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Tertiary Volcanic Rocks of the Central Talkeetna Mountains, Alaska

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Abstract

Volcanic rocks of the central Talkeetna Mountains consist of more than 400 m of shallow-dipping basaltic and andesitic lavas with subordinate dacitic and rhyolitic lavas and tuffs. All of the lavas are intruded by rhyolite and dacite dikes, sills, and small domes and by minor basaltic dikes. The eruption of these rocks began with the outpouring of mafic lavas, followed by alternating mafic, intermediate-composition, and felsic lava flows. The youngest phase of magmatism is recorded by the shallow rhyolite and dacite intrusions that crosscut the lavas. Geochemically, the basalt samples are relatively depleted in light-rare-earth elements (chondrite-normalized La/Yb ratios of 0.9–2.3, with La 9.5–31.3 times chondrite) and have compatible-element contents similar to those of midocean-ridge basalts, indicating a depleted mantle source for the basalts. The felsic lavas and intrusions are the most evolved rocks in the study area (chondrite-normalized La/Yb ratios of 3.7–7.6, with La 32.7–64.0 times chondrite and highest Ba, Rb, Th, and K contents) and evolved from the mafic magmas by a combination of fractional crystallization and crustal assimilation. All of the samples (basalts through rhyolites) show enrichment in Cs, Ba, Th, and Pb, which is consistent with metasomatism of the depleted mantle source.

Introduction

This study is focused on unnamed Tertiary volcanic rocks that are exposed along a northwest- trending belt through the central Talkeetna Mountains (fig. 1). These volcanic rocks occur 50 to 75 km north of the Border Ranges Fault system, which forms the south boundary of the Wrangellia composite terrane. The Wrangellia composite terrane includes varyingly metamorphosed magmatic-arc rocks and oceanic sedimentary rocks of the Wrangellia, Peninsular, and Alexander terranes (Nokleberg and others, 1994). The volcanic rocks of the central Talkeetna Mountains are enigmatic because they were erupted through the Wrangellia composite terrane during an apparent lull in arc magmatism across south-central Alaska, and their tectonic and petrogenetic histories are poorly known. The specific goals of this report are to (1) provide a geologic overview, including new stratigraphic and geochemical results, for Tertiary volcanic rocks at two localities in the northern part of the central Talkeetna Mountains; and (2) to develop a working hypothesis for the origin of the Tertiary volcanic rocks in this area. The two study areas are in the central part of the Talkeetna Mountains 1°×3° quadrangle adjacent to the Tafia vertical-azimuth bench mark (VABM) and the Sedan VABM (fig. 2). The results reported here are based on fieldwork conducted during June 2001 at these two localities with helicopter and logistical support provided by the U.S. Geological Survey Talkeetna Mountains Transect project.

Background

The volcanic rocks of the central Talkeetna Mountains were described by Csejtey and others (1978) as more than 1,500 m of felsic to mafic subaerial volcanic rocks and related shallow-intrusive rocks. Csejtey and others (1978) further described that the lower part of the volcanic sequence consists dominantly of rhyolite and latite small-scale intrusions, lavas, and pyroclastic rocks and that the upper part consists mostly of andesite and basalt flows interlayered with minor amounts of tuff and fluvial conglomerate. More detailed mapping by Adams and others (1985) showed that the volcanic rocks of the central Talkeetna Mountains consist mostly of mafic to intermediate-composition lavas, with subordinate felsic lavas and interbedded tuff, all of which are intruded by dacite and rhyolite dikes and domes and minor mafic dikes. Our field observations are consistent with their mapping.

Existing K-Ar ages yield an Early to Middle Eocene range for the volcanic rocks of the central Talkeetna Mountains. Csejtey and others (1978) reported a K-Ar age of 51.3±2.5 Ma on an andesite whole-rock sample from the middle of the volcanic sequence at the north edge of the volcanic field and an age of 56.3±2.5 Ma on an andesite whole-rock sample from the south edge of the volcanic field (fig. 2A). Csejtey and others (1978) also reported a K-Ar age of 50.4±2.0 Ma on hornblende from an andesite flow in a pod of volcanic rocks exposed about 14 km west of the main part of the central Talkeetna Mountains volcanic field. In addition, hornblende from two rhyodacite dikes that intrude mafic and intermediate-composition lavas in the central

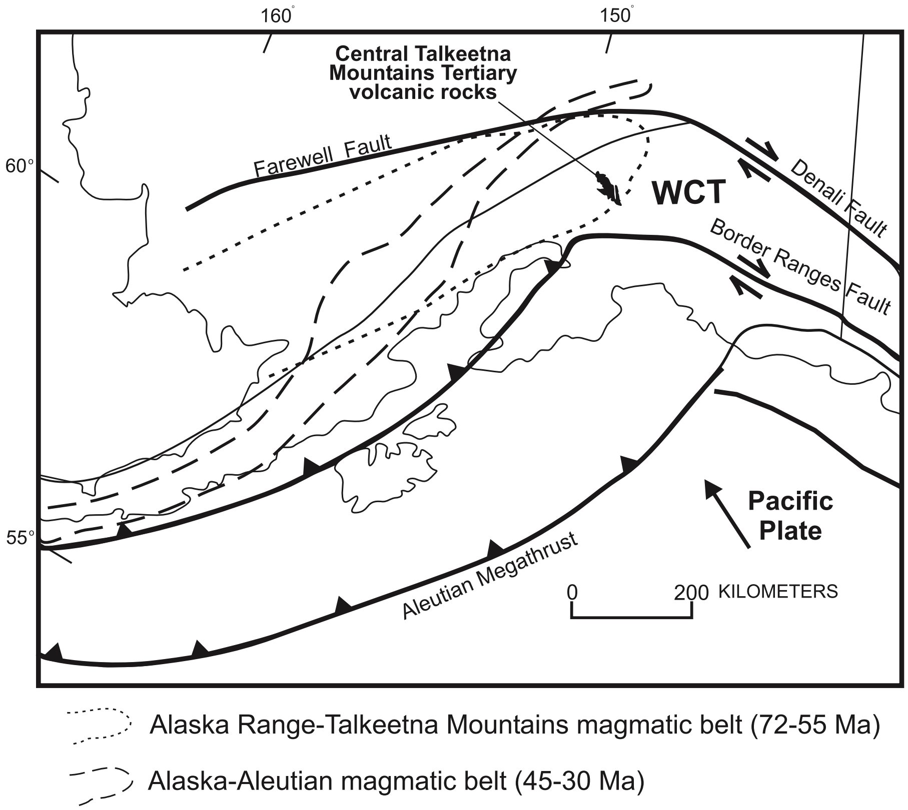

Figure 1. South-central Alaska, showing volcanic rocks of the central Talkeetna Mountains, major fault systems, the Wrangellia composite terrane (WCT), and regional magmatic belts. Boundaries of WCT from Nokleberg and others (1994) and of magmatic belts from Moll-Stalcup and others (1994).

