U.S. DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

Preliminary geochemistry of volcanic rocks from the McHugh Complex and Kachemak terrane, southern Alaska

by

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Open-File Report 91-134

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Introduction

In southern Alaska, between Anchorage and the southern Kenai Peninsula (fig. 1) are two belts of Mesozoic age that make up the Chugach terrane (Jones and others, 1981). One is a landward belt that consists of a discontinuous melange named the McHugh Complex (Clark, 1973; Cowan and Boss, 1978) and the other a seaward belt of Late Cretaceous turbidites (Valdez Group). These belts comprise a small part of what may be the best preserved, most complete paired belts of melange and turbidites in the world. The belts extend for more than 2,000 km along the Gulf of Alaska margin from southeastern Alaska on the east to near the tip of the Alaska Peninsula on the west (Plafker and others, 1977). Early workers (Clark, 1973; Moore and Connelly, 1977) suggested that the melange belt was produced by tectonic processes in a subduction zone. More recent study suggests the additional process of surficial mass wasting for the formatting of correlative melange on Vancouver Island (Brandon, 1989a,b).

On the southern Kenai Peninsula the Seldovia Bay complex was correlated with the McHugh Complex in the type area near Anchorage (Cowan and Boss, 1978). However, Jones and others (1981, 1984, 1987) subdivided the Seldovia Bay complex into two units--the McHugh Complex of the Chugach terrane and the Kachemak terrane. They defined the Kachemak terrane as a fault-bounded block of Triassic chert and basalt between the Peninsular and Chugach terranes.

Recent fossil studies suggest that the Triassic age of the Kachemak terrane is too restrictive. Blome and others (1990 and unpublished data) indicate that the Kachemak terrane contains Triassic and younger cherts similar to those found in the McHugh Complex (Winkler and others, 1981; Nelson and others, 1987).

Throughout southern Alaska, the melange of the McHugh Complex is composed of slabs and blocks (up to 40 km long) of various rock types such as chert and basalt, ultramafic rock, marble, and schist. These lithologies are intermixed in a deformed argillaceous matrix. Paleontologic and radiometric ages of the blocks range in age from late Paleozoic to mid-Cretaceous (Nelson and others, 1986, 1987; Blome and others, 1990).

Several source terranes have been proposed for the blocks in the melange. Plafker (1987) suggested that the melange contains exotic blocks derived from the Wrangellia terrane. Winkler and others (1984), based on fossils and radiometric ages, suggested that the Peninsular terrane was a likely source. The lithology and geochemistry of the

McHugh Complex, in the central Valdez quadrangle, along the Trans Alaska Pipeline suggests an origin as an assemblage of tholeiitic oceanic basalt mixed with minor amounts of clastics derived from an active arc sources (Plafker, Nokleberg, and Lull, 1989). In the western Valdez quadrangle the McHugh is characterized by exotic blocks derived from the Peninsular and Wrangellia terranes (Winkler and others, 1981). Brandon (1989b), in examining a similar melange in British Columbia, determined that the igneous rocks in the melange could not have been derived from subducting oceanic crust or the overriding Wrangellia terrane, but instead are derived from the unconformably underlying Ucluth Formatión of Late Triassic to Early Jurassic age. Triassic chert/basalt found in the McHugh Complex suggests the possibility of some input from the Kachemak terrane. Clearly the igneous rocks from the melange vary compositionally and may therefore provide important information on possible source terranes.

Purpose

Previous studies of the melange have focused on structural and paleontologic aspects. Only a few workers have published geochemical data of the igneous rocks from the melange or its correlative units (Hill, 1979; Luchetti and others, 1984; Plafker, Nokleberg, and Lull, 1989; Brandon, 1989a) and little geochemical data exists for igneous rocks from or near the type area. This paper presents a suite of analyses (Table 1), from the Kenai Peninsula area, of volcanic rocks from the melange and compares the composition of the McHugh complex volcanic rocks in Turnagain Arm and southern Kenai Peninsula with published analyses of volcanic rocks form the McHugh and its correlative units in Alaska and Vancouver Island and the Kachemak terrane.

The geochemistry of volcanic rocks from the Kachemak terrane are also compared with those from the McHugh Complex to see if there is any similarity in composition as suggested by the similar age range of cherts associated with basalt from the McHugh Complex. Compositions of igneous rocks from suggested source terranes such as Wrangellia (Nikolai Greenstone) and Peninsular terranes (Shuyak and Talkeetna Formations) are also compared to determine whether or not they contributed blocks to the melange. In 1989, additional samples of basalts for chemical analyses and cherts for fossil determinations, were collected for future follow-up reports (C. D. Blome, D. Bradley, and S. K. Karl, oral commun., 1989).

