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ROCK-FRAGMENT PETROGRAPHY OF THE UPPER CRETACEOUS CHUGACH TERRANE, SOUTHERN ALASKA

By Gian G. Zuffa, Tor H. Nilsen, and Gary R. Winkler

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ABSTRACT

The Cretaceous Chugach terrane crops out in southern Alaska in a belt as wide as 100 km and as long as 2000 km from Baranof Island in the southeast to Sanak Island in the southwest. It consists of a thick sequence of terrigenous turbidites previously described as a trench-fill deposit. It is structurally bounded to the north by melange terranes and to the south by Paleogene turbidites. Rock-fragment petrography of samples of Chugach terrane turbidites indicates derivation primarily from a volcanic arc source area, with secondary inputs from a magmatic arc, an older or penecontemporaneous subduction complex, and recycled sedimentary debris. Regional trends indicate an eastward-increasing amount of magmatic arc dissection. The data are consistent with a model of trench sedimentation characterized chiefly by longitudinal fill, which yielded progradation of a very large and restricted deep-sea fan westward down the trench axis, and secondary lateral infilling from the north, primarily from a dissected arc provenance.

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INTRODUCTION

Southern Alaska consists of large number of terranes (Plafker, 1972; Karig and Sharman, 1975; Moore and Connelly, 1977; Plafker and others, 1977; Dickinson and Seely, 1979; Jones and Silberling, 1979) of Paleozoic, Mesozoic, and Cenozoic age which have been accreted to the northwestern margin of the North American continent. The Chugach terrane (Berg and others, 1972) of Late Cretaceous age (Jones and Clark, 1973) or Early and Late Cretaceous (Brew and Morrell, 1979) age forms a belt as wide as 100 km and as long as 2000 km from Baranof Island in the southeast to Sanak Island in the southwest (fig. 1). Turbidites of the Chugach terrane have been considered to be a trench deposit (Burk, 1965; Moore, 1972, 1973; Nilsen and Bouma, 1977; Connelly, 1978; and Nilsen and Moore, 1979). In places an older chaotic assemblage, the Uyak and McHugh Complex structurally overlies the Chugach terrane to the north (Moore, 1969; Connelly, 1978; Clark, 1972, 1973) along the Eagle River and related faults (Plafker and others, 1977). Paleogene turbidites and associated mafic volcanic rocks structurally underlie the Chugach terrane to the south along the north-dipping Contact fault system (Plafker and others, 1977).

Sedimentary facies of the Chugach terrane turbidities have been studied in the Sanak and Shumagin Islands by Moore (1973), on Kodiak Island by Nilsen and Moore (1979), and in the Sitka area by Decker, Nilsen and Karl (1979). These studies indicate a dominant westward transport along the postulated Cretaceous trench, longitudinal deep-sea fan progradation from a point source to the south (Nilsen and Bouma, 1977), and a marginal trench-slope facies to the north.

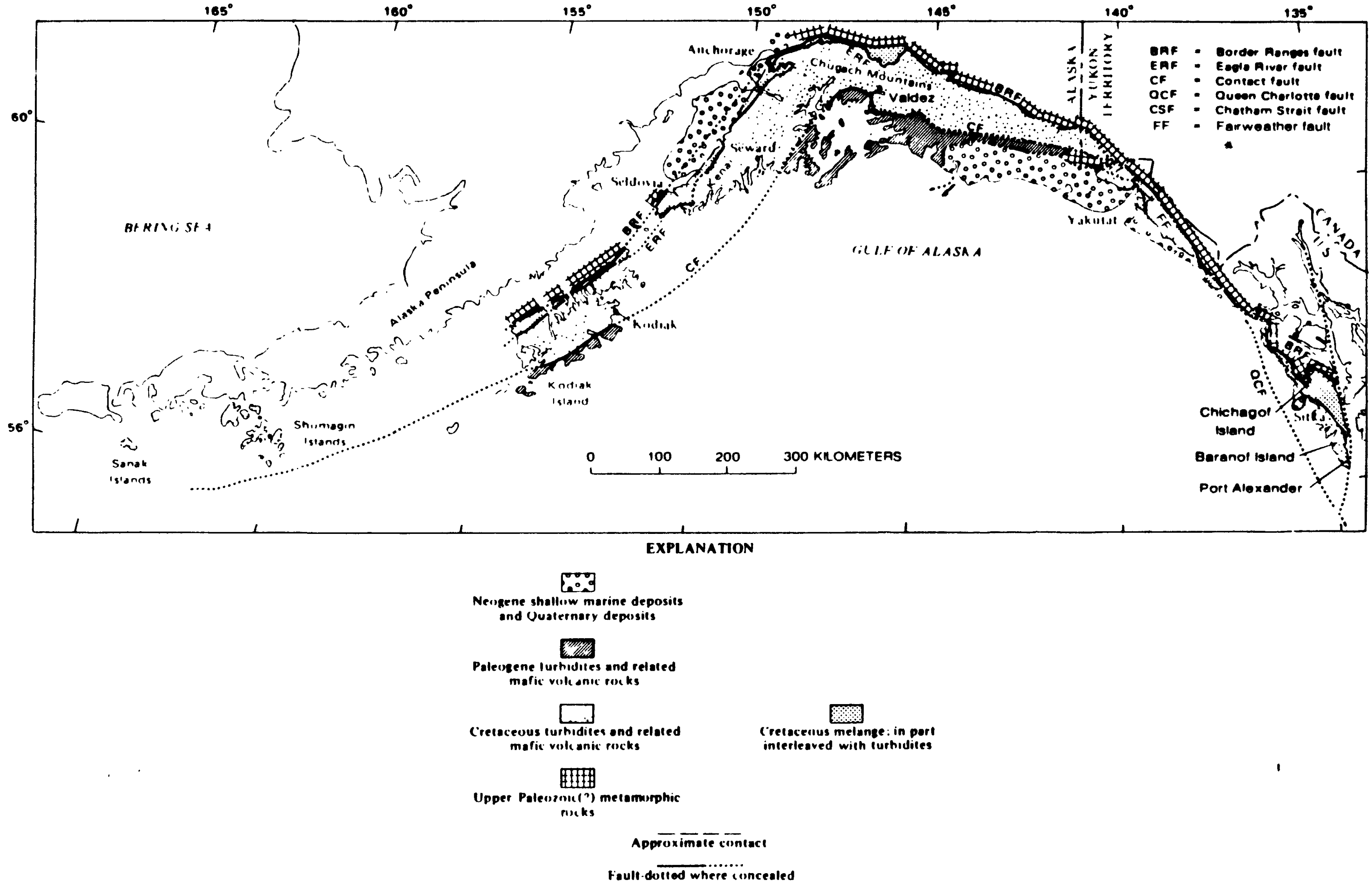

Figure 1.--Distribution of Chugach and other accreted terranes and major faults along the margins of the Gulf of Alaska. Geology modified from Beikman (1974a, b, 1975a, b; Plafker, Jones and Pessagno (1977) and Nilsen and Moore (1979).

