UNITED STATES DEPARTMENT OF INTERIOR

GEOLOGICAL SURVEY

POINT COUNT DATA AND SAMPLE LOCATIONS FOR SELECTED SAMPLES FROM PALEOGENE NONMARINE SANDSTONES, WASHINGTON

by

Virgil A. Frizzell, Jr.
U.S. Geological Survey
Menlo Park, California

OPEN-FILE REPORT
79-293

Introduction

The Cascade Range north of 47° latitude is composed predominantly of probable Paleozoic and Mesozoic metamorphic rocks and Mesozoic and Tertiary plutonic rocks (Misch, 1966; McKee, 1974).

Fringing and, in part, occurring within the complex crystalline core are several Paleogene (one in part Cretaceous?) nonmarine arkosic sandstone units. Although these units have been studied as part of various mapping projects, primarily by workers at the University of Washington, few attempts have been made to describe in detail the composition of these geographically separated sandstone units (see an initial attempt by Pongsapich, 1970).

In this open-file report, I present point count data and sample localities and discuss briefly the framework grain composition of the Paleogene sandstone units. The results are preliminary and stem from an ongoing U.S. Geological Survey mapping project in the area covered by the Wenatchee 2° Sheet (120-122°W, 47-48°N).

A majority of the samples included in this report were collected by the author. I am indebted, however, to the following colleagues for sharing with me both samples and edifying thoughts: Rowland W. Tabor (RWT), John T. Whetten (W), James D. Vine (V), James C. Yount (JY), and Betsey L. Mathieson (BL). Martha J. Hetherington provided skilled assistance in the preparation of tables and maps.

Brief Description of Units Studied

Correlation of the six units described in this report is summarized in Figure 1, and their generalized outcrop areas are shown in Figure 2. The Chuckanut Formation, the northwesternmost of the six units, is a strongly folded, coal-bearing fluvial unit composed predominantly of well-stratified light-tan sandstone with subordinate shale and conglomerate. Detailed descriptions of the Chuckanut are found in Glover (1935), Weaver (1937), and Miller and Misch (1963). Griggs (1970), on the basis of analysis of palynomorphs, assigned an age of Late Cretaceous to early Eocene to the lower half of the Chuckanut Formation. No contact has been found between the Chuckanut Formation and any of the other units under consideration here. Plate 1 and Table 1[1] show sample localities and point count data, respectively, for the Chuckanut Formation.

The Swauk Formation is present in the western foothills of the Cascades from the vicinity of the Stillaguamish River southward to the Yakima River and in the area between the Yakima River and Mt. Stuart. The Swauk is composed of crossbedded, moderately indurated, dark-colored sandstone that is interbedded with carbonaceous shale, pebbly sandstone, and locally conglomerate. Descriptions of this unit and its sub-units and the stratigraphic relations with adjacent units are found in Tabor and others (1977; see also Gresens and others, 1977; and Tabor and others, in press). The Swauk ranges in age from early Eocene, based on zircon fission track ages from intercalated tuffs, to perhaps as young as middle Eocene (J. Vance and C. Naeser, 1977 and 1978, written comm.; Whetten, 1976; Frizzell and Tabor, 1977; and Tabor and others, in press). Plate 2 and Table 2 show sample localities and point count data, respectively, for the Swauk Formation.

[1] See page 5

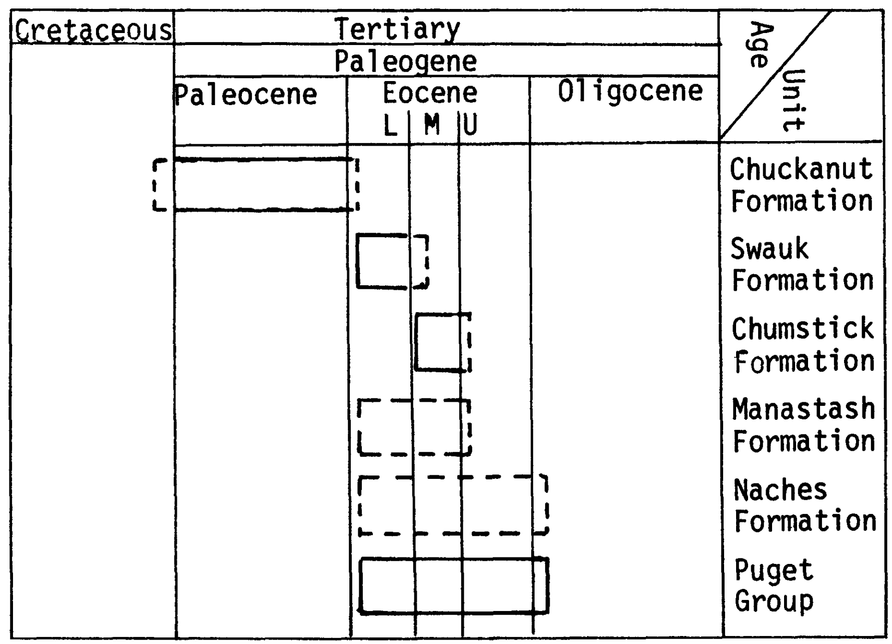


Fig. 1 - Correlation chart of six nonmarine sandstone units, Washington. Dashed lines indicate possible age range.

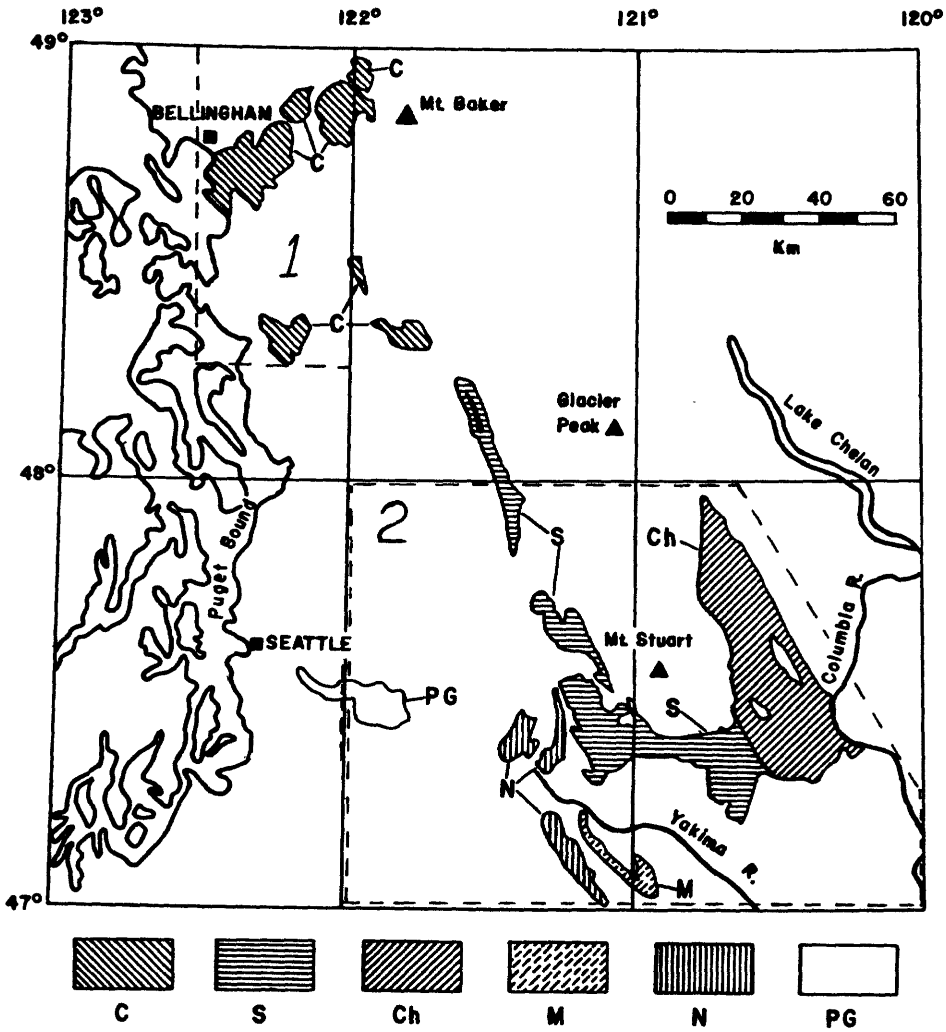


Fig. 2 - Map showing generalized outcrop pattern for nonmarine sandstone units in Washington and locations of Plates 1 thru 3. C, Chuckanut Formation; S Swauk Formation; Ch, Chumstick Formation; M, Manastash Formation; N, Naches Formation; PG, Puget Group.

