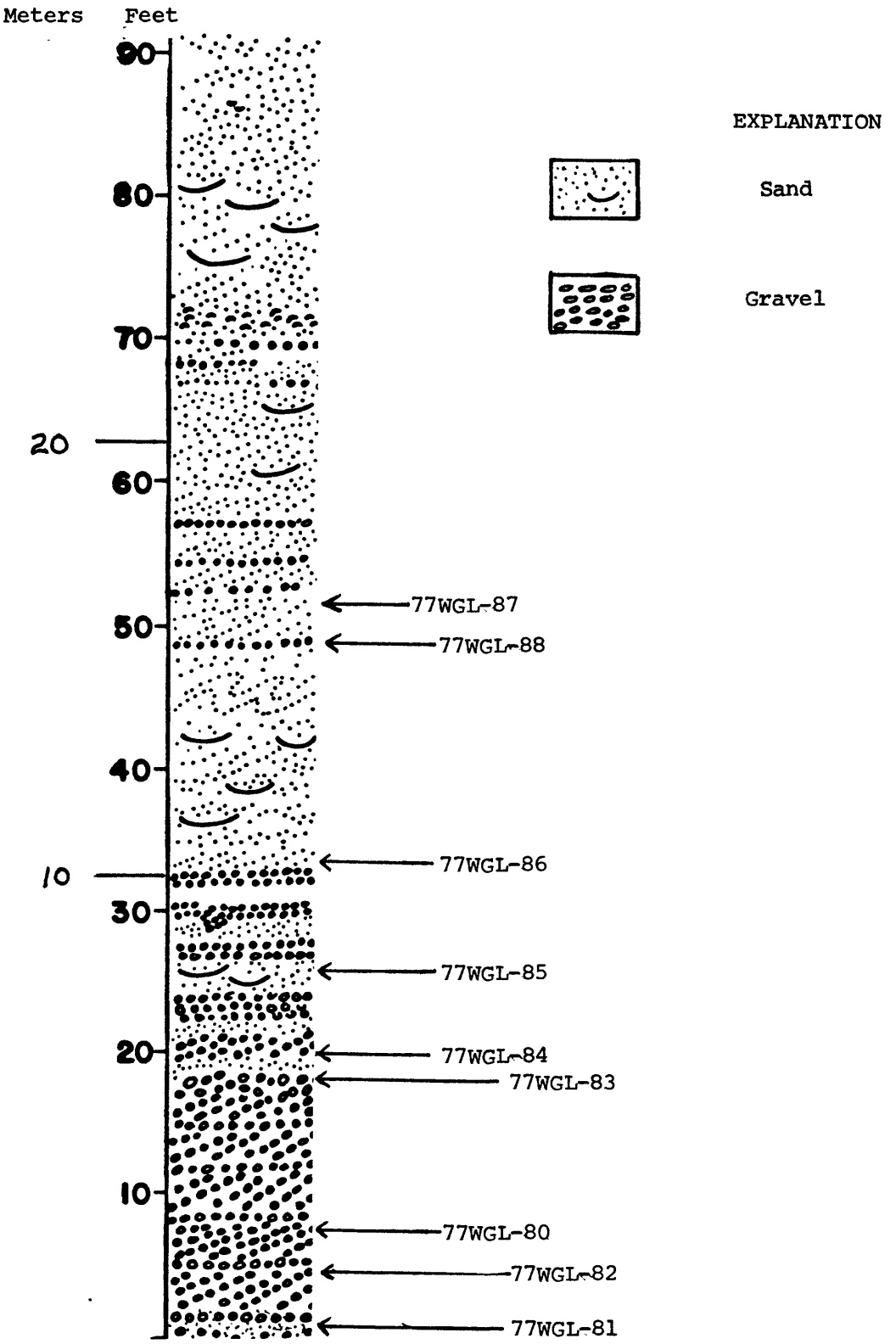

Figure 3. Stratigraphic section of Pleistocene terrace near North Cove, Washington, showing position of samples within the section. From a drawing by H.E. Clifton (pers. comm., 1982). See Table 11 for heavy-mineral analyses of above samples.