Geochemical Results

Table 1 presents the chemical analyses and a brief petrographic description of eight volcanic rock samples. One sample is andesite from the type area of the McHugh Complex in Turnagain Arm (fig. 1) and four samples are of basalt from the Kachemak terrane.

These samples were collected at the same time as associated chert samples for a paleontologic study described by Blome and others (1990). Three of the volcanic samples are not associated with dated fossiliferous chert (Table and fig. 1). The sample from Turnagain Arm was collected from a road cut section containing Late Jurassic and Early

Cretaceous cherts (Nelson and others, 1986). Three of the Kachemak terrane samples were in depositional contact with dated chert. Analyses of the undated samples from the McHugh Complex correlate well with analyses of basalts from the McHugh Complex in the Valdez Quadrangle (Plafker and others, 1989) and Kodiak Island (Uyak Complex of Hill, 1979 (figs. 4-6).

The degree of hydrothermal alteration and metamorphism of rocks is important to determine for any geochemical study. To minimize any secondary influences only fresh-appearing samples were collected. The cores of pillow basalts were analyzed to minimize the effect of contact with sea water, and obvious veins or amygdules were discarded during collection. Petrographic observations (Table 1) indicated good igneous textures and primary mineralogy. Only a small amount of secondary minerals are present, suggesting that secondary influences are minor. Zr/Hf rations are moderately consistent (avg. 39) and range within the values for unaltered rock (Wood and others, 1979). Using the fresh vs. altered curve for young basalts of Miyashiro (1975) only one (87 Ans 17A) of the eight samples plots in the altered field indicating a loss of K_2O.

Major Oxides (values in text recalculated volatile free)

Except for one sample of andesite (63% SiO_2), the rocks are classified as basalt or Hawaiite with most falling into the alkalic field (fig. 2). The Triassic samples from the Kachemak terrane are moderately well grouped (46-50% SiO_2) as are the McHugh Complex samples (48-51% SiO_2). The Kachemak terrane samples are richer in alkalis than the samples from the McHugh Complex (fig. 2).

On the AMF plot (fig. 3) all the samples fall near the boundary between the calc-alkaline and tholeiitic fields. The andesite from Turnagain Arm is calc-alkalic as are two of the Triassic basalts. The McHugh Complex samples are less alkalic than samples form the McHugh Complex in the Valdez quadrangle (Plafker, Nokleberg, and Lull, 1989), although there is some overlap with reported analyses from basalts of the Uyak Complex on Kodiak Island (Hill, 1979). The Kachemak terrane samples do not correlate well with Triassic samples form either the Peninsular or Wrangellia terranes or the Ucluth Formation. The Nikolai Greenstone (and equivalent rocks) of the Wrangellia terrane shows the most similarity (fig. 3) with our samples from the McHugh Complex.

Rare Earth Elements

Chondrite-normalized rare earth element (REE) abundances show two distinct groups (fig. 4a). One grouping is represented by three samples from the Kachemak terrane and one sample from the McHugh Complex. These four samples are strongly light rare earth (LREE) enriched (La 24-115x chondrite) and have no Eu anomaly. This pattern is similar to analyses of basalts from several settings, including island arc and oceanic island (Wilson, 1989).

Four samples from the McHugh Complex make up the second grouping. These samples have flat to slightly convex upward patterns (La 5-12x chondrite and overall abundances between 12-22x chondrite) and no Eu anomaly. This pattern is similar to MORB. REE abundances reported (fig. 4b) for samples of the McHugh Complex (Plafker and others, 1989) and the Uyak Complex (Hill, 1979) have REE distributions similar to group two.

REE abundances from Wrangellia samples reported by Davis and Plafker (1985) have a LREE enriched distribution (fig. 4b). The Triassic Shuyak Formation on Kodiak Island (Peninsular terrane) can be divided into a LREE enriched group (broadly similar to Wrangellia samples) and a strongly LREE depleted group (Hill, 1979). The Early Jurassic Talkeetna Formation of the Peninsular terrane has REE abundances (F. Barker, written commun. 1990) similar to group two of the McHugh Complex and weak to moderate LREE enrichment.

Discrimination Diagrams

Several types of variation diagrams have been proposed to aid in the discrimination of the tectonic environment for generation of various basalts (Pearce and Cann, 1973; Wood, 1980; Wood and others, 1979). The boundaries for some of the tectonic environments have been found to be artificial (Wilson, 1989) or ambiguous (Coleman, 1977) with some environments overlapping others (Pearce and Cann, 1973; Wood, 1980; Barker and others, 1989). Despite the shortcomings recognized for some of these diagrams, they are still useful when combined with other geologic knowledge for comparison and tectonic interpretation. In this study they are also useful for chemically comparing volcanic rocks from the McHugh Complex with volcanic rocks from possible source terranes.