Talkeetna Mountains yielded K-Ar ages of 39.8±2.5 and 43.6±2.6 Ma (fig. 2*A*; Adams and others, 1985; Little, 1988).

The volcanic rocks of the central Talkeetna Mountains overlie Late Paleozoic and Jurassic rocks (fig. 2). The Late Paleozoic rocks include Pennsylvanian(?) and Early Permian basaltic to andesitic metavolcanic rocks, with subordinate mudstone, bioclastic marble, and dark-gray to black phyllite (Csejtey and others, 1978). These rocks are tightly folded and complexly faulted and are regionally metamorphosed to greenschist and, locally, amphibolite facies (Csejtey and others, 1978). The Jurassic rocks include Lower to Upper Jurassic trondhjemite, granodiorite, quartz diorite, amphibolite, and migmatite, with lesser greenstone and pelitic mica schist (Csejtey and others, 1978).

Volcanic and Shallow-Intrusive Rocks

Approximately 400 m of horizontal to shallow-dipping lavas, minor pyroclastic units, and small intrusions is exposed in the Tafia and Sedan study areas (figs. 3, 4). On the basis of their silica and alkali composition, the rocks include basalt, basaltic andesite, andesite, dacite, and rhyolite (fig. 5). The lavas are predominantly basaltic through andesitic, with subordinate dacite and rhyolite flows (figs. 2*B*, 2*C*). The intrusive rocks are predominantly dacite and rhyolite dikes and small stocks, with subordinate basaltic dikes. The general stratigraphic sequence in the study areas includes a lower interval of mafic lavas, overlain by interlayered mafic, intermediate-composition, and felsic lavas. In the Sedan study area, a felsic pyroclastic lens that is present at the base of the volcanic sequence unconformably overlies folded and sheared Paleozoic metamorphic rocks. Pyroclastic deposits are also present as minor lenses throughout the sequence. The dacite and rhyolite intrusions are the youngest units observed in the study areas.

Mafic Lavas

Mafic lavas, including basalt and basaltic andesite, are the most abundant lavas observed. Individual lava flows range from about 2 to 8 m in thickness and typically form elongate lenses that extend for a few to tens of meters across. Several beds display internal flow folding, and overall the mafic lava beds are generally less vesicular at the base and highly vesicular to scoriaceous at the top. Weathering colors range from light medium gray to red-brown, and fresh colors are typically dark gray to black. Nearly all of the mafic lavas are aphanitic to finely porphyritic, with phenocrysts of plagioclase, pyroxene, minor olivine, and Fe-Ti oxides in a glassy

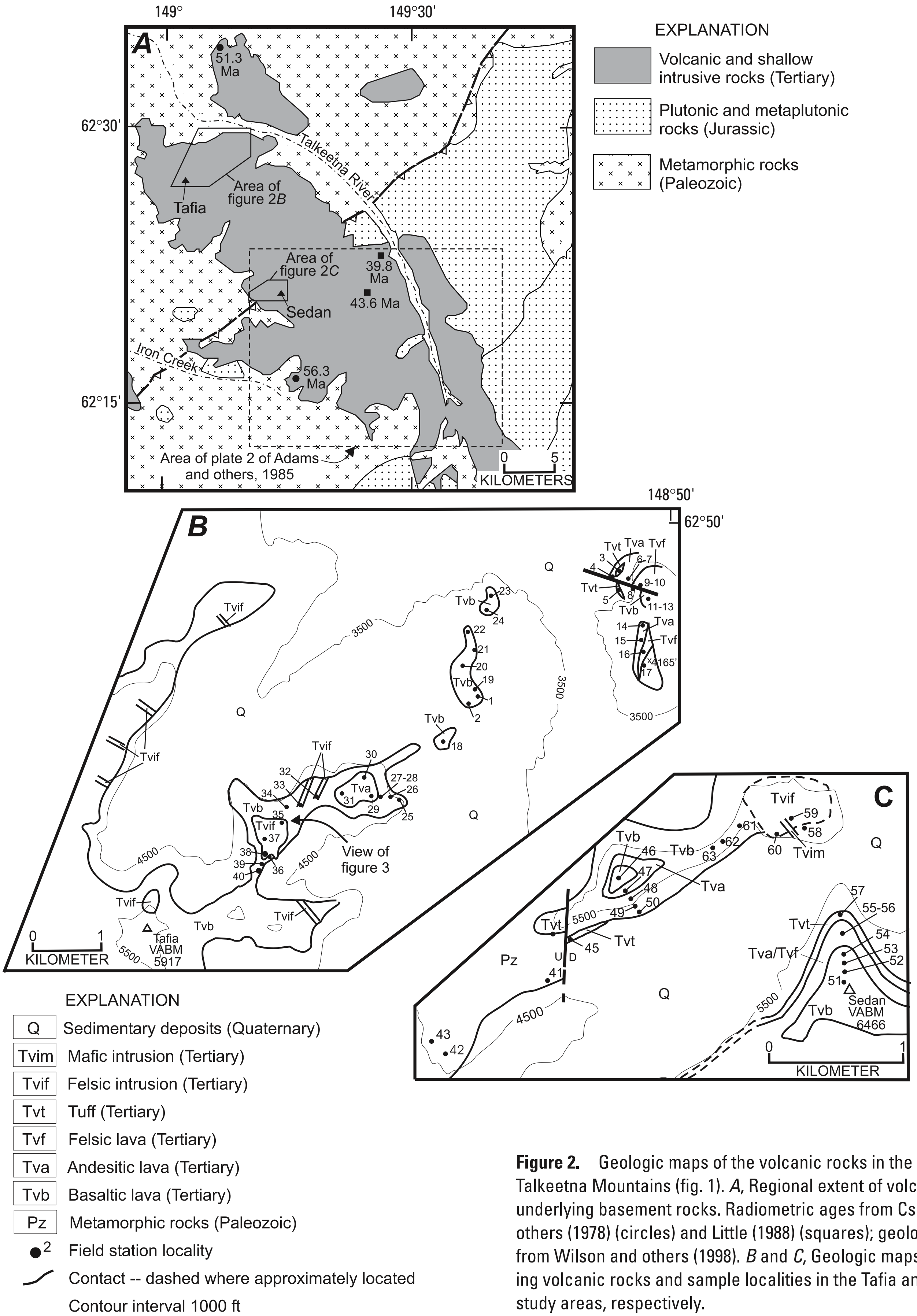

Figure 2. Geologic maps of the volcanic rocks in the central Talkeetna Mountains (fig. 1). *A*, Regional extent of volcanic and underlying basement rocks. Radiometric ages from Csejtey and others (1978) (circles) and Little (1988) (squares); geologic base from Wilson and others (1998). *B* and *C*, Geologic maps showing volcanic rocks and sample localities in the Tafia and Sedan study areas, respectively.

Figure 3. Rhyolite-dacite dome (unit Tvif, fig. 2) intruded through shallow-dipping basalt lava flows (Tvb) in the Tafia study area (fig. 2*B*). Dome is approximately 200 m across.