SAMPLE No.	Opaque Minerals	Aggregates	Nonopaque Minerals	Orthopyroxene	Clinopyroxene	Hornblende	Tremolite/Actinolite	Epidote	Garnet	Sphene	Zircon	Kyanite	Staurolite	Apatite	Unknown	Others
74Na-1	13.9	21.0	65.1	13.4	58.2	17.9	0	4.0	1.0	1.0	0	0	0.5	2.0	2.0	
74Na-2	7.0	7.0	86.0	9.9	83.7	4.1	0	2.3	0	0	0	0	0	0	0	
74Na-3	13.5	12.0	74.5	5.4	87.9	4.0	0	2.7	*	0	*	0	0	0	0	*rutile
74Na-4	14.2	6.1	79.7	1.9	86.5	7.2	0	3.4	*	*	*	0	0	0	1.0	*rutile
74Nem-1	47.4	7.2	45.4	12.4	78.1	3.0	0	6.5	0	0	0	0	0	0	0	
74Nem-2	22.7	10.3	67.0	9.0	74.1	11.4	0	3.5	*	*	0.5	0.5	0	0	1.0	
74Nem-3	29.9	10.2	59.9	16.0	61.0	12.5	0	10.5	0	0	*	0	0	0	0	
74Nem-4	33.0	22.3	44.7	6.7	82.1	6.7	0	4.5	0	0	0	0	0	0	0	
74Wi-1	22.3	7.7	70.0	12.4	71.0	12.4	0	2.9	0.5	*	*	0	0.5	0	0.5	*tourmaline
74Wi-2	15.0	8.3	76.7	11.7	77.0	5.7	0	5.7	*	*	*	*	0	*	0	
74Wi-3	18.0	11.5	70.5	2.1	91.5	3.5	0.7	2.1	0	*	0	0	0	0	0	*topaz
74Wi-4	14.0	6.7	79.3	12.6	77.7	5.5	0	3.4	*	0.4	*	0	0	0	0.4	
74P-1	10.7	9.3	80.0	7.5	79.6	6.3	0	4.2	0	0	*	0.4	0.4	0	1.2	*topaz
77NP-1	13.1	3.6	83.3	6.3	63.8	18.5	0	8.3	0.4	0.4	*	0.4	0.4	0	1.6	
77C-1	3.3	2.7	94.0	5.0	91.5	1.4	0	1.8	0	0	0	0	0	*	0.4	
77C-2	2.3	4.3	93.4	6.8	88.9	1.8	0	1.8	0	0.7	0	0	0	0	0	

Table 1. Samples collected from rivers draining into Willapa Bay from the east, (See Fig. 1).

SAMPLE No.	Opaque Minerals	Aggregates	Nonopaque Minerals	Orthopyroxene	Clinopyroxene	Hornblende	Tremolite/Actinolite	Epidote	Garnet	Sphene	Zircon	Kyanite	Staurolite	Apatite	Unknown	Others
74No-1	28.0	6.5	65.5	14.5	24.8	33.6	0.4	18.7	3.8	2.3	0.8	*	0.4	0	0.4	0.4 rutile
74No-2	50.7	3.0	46.3	21.0	26.5	28.5	0	13.5	2.5	1.0	4.5	*	0.5	0	0.5	1.0 rutile, 0.5 tourmaline
74No-3	45.5	9.2	45.3	9.9	32.6	32.6	0.6	12.7	1.1	3.3	3.9	*	0	0	1.7	1.1 rutile, 0.6 tourmaline
74No-4	39.2	5.2	55.6	17.1	32.9	34.7	0	7.2	2.3	0.9	3.2	*	0.5	0	0.5	0.9 tourmaline, *rutile
77No-1	29.9	5.0	65.1	19.6	22.0	36.4	0	16.3	1.4	0.5	1.0	*	1.0	0	0.5	1.0 rutile, 0.5 tourmaline, *sillimanite, aegerine-augite
77No-2	21.9	4.8	73.3	16.7	25.0	36.0	0	17.5	2.2	0.9	*	0.4	0	0	0	0.4 rutile, 0.4 tourmaline, 0.4 aegerine-augite
77No-3	27.2	7.7	65.1	16.2	23.5	39.6	0	17.7	*	0.4	0.8	0.4	0	0	0.4	0.8 aegerine-augite, 0.4 rutile
77No-4a	40.7	6.1	53.2	15.2	27.6	35.1	0	18.0	1.4	0.5	0.9	*	0	0	0.9	0.5 rutile
77No-4b	25.6	7.7	65.8	22.1	38.0	27.2	0	12.2	*	0	*	*	0	0	0.5	
77S-1	24.7	8.7	66.6	14.7	16.9	43.3	0	16.5	3.4	1.1	0.4	0.8	0.4	0.4	*	1.5 tourmaline, 0.8 rutile, *chloritoid
77S-2	32.2	7.0	60.8	13.8	13.5	34.2	0	20.7	6.6	4.3	2.6	*	2.0	0.7	1.0	0.3 tourmaline, 0.3 glaucophane, *rutile, chloritoid

Table 2. Samples collected from rivers draining into Willapa Bay from the north. (See Fig. 1).