Burk (1965) concluded that the western part of the terrane was derived chiefly from a volcanic provenance. Moore (1973) concluded that samples of sandstone from the Chugach terrane on Sanak and the Shumagin islands are litharenites derived mainly from andesitic volcanic rocks, with minor contributions from plutonic, sedimentary and metamorphic rocks. Connelly (1978) reported that Chugach terrane sandstones from Kodiak Island are more feldspathic than those of the Shumagin Islands and Sanak Island, although Winkler (in Nilsen and Moore, 1979) noted a composition from Kodiak Island similar to that obtained by Moore (1973). Mitchell (1979, 1980) concluded that Chugach terrane samples from the Valdez Group southeast of Anchorage are litharenites containing volcanic (60 percent), metamorphic (30 percent), and plutonic (10 percent) lithic clasts. G. R. Winkler (unpub. data) concluded that Chugach terrane sandstones of the Yakutat area are arkosic in composition.

Available sedimentologic and petrographic data suggest that the Chugach terrane turbidites form a Cretaceous trench-fill deposit of predominantly volcanic derivation. Although compositional differences between various parts of the Chugach terrane are apparent, the scarcity of samples analyzed, variable analytical techniques, lack of data from many areas, and absence of stratigraphic control of the samples have hindered the establishment of a comprehensive petrographic framework for the Chugach terrane.

Rock-fragment grains, more than other framework components such as quartz and feldspar, can furnish definitive data regarding source areas. In addition, rock fragments may be identified in thin section by their textural characteristics, even where modified by strong postdepositional mineralogical changes. For mineralogically complex sandstones like those of the Chugach terrane, better provenance information can be obtained from counts of rock-fragment types than from the more common technique of 500 randomly selected point counts per sample. This report summarizes a reconnaissance petrographic study of rock fragment composition of sandstone and microbreccia from numerous samples of the Chugach terrane between Sitka and Sanak Island. The detailed analyses of the rock-fragment petrography were made by Zuffa during the summer of 1979 as a visiting scientist at the U.S. Geological Survey; Nilsen and Winkler facilitated the petrographic work and provided regional control and data.

METHODS

Rock fragments were identified in this study from inspection of about 150 thin sections from 9 geographically defined parts of the Chugach terrane. These areas, from southeast to southwest, are the Port Alexander, Chichagof, Yakutat, Valdez, Seward, Seldovia, Kodiak, Shumagin, and Sanak areas. Because of extensive folding and faulting, there is little stratigraphic control of the samples. A total of 58 samples that were least affected by textural or compositional modifications were selected for modal analysis. In order to minimize the dependence of rock composition on grain size (Zuffa, 1980), only samples of medium- and coarse-grained sandstone (Folk, 1974) were analyzed. Where possible, one or more microbreccia samples (mean grain size=2mm) per group were also studied in order to verify the lithic type identified in the sandstone samples. By this technique, identification errors from counts of sandstones in which rock-fragment grains were too small to be confidently identified were minimized. Either 100 or 200 individual rock-fragment grains were counted for each thin section by moving the section across a 1- or 2-millimeter square grid (table 1). With that number of counts, a significant quantitative comparison can be made only between the most abundant components of the sample analyzed (van der Plas and Tobi, 1965).

ROCK-FRAGMENT CATEGORIES

The twenty-six rock fragment categories (table 1) used in the counting analyses were divided into six groups, permittng the recognition of key petrotectonic assemblages. The composition of the six groups is the following:

I. Plutonite and medium- and high-grade metamorphite, including coarse-grained polycrystalline quartz grains whose texture is clearly of these types.

II. Microgranular quartz-feldspar pluton-related rock fragments and hypabyssal lithic grains, usually with plagioclase, and often showing volcanic textures. Though the relative percentages were annotated during analyses, only the total amount is shown in table 1.

III. Volcanogenic rock fragments of all kinds. Distinctions were made according to Dickinson (1970) with the following modifications:

Table 1.--Modal point counts of rock fragments of selected samples from the Chugach terrane

	Field numbers	Port Alexander							Chichagof					
		61APy-265	62ABd-17	63AMp-23	61ABd-347	62Abd12	62ABd6	S1A4D97	S1A4D-100	S1A5K-75	S1B6D3	S1C7D-115a	S1C6D-64b	S1C7D-331
[1]	Types of rock fragments	1	2	3	4	5	6	7	8	9	10	11	12	13
I	1. Polycrystalline quartz	1	1.5	--	0.5	1.0	--	5	1	6	3	6.0	1.5	5
	2. Plutonic	4	1.0	3.5	1.0	9.0	1.5	7	7	5	tr	3.5	2.0	2
	3. Gneiss	1	--	.5	--	--	--	--	1	1	--	.5	1.5	1
	4. Schist	--	--	--	--	--	--	--	--	--	--	3.0	.5	--
II	5. Microgranular (plutonic) and hypabyssal (volcanic)	12	14.5	13.5	11.0	14.5	23.5	6	9	6	7	5.5	4.0	4
III	6. Felsite and quartz felsite.	51	57.5	46.5	59.0	54.5	47.5	23	16	17	52	22.5	29.0	21
	7. Slightly foliated felsite	5	--	--	9.0	3.0	5.5	4	16	8	4	11.5	9.0	14
	8. Microlitic grains	15	6.5	12.5	5.5	5.0	6.5	11	7	17	12	8.0	7.5	2
	9. Slightly foliated microlitic grains	3	--	--	.5	1.0	2.5	--	1	--	--	1.5	4.5	--
	10. Ophitic grains	--	--	--	--	--	--	2	tr	--	tr	1.5	1.5	2
	11. Vitrophyric grains	--	--	--	.5	1.0	--	1	--	tr	--	--	--	--
	12. Undetermined cherty grains	--	--	--	--	.5	1.0	4	2	4	2	--	1.0	--
IV	13. Noncarbonate sandstone	--	--	--	--	.5	--	1	--	--	--	1.0	--	--
	14. Carbonate sandstone	--	--	--	tr	.5	--	--	--	--	--	--	--	--
	15. Noncarbonate siltstone	--	1.0	6.5	.5	--	1.0	2	4	8	3	2.5	1.0	--
	16. Carbonate siltstone	--	--	--	--	--	--	--	--	--	--	--	--	--
	17. Argillaceous siltstone	--	--	--	--	--	--	6	5	--	1	--	--	--
	18. Limestone and silty limestone	--	--	--	--	.5	--	--	1	2	--	--	tr	--
	19. Argillite and silty argillite	2	2.0	4.0	2.0	--	2.0	2	5	8	tr	3.0	5.5	--
	20. Cherty argillite	--	--	--	--	--	--	6	--	5	--	--	--	--
	21. Chert	--	--	--	.5	2.0	tr	8	5	4	1	1.5	2.0	tr
	22. Radiolarian chert	--	--	--	--	--	--	tr	--	tr	--	--	--	--
V	23. Shale	5	9.0	7.5	6.5	4.5	8.5	7	10	4	7	13.0	20.5	26
	24. Slate	--	1.0	.5	--	.5	--	1	3	--	--	4.0	--	--
VI	25. Phyllite	--	1.0	--	.5	1.0	tr	3	3	3	8	3.5	5.5	19
	26. Polycrystalline quartz	1	5.0	5.0	3.0	1.0	.5	1	4	2	--	8.0	3.5	4
	Total	100	100.0	100.0	100.0	100.0	100.0	100	100	100	100	100.0	100.0	100