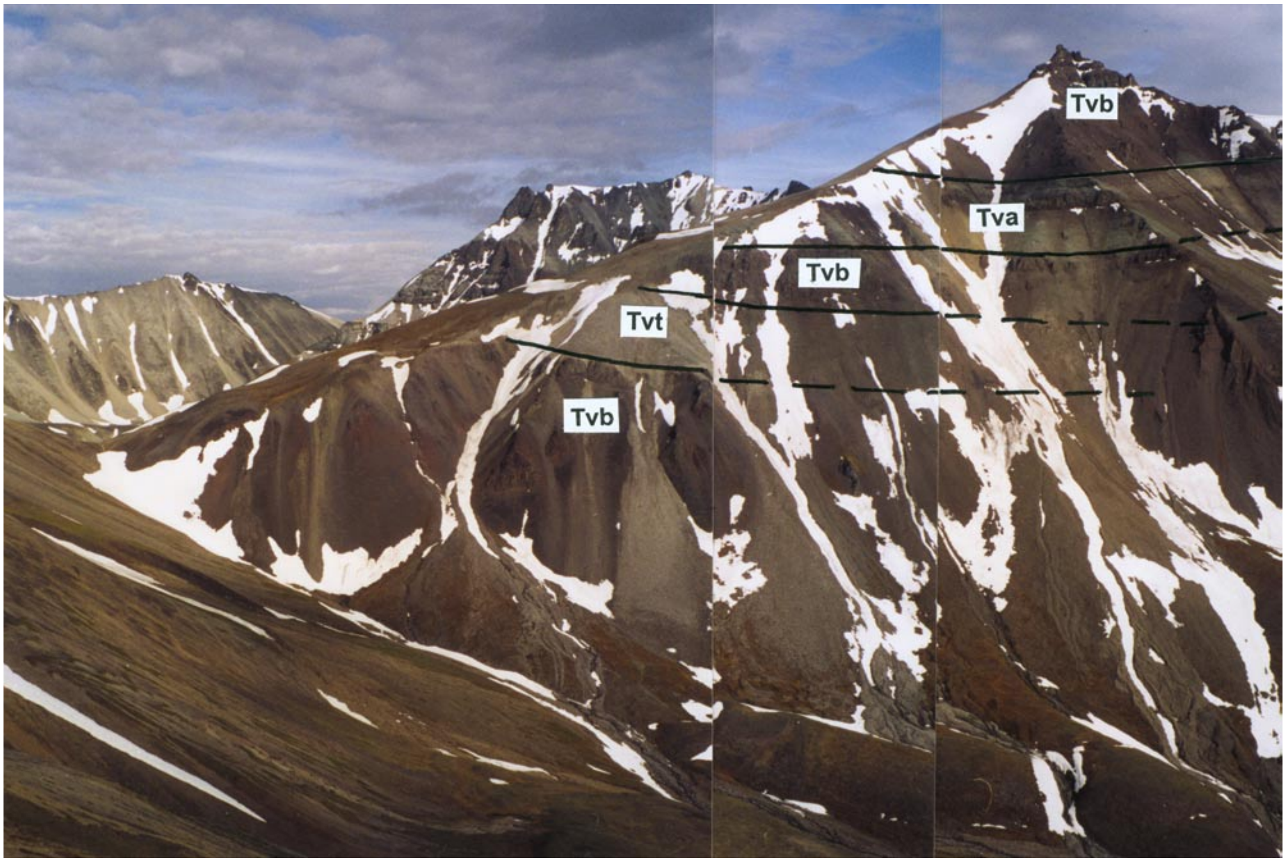

Figure 4. Basalt (unit Tvb, fig. 2) and andesite (unit Tva) lavas with interbedded tuff (unit Tvt) in the Sedan study area (fig. 2*C*); vertical-azimuth bench mark (VABM) Sedan (elev 1,971 m) is located at peak.

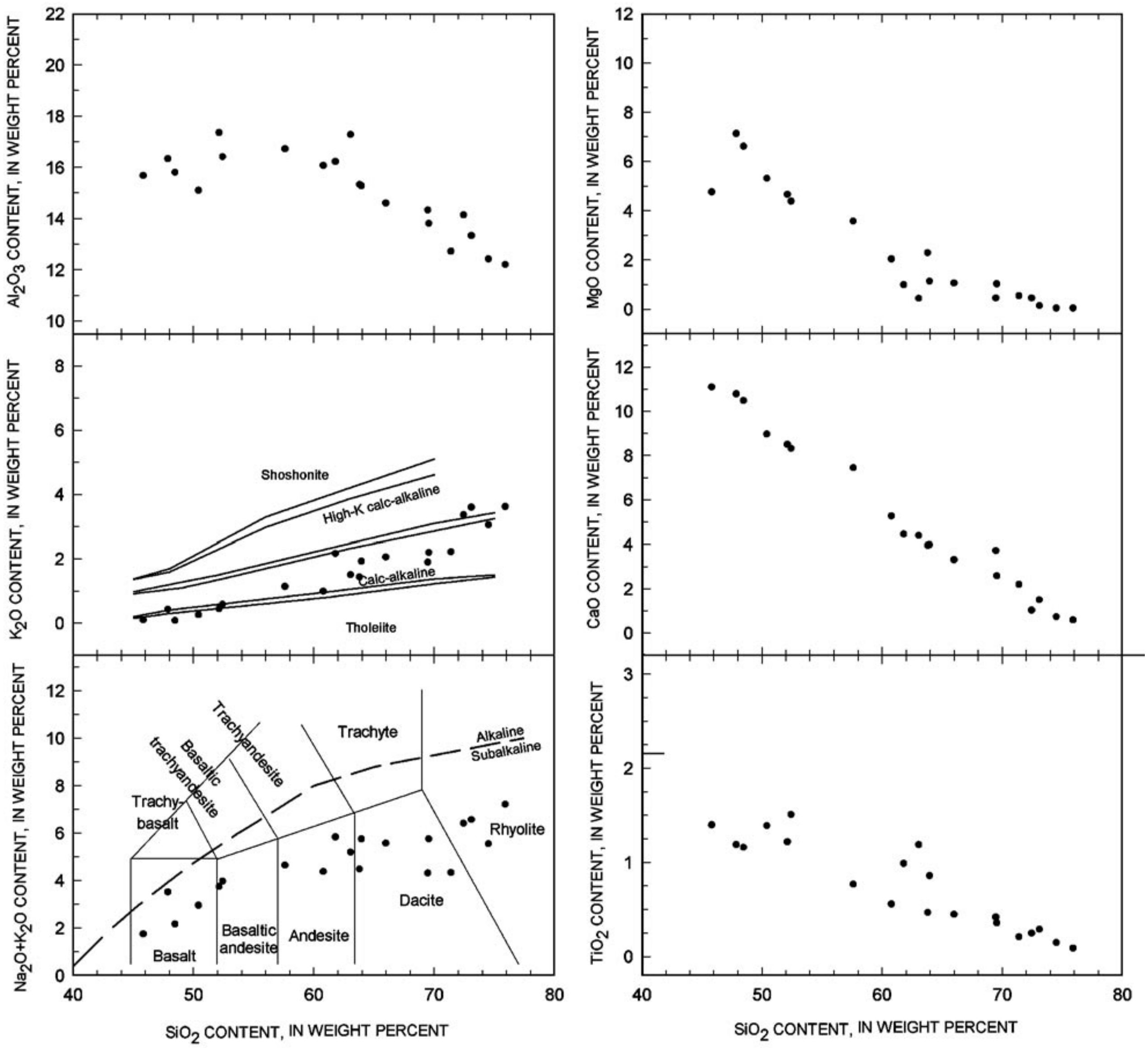

Figure 5. Major-element variation diagrams for volcanic rocks of the central Talkeetna Mountains (fig. 1). Rock classification scheme from Le Bas and others (1986); rock series from Rickwood (1989).