SAMPLE No.	Opaque Minerals	Aggregates	Nonopaque Minerals	Orthopyroxene	Clinopyroxene	Hornblende	Tremolite/Actinolite	Epidote	Garnet	Sphene	Zircon	Kyanite	Staurolite	Apatite	Unknown	Others
74WGL-51	22.0	12.0	66.0	39.4	18.9	14.4	0	14.4	9.1	0.8	*	0	0	0.8	0.8	1.5 rutile
77WGL-53	3.0	5.0	92.0	24.6	19.2	36.3	0	15.9	1.4	0.4	*	1.4	0.4	*	0	0.4 aegerine-augite
77WGL-54	8.3	10.3	81.4	25.0	16.4	41.4	0.8	13.1	0.4	0	0	1.2	0.4	*	0.4	0.4 aegerine-augite, 0.4 tourmaline
77WGL-55	29.7	6.2	64.1	39.3	26.5	16.8	0	14.4	1.9	0.4	*	0.4	0	0.4	0	*tourmaline
Q820-13b	10.2	11.5	78.3	18.4	31.0	41.4	0.8	6.7	0.8	0.4	*	0.4	0	*	0	
Q823-12b	13.3	12.4	74.3	20.9	15.0	41.4	0	15.0	5.1	*	0.4	0.4	*	0	0.4	0.4 rutile, 0.4 tourmaline, 0.4 chloritoid
Q823-18	12.3	9.3	78.4	30.2	22.6	30.2	0	10.6	4.7	0.4	*	0.4	*	0	0.9	
Q824-6	11.0	7.7	81.3	23.4	20.9	36.5	0	13.1	4.1	0.4	0.4	0.4	0	*	0.8	
Q824-10	10.0	11.6	78.4	30.5	18.9	29.7	0	11.9	7.0	0.4	*	0.8	0.4	*	0.4	*rutile
77TF-1	52.0	6.9	41.1	34.1	24.3	27.5	0	10.6	2.7	0.4	*	0	*	0.4	0	*aegerine-augite, topaz
77TF-2	43.4	8.2	48.4	39.7	18.6	24.4	0	7.9	7.4	*	*	1.2	*	0	0	0.4 aegerine-augite, 0.4 topaz

Table 3. Samples collected on the bay side of Long Beach Peninsula (WGL series), at the mouth of the Palix River (Q82 series); and at the mouth of the Columbia River at Cape Disappointment, Washington (TF series). (See Fig. 1 & 2).

SAMPLE No.	Opaque Minerals	Aggregates	Nonopaque Minerals	Orthopyroxene	Clinopyroxene	Hornblende	Tremolite/Actinolite	Epidote	Garnet	Sphene	Zircon	Kyanite	Staurolite	Apatite	Unknown	Others
74WGL-52	10.2	15.8	74.0	36.9	16.4	40.0	0.4	2.7	*	0.4	0.4	*	0	0.3	1.8	0.4 tourmaline
74WGL-53	6.3	8.7	85.0	27.1	18.0	50.2	0	2.0	0.4	*	0.4	0.4	0	0.8	0.8	
74WGL-54	6.5	14.0	79.5	28.3	20.1	35.9	1.3	10.7	*	0	0	1.3	0	*	1.9	0.6 tourmaline
74WGL-55	7.0	15.3	77.7	39.1	18.9	29.7	0	8.2	2.1	*	*	*	*	0.4	1.3	0.4 glaucophane
74WGL-56	19.9	8.3	71.8	45.8	22.2	20.4	0	5.1	3.2	0.9	*	*	*	0.9	0.5	0.5 tourmaline, 0.5 sillimanite
74WGL-57	20.4	11.8	67.8	42.7	27.7	15.0	0	6.1	3.8	0.9	0.5	0.9	0	0.9	0.9	0.5 aegerine-augite, *rutile
74WGL-58	34.4	9.3	56.3	35.1	28.0	22.7	0	7.6	3.3	1.4	*	*	0.5	0.5	0.5	0.5 rutile, *aegerine-augite
77WGL-56	6.0	7.7	86.3	30.9	18.1	35.2	0.4	12.0	1.2	*	*	0.8	*	0.4	0.4	0.4 tourmaline, 0.4 aegerine-augite
77WGL-57	10.3	8.0	81.7	26.9	14.3	42.4	0	15.9	0.4	*	0	*	0	*	0	*tourmaline. *glaucophane, *aegerine-augite

Table 4.

SAMPLE No.	Opaque Minerals	Aggregates	Nonopaque Minerals	Orthopyroxene	Clinopyroxene	Hornblende	Tremolite/Actinolite	Epidote	Garnet	Sphene	Zircon	Kyanite	Staurolite	Apatite	Unknown	Others
77WGL-58	4.3	7.7	88.0	23.1	13.6	46.2	0	13.6	1.5	0	0	0.8	0	0.8	0	0.4 aegerine-augite
77WGL-59	7.0	6.7	86.3	25.5	19.3	44.0	0	9.7	1.2	0	0	*	0	0.4	0	
77WGL-60	7.0	10.3	82.7	28.2	19.4	43.6	*	7.7	0	*	0	0.4	0	0.4	0	0.4 glaucophane
77WGL-61	6.0	9.0	85.0	25.1	18.8	48.6	0.4	5.9	0.8	*	0	*	0	0.4	0	
77WGL-62	8.3	8.0	83.7	25.0	18.3	40.5	0	14.3	0.8	0	0	0.8	0.4	*	0	*topaz
77WGL-63	10.7	6.8	82.5	26.2	11.5	52.7	0	9.0	0	0.4	0	0	0	0	0	0.4 chloritoid
77WGL-64	10.0	10.7	79.3	26.9	19.7	41.2	0	8.8	0.4	0.4	0	0.8	0	*	0.4	0.8 aegerine-augite, 0.4 topaz
77WGL-65	10.7	9.3	80.0	32.5	17.1	35.9	0.4	12.5	0.4	0.8	0	0	0	0.4	0	*rutile
77WGL-66	26.2	5.0	68.8	36.7	21.1	25.9	0	10.9	2.2	*	0.4	1.1	0	0.7	0	0.7 rutile, 0.4 chloritoid
77WGL-67	20.7	10.2	69.1	33.0	13.0	38.4	0	12.0	1.8	0.4	0.4	0	0	1.1	0	*aegerine-augite, rutile
77WGL-68	11.3	7.3	81.4	29.9	15.2	44.3	0	10.2	*	*	0	0.4	0	*	0	*chloritoid, topaz
77WGL-69	10.7	12.3	77.0	30.3	17.7	42.0	0	8.2	0.9	0.4	0	0	0	0.4	0	