[1]In Tables 1-7, abbreviations of point count catagories

Mono quartz	:	monocrystalline quartz
Fol quartz agg	:	foliated quartz aggregate
Equi quartz agg	:	equidimensional quartz aggregate
Undif poly quartz agg	:	undifferentiated polycrystalline quartz aggregate
Chert	:	chert
Plagioclase	:	plagioclase
Kspar + microcline	:	potassium feldspar + microcline
Clastic fragments	:	sedimentary rock fragments
Qtz mica tectonite	:	quartz mica tectonite
Micro hornfels	:	microgranular hornfels
Felsitic vrf	:	felsitic volcanic rock fragment
Microlitic vrf	:	microlitic volcanic rock fragment
Misc vrf	:	miscellaneous volcanic rock fragment
Granitics	:	granitic rock fragment
Micas	:	micas (biotite + muscovite)
Pyriboles	:	pyroxenes + amphiboles
Epidote	:	epidote
Garnet	:	garnet
Calcite	:	calcite (some with hematite stain)
Kaolinite	:	kaolinite (?)
Chlorite	:	chlorite
Alt products	:	miscellaneous alteration products
Matrix	:	matrix
Misc	:	miscellaneous
Unknown	:	unknown

Grain Type \ Field Sample Number	C1 JY-76-36	C2 JY-76-38	C3 JY-76-58	C4 JY-77-34	C5 JY-77-35	C6 JY-77-37	C7 VF-78-142	C8 VF-78-143	C9 VF-78-144	C10 VF-78-145	C11 VF-78-146	C12 VF-78-147	C13 VF-78-149	C14 VF-78-150	C15 VF-78-151	C16 VF-78-152	C17 VF-78-153	C18 VF-78-155	C19 VF-78-158	C20 VF-78-159	C21 VF-78-160	C22 VF-78-161	C23 VF-78-162	C24 VF-78-163
(Total Points Counted)	692	603	577	598	528	591	597	476	553	460	478	449	443	501	424	625	653	598	485	445	470	489	481	525
Mono Quartz	42	40	24	43	44	49	21	26	29	29	27	38	27	18	26	20	37	19	25	31	29	25	21	13
Fol. qtz. agg.							1							1	1									
Equi. qtz. agg.			17				1	2			1		1		1			1	1			2	1	
Undif. Poly. qtz. agg.	17	13		8	6	13	23	13	10	14	12	5	13	19	9	11	16	14	12	8	18	17	11	25
Chert		1	1	1		1	3		3	1	1	1		16	7	12		8	1		1	2		13
Plagioclase	9	29	37	30	29	19	33	49	43	41	40	45	42	24	32	31	27	31	44	45	34	41	51	19
K-spar + Microcline	25	15	11	15	17	14	7	7	4	11	14	9	14	3	4	2	9	6	9	9	11	8	8	3
Clastic fragments	2		3	1	1		4	1	2	2	3	1	1	8	5	6	3	8	4	3	4	1	3	4
Qtz. Mica tect.			2		1	1	1	2	2	1	1				1	1	1	1	1					1
Micro. hornfels													1				1	1						1
Felsitic vrf			3			1			6	1	1			3	3	5	3	4		1			1	2
Microlitic vrf			1				3							1				1						1
Misc.vrf	4	1	2	1	1	2	2							8	12	11	4	7	2	2	2	3	3	17
Granitics	1	2	3	2		2	7	4	2	4	2	1	1	4	2	3	2	5	1	2	5	6	4	7
Micas	4	4	3	2	13	1	4	8	4	11	9	13	13	4	9	4	21	7	10	6	4	4	4	5
Pyriboles																								
Epidote								1	2		1	1		2	1	1		1	1	1		3	1	1
Garnet								1																
Calcite			15	3		2			5															
Kaolinite	13	8	3	8	7	3	1									1	12	3						
Chlorite													1											
Alt. products																								
Matrix								4	14	2	2	13	3	2	6	16	8	2	3	7	2	2	5	2
Misc.	20	8	1	8	2	1	1	1	2			1	1	1	2	2	1		1	1		1		
Unknown	2		2		2	1	2	1	3	1	1		1	5	4	4	2	1	2	1		1	1	2

Table 1 - Point count data for the Chucknut Formation.
See text for explanation of abbreviations.

Field Sample Number / Grain Type	S1 RWT-11-75	S2 RWT-12-75	S3 RWT-186-76	S4 RWT-223-76	S5 RWT-275-76	S6 RWT-334-76	S7 RWT-500-76	S8 RWT-503-76	S9 VF-75-151	S10 VF-75-234	S11 VF-75-328	S12 VF-75-345b	S13 VF-75-381	S14 VF-75-440	S15 VF-75-443	S16 VF-76-143	S17 VF-76-167	S18 VF-76-173	S19 VF-76-176	S20 VF-76-177	S21 VF-76-180	S22 VF-76-209	S23 VF-76-242	S25 VF-76-244	S26 VF-76-245	S27 VF-76-256
(Total Points Counted)	304	590	483	500	530	500	522	531	612	479	414	455	506	350	445	439	521	463	511	626	529	453	533	628	480	60
Mono Quartz		29	29	48	24	29	40	38	24	22	35	32	26	38	25	28	31	24	21	25	28	44	23	29	27	34
Fol. qtz. agg.			1						1			1		1	2				2							
Equi. qtz. agg.		1							4	3	1	2	2		3		2			1	5				1	1
Undif. poly. qtz. agg.		11	5	5	4	4	8	27	6	6	3	2	2	5	8	4	3	6	6	5	2	4	5	3	3	8
Chert			4					2	18	1		1		1	4	5	1	4	6		2					
Plagioclase		43	29	28	46	37	34	9	31	48	49	46	42	38	49	37	38	44	41	51	37	45	58	42	48	34
K-spar + Microcline		9	12	9	10	10	11		2	3	13	3	21	15	1	11	10	7	7	9	3	6	9	2	2	4
Clastic fragments			2	2	2		1	3	7	5		4	2	1	4	5	1	5	4	1	2			2		1
Qtz. Mica tect.		3	2	2	1	1				1		1	1	1	2		1	1		1		2	2	2	1	12
Micro. hornfels		1	1	4	1				1	5		2	2	1	1	3			1		1	1	2	1		7
Felsitic vrf			7		4				2	6		4	2			1	4	3	7	3	10			9	6	
Microlitic vrf			2		2				4	1		2				1	3	2	4	2	3			1		
Misc. vrf	79	3	5	1	7		8	2	1	1		1			1	3	3	5	2	3	4		1	6	11	
Granitics		9	6	5	3	8	1		2	3		2	3		2		1		1	2	2	2	11	4	4	7
Micas		14	1	4	3	8		1	1	4	9	14	10	3	6	11	6	4	1	10	2	15	9	4	4	8
Pyriboles			2	4	2	3							2													
Epidote			2	3	2	1			2				2			2	2	1	6	2				1		3
Garnet										1									3							
Calcite	20	1		14																	3			8		
Kaolinite																										
Chlorite		1																								
Alt. products																										
Matrix		9			3			9	11	13	1	5	8	2	1	5	6	6	14	1	2		2			
Misc.	46	1	1	2	1	2	3	1	2	1	8	1	1	2	5	2	7	3	13	5	14	1		2	1	2
Unknown		2	7	1	1				4	4		3	2	2	2	2	2	3	3	3	1		1	1	1	1

Table 2 - Point count data for the Swauk Formation.