and (or) plagioclase-rich matrix. The pyroxene and plagioclase phenocrysts are commonly intergrown, and ophitic texture is common. Secondary replacement of plagioclase with calcite is also common.

Intermediate-Composition Lavas

The andesitic lavas are interbedded with the mafic lavas. Individual andesite flows are approximately 5 to 10 m thick and form broad lenses. Individual lava flows are commonly vesicular and amygdaloidal. Weathering colors include light gray, light green, and red-brown, and fresh colors are typically medium to dark gray. The rocks are aphanitic to porphyritic, with plagioclase and minor pyroxene phenocrysts in a glassy, devitrified-glass, and plagioclase-rich matrix. Plagioclase phenocrysts are commonly zoned and exhibit resorption textures.

Felsic Lavas

The felsic lavas include dacite and rhyolite and are less abundant than the mafic and intermediate-composition lavas. Beds are massive and generally more than 5 m thick, although bedding contacts are difficult to discern. Thin wispy laminations and banding are typical in the felsic lavas. Weathering colors range from tan through light gray to light purple, and fresh colors are light pink to light gray. The felsic rocks range in texture from aphanitic to coarsely porphyritic. The felsic lavas are typically hypocrystalline, with a glassy matrix containing phenocrysts of quartz and zoned plagioclase. The dacites also include some amphibole and rare pyroxene phenocrysts. Embayments are typical in all phenocrysts.

Pyroclastic Deposits

Lithic vitric tuff and lapilli tuff deposits occur at several localities within the study areas. These pyroclastic deposits are typically lens shaped and range in thickness from tens of centimeters to about 10 m. The predominant grains within the deposits include cuspate glass shards, pumice grains (approx 0.5–3-cm diam), felsic porphyritic lithic grains (approx 1–12-cm diam), and dark-gray to black argillite grains (approx 1–6-cm diam).

Felsic Intrusive Rocks

Felsic intrusive rocks crosscut all of the lavas in the Tafia and Sedan study areas (figs. 3, 4). These intrusive rocks range in composition from dacite to rhyolite and in size from small dikes (0.5–1 m across) to small domes (a few hundred meters across) (fig. 3). In the Tafia study area, a radial pattern of felsic dikes is apparent around a rhyodacite dome (fig. 2*B*) that exhibits well-developed columnar jointing. Weathering colors in the felsic intrusive rocks are light gray, tan, and pink, and fresh color is typically light gray. The felsic intrusive rocks are typically porphyritic, with phenocrysts of zoned plagioclase and quartz and minor biotite and amphibole in a glassy or plagioclase-rich matrix. Embayments are common in all mineral phases.

Geochemical Results

New major- and trace-element data were collected for 20 samples of volcanic and intrusive rocks in the central Talkeetna Mountains (tables 1, 2). The samples were prepared and powdered by using an alumina ceramic mixing mill at Allegheny College and analyzed for major oxides by X-ray fluorescence and for trace elements by inductively coupled mass spectrometry at ALS Chemex Labs, Inc.

The volcanic and shallow-intrusive rocks of the central Talkeetna Mountains are subalkalic and lie in the medium-K calc-alkaline field of Rickwood (1989) (fig. 5). The entire suite of rocks shows coherent trends among major oxides, with decreases in MgO, CaO, and Al_2O_3 contents and an increase in K_2O content with increasing SiO_2 content.

All but one of the samples exhibit some degree of light-rare-earth-element (LREE) enrichment (fig. 6), with La(n)/Yb(n) ratios of 0.9 to 2.3 for basalts, 3.4 to 4.5 for andesites, and 3.7 to 7.6 for rhyolites and dacites. Basalt sample CTM01–AC49, which shows a slight LREE depletion, represents the most primitive sample in the set. Overall, the basalt samples exhibit relatively flat to slightly enriched LREE patterns. Progressive LREE enrichment and Eu depletion occurs from the basalt through the andesite, dacite, and rhyolite samples.

Normalized to chondrite, the basalt samples exhibit moderate Ba enrichment, a high degree of Th enrichment, and low Rb and K contents relative to Ba and Th (fig. 7). The basalt samples show less overall variation in the more compatible trace elements (Zr, Hf, Ti, Y, and rare-earth elements) and have relatively high Ta contents relative to Nb (fig. 7). This trend is also apparent by comparing the basalt samples with midocean-ridge basalt (MORB) (fig. 8); for the more compatible trace elements, the basalts display flat MORB-normalized patterns that are close to unity, especially for sample CTM01–AC49. All of the basalt samples exhibit varying enrichment of Sr, P, and Zr. Relative to the basalt samples, the andesite, dacite, and rhyolite samples show a progressive enrichment of incompatible elements, especially Rb and K (fig. 7). The andesite, dacite, and rhyolite samples also show progressive depletion in Sr, Eu, P, and Ti. All of the samples of volcanic rocks of the central Talkeetna Mountains have a relatively high Ta/Nb ratio.

Discussion

The stratigraphy of the volcanic rocks of the central Talkeetna Mountains reveals that a volcanic episode began with the outpouring of mafic lavas punctuated by minor felsic pyroclastic eruptions. Felsic lavas were erupted intermittently with intermediate-composition and mafic lavas after the initial mafic outpouring. This eruptive sequence suggests to us that mafic magmas were formed and erupted first and that the intermediate-composition and felsic magmas evolved later, probably from the mafic magmas.