Table 4. Samples collected on the ocean side of Long Beach Peninsula, Washington. (See Fig. 1).

SAMPLE No.	Opaque Minerals	Aggregates	Nonopaque Minerals	Orthopyroxene	Clinopyroxene	Hornblende	Tremolite/Actinolite	Epidote	Garnet	Sphene	Zircon	Kyanite	Staurolite	Apatite	Unknown	Others
74T1-1	25.0	11.0	64.0	39.1	20.3	20.9	0	8.3	7.3	2.1	1.0	0	*	*	1.0	*rutile, aegerine-augite
74T1-6	10.3	13.3	76.4	33.2	22.7	27.0	0.4	10.9	3.1	*	*	0.4	0.9	0.4	0.4	0.4 tourmaline, *rutile, sillimanite
74T1-7	7.3	12.7	80.0	33.7	20.4	21.6	0	14.6	5.4	0.8	0.4	0.4	*	0.8	0.4	0.4 tourmaline, 0.4 chloritoid, 0.4 sillimanite, *aegerine-augite
74T1-8	11.0	7.7	81.3	38.1	23.0	22.9	0	10.7	2.0	0.4	0	0.8	*	0.8	0.8	0.4 chloritoid, *sillimanite, *rutile, aegerine-augite
74T1-9	7.5	13.0	79.5	45.9	23.3	17.6	*	6.9	2.5	1.3	0.6	*	0	0.6	1.3	*rutile
74T2-2	12.5	12.5	75.0	23.3	26.7	32.7	0	12.0	2.0	1.3	*	*	0	0.7	1.3	
74T2-5	11.0	13.7	75.3	34.1	24.3	28.7	0.4	9.3	1.3	0.4	0.4	*	0.4	*	0.4	*aegerine-augite
74T2-6	11.3	11.3	77.4	34.5	26.7	20.3	0	11.2	3.9	1.3	*	*	0.4	0.4	0.9	0.4 aegerine-augite, *rutile
74T3-3	21.0	8.0	71.0	34.3	28.2	18.3	0	8.9	6.6	0.5	0.9	0.9	0.9	*	0	0.5 rutile

Table 5.

SAMPLE No.	Opaque Minerals	Aggregates	Nonopaque Minerals	Orthopyroxene	Clinopyroxene	Hornblende	Tremolite/Actinolite	Epidote	Garnet	Sphene	Zircon	Kyanite	Staurolite	Apatite	Unknown	Others
74T3-4	26.7	6.3	67.0	31.8	22.3	24.2	0	10.0	7.6	1.4	0.5	0.5	0.5	*	0.5	0.5 aegerine-augite, 0.5 tourmaline, *rutile
74T3-5	20.5	7.1	72.4	31.0	23.0	19.4	*	14.2	7.1	1.3	0.4	1.8	0.9	0.4	0	0.4 chloritoid, *rutile
74T4-4	15.3	11.7	73.0	29.2	27.4	22.8	0	11.9	5.9	1.4	0.9	0.5	*	*	0	
74T4-6	19.3	6.7	74.0	25.7	23.0	28.9	0	12.2	6.3	*	0.9	0	0.9	*	1.4	0.5 sillimanite
74T4-7	22.7	7.3	70.0	39.5	18.6	19.5	0	10.5	7.6	2.4	0.5	1.0	0.5	*	0	*rutile
S711-2	15.0	7.7	77.3	21.7	25.6	29.1	0	20.4	1.0	1.0	0	*	*	0.6	0	0.3 chloritoid, 0.3 aegerine-augite
S801-1	14.7	5.7	79.6	20.5	37.7	20.5	0	19.7	0.8	0	*	*	0	0.8	0	*chloritoid
S801-3	21.7	4.7	73.6	31.6	16.0	27.9	0	18.0	5.4	*	*	*	0.3	*	0	0.3 rutile, 0.3 topaz, *aegerine-augite
S805-3	62.3	1.2	36.5	24.7	21.5	21.4	0	21.0	6.8	0	0.9	0.5	0.5	0.9	0	1.8 rutile

Table 5. Samples collected on the tidal flats bordering the eastern shore of Willapa Bay from Goose Point to Pickernell Creek. (See Fig. 2).

