THE TEKLANIKA FORMATION - A NEW PALEOCENE VOLCANIC FORMATION IN THE CENTRAL ALASKA RANGE

By
Wyatt G. Gilbert, Virginia M. Ferrell, and Donald L. Turner

GEOLOGIC REPORT 47

THE SEAL OF THE STATE OF ALASKA

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THE TEKLANIKA FORMATION - A NEW PALEOCENE VOLCANIC FORMATION IN THE CENTRAL ALASKA RANGE

By Wyatt G. Gilbert,[1] Virginia M. Ferrell,[1] and Donald L. Turner[2]

ABSTRACT

A series of andesite, rhyolite, and basalt flows, felsic pyroclastic rocks, and related intrusive rocks covers about 165 square kilometers in the eastern part of Mount McKinley National Park. These rocks, once considered part of the Cantwell Formation, are now defined as the Teklanika Formation. The formation, which locally reaches a minimum thickness of 3,750 meters overlies the Cantwell Formation both conformably and unconformably. The type section of the Teklanika Formation forms the ridge east of the upper Teklanika River drainage and is composed of six conformable units.

Felsic volcanic flows are generally amygdaloidal porphyritic rhyolites with sanidine phenocrysts. Pyroclastic rocks are dominantly a combination of andesitic to rhyolitic vitric, lithic, and crystal welded tuffs. Mafic flows range from olivine basalt to andesite.

Chemically, the Teklanika Formation is part of a calc-alkali series and may be cogenetic with early Tertiary plutonic rocks in south-central Alaska.

Minimum radiometric ages of 60.6 and 41.8 m.y., together with an age of 57.2 ± 4. m.y. from a related plug, suggest that eruption of the Teklanika Formation and orogeny occurred during Paleocene time.

INTRODUCTION

PURPOSE

The intent of this report is to name, describe, and radiometrically date a new volcanic formation—the Teklanika Formation—in the central Alaska Range, Alaska. This formation has previously been included in the Cantwell Formation. The Teklanika Formation is named after the Teklanika River, a major tributary of the Toklat River, where the formation is particularly well exposed and where its thickest known section is found. The report does not completely describe the Teklanika Formation, however, because much of its outcrop area remains unmapped in detail.

PREVIOUS USAGE

The Cantwell Formation was first recognized by Eldridge, who described the "Cantwell Conglomerate" as being "...a series of conglomerates and coarse sandstones which was encountered in the banks of the Cantwell River [Nenana River] about 10 or 15 miles above the lower forks" (Eldridge, 1900, p. 16). The next reference to the Cantwell Formation was by Brooks (1911), who mapped and thoroughly described the Cantwell Formation in the Mount McKinley National Park area and first included volcanic rocks as part of the formation. He states: "In this area, especially toward the Nenana, lava flows interbedded with the conglomerate are very prevalent. In some localities these volcanic rocks form over half of the thickness of strata exposed belonging to this formation. These lavas appear to be chiefly andesites, but also include rhyolites and basalts. That they were surface flows is indicated both by their stratigraphic relations and by the amygdaloidal and columnar structure that some of them exhibit. Some tuffaceous beds also occur in this formation" (Brooks, 1911, p. 79).

The "interbeds," which Brooks describes on the next two pages of his report, are apparently metavolcanic rocks and quartz latite interbeds in the Mount Sheldon—Wyoming Hills area, which he probably mistakenly correlated with the andesite and rhyolite flows to the south (fig. 1). From 1911 onward, workers have generally included the volcanic rocks described in this paper as part of the Cantwell Formation (Capps, 1919, 1930, 1940; Reed, 1961; Wolfe and Wahrhaftig, 1970). Our study of these rocks, however, shows that the andesite-rhyolite flows lie above the sedimentary section of the Cantwell Formation, are in part unconformable on it, and form a distinct lithologic contrast with the sedimentary rocks of the Cantwell Formation. We do not wish to imply that the Cantwell Formation contains no volcanic interbeds. However, they are minor compared with sedimentary rocks of the Cantwell Formation; they also differ petrologically. The Cantwell Formation, therefore, is herein restricted to the generally conformable sequence of sandstone, siltstone, and conglomerate, as suggested originally by Eldridge (1900).