[1]Roman numerals I-VI designate key rock assemblages.

Table 1.--Modal point counts of rock fragments of selected samples from the Chugach terrane--Continued

	Field numbers	Yakutat											Valdez		
		68APs-9C1	68APs-9C3	68APs-7A2	68APs-17A	68APr-26B	68APs-1A1	6APs-1A3	68APr-3A2	68APs-24G	68APr-75C	68APr-35B2	78AWK-226	78AWK-230	78AWK-221
[1]	Types of rock fragments	14	15	16	17	18	19	20	21	22	23	24	25	26	27
I	1. Polycrystaline quartz	2	8.0	3.0	2.0	7.5	2.5	1.5	1.5	7.0	5	4	2	1	--
	2. Plutonic	19	19.5	6.5	27.5	22.5	9.5	13.5	25.0	27.0	31	10	1	--	--
	3. Gneiss	3	9.0	1.0	--	3.0	--	3.0	1.0	1.0	--	2	--	--	--
	4. Schist	2	--	tr	.5	2.0	--	--	3.5	3.0	1	1	--	tr	tr
II	5. Microgranular (plutonic) and hypabyssal (volcanic)	11	7.5	30.0	23.5	3.5	2.0	20.0	3.0	5.5	16	25	6	13	2.0
III	6. Felsite and quartz felsite	17	16.5	16.0	23.0	17.5	13.5	16.0	20.0	24.0	26	20	65	46	67.5
	7. Slightly foliated felsite	--	.5	.5	1.0	3.0	1.0	1.0	2.0	1.5	--	--	1	5	2.5
	8. Microlitic grains	32	26.0	28.5	11.5	28.5	12.5	34.5	17.0	15.0	8	26	6	15	.5
	9. Slightly foliated microlitic grains	--	--	--	1.5	2.0	1.0	.5	--	--	--	--	1	1	1.0
	10. Ophitic grains	--	.5	6.0	--	tr	4.5	--	1.0	2.0	--	--	--	--	7.0
	11. Vitrophyric grains	--	.5	--	tr	--	tr	--	--	.5	--	--	2	1	--
	12. Undetermined cherty grains	--	.5	--	--	--	--	--	.5	.5	--	--	--	--	.5
IV	13. Noncarbonate sandstone	--	.5	--	--	--	2.5	--	--	--	--	--	--	--	--
	14. Carbonate sandstone	--	--	--	--	--	1.0	--	--	--	--	--	--	--	--
	15. Noncarbonate siltstone	--	--	1.0	1.5	1.0	19.5	tr	1.5	2.0	--	2	tr	4	2.5
	16. Carbonate siltstone	--	tr	--	--	--	--	--	--	--	--	--	--	--	--
	17. Argillaceous siltstone	--	--	--	--	--	--	--	--	--	--	--	--	--	2.0
	18. Limestone and silty limestone	--	.5	tr	--	--	3.0	--	--	--	--	--	--	--	--
	19. Argilite and silty argillite	3	4.5	3.0	4.5	1.5	12.5	3.0	8.5	2.0	5	1	5	4	6.0
	20. Cherty argillite	--	--	--	--	--	1.5	--	1.0	.5	--	--	--	--	.5
	21. Chert	3	2.0	--	--	tr	1.5	--	1.5	.5	tr	1	--	--	tr
	22. Radiolarian chert	--	--	--	.5	--	--	--	--	--	--	--	--	--	--
V	23. Shale	4	.5	1.5	1.5	4.5	6.0	1.5	5.5	3.0	--	4	5	7	5.5
	24. Slate	tr	--	.5	--	--	1.0	tr	1.5	1.5	2	--	--	--	--
VI	25. Phyllite	3	1.0	1.0	1.5	1.5	--	2.0	1.5	2.0	--	1	tr	1	1.5
	26. Polycrystalline quartz	1	2.5	1.5	--	2.0	5.0	3.5	4.5	1.5	6	3	6	2	1.0
	Total	100	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100	100	100	100	100.0

[1]Roman numerals I-VI designate key rock assemblages.