Field Sample Number / Grain Type	VF-76-262	VF-76-319	VF-76-348	VF-76-351	VF-77-106	VF-77-236	VF-77-327	VF-77-465	VF-77-510	VF-77-588	VF-77-644	VF-77-666	VF-78-364	VF-78-365	VF-78-366	VF-78-383
	528	529	530	531	532	533	534	535	536	537	538	539	540	541	542	543
(Total Points Counted)	532	510	536	507	420	325	601	465	565	608	489	578	258	464	454	437
Mono Quartz	25	30	20	24	26	19	36	40	25	35	30	37	17	30	23	16
Fol. qtz. agg.			1	1			1				1	1		1		
Equi. qtz. agg.			1		2	1	1		1	2		4	1	3		
Undif. poly. qtz. agg.	8	8	3	2	3	8	2	3	2	10	4	7	39	28	33	23
Chert			9	7	1	1	6		2		3	1	3	2		
Plagioclase	60	52	30	26	41	40	24	38	48	47	39	39	21	23	38	50
K-spar + Microcline	7	8	8	7	14	4	7	13	6	1	10	4				3
Clastic fragments			6	7		4	4	1	4		7	1	1	4	2	1
Qtz. Mica tect.		1			1	2				1		2	13	5	2	2
Micro. hornfels		.1			1	1				2	1	2	2	1		
Felsitic vrf			12	8	5	18	13	3	9		2	3				
Microlitic vrf			5	7	7	1	2		2	1	2					
Misc. vrf			4	9		1	3			3	3			2	3	5
Granitics	19	6	1		1	5	1		4	4	2	6	2		2	4
Micas	13	9	1	3	3	7	1	2	1	1	1	2	5	4	6	5
Pyriboles		2														
Epidote		3						1	3	4	2					3
Garnet										4						1
Calcite							18				14		2	1		2
Kaolinite																
Chlorite																2
Alt. products																
Matrix		2	1	3	3	3		2	4							
Misc.	3	2	3	2	4		6	1	2	6	2	5				1
Unknown		2	2	2	2	6	2	1	2	5		5	3	2	1	3

Table 2 - continued

The Chumstick Formation of Gresens and others (in press) is confined to the Chiwaukum graben, a downfaulted block within the crystalline core. Its white micaceous sandstone is intercalated with lesser amounts of shale, conglomerate, fanglomerate, and rare siliceous tuff (Whetten, 1976; Gresens and others, 1977; and (to be formally named in) Gresens and others, in press). In addition to their utility as marker beds which help to define the tructure of the fluvial rocks (Whetten and Laravie, 1976), the siliceous tuffs yield middle to late Eocene fission-track ages from zircon (Whetten, 1976). The contact between the Chumstick Formation and the Swauk Formation is the western graben-bounding fault of the Chiwaukim graben, the Leavenworth fault (Tabor and others, 1977 and in press). Plate 2 and table 3 show, respectively, localities and point count data for the Chumstick Formation.

The Manastash Formation is present in an area south of the Yakima River. It consists of relatively quartz-rich sandstone interbedded with shale, conglomerate, and minor coal beds (Smith, 1904). The unit may be as old as the Swauk Formation but could also be somewhat younger (Tabor and others, 1977 and in press). Plate 2 and table 4 show, respectively, localities and point count data for the Manastash Formation.

The lithologically heterogeneous Naches Formation consists of volcanic rocks ranging compositionally from rhyolite to basalt interbedded with sandstone. This unit forms a north-trending body of rock that crosses the Yakima River. It is described by Foster (1960) (and by Stout (1964) who included the Manastash as part of the Naches). Estimates of its age range from early Eocene to early Oligocene, based upon correlations with the Puget Group (Foster, 1960) to as young as Oligocene (J. Vance and C. Naeser, pers comm.,1977). Tabor and others (1978) consider it to be late Eocene and

Grain Type \ Field Sample Number	Ch1 RWT-104-76	Ch2 RWT-218-76	Ch3 RWT-347-76	Ch4 RWT-355-76	Ch5 VF-76-108	Ch6 VF-76-111	Ch7 VF-76-280	Ch8 VF-76-288	Ch9 VF-76-289	Ch10 VF-76-379	Ch11 VF-76-404	Ch12 VF-77-132	Ch13 VF-77-161
(Total Points Counted)	490	512	366	522	418	444	444	491	525	404	411	394	399
Mono Quartz	31	26	30	29	28	25	38	31	28	29	35	26	35
Fol. qtz. agg.				1	1		2				1	2	1
Equi. qtz. agg.					3	1	10	2	1	3	5	4	2
Undif. poly. qtz. agg.	29	7	9	9	8	4	15	3	2	10	18	5	4
Chert													
Plagioclase	26	32	40	40	44	44	32	40	28	42	27	40	55
K-spar + Microcline	6	11	7	6	9	16	3	21	7	11	9	15	2
Clastic fragments			1	1	1					1		1	
Qtz. Mica tect.			2										
Micro. hornfels			1									1	
Feleitic vrf			3	4	3	4				1	5	3	
Microlitic vrf		1	1	6	2	2		1				2	
Misc. vrf	7	2	7	6		5		2	37	2		2	1
Grenitice	18	7	12	13	2	1	2	2		2	5		2
Micas	8	6	10	2	8	15	3	6	4	6	13	7	11
Pyriboles				1	1								
Epidote		1			1	2		1					
Garnet	1												
Calcite	21		1						9				
Kaolinite													
Chlorite													
Alt. products													
Matrix		2	2	6	1	7	3	3	18	6	2	3	5
Misc.	3	1	2	2	2	1	2		3	1	1	1	2
Unknown		1	2	1	3	1		1	2	1	1	1	1

Grain Type \ Field Sample Number	Ch14 VF-77-208	Ch15 VF-77-211	Ch16 VF-77-212	Ch17 VF-77-214	Ch18 VF-77-216	Ch19 VF-77-217	Ch20 VF-77-218	Ch21 VF-77-221	Ch22 VF-77-222	Ch23 VF-77-223	Ch24 VF-77-226	Ch25 VF-78-174	Ch26 VF-78-175
(Total Points Counted)	415	564	417	515	423	459	457	462	528	522	506	495	491
Mono Quartz	26	51	51	24	29	27	25	26	28	25	22	28	24
Fol. qtz. agg.				2	1			2					
Equi. qtz. agg.	2		8	13	3	1		3	1	1			
Undif. poly. qtz. agg.	3	8	5	5	5	1	5	7	4	5	1	16	12
Chert			1	1									
Plagioclase	51	33	27	45	56	53	56	40	53	54	67	44	53
K-spar + Microcline	15	7	7	8	5	11	7	15	9	10	6	8	5
Clastic fragments	2			1		2		1				1	
Qtz. Mica tect.													
Micro. hornfels				1		1							
Feleitic vrf	1						4	3	1	1	1	1	3
Microlitic vrf								1	4	2			
Misc. vrf		1				3	3	4	1	4	1	2	4
Grenitice	1	1		11	2	1	2	3	7	2	4	3	4
Micas	7	24	10	6	20	17	4	4	7	7	13	8	10
Pyriboles													
Epidote	3								1	1	1	2	1
Garnet												1	
Calcite				21		5	12	3				19	
Kaolinite					2	6	4	8					
Chlorite													
Alt. products													
Matrix	4		6		5	2	1	3	4	4	2		3
Misc.	10	8	2	8	5	3	4	1		1	3		
Unknown	1	1		1	1	1	2	1	1	1	1	1	1

Table 3 - Point count data for the Chumstick Formation.