SAMPLE No.	Opaque Minerals	Aggregates	Nonopaque Minerals	Orthopyroxene	Clinopyroxene	Hornblende	Tremolite/Actinolite	Epidote	Garnet	Sphene	Zircon	Kyanite	Staurolite	Apatite	Unknown	Others
77WGL-23	8.3	5.0	86.7	21.9	32.3	26.9	0	9.2	6.5	1.5	*	0.8	0.4	0	0	0.4 tourmaline
77WGL-24	11.0	3.7	85.3	17.6	29.3	29.3	0	16.8	4.7	0.8	0.4	0.8	0	*	0	0.4 chloritoid, *aegerine-augite
77WGL-25	9.3	4.7	86.0	21.3	33.7	25.9	0	11.6	5.4	*	*	1.2	*	0	0.4	0.4 chloritoid
77WGL-26	20.0	4.2	75.8	14.3	35.2	30.8	0	7.7	7.3	0.7	*	1.1	0.7	*	0.7	1.1 chloritoid, 0.4 aegerine-augite, *tourmaline, rutile
77WGL-49	12.7	1.7	85.6	14.0	37.0	33.5	0	10.5	2.3	1.2	*	0.8	0.4	0.4	0	*chloritoid
77WGL-75	21.5	3.1	75.4	26.9	14.3	30.7	0	18.4	6.5	0.8	*	*	0.8	0	0.8	0.8 chloritoid, *rutile
77WGL-76	45.4	1.7	52.9	14.0	6.6	40.5	0	24.8	7.4	0.8	3.3	0.8	0	0.8	0	0.8 rutile
77WGL-77	6.7	2.3	91.0	24.2	13.3	42.5	0	14.3	2.7	0.4	0	0.4	0.2	0.2	0	0.6 chloritoid, 0.4 rutile, 0.4 tourmaline, 0.2 topaz, 0.2 aegerine-augite
77WGL-78	11.3	9.0	79.7	15.5	13.4	45.6	0	19.7	2.1	1.3	*	0.4	*	0.8	0	0.8 tourmaline, 0.4 chloritoid, *rutile
77WGL-79	24.1	6.6	69.3	19.4	16.2	44.2	0	12.6	5.0	1.4	0.5	0.5	*	*	0	0.5 tourmaline, *glaucophane, *rutile

Table 6.

SAMPLE No.	Opaque Minerals	Aggregates	Nonopaque Minerals	Orthopyroxene	Clinopyroxene	Hornblende	Tremolite/Actinolite	Epidote	Garnet	Sphene	Zircon	Kyanite	Staurolite	Apatite	Unknown	Others
P113-3	16.7	6.3	77.0	16.5	38.1	29.4	1.3	9.1	3.9	0.4	0.4	*	*	*	0.4	0.4 tourmaline, *rutile
P113-11	11.3	7.7	81.0	29.2	31.7	26.7	0	7.4	3.3	0	*	*	0	*	1.2	0.4 tourmaline, *rutile
P114-1	2.3	9.0	88.7	16.5	27.8	42.1	1.1	9.4	1.9	0.4	*	*	0	0.4	0.4	
P114-4	15.7	9.0	75.3	27.4	19.5	27.9	0	14.6	8.4	0.4	0.4	0.4	*	0.4	0	0.4 tourmaline, *rutile
R901-6	29.1	5.7	65.2	35.4	9.2	20.1	0.4	12.7	17.1	1.8	0.4	1.3	0.4	0.4	0.4	
R901-8	38.2	2.2	59.6	13.0	62.2	13.0	0	8.8	1.3	0.8	*	*	*	*	0	0.4 tourmaline, 0.4 chloritoid
R901-9	20.7	6.0	73.3	12.3	51.8	20.9	0.5	11.8	1.8	*	*	*	0.5	*	0	0.5 chloritoid
R902-3	20.3	4.3	75.4	5.9	59.2	19.2	0	13.5	0.8	*	*	0.8	*	0	0.4	0.4 rutile, *chloritoid, topaz
R902-6	20.3	7.7	72.0	29.5	12.0	28.6	0	21.4	6.8	0.4	*	0.4	*	0.4	0	0.4 chloritoid, *rutile
S828-1	8.7	4.8	86.5	19.8	16.0	39.2	0	19.4	3.4	0.4	0	0.4	0	*	0	0.7 tourmaline, 0.4 chloritoid; 0.4 aegerine-augite, *rutile

Table 6, Samples collected from Unit I, beneath the 13-m terrace on the eastern shore of Willapa Bay. (See Fig. 2).