Table 1.--Modal point counts of rock fragments of selected samples from the Chugach terrane--Continued

		Valdez--Continued						Seward				Seldovia	
	Field numbers	78AWK-234	78AWK-141	78AWK-146	78AWK-202	78AWK-119	78AWK-299A	75ATz-209	75ATz-347	75ATz-200	75ACe-398	75Atz-161	75Jk395B
1	Types of rock fragments	28	29	30	31	32	33	34	35	36	37	38	39
I	1. Polycrystalline quartz	0.5	3.5	--	2.0	--	2	3.0	1	1	2	8	--
	2. Plutonic	1.0	1.5	3	1.0	--	8	15.5	1	2	3	14	--
	3. Gneiss	--	--	--	--	tr	tr	11.0	2	1	--	1	--
	4. Schist	tr	1.5	--	2.0	--	tr	--	--	--	--	--	1.5
II	5. Microgranular (plutonic) and hypabyssal (volcanic)	2.0	5.5	2	18.5	3.0	37	19.5	6	6	3	8	12.5
	6. Felsite and quartz felsite	36.0	51.5	37	46.0	42.5	36	1.0	6	31	20	8	56.5
	7. Slightly foliated felsite	7.0	1.5	--	2.0	4.5	--	13.0	18	8	2	3	4.5
	8. Microlitic grains	2.5	7.5	8	8.0	25.0	5	--	8	8	14	3	7.5
	9 Slightly foliated microlitic grains	1.5	--	--	--	--	--	12.0	6	--	6	--	--
	10. Ophitic grains	--	--	--	--	--	--	--	32	--	--	--	.5
	11. Vitrophyric grains	--	--	--	--	--	--	--	--	--	--	--	.5
	12. Undetermined cherty grains	.5	1.0	--	--	.5	--	--	--	3	--	--	--
	13. Noncarbonate sandstone	.5	--	5	--	--	--	--	--	--	1	--	--
	14. Carbonate sandstone	--	--	--	--	--	--	--	--	--	--	--	--
	15. Noncarbonate siltstone	1.5	1.5	5	--	--	--	1.0	--	2	--	4	1.0
	16. Carbonate siltstone	--	--	--	--	--	--	--	--	--	--	--	--
	17. Argillaceous siltstone	--	--	--	--	2.5	--	--	--	4	1	11	--
IV	18. Limestone and silty limestone	.5	--	--	--	--	--	1.5	--	--	--	4	--
	19. Argillite and silty argillite	16.5	8.5	11	7.0	6.5	1	--	5	4	12	22	6.5
	20. Cherty argillite	1.0	--	6	--	--	--	--	--	--	1	--	.5
	21. Chert	4.0	1.0	10	.5	1.0	--	--	1	1	--	--	tr
	22. Radiolarian chert	--	--	10	--	--	--	--	--	--	--	--	--
V	23. Shale	15.5	7.5	2	3.0	10.5	5	6.0	4	15	23	5	2.0
	24. Slate	--	--	--	1.0	tr	1	1.0	1	--	3	--	1.5
VI	25. Phyllite	3.5	3.0	--	2.5	1.0	2	10.5	4	2	1	3	2.5
	26. Polycrystalline quartz	6.0	5.0	1	6.5	3.0	3	5.0	5	12	8	6	2.5
	Total	100.0	100.0	100	100.0	100.0	100	100.0	100	100	100	100	100.0

[1]Roman numerals I-VI designate key rock assemblages.

Table 1.--Modal point counts of rock fragments of selected samples from the Chugach terrane--Continued

		Kodiak					Shumagin							Sanak						
	Field numbers	AMe-76-32	32	R12F	N14m	U20A	N115K	102A	82A	35B	7B	213c	130D	677-19-1c	677-19-1d	677-19-1f	677-19-5	677-19-7a	677-19-7b	677-19-7c
1	Type of rock fragments	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58
	1. Polycrystalline quartz----------	3.0	2	1.0	6	3.0	--	--	2.0	1.0	--	--	3.5	--	--	--	--	--	--	--
	2. Plutonic---------	1.0	4	.5	1	--	.5	2.0	--	2.0	.6	1.0	1.5	--	--	--	--	--	2	--
I	3. Gneiss-----------	3.5	2	--	--	--	--	.5	.5	--	--	--	.5	--	--	--	--	--	--	--
	4. Schist-----------	2.0	--	1.0	--	4.5	--	--	--	.5	--	--	--	--	--	--	--	--	--	--
II	5. Microgranular (plutonic) and hypabyssal (volcanic)------	2.0	6	7.0	5	23.5	27.0	11.0	9.0	9.0	5.0	18.0	18.5	13	12	22	6.0	13	4	10
	6. Felsite and quartz felsite---------	26.5	30	35.0	66	32.0	38.0	43.5	46.5	40.0	40.4	30.5	57.5	45	29	23	27.5	46	10	58
	7. Slightly foliated felsite---------	5.5	7	8.0	--	4.5	2.5	2.5	2.5	--	--	1.0	2.0	2	--	--	.5	1	3	--
III	8. Microlitic grains----------	13.0	--	12.0	2	7.5	27.0	30.0	12.0	34.0	35.4	36.5	10.5	40	41	54	58.0	34	15	30
	9. Slightly foliated microlitic grains----------	3.5	16	--	--	--	--	--	--	--	--	--	--	--	13	--	--	1	1	--
	10. Ophitic grains---	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	57	--
	11. Vitrophyric grains----------	--	--	8.0	5	.5	.5	tr	--	--	1.7	1.0	--	--	--	--	--	--	--	--
	12. Undetermined cherty grains---	1.5	--	--	--	--	--	--	4.5	1.0	--	--	--	--	--	--	--	--	1	--
	13. Noncarbonate sandstone-------	--	--	--	--	--	--	.5	--	--	.6	--	--	--	--	--	--	--	--	--
	14. Carbonate sandstone-------	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	15. Noncarbonate siltstone-------	2.0	tr	3.0	--	.5	--	.5	2.0	.5	2.2	2.0	tr	tr	--	--	2.5	3	--	--
	16. Carbonate siltstone-------	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	.5	tr	--	--
	17. Argillaceous siltstone-------	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	tr	--
IV	18. Limestone and silty limestone-------	--	5	--	1	tr	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	19. Argillite and silty argillite-------	7.5	10	5.0	5	8.5	4.5	4.5	2.0	6.5	12.4	6.5	2.5	tr	3	tr	2.0	2	3	1
	20. Cherty argillite-------	1.5	2	--	--	2.0	--	--	.5	--	--	--	.5	--	--	--	--	--	--	--
	21. Chert-----------	1.5	3	tr	--	1.5	--	1.0	7.5	1.0	1.1	tr	--	--	--	--	--	tr	--	--
	22. Radiolarian chert-----------	--	tr	--	--	--	--	--	2.0	--	--	--	--	--	--	--	--	--	--	--
V	24. Shale------------	14.0	3	3.0	--	3.0	--	.5	1.5	1.5	.6	1.5	--	--	--	--	1.0	--	--	--
	25. Slate------------	--	1	2.0	--	2.0	--	.5	.5	--	--	--	--	--	--	--	--	--	--	--
VI	25. Phyllite---------	4.5	1	6.0	--	.5	--	.5	1.5	.5	--	tr	.5	--	--	--	1.0	--	1	--
	26. Polycrystalline quartz----------	7.5	8	8.5	9	6.5	tr	2.5	5.5	2.5	--	2.0	2.5	tr	2	1	1.0	--	3	1
	Total-----------	100.0	100	100.0	100	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100	100	100	100.0	100	100	100

(a) felsitic grains constitute a textural class which ranges from acidic to intermediate in composition,

(b) felsitic and microlitic composite grains were assigned to the dominant category,

(c) slightly foliated felsitic and microlitic grains were distinguished because of their possible second-cycle significance, and

(d) ophitic grains include both paleovolcanic and neovolcanic particles, which cannot be quantitatively distinguished from one another.