Figure 5 displays La/Ta variation for the eight samples and two groups can be identified. Group one has La/Ta<14. These samples correspond to basalts from the Kachemak terrane and one from the McHugh Complex and plot in the E-MORB region. Rocks of the McHugh Complex comprise group two and plot in the N-MORB region corresponding to La/Ta of 15-30. Overall La and Ta values are less than group one. Other analyses of La/Ta form the Uyak Complex (Hill, 1979) on Kodiak Island and from the McHugh Complex in the Valdez quadrangle (Plafker and others, 1989) are similar to the group two values corresponding to N-MORB.

La/Ta values reported from possible source terrane rocks vary. The Early Jurassic subduction-related Talkeetna Formation has La/Ta=48 (F. Barker, written commun., 1990). Two analyses from the Triassic Shuyak Formation (Hill, 1979) plot in the N-MORB field and have higher La and Ta values than group two. The small number of analyses from this unit make comparison inconclusive. La/Ta for Wrangellia samples (Davis and Plafker, 1985) are intermediate between groups one and two with the majority of samples plotting in the E-MORB field.

The McHugh Complex samples plot in several tectonic settings on the Th-Hf-Ta discrimination diagram (fig. 6). Three samples plot in the N-MORB field (fig. 6) and correlate well with analyses from McHugh Complex samples form the Valdez Quadrangle and less well with analyses of rocks from the Uyak Formation. The other two McHugh Complex samples plot in overlap fields between N-MORB/E-MORB or E-MORB/Within Plate settings.

Analyses of rocks form the Kachemak terrane plot in several overlap fields (fig. 6). One sample plots in the N-MORB/E-MORB region and two in the overlap between E-MORB/WP setting. Analyses of other Triassic units plot in the E-MORB region but do not correlate well with the plot of Kachemak terrane rocks.

Samples from proposed source terranes for blocks in the McHugh Complex plot (fig. 6) either as E-MORB (Shuyak Formation and Wrangellia) or are subduction related (Talkeetna Formation). None of these analyses correlate well with analyses form the McHugh Complex or Kachemak terrane.

Conclusions

The geochemical results suggest several important conclusions:

1. Chemical criteria may be successful in distinguishing basalts from the McHugh Complex from basalts from the Kachemak, Wrangellia, and Peninsular terranes.

2. Geochemistry of samples from this study do not show an arc affinity for basalts from the McHugh Complex or the Kachemak terrane.

3. Basalts from the McHugh Complex appear to be chemically most similar to MORB. A few samples show chemical similarity with enriched MORB suggesting oceanic islands formed in an off-axis setting.

4. Basalts from the Kachemak terrane are strongly similar to E-MORB and alkalic within plate basalts confirming an earlier interpretation (Luchetti and others, 1984) that these rocks formed as oceanic islands.

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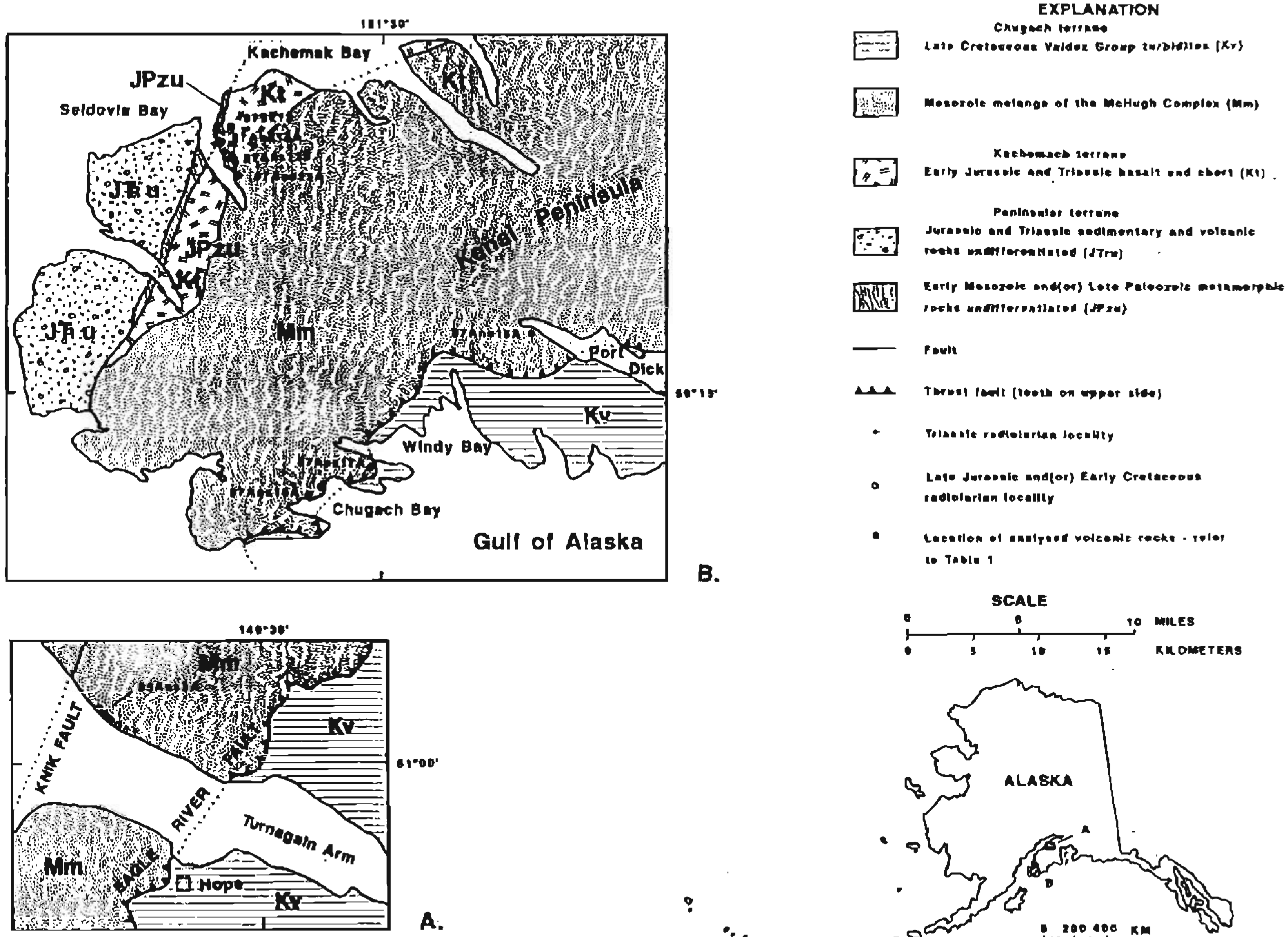