All the basalt samples show some degree of fractionation or enrichment in incompatible elements and have relatively low Mg numbers of 0.35 to 0.42 (determined as MgO/(MgO+total FeO), where total FeO is calculated from Fe_2O_3). Although the basalts are not likely primary, sample CTM01–AC49 (figs. 6–8; tables 1, 2) shows the least incompatible-element enrichment and is the most reasonable sample for estimating primary magma composition. Its depletion in LREEs relative to chondrite (fig. 6) and its uniform contents of compatible trace elements similar to that of MORB (fig. 8) indicates a depleted mantle source for the primary magmas. The remaining basalt samples show some degree of LREE enrichment, but they all exhibit chondrite-normalized rare-earth-element contents and La(n)/Yb(n) ratios in the range of normal to enriched MORB (fig. 6). Some of the trace-element trends for basalt sample CTM01–AC47A (figs. 6–8; tables 1, 2) are similar to that of average oceanic-island basalts of Hawaii (fig. 7); however, this sample has a lower La(n)/Yb(n) ratio and less enrichment of more compatible elements (Zr, Hf, Ti, HREE) than do average Hawaii basalts

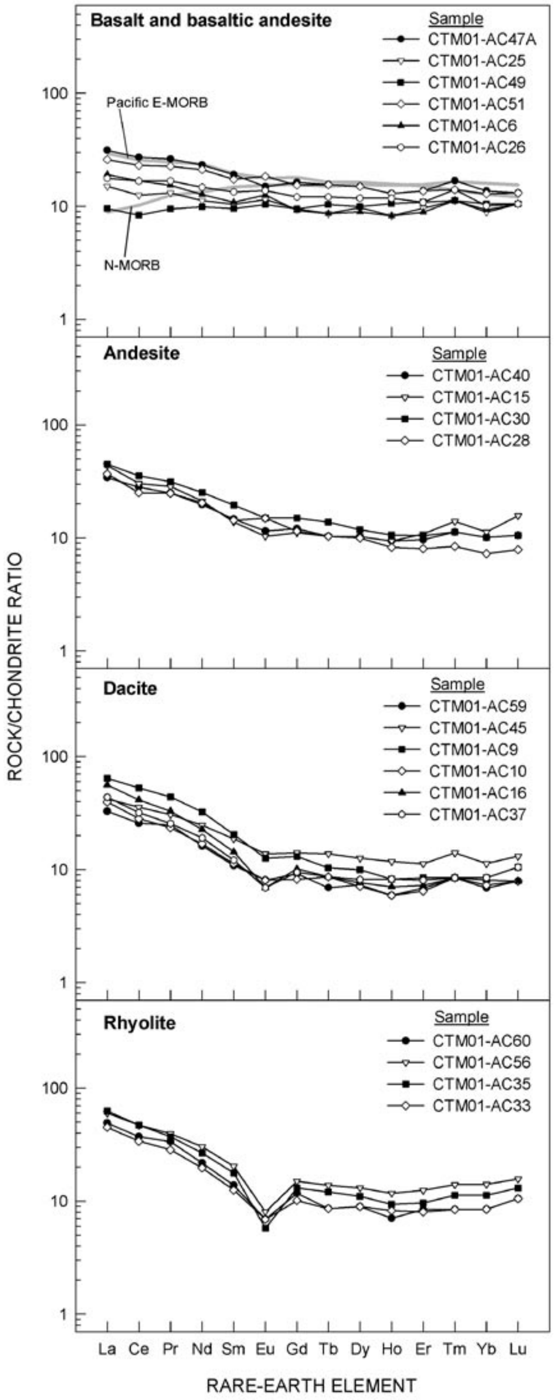

Figure 6. Chondrite-normalized rare-earth-element diagrams for volcanic rocks of the central Talkeetna Mountains (fig. 1). Normalizing values from Taylor and McLennan (1985); data for normal midocean-ridge basalt (N–MORB) and Pacific enriched midocean-ridge basalt (E–MORB) from Klein and Langmuir (2000).

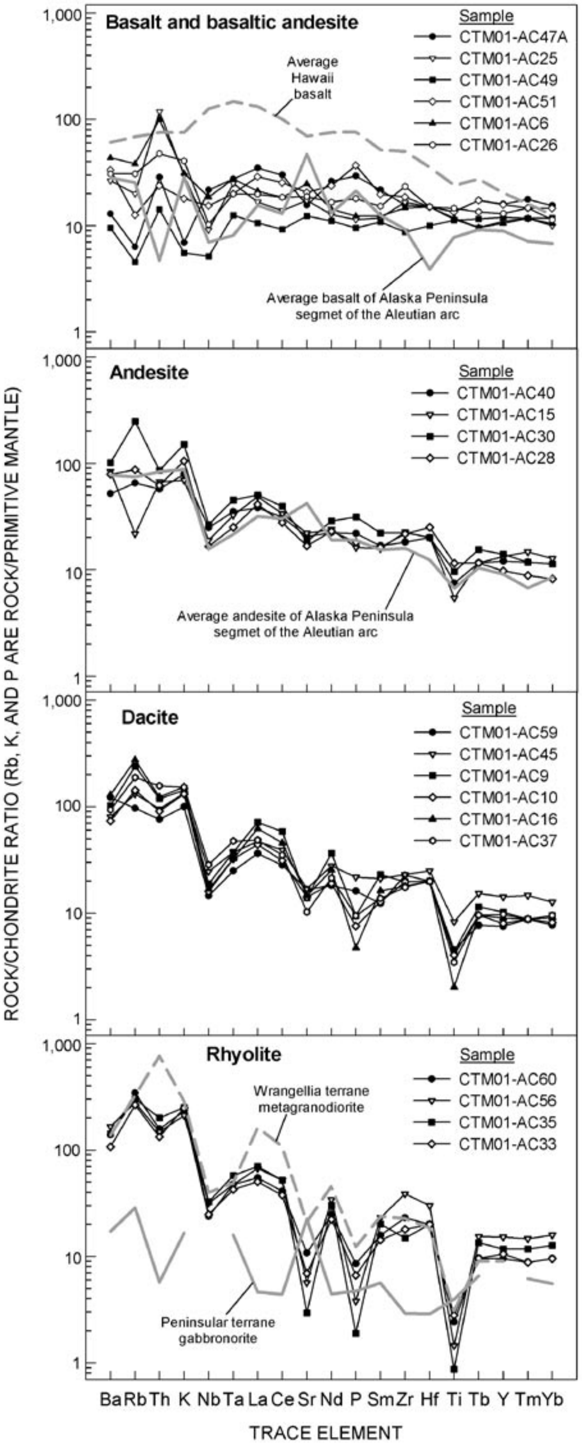

Figure 7. Normalized trace-element plots for volcanic rocks of the central Talkeetna Mountains (fig. 1). Normalizing values from Thompson and others (1984) and Sun (1980). Data for average Hawaii basalt compiled from Feigenson and Spera (1983), Hofman and others (1984, 1987), Spengler and Garcia (1988), Wright and Helz (1996), and Sims and others (1999); average Aleutian Alaska Peninsula basalt and andesite compiled from Hildreth (1983), Nye and Turner (1990), Nye and others (1994), Till and others (1994), Johnson and others (1996), Coombs and others (2000); and Wrangellia and Peninsular terrane rocks from Plafker and others (1989).

Table 1. Major-element composition of samples of volcanic rocks of the central Talkeetna Mountains.