Undetermined chert-like grains were separately recorded where the distinction between homogeneous quartz-felsite and chert was not objectively possible. In table 1, they are positioned between group II and IV in order to evaluate their possible influence, if associated with either group.

IV. Unmetamorphosed sedimentary grains of all types.

V. Shale and slate.

VI. Epimetamorphic grains, generally fine-grained, of phyllitic composition and texture. Polycrystalline fine-grained quartz and minor polycrystalline coarse-grained quartz with strong undulosity and crenulated crystal borders (probably phyllite nodules) may be associated with this group.

RESULTS

All the samples examined have been affected more or less by postdepositional processes (Moore, 1973; Winkler, in Nilsen and Moore, 1979). The framework clasts are by far the most abundant component of these sandstones, with about 40 percent of volcanic (mainly andesitic) origin and quartz, plagioclase, and many other lithic fragments comprising the remainder. Only samples from the Yakutat area contain enough single grains of K-feldspar to make it one of the main components of the framework, with an average value of 5 percent and maximum and minimum values of 14.5 percent and 0.4 percent (G. R. Winkler, unpub. data); however, lesser amounts of K-feldspar are present in almost all samples. Significant amounts of mafic minerals such as pyroxene and amphibole are present in some samples.

Interstitial materials (matrix and cement) are not easily separable. Different varieties of matrix such as orthomatrix and epimatrix (Dickinson, 1970) are present. Deformed fine-grained lithic grains, mainly of volcanic felsite but also including some sedimentary types that are stretched between other more rigid grains, are common. Phyllosilicate and zeolite cements are present, probably derived from the original matrix and from the framework grains (especially from feldspars). Even if the distinction between framework and interstitial material is generally possible, a quantitative optical distinction between cement and matrix and among matrix types is not convenient because of its low reliability and tedious nature. Carbonate cement is generally absent but where present has a patchy distribution.

The framework grain-size distribution of the sandstone samples is generally bimodal with the composition of the larger clasts different from the smaller. The larger clasts are predominantly sedimentary and volcanic but include some plutonites in the southeastern part of the terrane, whereas the smaller clasts are mainly volcanic.

Sedimentary grains such as argillite, siltstone, radiolarian chert, quartz-vein-bearing chert, volcanic wacke, and micritic limestone are commonly subangular or rounded. Strongly deformed and elongated particles of argillite or siltite can be observed among the more rigid grains in some samples and have been interpreted, according to Moore (1973) and Winkler (in Nilsen and Moore, 1979), as intraformational rip-up clasts. However, the presence in the same sample of a large spectrum of sedimentary rock types, with rounded boundaries on most, suggests a terrigenous rather than intrabasinal origin for most sedimentary grains.

Volcanic types vary from perfectly euhedral plagioclase and quartz crystals to subangular felsite and microlite to rounded and strongly altered basaltic andesite and basalt. Plagioclase feldspar is zoned and has internal vesicular rims and embayments full of felsitic material. Felsite grains have a cherty groundmass and normally include euhedral embayed quartz and plagioclase phenocrysts, but stained devitrified K-rich groundmasses are also common. Microlithic particles are varied in composition but are dominantly andesitic. The presence of slightly foliated felsite together with nonfoliated volcanic particles of the same composition may indicate that the former were incorporated in an accretionary wedge domain and have, therefore, an almost penecontemporaneous second-cycle origin (Zuffa, 1980). Some samples from Sanak Island contain very fresh clinopyroxene and olivine, including glassy material together with rounded and altered ophitic particles, which are smaller than other framework grains. The character of volcanism that produced these strongly altered particles is hard to determine. The presence of rounded and weathered basaltic andesite and basalt grains mixed with detritus of andesitic arc volcanism may indicate:

(1) derivation from the erosion of weathered first products of penecontemporaneous volcanic arc activity,

(2) derivation from an old terrane of distinct orogenic origin, or

(3) derivation of the andesitic materials intrabasinally (Tysdal and others, 1977), although this is most unlikely because of the rounded shape of these particles.

Plutonite fragments, sufficiently large for a compositional description, are present in microbreccia samples only. Their composition varies from granitic to granodioritic.

The framework grains, which form the finer grain-size population of the sandstone, are mainly single grains of quartz, plagioclase, K-feldspar, amphibole, pyroxene, biotite, volcanic felsite, and microlite particles, and minor amounts of sedimentary rock fragments.

Each rock-fragment category listed in table 1 has been counted and distinguished on the basis of objective criteria, but the source-domain significance of each group is uncertain. However, if we think in terms of a continental-margin arc-trench system during the deposition of the Chugach terrane, as suggested by other geological evidence, the following conclusions can be drawn:

(1) group I (with the exclusion of polycrystalline quartz) suggests a dissected magmatic arc provenance,

(2) group III suggests a volcanic arc provenance (including possible contributions from a paleovolcanic terrane), and

(3) group IV may indicate a recycled provenance from an older or penecontemporaneous subaqueous or emergent subduction complex.

It is much more difficult to speculate on the significance of the other groups. Group II may be split in two parts, with plutonic- and volcanic-related particles associated, with some bias, with groups I and III, respectively. Groups V and VI may represent low-grade metamorphosed oceanic argillite and siltite within penecontemporaneous accretionary wedge domain, an older and slightly metamorphosed subduction complex, or a dissected magmatic arc rock association. All of these sources may have been uplifted at the same time.