Figure 1.

Generalized geologic maps with locations of volcanic rock samples and dated fossils. Geology adapted from Cowan and Boss (1978) and Magoon and others (1976).

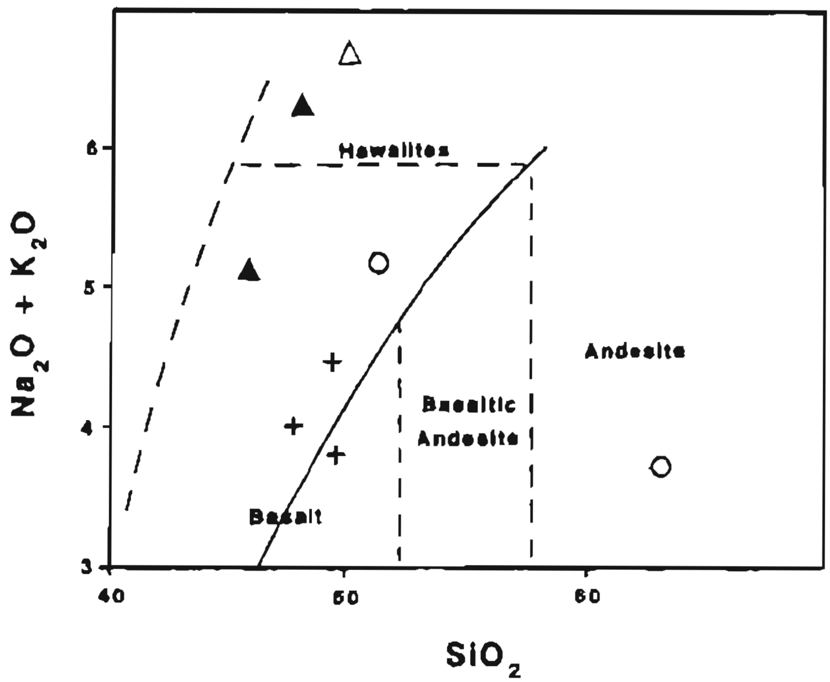

Figure 2. Total alkalis vs. silica diagram (recalculated volitale free) for samples from the McHugh Complex and Kachemak terrane. Nomenclature after Cox and others (1979).