[All values in weight percent. See figure 1 for locations. Do., ditto]

Sample	Description	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	MnO	LOI	Total
Tafia study area													
CTM01-AC25	Basalt	47.86	16.34	10.77	7.14	10.79	3.09	0.43	1.19	0.12	0.16	1.38	99.27
CTM01-AC6	Basaltic andesite	52.11	17.36	9.84	4.67	8.51	3.3	.45	1.22	.13	.16	1.46	99.51
CTM01-AC26	do	52.41	16.42	10.85	4.39	8.33	3.39	.59	1.51	.19	.17	1.04	99.29
CTM01-AC40	Andesite	57.59	16.73	7.18	3.58	7.45	3.51	1.14	.77	.23	.15	.65	98.98
CTM01-AC15	do	60.77	16.08	4.83	2.05	5.27	3.38	1.00	.56	.17	.09	4.29	98.49
CTM01-AC30	do	61.79	16.23	5.33	1.00	4.46	3.67	2.17	.99	.33	.1	3.09	99.16
CTM01-AC28	Dacite	63.04	17.29	5.53	.45	4.39	3.69	1.51	1.19	.19	.05	2.5	99.83
CTM01-AC9	do	65.98	14.61	3.66	1.07	3.32	3.52	2.06	.45	.1	.07	4.44	99.28
CTM01-AC10	do	69.46	14.34	2.27	.46	3.73	2.42	1.9	.42	.08	.02	4.62	99.72
CTM01-AC16	do	71.39	12.73	1.95	.55	2.2	2.12	2.22	.21	.05	.03	6.06	99.51
CTM01-AC33	Rhyolite dike	73.09	13.34	2.55	.15	1.51	2.97	3.6	.29	.07	.05	1.71	99.33
CTM01-AC37	Rhyolite-dacite plug	69.54	13.82	3.35	1.04	2.59	3.56	2.2	.36	.1	.04	2.42	99.02
CTM01-AC35	do	75.89	12.21	1.39	.05	.6	3.6	3.62	.09	.02	.03	1.29	98.79
Sedan study area													
CTM01-47A	Basalt	45.81	15.69	9.99	4.77	11.1	1.65	0.1	1.4	0.31	0.18	8.45	99.45
CTM01-AC49	do	48.46	15.81	10.33	6.62	10.49	2.09	.08	1.16	.1	.15	4.45	99.74
CTM01-AC51	do	50.4	15.11	11.42	5.32	8.97	2.7	.26	1.39	.39	.18	2.61	98.75
CTM01-AC59	Rhyolite-dacite plug	63.79	15.34	4.8	2.30	3.96	3.05	1.44	.47	.17	.06	4.25	99.63
CTM01-AC45	Dacite	63.94	15.28	5.12	1.15	3.99	3.83	1.93	.86	.23	.11	1.55	97.99
CTM01-AC60	Rhyolite-dacite plug	72.43	14.15	2.59	.46	1.04	3.06	3.36	.25	.09	.04	2.23	99.7
CTM01-AC56	Rhyolite	74.5	12.43	2.07	.05	.74	2.5	3.05	.15	.04	.04	2.34	97.91
Limit of detection		.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01

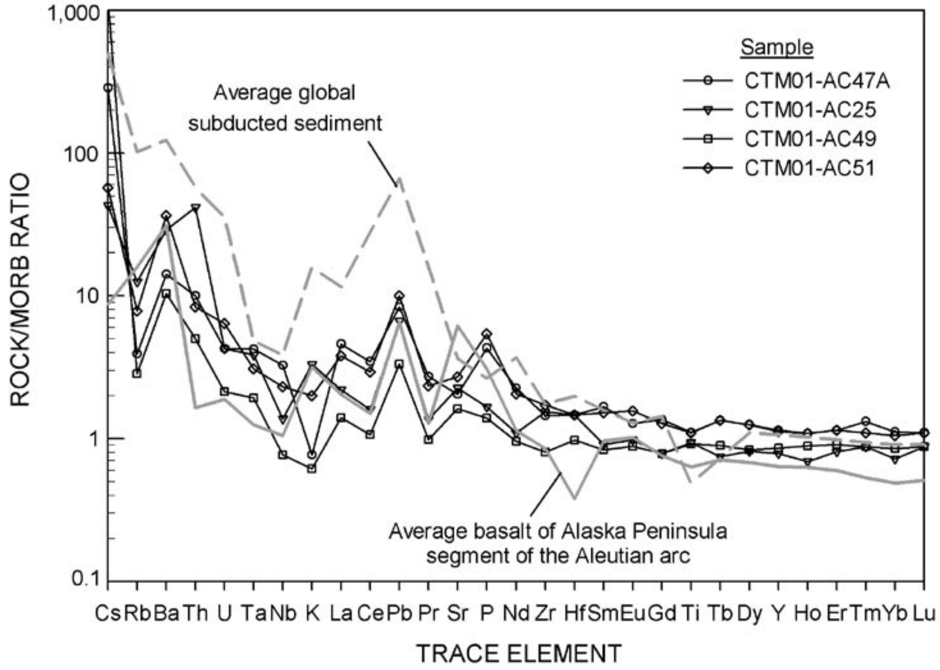

Figure 8. Midocean-ridge basalt (MORB)-normalized trace-element plot for volcanic rocks of the central Talkeetna Mountains (fig. 1). Normalizing values and arrangement of elements from Pearce and Parkinson (1993); data for average Aleutian basalt from same references as cited in figure 7; data for average subducted sedimentary rocks from Plank and Langmuir (1998).

Table 2. Trace-element composition of samples of volcanic rocks of the central Talkeetna Mountains.

[All values in parts per million. Descriptions: A, andesite; B, basalt; BA, basaltic andesite; D, dacite; R, rhyolite. See figure 1 for locations]