Polycrystalline quartzose lithic fragments (Qp), volcanic-metavolcanic lithic grains (Lv), and sedimentary-metasedimentary lithic grains (Ls) are plotted on a ternary diagram (fig. 2), which shows the representative point distribution within the arc-orogen source field defined by Dickinson and Suczek (1979). Most of the analytical data used by Dickinson and Suczek for defining this field were from common 500-point counts representative of the total rock volumes. Thus it seems reasonable to consider that our 100 and 200 counts of rock fragments, which represents only a partial grain population, can be plotted with sufficient confidence in this diagram. The volcano-plutonic arc provenance of the Chugach terrane, previously pointed out by Moore (1973) and Winkler (in Nilsen and Moore, 1979) for the Sanak,

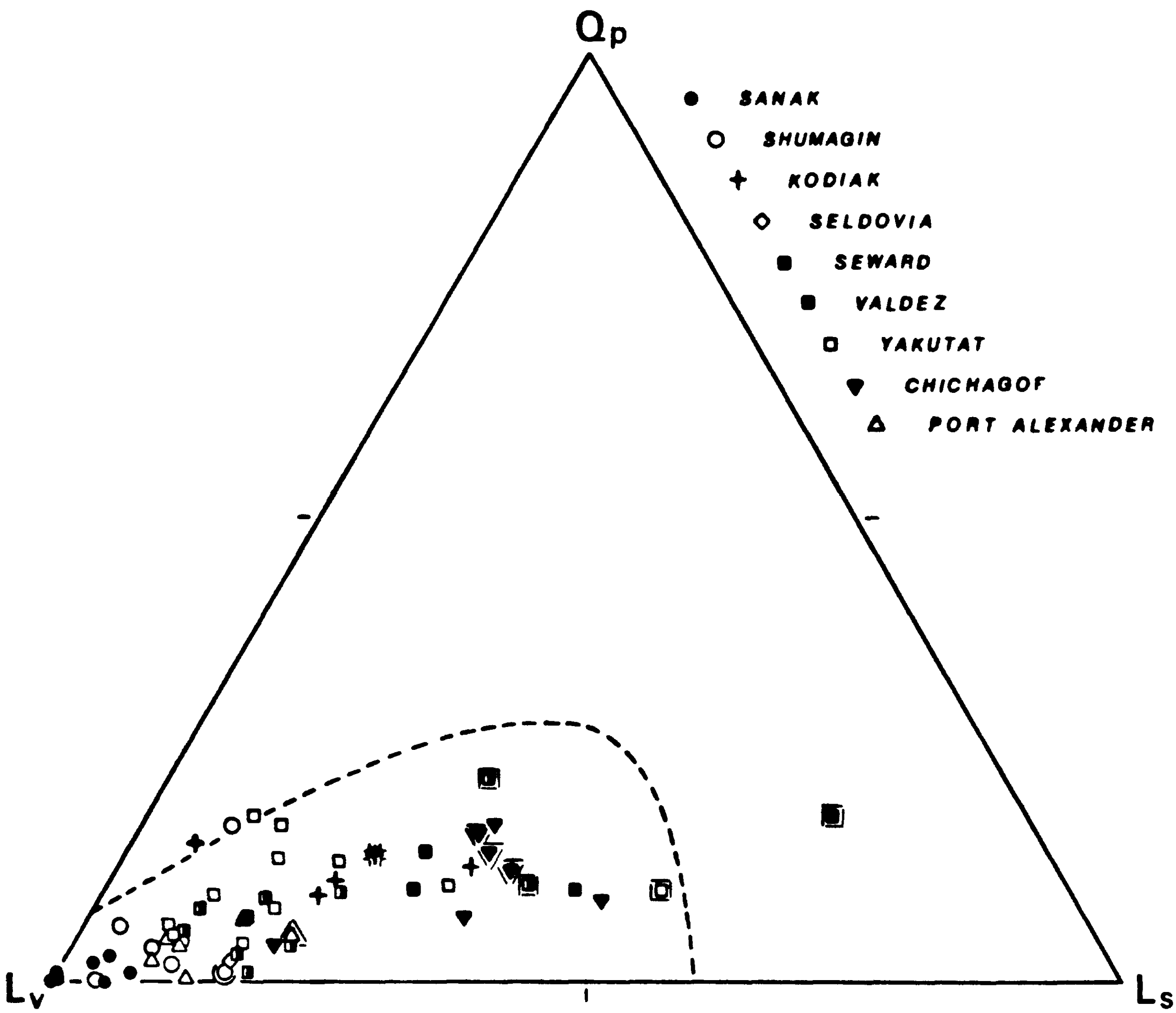

Figure 2.--Ternary diagram for polycrystalline quartzose lithic fragments (Q_p = 1 + 21 + 22 + 26; for explanation of numbers see table 1), volcanic and metavolcanic lithic fragments (L_v = III + hypabyssal volcanic rock fragments of group II), and sedimentary and metasedimentary lithic fragments (L_s = 4 + IV + V + 25). Dashed lines define the arc-orogen-source field as proposed by Dickinson and Suczek (1979). Double symbols indicate microbreccia samples.

Shumagin, and Kodiak islands can, in conjunction with the data presented herein, be extended to include the entire arc. Moreover, our data indicate, with the exception of the Port Alexander area, an increasing amount of magmatic arc dissection from Sanak Island eastward to Baranof Island.

Figure 3 shows a ternary diagram for the most objective grouping, plutonite and metamorphite, volcanic, and sedimentary grains. The Yakutat samples, which contain the highest amount of plutonite and medium-high grade metamorphite rock fragments, are separable from the other sampled areas, which are scattered in a narrow elongate field showing a rough progressive increase in sedimentary components to the southeast. The coarsest samples within each area are invariably the richest in sedimentary rock content.