SAMPLE No.	Opaque Minerals	Aggregates	Nonopaque Minerals	Orthopyroxene	Clinopyroxene	Hornblende	Tremolite/Actinolite	Epidote	Garnet	Sphene	Zircon	Kyanite	Staurolite	Apatite	Unknown	Others
77WGL-1	15.7	7.0	77.3	28.4	3.0	40.1	0	15.1	10.8	0.4	*	0.4	0.9	0.9	0	*glaucophane
77WGL-2	10.9	6.6	82.5	37.5	18.3	23.1	*	12.4	5.6	1.2	*	0.4	0	0	1.6	*rutile
77WGL-3	9.9	4.9	85.2	23.6	2.3	49.4	1.5	13.1	4.6	0.4	0.4	1.5	0	0.4	0.8	0.8 aegerine-augite, 0.4 glaucophane, 0.4 tourmaline 0.4 sillimanite, *rutile
77WGL-5	12.6	6.0	81.4	33.0	9.8	27.8	0	13.3	13.0	1.4	*	0.7	0.7	*	0	0.4 sillimanite, *glaucophane
77WGL-6	10.3	7.3	82.4	35.6	12.6	31.6	0	7.7	8.9	0.8	0.8	0.8	*	*	1.2	*tourmaline, topaz
77WGL-11	8.3	7.7	84.0	41.7	9.9	33.4	0	9.1	2.8	1.2	0	1.2	*	*	0.4	0.4 rutile
77WGL-12	5.7	6.7	87.6	33.5	3.4	41.8	0	14.8	3.4	0.4	0	1.5	*	0.8	0.4	*tourmaline
77WGL-16	10.5	6.2	83.3	22.4	36.5	27.5	0	7.5	4.7	0.4	*	*	*	0.4	0.4	0.4 glaucophane
77WGL-17	15.9	3.5	80.6	29.5	29.1	25.2	0	9.1	5.5	0.4	*	0.4	0.4	*	0	0.4 rutile
77WGL-19	24.2	4.7	71.1	27.1	21.8	27.5	0	10.2	10.9	1.1	*	*	*	0.7	0.4	0.4 rutile
77WGL-21	17.2	7.5	75.3	24.3	31.9	25.3	0	10.0	6.0	0.7	1.0	0.3	0.7	*	0	*glaucophane

Table 7.

SAMPLE No.	Opaque Minerals	Aggregates	Nonopaque Minerals	Orthopyroxene	Clinopyroxene	Hornblende	Tremolite/Actinolite	Epidote	Garnet	Sphene	Zircon	Kyanite	Staurolite	Apatite	Unknown	Others
77WGL-27	12.2	8.9	78.9	33.5	11.3	33.1	0	11.3	6.7	1.3	*	1.3	0	1.3	0	0.4 chloritoid
77WGL-28	24.4	5.6	70.0	37.8	18.1	17.3	0	8.0	16.0	0.4	0.4	0.8	1.3	0	0	*rutile
77WGL-44	26.9	7.4	65.7	25.7	39.1	15.6	0	8.3	8.3	1.3	0.4	0.4	*	0	0.4	0.4 aegerine-augite, *rutile, topaz
77WGL-45	23.3	5.6	71.1	28.9	29.3	21.5	0	7.8	8.2	1.2	0.4	1.2	0.4	*	0.4	0.8 rutile, *tourmaline, *chloritoid
77WGL-46	30.3	2.0	67.7	27.8	27.8	22.0	0	11.0	8.9	1.3	0.4	*	0.8	0	0	*rutile
77WGL-47	12.0	4.0	84.0	40.1	19.0	23.0	0	11.9	4.4	0.4	1.2	*	0	*	0	*rutile
77WGL-48	16.8	4.9	78.3	39.9	18.5	20.6	0	10.9	7.6	0.4	0.4	0.8	*	0	0.4	0.4 chloritoid
P113-1	22.7	5.7	71.6	22.8	31.2	24.2	0	10.2	8.4	0.9	0.5	*	0.5	0	1.4	*rutile
P113-7	34.3	8.6	57.1	26.0	29.5	23.5	0.5	6.5	9.5	1.0	2.0	0.5	*	0	1.0	
P113-12	12.7	17.0	70.3	36.0	22.7	15.6	0	10.0	13.3	0.5	*	0.5	*	*	0.9	0.5 rutile
S825-2	10.3	5.7	84.0	45.6	13.3	21.4	0	11.9	5.8	1.0	*	*	0.3	0	0	0.3 glaucophane, 0.3 chloritoid, *aegerine-augite, *rutile

Table 7. Samples collected from Unit II, beneath the 13-m terrace on the eastern shore of Willapa Bay. (See Fig. 2).