Sample	Description	Ag	Ba	Be	Cd	Ce	Co	Cr	Cs	Cu	Dy	Er	Eu	Ga	Gd	Ge	Hf	Ho	La	Lu	Mo
CTM01-AC47A	B	0.3	89	0.5	0.08	26	43.8	69	2	56.9	5.7	3.4	1.3	17.4	5	0.25	3	1.1	11.5	0.5	0.6
CTM01-AC25	B	.4	182.5	.6	.1	12	35.7	72	.3	47	3.7	2.4	1	17.55	2.9	.15	3	.7	5.5	.4	.55
CTM01-AC49	B	.06	65.5	.3	.06	8	46.1	141	8.1	84.4	3.8	2.7	.9	16.35	2.9	.15	2	.9	3.5	.4	.5
CTM01-AC51	B	.24	230	.65	.1	22	33.2	80	.4	59.7	5.7	3.4	1.6	16.85	4.7	.25	3	1.1	9.5	.5	.65
CTM01-AC6	BA	.28	301	.55	.08	16	28.6	39	.4	42.4	3.4	2.2	1.1	19.7	2.8	.15	3	.7	7	.4	.9
CTM01-AC26	BA	.4	213	.65	.08	16	32.4	20	.3	44.2	4.5	2.7	1.2	19.2	3.7	.25	3	1	6.5	.4	1.35
CTM01-AC40	A	.44	356	.95	.1	27	21.8	19	.6	44.2	3.9	2.4	1	16.9	3.7	.15	4	.8	12.5	.4	.95
CTM01-AC15	A	.1	577	1	.16	29	11.5	34	.4	37.2	3.9	2.7	.9	17.25	3.4	.2	4	.8	16	.6	.8
CTM01-AC30	A	.66	700	1.85	.08	34	7.7	9	4.4	19.6	4.5	2.6	1.3	21.3	4.6	.2	4	.9	16.5	.4	1.15
CTM01-AC28	D	.48	542	.95	.06	24	8.7	6	.9	21.8	3.8	2	1.3	20.15	3.5	.2	5	.7	13.5	.3	.85
CTM01-AC59	R-D plug	.28	843	.65	.04	24.5	11.2	47	1.5	29.4	2.8	1.7	.7	15.05	2.8	.15	4	.5	12	.3	.7
CTM01-AC45	D	.5	555	.95	.08	34	8.2	16	.7	22.6	4.8	2.8	1.2	17.1	4.3	.25	5	1	15.5	.5	1.4
CTM01-AC9	D	.24	706	1.45	.08	50.5	6.5	27	5.7	29.2	3.8	2.1	1.1	15.85	4	.15	4	.7	23.5	.4	1.3
CTM01-AC10	D	.04	508	1.75	.04	27	3.8	22	7.1	21.6	2.7	1.6	.7	14.6	2.5	.05	4	.5	14.5	.3	.55
CTM01-AC37	R-D plug	.48	646	1.15	.02	30.5	6.2	30	1.5	20.2	3.1	2	.6	15.5	2.9	.2	4	.7	16	.4	1.2
CTM01-AC16	D	< .1	892	1.2	.06	39.5	2.4	22	6.6	11.8	2.9	1.8	.6	14.15	3.1	.15	4	.6	20.5	.3	.95
CTM01-AC60	R-D plug	.4	957	1.95	.06	35.5	2.6	14	5.4	14	3.4	2.1	.6	16.65	3.6	.15	4	.6	18	.4	.7
CTM01-AC33	R dike	.56	740	1.2	.1	32.5	3.3	16	1.3	15.2	3.4	2	.6	14.15	3.1	.15	4	.7	16.5	.4	1
CTM01-AC56	R	.5	1,145	1.5	.06	45	1	11	4.5	12	5	3.1	.7	14.35	4.6	.15	6	1	22	.6	.85
CTM01-AC35	R-D plug	.52	978	1.45	.02	45	.6	28	2.5	9.2	4.2	2.4	.5	13.95	4	.15	4	.8	23	.5	1.8
Limit of detection		.1	.5	.1	.02	.5	.5	5	.1	5	.1	.1	.1	1	.1	.05	1	.1	.5	.1	.5

Sample	Description	Nb	Nd	Ni	Pb	Pr	Rb	Sm	Sn	Sr	Ta	Tb	Th	Tm	U	V	W	Y	Yb	Zn	Zr
CTM01-AC47A	B	7.6	16.5	70.9	2.5	3.6	2.2	4.4	0.4	184	0.55	0.9	1.2	0.6	0.2	204	1.1	32	3.4	80	107
CTM01-AC25	B	3.2	8	49.6	2	1.8	7	2.4	.4	204	.5	.5	5	.4	.2	219	.3	22	2.2	74	114
CTM01-AC49	B	1.8	7	137.5	1	1.3	1.6	2.2	.4	146	.25	.6	.6	.4	.1	251	.1	24	2.6	66	59.5
CTM01-AC51	B	5.4	15	69.9	3	3.1	4.4	4	.6	244	.4	.9	1	.5	.3	174	.5	31.5	3.2	76	127.5
CTM01-AC6	BA	6.5	9	11.8	4.5	2.1	13.4	2.5	.6	293	.55	.5	4.2	.4	.5	191	.4	21	2.3	86	100.5
CTM01-AC26	BA	3.6	10.5	23.4	2.5	2.3	10.8	3.1	.6	222	.4	.7	2	.5	.3	238	.3	26	2.5	84	160.5
CTM01-AC40	A	8.7	14	17	4.5	3.4	22.8	3.4	.6	242	.7	.6	2.4	.4	.7	137	.5	24	2.5	68	124
CTM01-AC15	A	6.6	15	18.2	7	3.9	7.6	3.2	.8	260	.65	.6	2.8	.5	.9	84	.4	26.5	2.8	72	153.5
CTM01-AC30	A	9.3	18	2.2	12.5	4.3	86.4	4.5	1.8	217	.9	.8	3.6	.4	1.8	93	1.2	28	2.5	94	152
CTM01-AC28	D	5.8	14.5	2	7	3.4	30.4	3.3	1	196.5	.5	.6	2.6	.3	.8	108	.4	19.5	1.8	96	148.5
CTM01-AC59	R-D plug	5.1	11.5	21.2	5	3.4	33.8	2.5	.6	197	.5	.4	3.2	.3	.9	84	.5	15	1.7	54	155.5
CTM01-AC45	D	8.6	17.5	2.4	7	4.2	46.2	4.3	1	199.5	.75	.8	4	.5	1.3	64	.6	28.5	2.8	62	158
CTM01-AC9	D	6.6	23	6.4	11	6	83.6	4.7	1.4	165	.75	.6	5	.3	2.6	47	1.1	20.5	2.1	50	134.5
CTM01-AC10	D	5.6	12	5.4	7.5	3.2	49.8	2.6	1.2	167	.65	.5	3.8	.3	1.1	41	3.1	16	1.8	28	134.5
CTM01-AC37	R-D plug	10.0	13.5	9.4	7.5	3.5	66	2.8	.8	121	.95	.5	6.6	.3	2	44	.8	19.5	2.1	46	120
CTM01-AC16	D	5.9	16	3	11	4.5	96.2	3.3	1.4	172.5	.65	.5	5.2	.3	2.4	16	.7	18	2	40	123
CTM01-AC60	R-D plug	8.3	15.5	2.6	13.5	4.6	120	3.2	2.2	127.5	.95	.5	6.6	.3	4	17	1.1	19	2.1	46	158
CTM01-AC33	R dike	8.7	14	3.4	9	3.9	93.2	2.9	.8	81.9	.85	.5	5.6	.3	2.1	25	1	21	2.1	50	123
CTM01-AC56	R	11.1	21.5	2.6	10.5	5.4	97.6	4.7	1.4	66.8	.95	.8	6.2	.5	3	3	3.1	30.5	3.5	46	265
CTM01-AC35	R-D plug	11.4	19	1.6	14.5	5.1	106	4.1	1	34.7	1.15	.7	8.4	.4	2.4	<1	.8	23.5	2.8	34	102
Limit of detection		.5	.5	2	1	.1	.2	.1	.2	.1	.5	.1	.2	.1	.1	1	.1	.5	.1	2	.5

(fig. 7). Our working hypothesis is that the central Talkeetna Mountain basalts were derived from a depleted source, similar to that of normal to enriched MORB.