A third ternary diagram for all groups (fig. 4), which also includes subjective categories such as polycrystalline quartz of uncertain origin and undetermined cherty grains, confirms the above-described distribution. In order to have a pole indicative of a magmatic arc provenance, groups I and II, together with microgranular plutonic-related rock fragments of group II (data not reported in table 1), were associated. In addition to group III, the indicated pole of volcanic-arc provenance contains hypabyssal rock fragments of group II and the undetermined cherty grains which may consist of silicified felsite and are therefore included in this group. Shale and slate (group V) were associated with the sedimentary rock types, as it was thought that they might as a whole indicate a subduction-complex provenance (oceanic cover sediments and trench-fill deposits). This

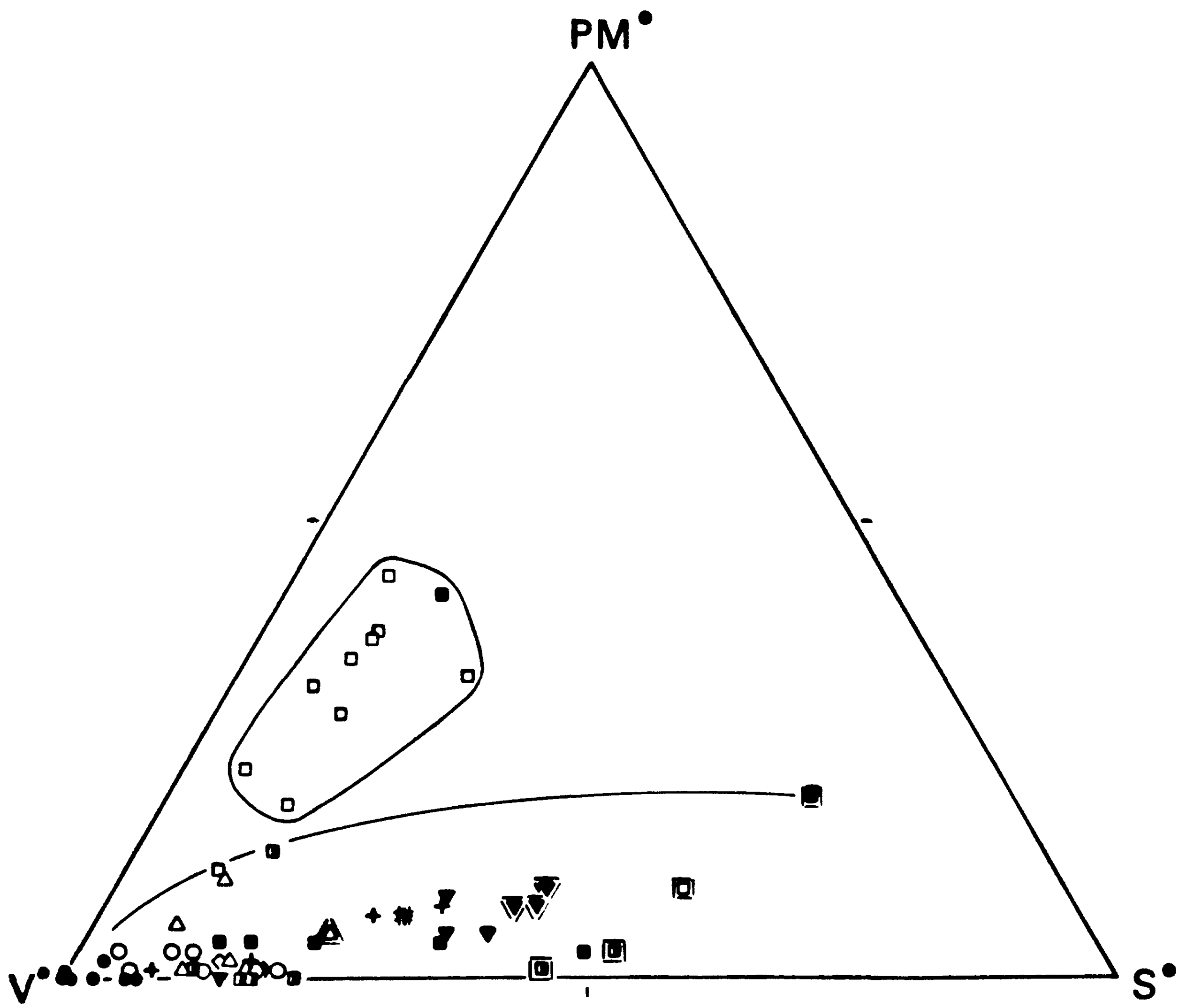

Figure 3.--Ternary diagram for plutonite and metamorphite (PM* = group I with the exclusion of polycrystalline quartz), volcanic and metavolcanic rock fragments (V* = group III), and sedimentary rock fragments (S* = IV + V). For explanation of symbols, see figure 2.