SAMPLE No.	Opaque Minerals	Aggregates	Nonopaque Minerals	Orthopyroxene	Clinopyroxene	Hornblende	Tremolite/Actinolite	Epidote	Garnet	Sphene	Zircon	Kyanite	Staurolite	Apatite	Unknown	Others
77WGL-8	37.7	2.0	60.3	34.0	14.1	22.0	0	12.9	11.6	1.7	0.4	2.5	*	0	0.4	0.4 rutile
77WGL-13	11.8	4.6	83.6	37.3	20.8	17.3	0.4	10.2	12.2	0.8	*	0.4	*	0	0.8	
77WGL-14	24.4	5.6	70.0	51.6	9.9	21.0	0	6.0	9.1	0.8	*	1.6	0	0	0	*rutile
77WGL-34	20.6	4.1	75.3	29.5	17.8	29.4	0	15.4	5.8	0.8	*	0.4	0.4	0	0	0.4 chloritoid
77WGL-35	13.3	4.3	82.4	44.1	9.3	19.0	0	14.6	10.5	0.4	*	0.8	1.2	*	0	
77WGL-36	18.8	5.2	76.0	42.1	15.0	21.0	0.4	10.1	8.5	1.2	*	0.4	*	0.4	0	0.4 chloritoid, 0.4 aegerine-augite
77WGL-40	54.1	3.5	42.4	25.0	30.5	20.5	0	10.9	10.0	0.9	1.8	*	0	0	0	0.4 rutile, *chloritoid
77WGL-41	42.4	5.3	52.0	29.8	20.7	18.1	0	10.6	13.3	1.6	4.3	0.5	0.5	0.5	0	
77WGL-42	58.0	2.8	39.2	33.9	19.6	10.7	0	1.8	30.4	1.8	0	0	0	0	0	1.8 rutile
77WGL-43	18.0	5.3	76.7	37.4	11.3	27.8	0	13.5	8.7	0.4	0.4	*	*	*	0.4	*rutile
P113-6	8.7	10.7	80.6	39.7	16.5	28.1	0	5.8	9.1	*	*	0.4	*	0.4	0	
R902-1	13.7	4.3	82.0	8.1	71.1	13.4	0	6.9	0	0	0	0.4	0	0	0	
S825-1	24.8	6.3	68.9	19.8	28.6	22.6	0	19.4	6.0	0.5	0	1.4	0.5	0	0	0.5 tourmaline, 0.5 rutile, 0.5 topaz

Table 8. Samples collected from Unit III, beneath the 13-m terrace on the eastern shore of Willapa Bay. (See Fig. 2).

SAMPLE No.	Opaque Minerals	Aggregates	Nonopaque Minerals	Orthopyroxene	Clinopyroxene	Hornblende	Tremolite/Actinolite	Epidote	Garnet	Sphene	Zircon	Kyanite	Staurolite	Apatite	Unknown	Others
77WGL-4	27.2	3.7	69.1	27.2	27.5	17.4	0	13.0	10.5	1.4	0.7	0.4	0.4	0.4	0.7	0.4 rutile, *sillimanite
77WGL-7	21.9	9.7	68.4	24.2	38.7	18.7	0	7.5	5.4	0.8	1.7	1.7	0.4	*	0.4	0.4 sillimanite, *glaucophane
77WGL-9	16.7	10.1	73.2	24.1	37.9	21.4	0.9	8.5	4.9	1.3	0.4	0.4	*	*	0	*tourmaline, aegerine-augite
77WGL-10	29.2	8.5	62.3	16.1	46.6	21.7	*	6.4	7.2	0.4	0.4	0.8	0	0	0	0.4 tourmaline
77WGL-15	10.7	7.1	82.2	33.2	9.5	40.3	0	11.9	2.0	*	0.4	0.8	0.8	0.8	0	0.4 glaucophane
77WGL-18	7.8	9.8	82.4	26.2	31.3	32.5	0	7.1	2.0	0.8	*	*	*	*	0	
77WGL-20	12.9	9.0	78.1	24.3	35.0	24.7	0	11.1	2.1	2.1	*	0	0.4	*	0.4	
77WGL-22	13.1	7.5	79.4	30.6	31.0	22.7	0	12.0	2.9	0.4	*	*	*	*	0	0.4 aegerine-augite
77WGL-29	8.0	5.7	86.3	32.8	17.0	26.3	0	11.2	10.4	0.8	0	*	1.2	*	0	0.4 chloritoid, *rutile
77WGL-37	31.1	6.4	62.5	19.1	35.6	22.7	0	12.0	7.1	1.3	0.9	*	0	0.4	0.4	0.4 rutile
77WGL-38	36.2	4.7	59.1	26.3	37.7	14.8	0	9.7	7.6	1.7	1.7	*	0.4	0	0	*topaz
77WGL-39	23.5	8.0	68.5	27.4	37.0	17.4	0.4	10.9	3.0	1.3	*	0.9	0.4	0	0	1.3 rutile
P113-2	13.7	11.0	75.3	29.6	22.6	30.5	0	9.3	4.9	1.3	0.4	0.4	*	*	0.9	*glaucophane
P113-8	25.0	13.3	61.7	27.0	22.7	22.2	0	13.0	8.6	2.7	0.5	0.5	2.2	*	0.5	
R901-4	23.0	3.0	74.0	28.3	29.2	19.4	0	13.3	6.2	0.4	*	1.3	0.4	0	0.4	0.4 chloritoid, 0.4 topaz, *tourmaline
S825-3	22.6	3.4	74.0	20.8	47.9	15.8	0	11.6	1.9	*	0.8	0.8	0	0.4	0	*chloritoid

Table 9. Samples collected from Unit IV, beneath the 13-m terrace on the eastern shore of Willapa Bay. (See Fig. 2I.