Grain Type \ Field Sample Number	Ch27 W-75-96	Ch28 W-75-97	Ch29 W-75-105	Ch30 W-75-117	Ch31 W-75-130	Ch32 W-75-141	Ch33 W-76-47	Ch34 W-76-65	Ch35 W-76-66	Ch36 W-77-51	Ch37 W-77-84	Ch38 W-77-86	Ch39 W-77-104	Ch40 W-77-113
(Total Points Counted)	499	457	538	463	530	515	434	399	399	454	513	464	488	528
Mono Quartz	27	20	16	19	19	21	23	12	22	37	13	15	15	30
Fol. qtz. agg.		1	1	1					1					
Equi. qtz. agg.														
Undif. poly. qtz. agg.	11	21	21	22	33	26		11	15	31	7	6	6	17
Chert														
Plagioclase	53	42	34	43	43	38	36	22	47	20	20	26	11	45
K-spar + Microcline	3	9	10	11	1	11	9	9	9	2	35	11	1	
Clastic fragment										2				
Qtz. Mica tect.										2				
Micro. hornfels														
Felsitic vrf	2		3	1		1	18	18	1	1	32	15	29	5
Microlitic vrf	2		1	1		1	8	1	1		1		1	
Misc. vrf	1	5	12	3	2	2	6	32	3	5	25	25	37	3
Granitics	1	6	5	5	8	8	5	11	5	4	10	3	2	7
Micas	5	5	5	9	2	8	8	3	10	12	5	5	2	12
Pyriboles	4									9				1
Epidote	1								2	2	2			1
Garnet				1						5	1			
Calcite						3	2							
Kaolinite					9	5	1							
Chlorite							1		1					1
Alt. products														
Matrix	4	1	3	1			6		3	1		1		5
Misc.	1				10	2				1				
Unknown	1		1				1	1		1	1			1

Table 3 - continued

Field Sample Number / Grain Type	M1 RWT-354-75	M2 RWT-420-76	M3 RWT-463-76	M4 RWT-467-76	M5 RWT-313-77	M6 RWT-324-77	M7 VF-76-512	M8 VF-76-515	M9 VF-76-567	M10 VF-76-570	M11 VF-76-616	M12 VF-76-617	M13 VF-77-258	M14 VF-77-265	M15 VF-77-322
(Total Points Counted)	430	562	509	481	553	177	540	441	599	589	461	516	520	535	364
Mono Quartz	36	61	51	45	33	43	39	42	43	45	33	43	54	50	49
Fol. qtz. agg.										1					
Equi. qtz. agg.	3	1		1	1	2	4	1	2	1	4	2	3	3	
Undif. poly. qtz. agg.	12	9	3	7	19	5	27	10	6	12	4	3	13	5	3
Chert		2		2			1						2		
Plagioclase	35	10	28	19	35	45	12	30	35	23	45	38	15	33	40
K-spar + Microcline	9	6	13	14	9	3	3	10	5	11	11	12	9	33	6
Clastic fragments		1		2	3		1	1		1		1	1	1	2
Qtz. Mica tect.									1	1					
Micro. hornfels				1				1	1		1		2		2
Felsitic vrf		9	3	9	1		12		6	4	1	1		5	
Microlitic vrf							1								
Misc. vrf	5				1	1				2	1	1		1	
Granitics		1	1	1	3	1	1	2		1		1			1
Micas	2	1	4	4	4	3		8	11	12	10	4	6		9
Pyriboles															
Epidote								1					1		1
Garnet															
Calcite			3											19	
Kaolinite															
Chlorite															
Alt. products															
Matrix	2	2		1	1	3		6	11	2	2	1	14		1
Misc.	2	1		6		2	4	2	5	1	2	13	1		2
Unknown	2	1				1	1	2	4	1			1		1

Table 4 - Point count data for the Manastash Formation.

Oligocene (?). The Naches Formation is in fault contact with both the Manastash Formation south of the Yakima River and Swauk Formation north of the river. Plate 2 and table 5 show, respectively, localities and point count data for samples from the Naches Formation.

The Puget Group underlies the Quaternary deposits of the Puget Lowland southeast of Seattle. This heterogeneous group consists of a lower sandstone, a middle volcanic sandstone, and an upper coal-bearing sandstone and ranges in age from early Eocene to early Oligocene (Vine, 1969). Plate 2 and Figure 5 show localities, and table 6 shows point count data for samples from the Puget Group.

Two units not described herein are the late Eocene Roslyn Formation and the early and middle Oligocene Wenatchee formation of Gresens (1976). Tabor and others (in press) summarize the lithology and age of the Roslyn, and Gresens and and others (1977 and in press) the Wenatchee.

Methods

Thin sections from 155 samples of selected predominantly fine- to medium-grained sandstone from the various units were stained for potassium feldspar. Twenty-five categories of grain type were counted using methods outlined by Dickinson (1970); the mean number of grains per section counted was 490.

Raw point count data were converted to percentages (Table 7) using methods modified from Dickinson (1970), Graham and others (1976), and K. Helmold (pers. comm., 1978). The sum of total points counted was divided into the unknown category which yielded percentage of total points which were unknown when counted. The number of unknown counts were subtracted from total points counted which yielded a figure that was divided into miscellaneous and matrix. This yielded the percentage of the known components of the rock which were either matrix or miscellaneous.

Grain Type \ Field Sample Number	N1 BL-105-78	N2 BL-115-78	N3 VF-77-299	N4 VF-77-301	N5 VF-77-338	N6 VF-77-366	N7 VF-77-318	N8 VF-77-384	N9 VF-77-405	N10 VF-77-410	N11 VF-77-411	N12 VF-77-417	N13 VF-77-535	N14 VF-77-540	N15 VF-78-201	N16 VF-78-241	N17 VF-78-246	N18 VF-78-247
(Total Points Counted)	414	429	527	525	430	627	460	556	533	620	499	574	518	520	466	419	223	453
Mono Quartz	28	18	34	46	48	32	33	39	33	36	34	25	34	36	26	25	3	2
Fol. qtz. agg.						1			1	1			1	1		1		
Equi. qtz. agg.	1			3	2	7	6	1	5	3		1			1			
Undif. poly. qtz. agg.	28	32	7	3	4	10	7	8	5	8	10	8	11	5	23	29	17	33
Chert							1		1								69	56
Plagioclase	40	47	46	42	43	38	36	47	30	35	49	47	48	46	42	39	7	2
K-spar + Microcline			10			3	4	1	9	3	5	9	2	4				
Clastic fragments		1	1		1	2	2		1	4			1	2	1	1	2	3
Qtz. Mica tect.	1			1		1		2	2	1				1		1		
Micro. hornfels																		
Felsitic vrf			1	3			2		6	3	2	3						
Microlitic vrf				1		1	2		2	1		1		1				
Misc. vrf	2	2	2		1	8	7	2	5	4		5	2	3	6	4	3	3
Granitics			2	1		1	5	3	1		3	7	4	6	1			
Micas	3	1	19	2	13	12	8	18	8	11	13	4	13	5	0	2		
Pyriboles																		
Epidote							1	4	1	1		1	1	6	1			
Garnet												1						
Calcite															2	7		
Kaolinite																		
Chlorite	4	3									4				1	1		
Alt. products																		
Matrix	1		8	7	9		2	1	1	2	2	1	1		7	10	9	5
Misc.			12	1	0			1	3	5	5	1	1	1	2	1		
Unknown	8	1	5	1	1	1	2	1	3	3	8	2	3	2	2	2	3	3

Table 5 - Point count data for the Naches Formation.