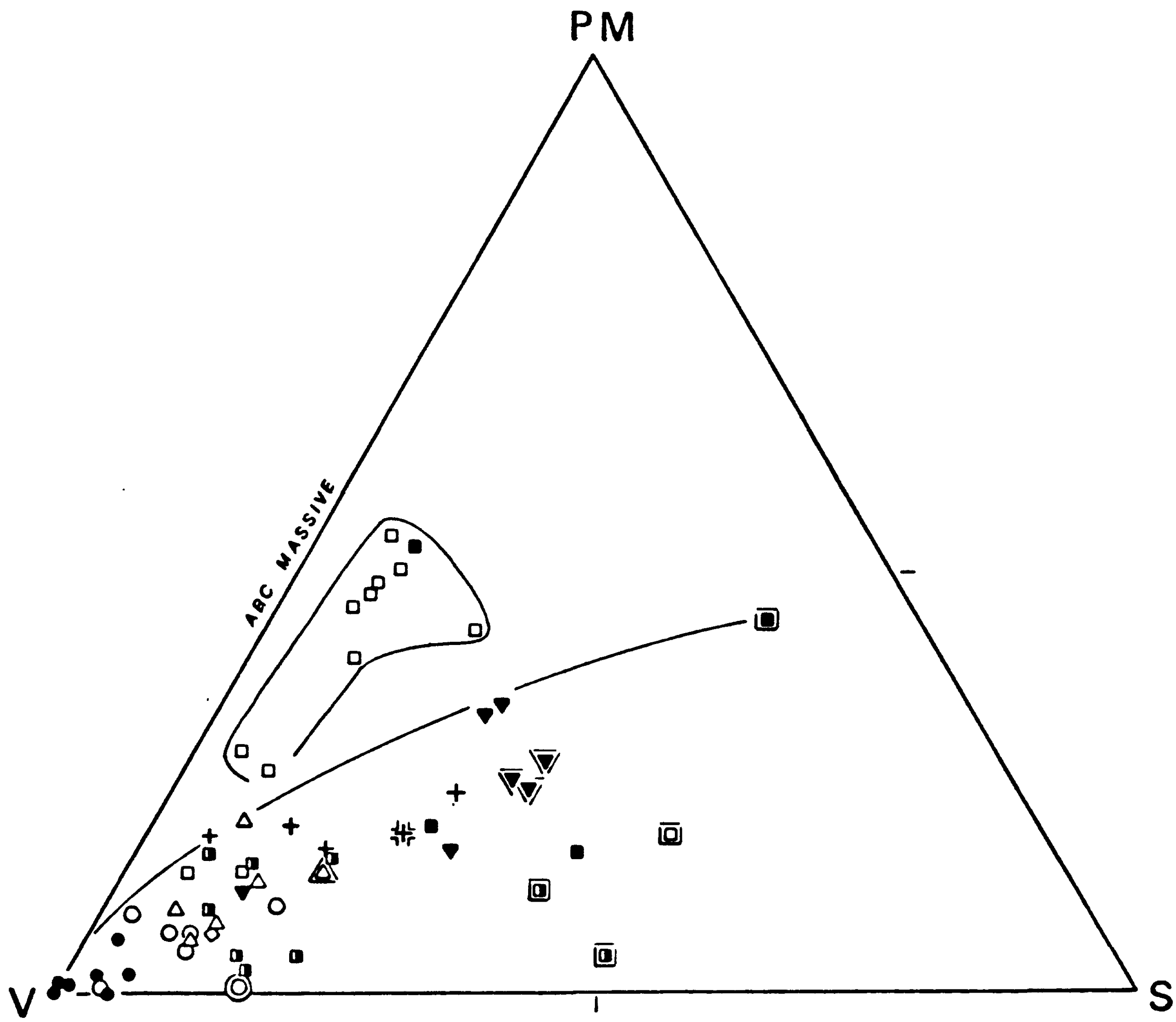

Figure 4.--Ternary diagram for all rock-fragment varieties (see table 1). PM = (group I + microgranular plutonic rock fragments of group II + group VI); V = (group III + hypabyssal volcanic rock fragments of group II + undetermined cherty grains); S = (group IV + group V). In a continental-margin arc-trench geometry, PM, V, and S poles may, respectively, indicate magmatic-arc roots, volcanic-arc and subduction complex sources. For explanation of symbols, see figure 2.

diagram is certainly largely interpretive but its reliability can be tested by comparison with the more objective ternary plot of figure 2.

SUMMARY AND CONCLUSIONS

Our reconnaisance petrographic study of rock fragments in microbreccia and sandstone from outcrops of the Cretaceous Chugach terrane was made from about 150 thin sections of samples collected without stratigraphic control from Baranof Island to Sanak Island. A total of 58 samples from 9 different areas that were not seriously affected by postdepositional modification were used for modal analysis.

Rock-fragment assemblages sugggest an arc-orogen source and suggest an increase in the degree of dissection in an easterly direction. Microbreccia samples contain mainly sedimentary grains (argillite, siltite, radiolarian chert and chert, volcanic wacke, micritic limestone), subordinate felsite and microlite, minor plutonite, and rounded, strongly altered basaltic andesite and basalt. The framework grain-size distribution of the sandstone is generally bimodal, with the larger clasts similar to the microbreccia particles and the smaller clasts composed of quartz and plagioclase in the form of single grains, felsitic and microlitic volcanic particles, minor sedimentary grains, K-feldspar in the form of single grains, amphibole, pyroxene and biotite. Samples from the Yakutat area contain the highest amount of plutonite and K-feldspar and exhibit a fairly distinct magmatic arc provenance. Sandstone samples from all other areas have a high volcanic lithic content and show a progressive increase in sedimentary components in an easterly direction.

Geological evidence indicates that the Chugach terrane was deposited in a continental-margin trench during Cretaceous time. Paleocurrents in the southwestern part of the Gulf of Alaska margin indicate sedimentary transport toward the southwest. At least three models may explain deposition of the Chugach terrane turbidites:

(1) the trench was supplied mainly by lateral canyons, with deep-sea fans deflected into the trench to the west as they are in the present trench;

(2) the trench was supplied mainly by longitudinal transport and a fan system developed from a point source to the east (Nilsen and Bouma, 1977; Nilsen and Moore, 1979); and

(3) the southeast and the northeast limbs of the southern Alaska margin developed independently during the Cretaceous (Moore and Connelly, 1977), so that either of the first two hypotheses may be considered for both limbs. However, available geologic and geophysical data do not support this suggestion, which has been abandoned by Moore and Connelly.

Both the observed bimodal grain-size distribution of sandstone and the different composition of the larger and smaller clasts indicate the existence of at least two different sources for the detritus. The first source shed argillite, siltite, chert, volcanic wacke, limestone, basaltic andesite, basalt, plutonite, felsite and microlite in different proportions in different areas. Since this supply is complex, numerous sources and sediment transport routes may have been present to yield this rock assemblage. Accreted terranes older than the Chugach, such as the McHugh and Uyak Complexes or Wrangellia, and a penecontemporaneous subaqueous or emergent subduction complex may have been source areas. Contributions from the active volcanic arc were also important, either by direct deposition into the trench or erosion of the arc. Intrabasinal sources that may have supplied some subangular basaltic particles and elongated argillite fragments cannot be excluded.

The second source shed mainly quartz, plagioclase, felsite and microlite volcanic particles and K-feldspar grains. Though this association is less characteristic than the former one, it suggests a dissected arc provenance. Qualitative observations indicate that K-feldspar is abundant in the Yakutat Group both in the form of single grains and rock fragments and is also present in small amounts among the finer grain sizes of all the other areas. Since the Yakutat terrane may have been displaced northward along the Fairweather fault system (Plafker and others, 1978), its southward restoration could reflect a primary, little-contaminated source of detritus which supplied axial trench turbidity currents.

A combination of models 1 and 2 seems to be most consistent with the rock-fragment data. In such a model, the trench-basin Chugach terrane turbidites were mainly supplied by westward longitudinal transport. Lateral fans along the trench, derived from emergent or submarine subduction complexes and magmatic arc materials that bypassed the arc-trench gap, became elongated westward by trench-axis turbidity currents. Microbreccia samples, together with the coarsest sandstone particles, may represent lateral contributions. The bimodal grain-size distributions of the sandstone suggest a lack of mixing between the lateral and longitudinal supplies, and an increase in lateral supply toward the west. Model 3 cannot be excluded on the basis of rock-fragment petrography, but further data would be required to test its validity.

Rock-fragment study of these strongly deformed wackes and litharenites has proved very useful from the methodological point of view. Key petrotectonic rock assemblages exposed in the paleosource areas can be recognized through qualitative and quantitative rock-fragment petrographic analysis.

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