McHugh Complex

+ Unknown age

O Late Jurassic and Early Cretaceous ages

Kachemak terrane

△ Late Triassic to Early Cretaceous

▲ Middle or Late Triassic

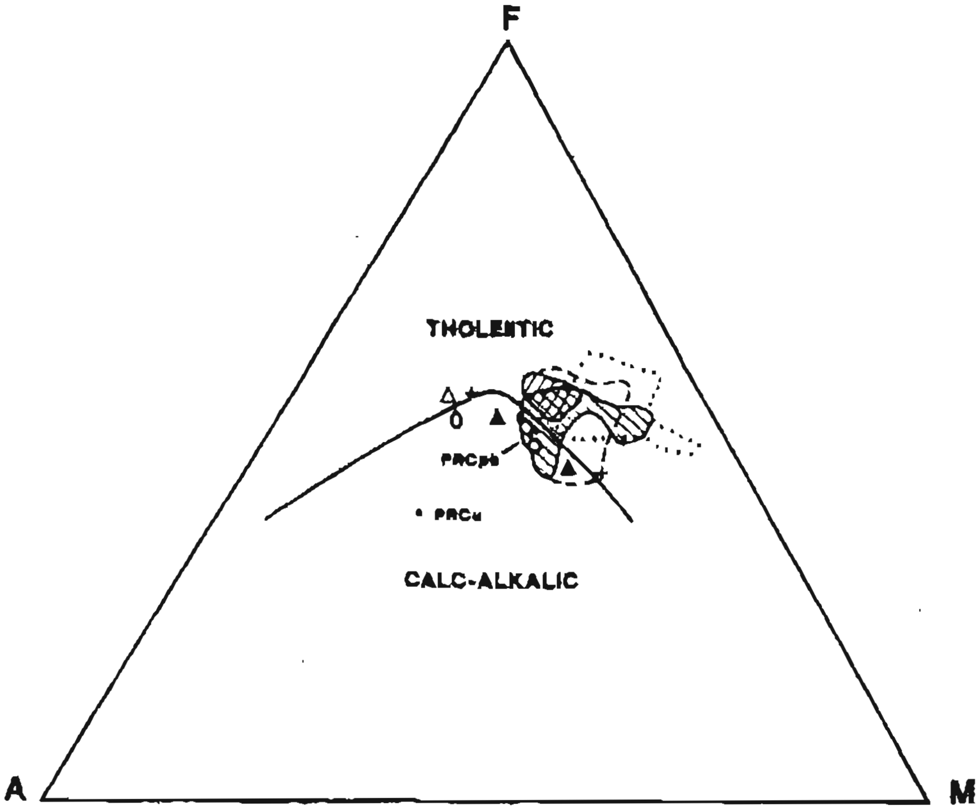

Figure 3. AFM diagram of samples from McHugh Complex, Kachemak terrane, and possible source terranes.

EXPLANATION

Chugach terrane

McHugh Complexe

+ Unknown age (this report)

o Late Jurassic and Early Crecaceous (this report)

Valdez quad. samples (Plafker and others, 1989)

Uyak Formation

Kodiak Island samples (Hill, 1979)

Pacific Rim Complex, Vancouver Island

PRCpb Early Jurassic pillow basalt avg. (Brandon, 1989b)

PRCu Triassic Ucluth Formation avg. (Brandon, 1989b)

Kachemak terrane

△ Late Triassic to Early Cretaceous (this report)

▲ Middle or Late Triassic (this report)

Peninsular terrane

0 Early Jurassic Talkeetna Fm. avg. (Barker and Grantz, 1982)

Triassic Shuyak Formation (Hill, 1979)

Wrangellia terrane

Upper Triassic Nikolai Greenstone and Chilkat Peninsula metabasalt (Davis and Plafker, 1985)