Grain Type \ Field Sample Number	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15
	V-H19	V-H20	V-H22	V-H56	V-H72	V-H77	V-H333	VF-78-106	VF-78-114	VF-78-124	VF-78-125	VF-78-127	VF-78-128	VF-78-129	VF-78-131
(Total Points Counted)	348	415	576	152	280	432	320	447	592	638	482	558	610	553	553
Mono Quartz	35	26	31	28	40	30	38	23	31	34	32	27	37	32	30
Fol. qtz. agg.	1	1				1			1					1	
Equi. qts. agg.			2					3	2	2	2	3	5	3	3
Undif. poly. qts. agg.	18	19	22	14	25	17	5	5	9	8	12	17	20	11	7
Chert	3	3				1		1		1					1
Plagioclase	19	30	38	31	14	30	50	34	13	32	29	32	17	23	41
K-spar + Microcline	1	1	2	13				9	25	16	14	14	13	17	10
Clastic fragment	5	2		5	5	3	2	9	1	5	3	1		1	3
Qtz. Mica tect.	5	2	4	1	3	2									
Micro. hornfels	4	1													
Felsitic vrf	1			2		1		12	12	3	6	4	6	5	3
Microlitic vrf				1		1		1							
Misc. vrf	8	5	2	5	12	7	4	2	6	1	3				1
Granitics	2	3	2		1	1			1	3	4	3	4	2	1
Micas	5	2	5	8	23	9	20	6	4	9	12	4	3	6	1
Pyriboles															
Epidote															
Garnet															
Calcite		32	18				2			37			4	1	13
Kaolinite		3	9		15	1		3	1		1	5	19	12	5
Chlorite						1	1	3	1	2	1				
Alt. products										13	46	17	7		8
Matrix	3				8	2		4	39			1			
Misc.	15			1				3	1						
Unknown	7	1	1	5	2	2	2	5		2	3	2	2	1	2
Formation Name	T_m	T_m	T_m	T	T	T_m	T	R	R	R	R	T?	T?	R?	R?

Table 6 - Point count data for the Puget Group. Formational assignments from Vine (1969) and H. D. Gower (pers. comm., 1978); T_m = Tiger Mountain Formation, T = Tukwila Formation, R = Renton Formation.

	Step 1	Step 2	
	Actual point counted	Percent Steps a-g	Percent framework clasts
Mono quartz	99	27	27
Fol quartz agg	0		
Equi quartz agg	2	1	1
Undif poly quartz agg	49	13	13
Chert	1		
Plagioclase	154	42	42
Kspar + microcline	50	14	14
Clastic fragments	4	1	1
Qtz mica tectonite	1		
Micro hornfels	2	1	1
Felsitic vrf	1		
Microlitic vrf	0		
Misc vrg	0		
Granitics	[1] (5)	(1)	
Micas	53	13	
Pyriboles	0		
Epidote	1		
Garnet	0		
Calcite	0		
Kaolinite (?)	0		
Chlorite	3	1	
Alt products	0		
Matrix	15	3	
Misc	5	1	
Unknown	3	1	
Total points counted T_1	443		99%

[1]Granitics not included in total of this column. Data derived for this category were distributed to either quartz or plagioclase (3 and 2 points respectively, in this case) depending upon which species occured under the cross hair.

Step 2

Conversion of raw point count data to percentages.

Step a: divide unknown by $Total_1$:

$(3 \div 443)\ 100 = 1\%$

Step b: subtract unknown from $total_1 = Total_2$

$443 - 3 = 440$

Step c: first divide misc and then matrix by $total_2$:

$(5 \div 440)\ 100 = 1\%$, $(15 \div 440)\ 100 = 3\%$

Step d: subtract the sum of misc and matrix from $total_2 = Total_3$

$440 - (5 + 15) = 420$

Step e: divide $total_3$ separately into mica, pyriboles, epidote, garnet, calcite, kaolinite, chlorite, and alteration products:

$(53 \div 420)\ 100 = 13\%$. $(1 \div 420)\ 100 = 0$,

$(3 \div 420)\ 100 = 1\%$

Step f: subtract the sum of the clasts in Step 5 from $total_3 = Total_4$:

$420 - (53 + 1 + 3) = 363$

Step g: divide $total_4$ into individual remaining clasts types = framework clast percentages.

monoquartz $\div\ total_4 = (99 \div 363)\ 100 = 27\%$
equi quartz agg $\div\ total_4 = (2 \div 363)\ 100 = 1\%$
undif poly quartz agg $\div\ total_4 = (49 \div 363)\ 100 = 13\%$
thru
Micro hornfels $\div\ total_4 = (2 \div 363) 100 = 1\%$

Table 7--Step-by-step example of conversion of raw point count data to framework grain parameters and ternary ratios for ample VF-78-149 (C 13 in Figure 3 and Plate 1). See text for brief explanation of procedure. (Cont).

Step 3

Conversion of framework clast percentages (column 3) to framework grain parameters.

	Qm	= Mono quartz	= 27
+	Qp	= Fol quartz agg + Equi quartz agg + undif poly quartz agg + chert	= 14
	Q	= total quartz	41

	P	= plagioclase	= 42
+	K	= Kspar	= 14
	F	= total Feldspar	56

	Lv	= felsitic + microlite + and misc vrf	= 0
+	Ls	= clastic + qtz mica tectonite + micro hornfels	= 2
	L	= lithics	2
+	Qp	= polycrystalline quartz	= 14
	L_T	= total lithics	16

Step 4

Conversion of framework grain parameters to ternary ratios and secondary parameters.

Q = 41%
F = 56
L = 2
99%

Qm = 27%
F = 56
L_T = 16
99%

Qm = (27) = 63%
Qp = (14) = 33
L = (2) = 5
101%

Qp = (14) = 88%
Lv = (0) =
Ls = (2) = 13%
101%

Qm = (27) = 33%
P = (42) = 51
K = (2) = 5
101%

Qm/Q = 27/41 = .66
P/F = 42/56 = .75
Lv/L = 0/2 = 0

Table 7 (Cont.)

Step 1: Assembling actual point count data. Step 2: Conversion to percentages. Step 3: Conversion of percentages to framework grain parameters. Step 4: Conversion of parameters to ternary ratios.

The components micas, pyriboles, epidote, garnet, calcite, kaolinite (?), chlorite, and alteration products were divided by the subtotal remaining after the miscellaneous and matrix components were subtracted from their divisor. After the percentages of the above eight categories were derived, the sum of the eight categories was subtracted from their divisor.

The resulting difference consists of total framework clasts. The framework clast total was then divided into all remaining categories of grain types. From these percentages, framework grain parameters (Figure 3) can be derived using methods outlined by Dickinson (1970) and Graham and others (1976).

Total quartz (Q) was derived by adding chert and polycrystalline quartz grains (collectively symbolized as Q_p) to monocrystalline quartz grains(Q_m). Total feldspar (F) was derived by adding plagioclase (P) to potassium feldspar (K). Sedimentary and metasedimentary lithic fragments (L_S) added to volcanic lithic fragments (L_V) yielded lithics (L) Which when added to Q_P produced total lithics (L_T).

These framework-grain parameters were variously combined to form ternary ratios. Such ternary ratios have been used to compare suitable sandstone units (Graham and others, 1976) or possibly to discriminate between sandstone units from differing tectonic regimens (Dickinson and Suczek, 1978). The components of the ternary ratios QFL and QFL_T were taken directly from the percentages derived from the point-count data. The components of the ratios Q_MQ_PL, $Q_PL_VL_S$, and Q_MPK however, were summed and recalculated to 100 percent before they were plotted on triangular diagrams. Ternary ratios and diagrams are shown in Table 8 and Figure 4, respectively. Note: The results in Table 8 differ somewhat from those published elsewhere (Frizzell, 1979) for two reasons: (1) data here published are based on more samples, and (2)