SAMPLE No.	Opaque Minerals	Aggregates	Nonopaque Minerals	Orthopyroxene	Clinopyroxene	Hornblende	Tremolite/Actinolite	Epidote	Garnet	Sphene	Zircon	Kyanite	Staurolite	Apatite	Unknown	Others
77WGL-50	14.7	4.7	80.6	8.3	74.8	7.9	0	5.4	2.9	*	*	*	0.4	0	0.4	*tourmaline
77WGL-51	7.7	1.7	90.6	3.7	83.5	7.0	0	5.5	*	*	*	0	0	0	0.4	
77WGL-52	6.7	3.7	89.6	3.3	89.2	3.0	0	3.0	0.7	0.4	0	0	0	*	0.4	
P113-4	40.9	12.8	46.3	28.4	35.1	13.5	0	10.1	8.8	*	1.4	0	*	0	2.0	0.7 tourmaline, *rutile
P113-5	15.7	14.3	70.0	17.6	48.6	20.0	0	4.8	6.2	0.5	*	*	*	0.5	1.4	0.5 rutile
P113-9	24.7	9.7	65.6	21.3	51.3	14.7	0	2.0	6.6	1.0	0.5	0.5	*	0.5	1.5	
R901-1	30.3	6.6	63.1	4.0	87.6	4.0	0	2.0	1.5	*	0.5	0	0	0	0	0.5 chloritoid
U822-2	17.2	3.4	79.4	6.6	72.1	6.2	0	13.6	0.8	0.4	*	*	0.4	0	0	
U822-3	21.1	5.7	73.2	26.6	35.2	15.2	0	16.4	3.5	0.8	0.4	1.2	0.4	*	0	0.4 tourmaline
U822-5	16.4	9.5	74.1	15.0	57.5	7.5	0	17.7	1.8	0	*	0.4	*	0	0	
U822-6	26.7	7.5	65.8	23.2	38.0	11.1	0	22.8	2.7	*	1.1	0.4	0	0.8	0	*glaucophane

Table 10. Samples collected from Unit V, beneath the 13-m terrace on the eastern shore of Willapa Bay. (See Fig. 2).

SAMPLE No.	Opaque Minerals	Aggregates	Nonopaque Minerals	Orthopyroxene	Clinopyroxene	Hornblende	Tremolite/Actinolite	Epidote	Garnet	Sphene	Zircon	Kyanite	Staurolite	Apatite	Unknown	Others
77No-3a	33.9	20.0	46.1	0	0.5	0.5	0	29.5	39.0	15.0	2.5	*	2.5	4.5	0	4.0 tourmaline, 2.0 rutile
77No-3b	9.0	13.0	78.0	17.9	39.3	24.4	0	14.1	3.4	0.4	*	*	0.4	0	0	*tourmaline
74WGL-15	5.5	14.1	80.4	8.2	52.4	29.6	0	6.0	2.1	*	0	0.4	0	0	0.9	0.4 tourmaline
77WGL-80	3.0	36.2	60.8	6.2	3.7	23.0	0	59.7	4.1	1.2	0.4	0.8	0.8	0	0	*rutile
77WGL-81	8.0	15.3	76.7	23.5	13.5	11.7	0	19.1	28.3	*	2.2	0.4	0.4	0.4	0.4	
77WGL-82	4.7	32.5	62.8	17.1	6.0	26.7	0	43.0	6.0	0.4	0.4	*	0	0.4	0	*rutile
77WGL-83	17.7	15.0	67.3	25.3	4.1	60.2	0	8.9	0.4	0.7	0.4	0	0	0	0	
77WGL-84	30.7	8.5	60.8	11.1	1.2	76.6	0	9.9	0.4	0	*	0	0	0	0.4	0.4 rutile
77WGL-85	41.8	7.3	50.9	9.6	1.3	77.7	0	7.9	0.4	0.4	0.9	0.4	0	0	0	0.9 rutile, 0.4 topaz
77WGL-86	40.4	5.8	53.8	2.1	1.2	78.5	0	15.7	0.8	0.4	0.8	0.4	0	0	0	*rutile
77WGL-87	24.7	5.2	70.1	51.1	2.9	27.1	0	15.4	1.8	0	*	0.4	0.7	0.4	0	0.4 rutile, *tourmaline
77WGL-88	24.0	6.3	69.7	48.4	2.2	32.6	0	10.4	1.4	1.1	1.1	1.4	0.4	0	0	0.4 rutile, 0.4 tourmaline, 0.4 aegerine-augite
74WGL-45	24.8	9.1	66.1	11.9	32.9	31.5	0	14.8	3.8	2.4	*	1.0	0	*	1.4	0.5 tourmaline, *rutile
0823-1	2.7	11.3	86.0	8.1	35.7	42.2	0.4	9.3	2.7	0.4	0.4	*	0	0.8	0	
U824-4	8.3	5.7	86.0	7.8	76.4	4.3	0	11.6	*	*	0	0	*	0	0	
U827-6	35.0	3.0	62.0	9.3	0.8	35.5	0	45.6	1.6	0	0.8	0	0	0	0	2.0 rutile, 0.4 tourmaline, 0.4 chloritoid

Table 11. Samples collected from terrace deposits older than the units beneath the 13-m terrace of Willapa Bay. (See Fig. 1 & 2).