The enrichment of Cs, Ba, Th, and Pb, coupled with the low Rb and K contents of the basalt samples, especially samples CTM01–AC49 and CTM01–AC47A (figs. 6–8; tables 1, 2), probably reflects characteristics of the mantle source, as opposed to crustal contamination of the basaltic magmas. If the basaltic magmas had undergone extensive crustal contamination, we would expect to find higher Rb and K contents, along with an increase in the contents of other incompatible elements, as is supported by the geochemical data of Plafker and others (1989) for rocks of the Wrangellia composite terrane, which forms the crust beneath much of south-central Alaska. The rocks of the Wrangellia composite terrane generally are more enriched in Rb and K and more depleted in Th relative to basalts of the central Talkeetna Mountains (fig. 7). One exception is a sample of Pennsylvanian metagranodiorite from the Wrangellia composite terrane (sample 84ANK186A of Plafker and others, 1989) that has a very high Th content (fig. 7). If this type of rock unit is present in the Talkeetna Mountains area, then the high Th content of the basalts in the central Talkeetna Mountains could reflect some degree of crustal contamination. This comparison is not ideal, however, because the data for the Wrangellia composite terrane are from samples collected in the Copper River Basin area, about 150 km southeast of the central Talkeetna Mountains. Geochemical studies of rocks of the Wrangellia composite terrane in the Talkeetna Mountains area are needed to better constrain the composition of the crust and the potential degree of crustal contamination during Tertiary magmatism in this region. Assuming, however, that crustal rocks generally have high incompatible-element contents (Taylor and McLennan, 1985), the progressive enrichment of LREEs and Ba, Rb, Th, and K from the basalts through the andesites, dacites, and rhyolites of the central Talkeetna Mountains (fig. 7) indicates that crustal assimilation was important in the formation of the felsic magmas (Thompson and others, 1984). The progressive depletion of Sr, Eu, P, and Ti from the basalts through the andesites, dacites, and rhyolites indicates that fractional crystallization of plagioclase, apatite, and Fe-Ti oxides also played a role in the evolution of the felsic magmas (Thompson and others, 1984).

The evolution of the volcanic rocks of the central Talkeetna Mountains from a depleted magma source, as well as the apparent age range of these volcanic rocks (approx 40–56 Ma, based on K-Ar ages of Csejtey and others, 1978, and Little, 1988), is enigmatic for Tertiary magmatism in south-central Alaska. Within this time frame, a lull in regional magmatic activity occurred across Alaska. The Alaska Range-Talkeetna Mountains magmatic belt, attributed to Kula Plate subduction, ranges in age from about 56 to 72 Ma (Wallace and Engebretson, 1984; Moll-Stalcup, 1994) (fig. 1). The Alaska-Aleutian Arc, a precursor to the modern Aleutian Arc, ranges in age from about 30 to 45 Ma (fig. 1; Moll-Stalcup, 1994). The volcanic rocks of the central Talkeetna Mountains were erupted during the time between these two regional magmatic episodes. Spatially, the volcanic rocks of the central Talkeetna Mountains are more closely related to the older Alaska Range-Talkeetna Mountains belt than to the younger Alaska-Aleutian Arc. The volcanic rocks of the central Talkeetna Mountains may represent the youngest and easternmost phase of Alaska Range-Talkeetna Mountains belt magmatism, a relation consistent with a general age trend illustrated by Moll-Stalcup and others (1994) in which the northeastern part of this belt is younger (mostly 55–65 Ma) than the rest of the belt (mostly 60–72 Ma). Although the volcanic rocks of the central Talkeetna Mountains do lie within the boundaries of the Alaska Range-Talkeetna Mountains magmatic belt and do display geochemical characteristics that are attributable to subduction-related processes, they also have characteristics that differ from those of typical subduction-related volcanic rocks.

The high Cs, Ba, Th, and Pb contents in the basalts of the central Talkeetna Mountains are characteristic of arc basalts, including basalts erupted along the Alaska Peninsula segment of the modern Aleutian Arc (figs. 7, 8). Of these elements, Cs, Ba, and Pb are highly mobile in fluids and are typically released into the mantle wedge beneath arcs during dehydration of the subducted slab (Kay, 1984; Class and others, 2000; Hochstaedter and others, 2001). Th is relatively immobile in fluids but is enriched in subducted sediment (fig. 8; Plank and Langmuir, 1998) and can be released into the mantle wedge beneath arcs during partial melting of subducted sediments (Class and others, 2000). Accordingly, the high Cs, Ba, Th, and Pb contents in the basalt samples could represent enrichment of the mantle beneath the Wrangellia composite terrane by fluids and partial melts derived from a subducted slab during the final phase of the Alaska Range-Talkeetna Mountains magmatic episode. The high Th content might also reflect some degree of crustal contamination, as discussed earlier. Except for a varying Rb content, the andesite samples from the central Talkeetna Mountains display chondrite-normalized trace-element concentrations that are nearly identical to those of modern andesites erupted along the Alaska Peninsula segment of the Aleutian Arc (fig. 7).

The characteristics of the basalts of the central Talkeetna Mountains that differ from those of typical subduction-related volcanic rocks include the absence of a paired Nb-Ta-depletion trend, high Ta contents (average Nb/Ta ratio of 10.3 among the basalts versus an average of 15 for Aleutian Arc basalts), low La/Nb ratios among the basalts (average of 1.64 versus an average of ~3 for Aleutian Arc basalts), and low Ba/Ta ratios (average of 407 and 815 for the basalts and andesites versus averages of 1,294 and 2,471 for Aleutian Arc basalts and andesites, respectively; see references in fig. 7). The primary source for the volcanic rocks of the central Talkeetna Mountains was therefore depleted mantle that was probably enriched in Ta relative to the mantle sources of average subduction-related volcanic rocks.

Conclusions

The results of this study provide new insight into the tectonomagmatic history of south-central Alaska. First, the timing and extent of subduction-related magmatism is poorly defined for early Tertiary time in south-central Alaska. The geochemistry of the volcanic rocks of the central Talkeetna Mountains indicates that subduction-related magmatic processes were important in the evolution of these rocks but that these rocks also lack some "typical" arc-volcanic geochemical affinities. This trend is consistent with the interpretation by Moll-Stalcup (1994) that in western Alaska, between about 56 and 50 Ma, there was "a transition from subduction-related magmatism to post subduction, possibly intraplate, magmatism during which rocks typical of both environments erupted." The mixed geochemical affinity of the volcanic rocks of the central Talkeetna Mountains indicates that a similar transition occurred in south-central Alaska during Eocene time. Second, the composition of the mantle beneath the Wrangellia composite terrane in south-central Alaska is poorly known. Our results indicate that a depleted mantle reservoir existed beneath south-central Alaska during early Tertiary time. This depleted mantle reservoir could represent the original composition of the upper mantle beneath the Wrangellia composite terrane, or it could have formed as a slab window beneath south-central Alaska after the passage of a trench-spreading ridge-trench triple junction (Bradley and others, 1993). Our ongoing work to compile the ages and regional geochemical trends of Tertiary volcanic rocks in south-central Alaska will help to further constrain these tectonomagmatic models.

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