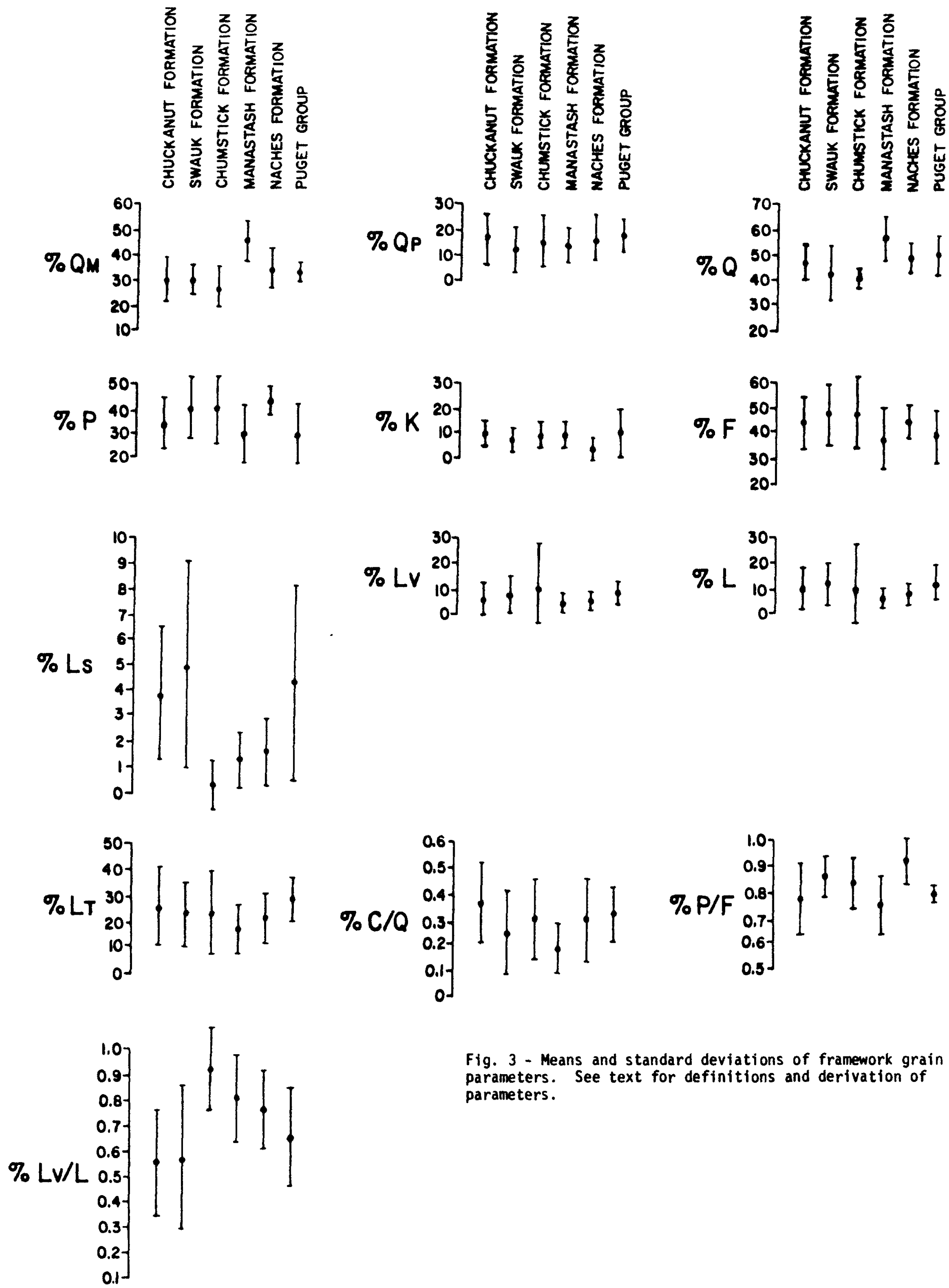
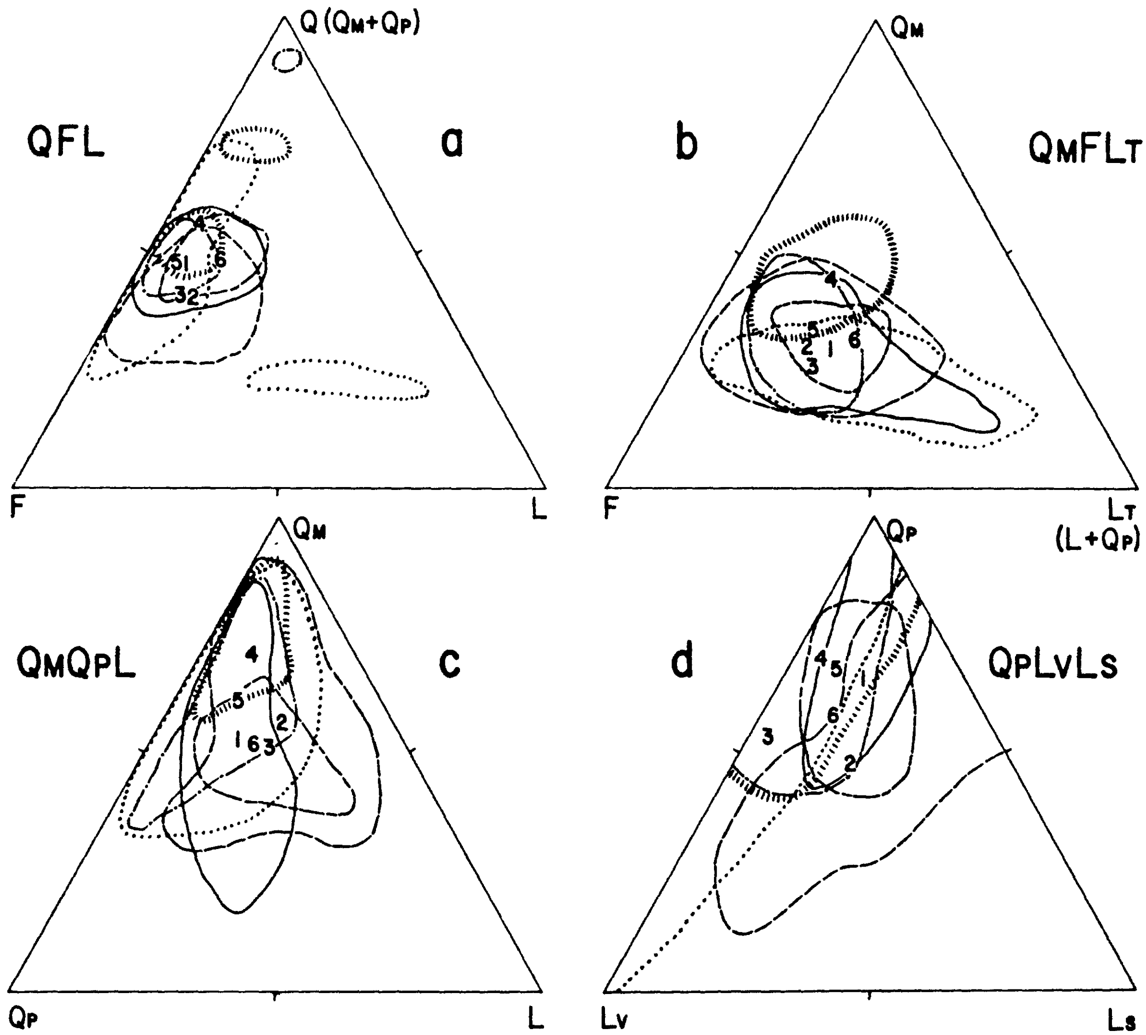
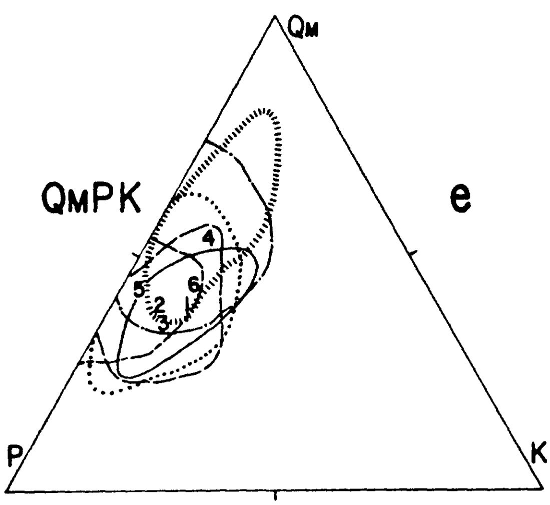


Fig. 3 - Means and standard deviations of framework grain parameters. See text for definitions and derivation of parameters.