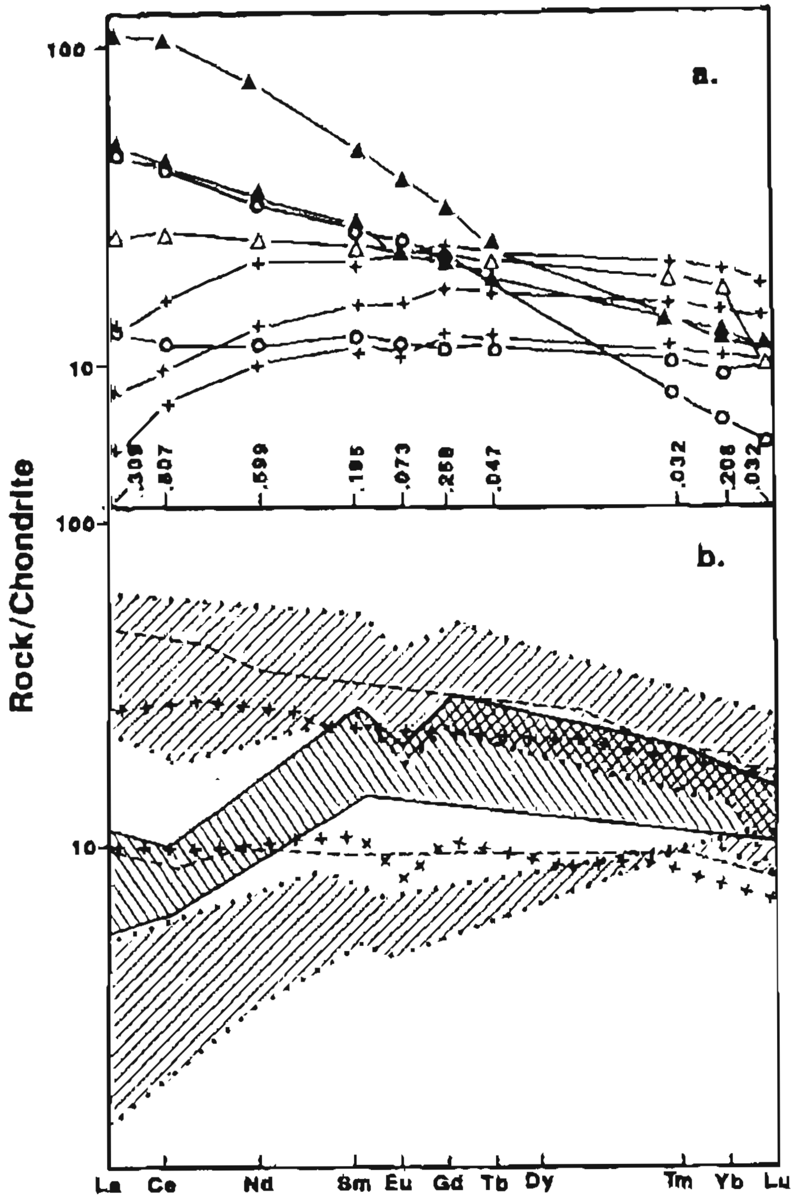

Figure 4. Chondrite-normalized REE distributions. a) Samples from the McHugh Complex and Kachemak terrane (normalizing factors shown-this report). b) Samples from other units and possible source terranes.

Explanation

Chugach terrane

McHugh Complex

+ Unknown age (this report)

o Late Jurassic and Early Cretaceous (this report)

Oyak Formation

Kodiak Island samples (Hill, 1979)

Kachemak terrane

△ Late Triassic to Early Cretaceous (this report)

▲ Middle or Late Triassic (this report)

Peninsular terrane

+++ Early Jurassic Talkeetna Fm. (Barker and Grantz, 1982)

Triassic Shuyak Formation (Hill, 1979)

Wrangellia terrane

Upper Triassic Nikolai Greenstone and Chilkat Peninsula metabasalt *(Davis and Plafker, 1985)*

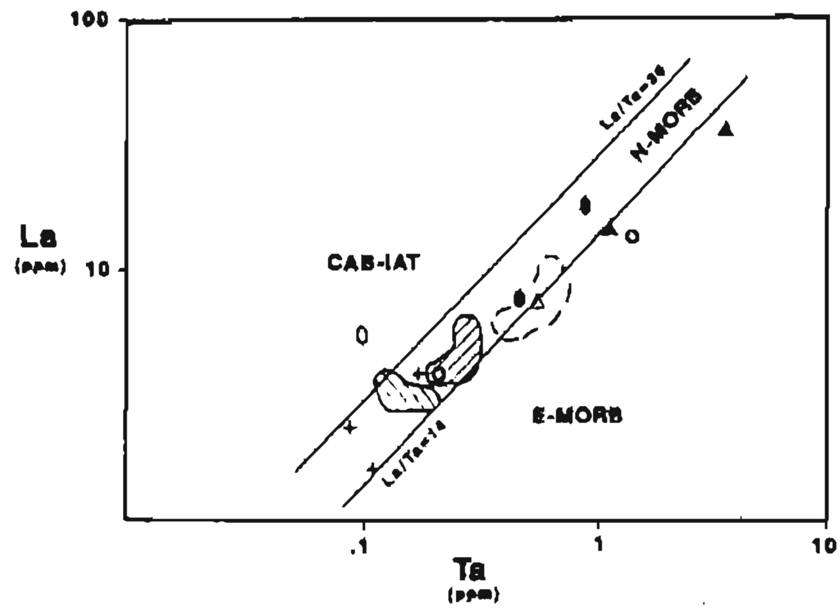

Figure 5. La-Ta variation diagram of samples from McHugh Complex and Kachemak terrane and possible source terranes. Calc-alkaline basalt-island are tholeiite (CAB-IAT), normal mid-ocean ridge basalt (N-MORB), and enriched-MORB (E-MORB) fields after Wood and others (1979).

EXPLANATION

Chugach terrane

McHugh and Seldovia Bay Complexes

+ Unknown age (this report)

o Late Jurassic and Early Cretaceous (this report)

Valdez quad. samples (Plafker and others, 1989)

Uyak Formation

Kodiak Island samples (Hill, 1979)

Kachemak terrane

△ Late Triassic to Early Cretaceous (this report)

▲ Middle or Late Triassic (this report)

Peninsular terrane

0 Early Jurassic Talkeetna Fm. avg. (Barker and Grantz, 1982)

Triassic Shuyak Formation (Hill, 1979)

Wrangellia terrane

Upper Triassic Nikolai Greenstone and Chilkat Peninsula metabasalt (Davis and Plafker, 1985)

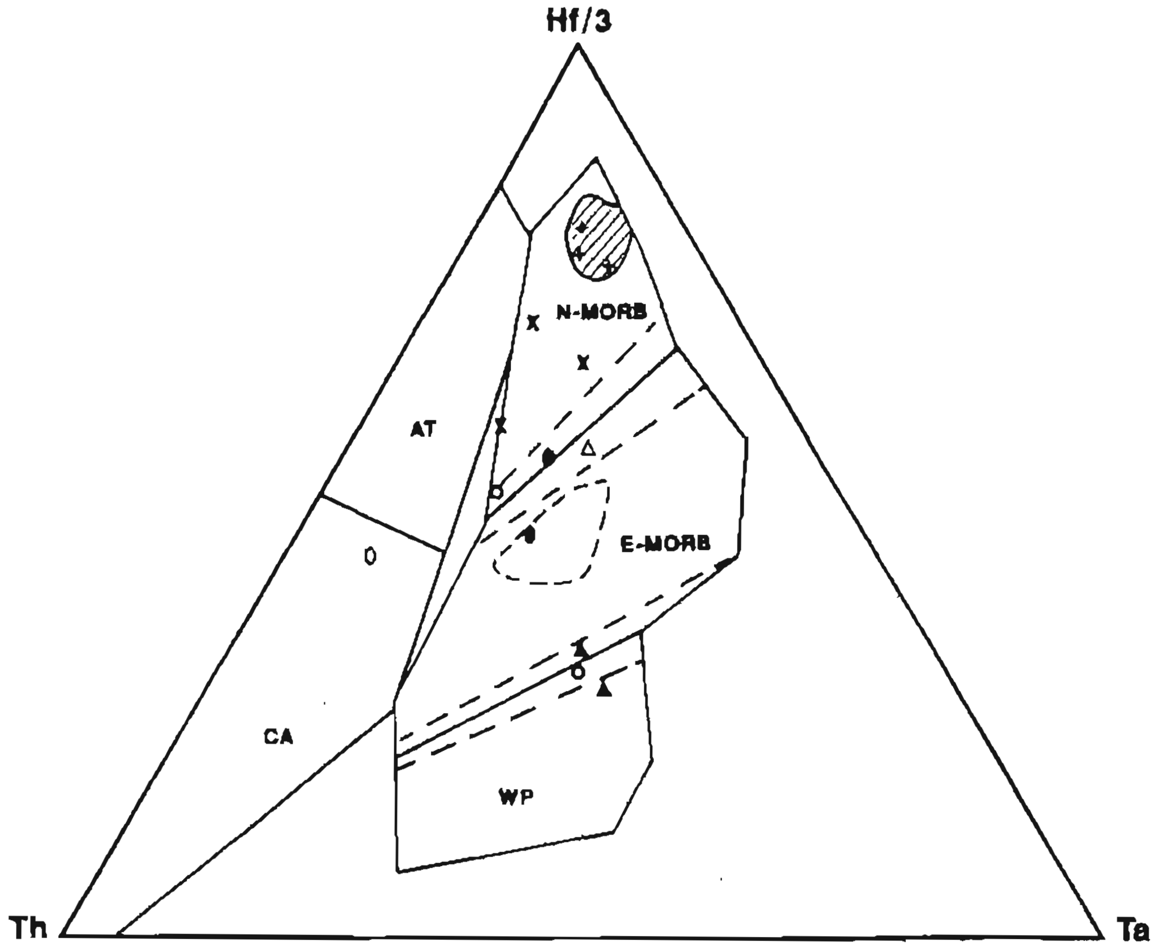

Figure 6. Hf-Th-Ta variation diagram for samples from the McHugh Complex and Kachemak terrane (this report) and possible source terranes. Calc-alkaline (CA), arc tholeiite (AT), normal-ocean floor basalt (N-MORB), enriched-ocean floor basalt/within-plate tholeitte (E-MORB), and alkalic within-plate basalts (WP) fields (dashed lines are overlap fields) after Wood (1980).