Ternary Ratios	Chuckanut Formation	Swauk Formation	Chumstick Formation	Manastash Formation	Naches Formation	Puget Group
(samples)	(24)	(41)	(42)	(15)	(18)	(15)
QFL	47,44,9	41,47,12	40,48,12	56,38,6	48,46,7	49,39,12
Q_MFL_T	29,44,26	29,47,23	27,48,25	45,38,17	33,46,21	32,39,29
Q_MQ_PL	53,31,16 (29,17,9)	56,21,23 (29,11,12)	51,26,23 (27,14,12)	71,19,10 (45,12,6)	60,27,13 (33,15,7)	52,28,20 (32,17,12)
$Q_PL_VL_S$	65,19,15 (17,5,4)	48,30,22 (11,7,5)	54,42,4 (14,11,1)	71,24,6 (12,4,1)	68,23,9 (15,5,2)	59,28,14 (17,8,4)
Q_MPK	40,47,14 (29,34,10)	38,52,10 (29,40,8)	36,53,11 (27,40,8)	54,36,11 (45,30,9)	42,55,4 (33,42,3)	44,43,13 (32,31,9)
C/Q	.37	.26	.31	.20	.30	.33
P/F	.77	.85	.83	.76	.93	.79
L_V/L	.56	.57	.92	.80	.75	.65

Table 8 - Table of ternary ratios and secondary parameters for six nonmarine sandstone units from Washington. Numbers in parentheses are recalculated to sum to 100 percent. See text for definitions and derivation of ratios.





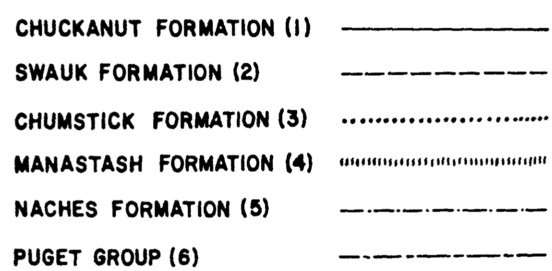


Fig. 4 - Triangular diagrams comparing detrital modes of six nonmarine sandstone units from Washington. Outlined are domains which include 90% or more of sample modes for each respective unit. Numbers are plotted means for each respective unit. See text for derivation of parameters. a. QFL plot; b. Q_MFL_T plot; c. Q_MQ_PL plot; d. $Q_PL_VL_S$ plot; and e. Q_MPK plot.

differing methods of calculating L_V were used. The previously published L_V included granitic lithic fragments which are here distributed to either Q_M, P, or K depending upon which species was counted within the plutonic grain.

Three secondary parameters, essentially ratios of six of the above mentioned framework grain parameters, are suggested by Dickinson (1970) as refinements which may help describe a given unit. These include polycrystalline quartz to total quartz (Q_M/Q), designated C/Q in Dickinson (1970); plagioclase to total feldspar (P/F); and volcanic lithic to lithics (L_V/L). These ratios are shown in Figures 3 and table 8.

Discussion of Data

All six sandstone units are predominantly either feldspathic or litho-feldspathic subquartzose sandstones (terminology after Crook, 1960, and Dickinson, 1970). Some samples of both the Naches and Manastash Formations, however, are classified as quartzose sandstone; and the Chumstick Formation contains samples more properly called feldspatholithic or lithic subquartzose sandstone.

While all six units have generally uniform framework clast composition, minor but significant differences exist between them. Basal or basement-onlap portions of the units differ locally from the overall composition of the whole unit, as do volcanic lithic sandstones and tuffaceous interbeds. Shown in Table 2, for an example, is RWT-11-75, essentially a serpentinite sandstone composed of serpentine clasts (here misc. vrf), opaques, and altered mafic minerals (misc.) which were derived from the underlying serpentinite body. Samples from these parts of the units have been excluded from the calculations of average framework grain parameters.

The amount of monocrystalline quartz (Q_M) ranges from 25 to 45 percent, with the Manastash Formation containing the most. Interestingly, while the

Manastash has nearly the least polycrystalline quartz (Qp, 12 percent), it still contains the most total quartz (Q, 56 percent). Chert content, not summarized in Figure 3, varies greatly. The Chuckanut and Swauk Formations contain 3 and 2 percent respectively; the Puget Group and Manastash Formation contain 0.7 and 0.6 percent respectively; and the Naches and Chumstick Formation have essentially no chert.

Plagioclase content ranges from 30 (Manastash Formation) to 42 (Naches Formation) percent. The Naches Formation has the least potassium feldspar and the Chuckanut Formation the most. The range in total feldspar is greater than for plagioclase alone, but four of the units contain from 44 to 48 percent.

The Chuckanut and Swauk Formations and the Puget Group contain more than 3 percent sedimentary and metasedimentary lithic grains. The Chumstick contains only 0.5 percent sedimentary lithic grains, but it has 11 percent volcanic lithic grains. The high volcanic-lithic percentage in the Chumstick is reflected by a sub-domain which trends to L on the QFL diagram (Fig 4a).

Dickinson (1970, p. 704-706 and table 4) gives "typical values for the various grain parameters in subquartzose sandstones derived from either idealized volcanic, plutonic, or "tectonic" provenances or mixtures of different types of provenances within orogenic belts. (Dickinson (1970) describes "tectonic" provenances as uplifted supracrustal strata composed mostly of chert, sediments, and metasediments). Dickinson and Suczek (1978) go one step further in stating that various triangular plots jointly discriminate the chief tectonic-provenance types. Based upon their criteria the following generalizations can be made about the units under consideration without any knowledge of the source terrain.

The total quartz content (40 to 56 percent) and "special parameters" such as mica (the mean amount of total mica, biotite plus muscovite, not shown in

Figure 3, ranges from 4 to 9 percent) and chert indicate a combination of plutonic and "tectonic" provenances. High feldspar content (38 to 48 percent, 45 percent overall mean) and lithic content (6 to 16 percent, 10 percent mean) suggest a plutonic source.

The ratio of polycrystalline quartz to total quartz (Q_M/Q) averages 0.29. This value is between the plutonic (near 0) and "tectonic" (0.5+) values.

Values for the plagioclase-to-total-feldspar ratio (P/F) are all between 0.75 and 1.0, which could be indicative of volcanic source terrane. The values for the other two terranes, however, are cited as variable by Dickson (1970). So evidence for a volcanic source terrane must be considered inconclusive.

A volcanic source terrane for the Chumstick Formation is emphasized by its high volcanic lithic to lithics ratio (L_V/L) OF 0.92. The Chuckanut and Swauk Formations, on the other hand, have L_V/L ratios of 0.56 and 0.57 respectively, indicative of "tectonic" provenances. (Plutonic source terranes have "variable" L_V/L ratios) L_V/L ratios for the other units are between these extremes.

SUMMARY

While all six sandstone units are predominantly feldspathic to lithofeldspathic subquartzose sandstone, significant differences do exist between them.

The data presented here and knowledge about the source terrane of these terrestrial sandstones (predominantly the crystalline core of the Cascades) verify, for this case, the generalizations made by Dickinson.

Although some uncertainty exists about the tectonic regimen within which these sandstone units were deposited, framework grain composition and ternary ratios provide some insight. The provenance was a combination of plutonic and "tectonic" terranes, with a minor but significant volcanic component. This provenance suggests a combination continental-block and magmatic-arc setting.