Explanation

Chugach terrane

McHugh Complex

+ Unknown age (this report)

O Late Jurassic and Early Cretaceous (this report)

Valdez quad. samples (Plafker and others, 1989)

Dyak Formation

X Kodiak Island samples (Hill, 1979)

Kachemak terrane

△ Late Triassic to Early Cretaceous (this report)

▲ Middle or Late Triassic (this report)

Peninsular terrane

O Early Jurassic Talkeetna Fm. avg. (Barker and Grantz, 1982)

Triassic Shuyak Formation (Hill, 1979)

Wrangellia terrane

Upper Triassic Nikolai Greenstone and Chilkat Peninsula metabasalt (Davis and Plafker, 1985)

Table 1.--Major oxide and minor element compositons, and petrographic observations of volcanic rocks from the McHugh Complex and Kachemak terrane

Chemical Analyses [1] Weight %

Sample	85Ans3A	87Ans11A	87Ans12B	87Ans13A	87Ans15A	87Ans17A	87Ans18A	87SK13
Unit [2] age assoc.	MC L.Jur/E.K	MC unk	Kt L.Tr - E.J.	Kt L.Tr.	MC unk	MC unk	MB E.K(?)	Kt M. or L.Tr.
SiO_2	60.2	47.4	47.1	43.3	46.1	47.2	49.4	43.5
Al_2O_3	11.9	15.6	15.1	15.9	14.6	16.7	14.3	11.2
Fe_2O_3	1.7	1.3	7.1	1.8	6.3	2.7	1.9	7.8
FeO	6.01	7.48	4.41	8.64	7.35	8.51	8.31	4.48
MgO	4.38	8.41	3.86	8.43	7.94	5.84	6.63	5.63
CaO	6.76	10.30	7.25	6.07	7.96	8.64	7.70	8.51
Na_2O	3.07	3.26	3.74	2.99	3.42	4.23	4.43	0.25
K_2O	0.45	0.33	2.55	1.80	0.41	0.03	0.61	5.39
TiO_2	1.04	1.02	2.15	3.68	2.12	1.36	2.43	1.86
P_2O_5	0.14	0.08	0.33	0.86	0.15	0.11	0.31	0.28
MnO	0.14	0.15	0.18	0.27	0.25	0.17	0.24	0.33
H_2O+	NA [4]	3.98	3.05	4.45	3.35	3.51	2.80	3.57
H_2O-	NA	0.29	0.22	0.76	0.24	0.24	0.28	0.99
CO_2	NA	0.59	3.49	0.39	0.36	0.93	0.69	6.30
		100.19	100.53	99.34	100.55	100.17	100.20	99.91
LOI	3.54	4.15	6.33	4.99	3.13	3.75	2.94	10.7
Minor Elements ppm INAA								
La	3.97	1.60	7.30	35.5	3.94	2.47	14.7	14.9
Ce	9.82	6.44	22.4	88.0	13.5	8.00	34.9	34.1
Nd	7.42	6.37	15.7	46.2	13.2	8.21	20.2	21.4
Sm	2.54	2.37	4.98	9.64	4.4	3.18	5.53	5.65
Eu	0.933	0.864	1.69	2.96	1.73	1.23	1.92	1.74
Gd	3.13	3.44	6.39	8.81	6.34	4.83	5.94	6.10
Tb	0.595	0.613	1.04	1.20	1.13	0.864	0.825	0.972
Tm	0.355	0.394	0.628	NA	0.733	0.540	0.279	0.491
Yb	2.20	2.47	3.84	2.98	4.51	3.42	1.54	2.86
Lu	0.344	0.354	0.538	0.401	0.629	0.480	0.204	0.404
Ba	237	79.6	226	2360	60.4	72.5	456	274
Sr	NA	174	72	482	461	247	461	194
Co	27.2	43.5	40.2	36.9	61.2	50.0	40.8	28.0
Ni	NA	131	151	95.0	88.0	77.8	72.6	64.4
Cr	135	343	267	91.4	170	304	185	101
Cs	0.365	0.441	1.58	1.78	2.24	0.526	8.36	5.26
Hf	1.97	1.57	3.54	7.38	3.37	1.98	3.61	3.39
Rb	10.8	<1.0	80.7	24.5	9.52	<1.0	30.2	119
Sb	<0.11	0.365	0.328	0.122	1.07	1.07	1.98	0.248
Ta	0.206	0.106	0.560	3.52	0.170	0.0871	1.45	1.17
Th	0.449	0.063	0.482	3.02	0.172	<0.081	1.45	1.18
U	0.23	0.083	0.227	1.06	0.345	0.140	0.437	0.929
Zn	<69	79	107	90.2	169	110	104	82.5
Zr	81	89.9	145	332	130	101	175	156
Sc	31.3	36.7	38.4	27.1	45.9	46.8	23.3	19.1
X-Ray Spectroscopy ppm								
Nb	<10	<10	14	46	<10	<10	22	20
Rb	<10	<10	60	24	<10	<10	18	104
Sr	210	134	110	475	330	270	390	165
Zr	80	56	138	320	124	76	140	134
Y	20	16	36	38	36	30	18	30
Cu	NA	80	58	36	80	46	82	20