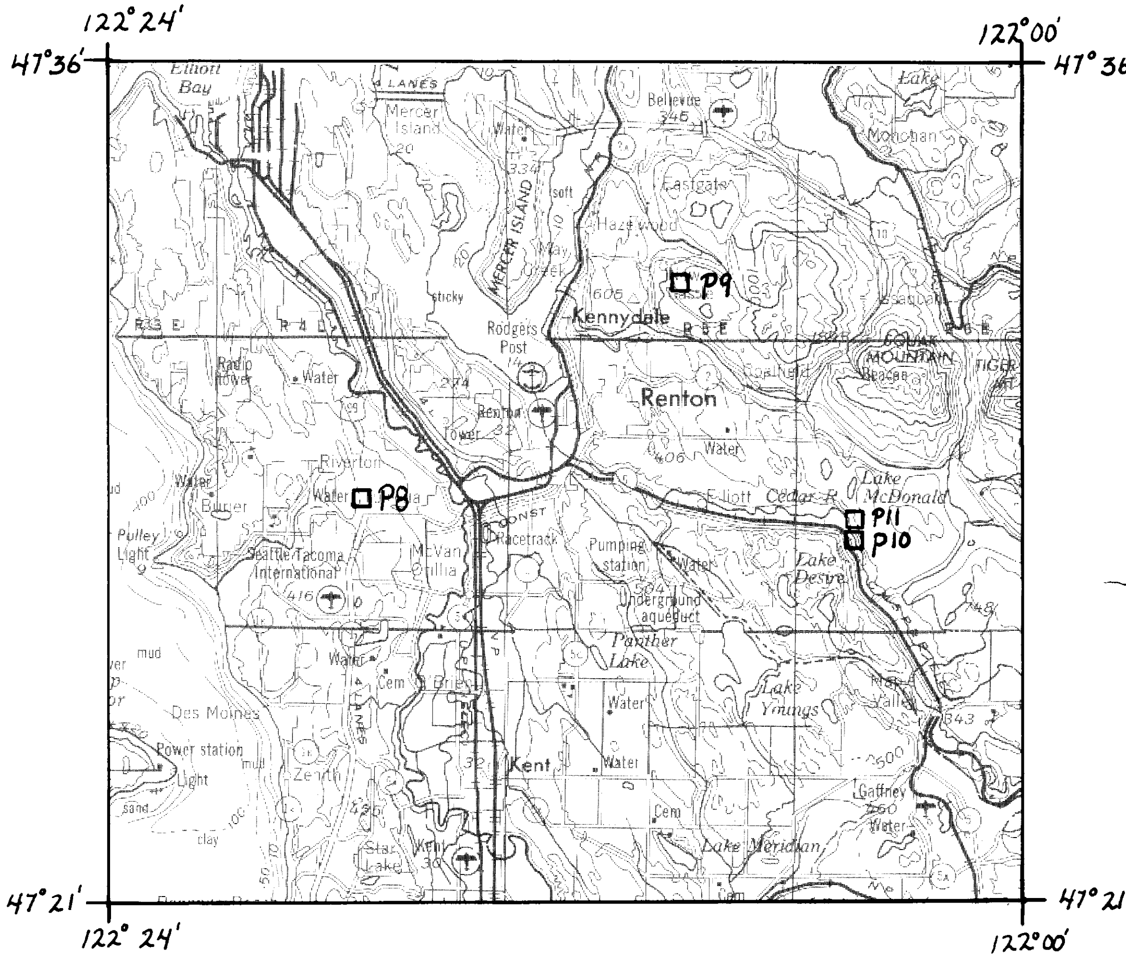


Figure 5 - Map showing sample localities for the Puget Group. (Base from U.S.G.S. 1:250,000 scale Seattle 1° × 2° quadrangle, 1961).

References Cited

Crook, K. A. W., 1960, Classification of arenites: American Journal of Science, v. 258, no. 6, p. 419-428.

Dickinson, W. R., 1970, Interpreting detrital modes of graywacke and arkose: Journal of Sedimentary Petrology, v. 40, no. 2, p. 695-707.

Dickinson, W. R., and Suczek, C. A., 1978, Plate tectonic influences on sandstone compositon: Geological Society of America, Abstracts with Programs, v. 10, no. 7, p. 389.

Foster, R. J., 1960, Tertiary geology of a portion of the central Cascade Mountains, Washington: Geological Society of America Bulletin, v. 71, p. 99-126.

Frizzell, V. A., 1979, Petrology of the Paleogene nonmarine sandstones in Washington: Geological Society of America Abstracts with Programs, v. 11, no. 3, p. 78-79.

Frizzell, V. A., and Tabor, R. W., 1977, Stratigraphy of Tertiary arkoses and their included monolithologic fanglomerates and breccias in the Leavenworth fault zone, central Cascades, Washington: Geological Society of America Abstracts with Programs, v. 9, no. 4, p. 421.

Glover, S. L., 1935, Oil and gas possibilities of western Whatcom County: Washington Division of Mines and Geology Report 2, 69 p.

Graham, S. A., Ingersoll, R. V., and Dickinson, W. R., 1976, Common provenance for lithic grains in carboniferous sandstones from Ouachita Mountains and Black Warrior Basin: Journal of Sedimentary Petrology, v. 46, p. 620-632.

Gresens, R. L., 1976, A new Tertiary formation near Wenatchee, Washington: Geological Society of America Abstracts with Programs, v. 8, no. 3, p. 376-377.

Gresens, R. L., Naeser, C. W., Whetten, J. T., in press, The Chumstick and Wenatchee Formations: Fluviatile and lacustrine rocks of Eocene and Oligocene age in the Chiwaukum graben, Washington.

Gresens, R. L., Whetten, J. T., Tabor, R. W., and Frizzell, V. A., Jr., 1977, Tertiary stratigraphy of the central Cascade Mountains, Washington State, in Brown, E. H., and Ellis, R. C., Geological Excursions in the Pacific Northwest: Geological Society American field guide annual meeting, Seattle, p. 84-126.

Griggs, P. H., 1970, Palynological interpretation of the type section, Chuckanut Formation, northwestern Washington, in Symposium on palynology of the Late Cretaceous and Early Tertiary: Geological Society of America Special Paper 127, p. 169-212.

Hunting, M. T., Bennett, W. A. G., Livingston, V. E., and Moen, W. S., 1961, Geologic map of Washington: Washington Department of Conservation, Division of Mines and Geology, 1:500,00.

McKee, B., 1974, Cascadia; the geologic evolution of the Pacific Northwest: San Francisco, McGraw-Hill, 394 p.

Miller, G. M., and Misch, Peter, 1963, Early Eocene angular unconformity at western front of northern Cascades, Whatcom County, Washington: American Association of Petroleum Geologists Bulletin, v. 47, p. 163-174.

Misch, P., 1966, Tectonic evolution of the northern Cascade of Washington State-A west-cordilleran case history, in Symposium on the tectonic history, mineral deposits of the western Cordillera in British Columbia and in neighboring parts of the U.S.A.: Canadian Institute of Mining and Metallurgy, Special v. 8, p. 101-148.

Pongsapich, W., 1970, A petrographic reconnaissance of the Swauk, Chuckanut, and Roslyn Formations, Washington: Washington University, Seattle, M. S. Thesis, 63 p.

Smith, G. O., 1904, Description of the Mount Stuart quadrangle, Washington: U.S. Geological Survey, Atlas Mount Stuart, folio 106, 10 p.

Stout, M. L., 1964, Geology of a part of the south-central Cascade Mountains, Washington: Geological Society of America Bulletin, v. 75, p. 317-334.

Tabor, R. W., Frizzell, V. A., Gaum, W., and Marcus, K. L., 1978, Revision of Naches Formation, In Geological Survey Research 1977: U.S. Geological Survey Professional Paper 1100, p. 78-79.

Tabor, R. W., Waitt, R. B. , Jr., Frizzell, V. A., Jr., Swanson, D. A., and Byerly, G. R., 1977, Preliminary map of the Wenatchee 1:100,000 quadrangle, Washington: U.S. Geological Survey Open-File Report 77-531.

Tabor, R. W., Waitt, R. B., Jr., Frizzell, V. A., Jr. Swanson, D. A., Byerly, G. R., and Bentley, R. D., in prep., Geologic map of the Wenatchee 1:100,000 quandrangle, Washington: U.S. Geological Survey Miscellaneous Geologic Investigations Map I- .

Vine, J. D., 1969, Geology and coal resources of the Cumberland, Hobart, and Maple Valley quadrangles, King County, Washington: U.S. Geological Survey Professional Paper 624, 67 p.

Weaver, C. E., 1937, Tertiary stratigraphy of western Washington and northwestern Oregon: University Washington Publications in Geology, v. 4, 266 p.

Whetten, J. T., 1976, Tertiary sedimentary rocks in the central part of the Chiwaukum graben, Washington: Geological Society of America Abstracts with Programs, v. 8, no. 3, p. 420-421.

Whetten, J. T., and Laravie, J. A., 1976, Preliminary geologic map of the Chiwaukum 4NE quadrangle, Chiwaukum graben, Washington: U.S. Geological Survey Miscellaneous Field Studies Map MF-794.