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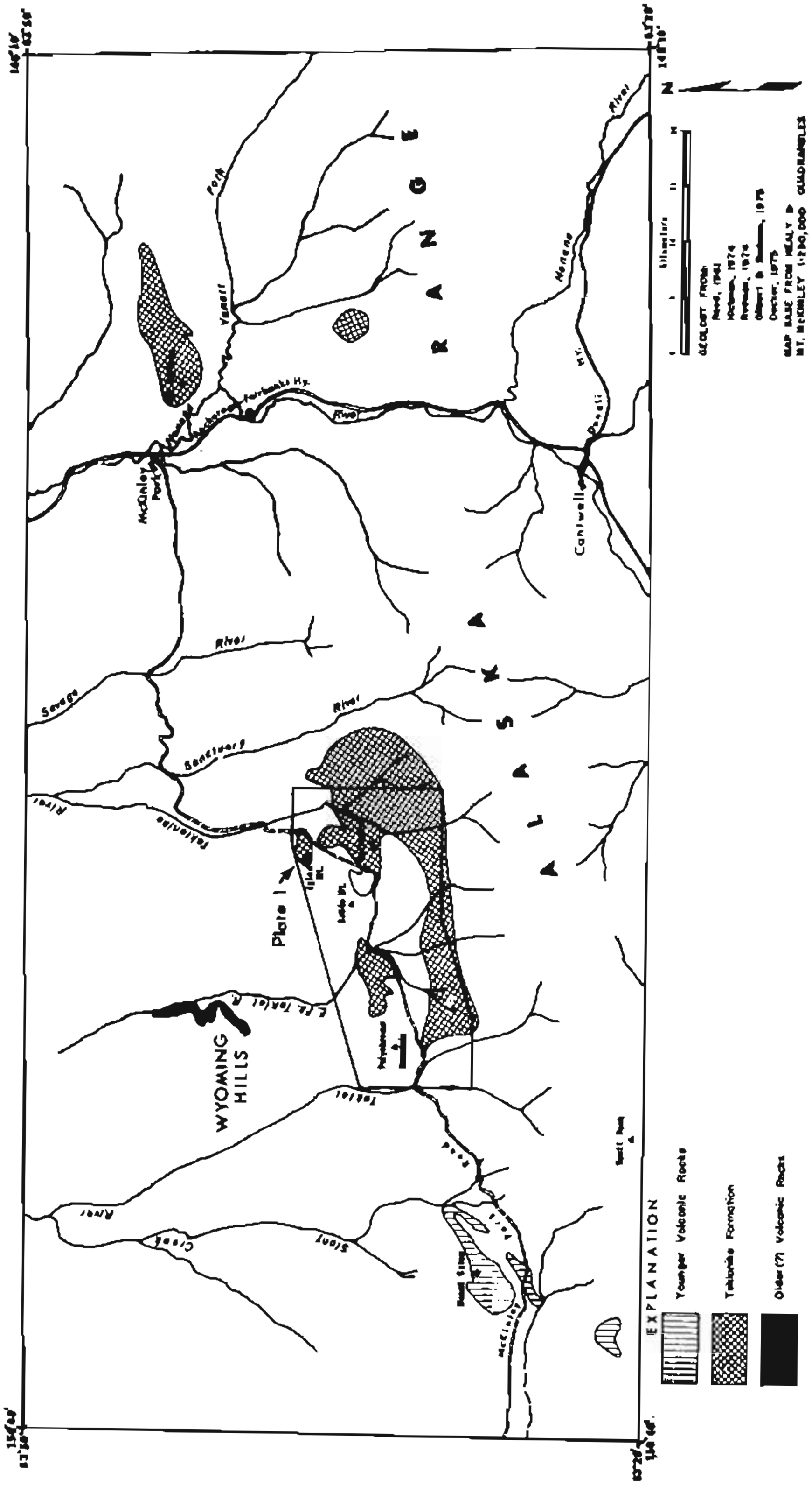

Figure 1. Distribution of Teklanika Formation and location of study area.

PRESENT STUDY

This paper is the result of a 3-year study of the geology of the Healy C-6 quadrangle and immediate vicinity by Gilbert (Gilbert and Redman, 1975). In addition, petrologic examination of many of the volcanic rocks by Ferrell and radiometric dating of three rock specimens by Ferrell and Turner are included as an important part of the study.

GENERAL DESCRIPTION OF THE TEKLANIKA FORMATION

The Teklanika Formation is primarily composed of flows of andesite and rhyolite, with lesser amounts of basalt and pyroclastic rocks (igneous rock classification after Peterson, 1961). The formation covers about 165 square kilometers in the upper Toklat, East Fork, Teklanika, and Sanctuary River drainages in Mount McKinley National Park (fig. 1), of which about 85 square kilometers has been mapped at 1:40,000 scale (Gilbert and Redman, 1975). In this area the Teklanika Formation is in sharp conformable or unconformable contact with the underlying sedimentary rocks of the Cantwell Formation. The contact is commonly marked by a 0.6- to 3.0-meter-thick light-colored tuff bed. On Igloo and Cathedral Mountains, the formation conformably overlies a lenticular pebble-cobble-boulder conglomerate with abundant sandstone and volcanic clasts, and typical sandstone, siltstone, and conglomerate of the Cantwell Formation (Gilbert and Redman, 1975) (pl. 1, fig. 2). This upper Cantwell conglomerate overlies a thick sequence of sandstone and siltstone and suggests that uplift of a nearby volcanic and sedimentary terrain took place concurrently with the beginning of volcanism. On Polychrome Mountain, the gently folded Teklanika Formation lies with apparent unconformity above a tightly folded sequence of Cantwell sandstone and conglomerate (pl. 1). Although this contact could be due of different mechanical responses by volcanic and sedimentary units during folding, no evidence of mechanical detachment was observed at the base of the volcanic sequence.

Basalt, andesite, and minor pyroclastic rocks that cover 30 square kilometers and cap Mount Fellows in the lower Yanert River drainage just east of Mount McKinley National Park (Hickman, 1974) are here considered part of the Teklanika Formation (fig. 1). These rocks overlie the Cantwell Formation concordantly or with slight discordance (Hickman, 1974).

Quartz latite flows interbedded with conglomerate in the Wyoming Hills (fig. 1) differ in petrology and stratigraphic position from the Teklanika Formation (Redman, 1974); they are not considered part of the Teklanika Formation, but rather as interbeds within the Cantwell Formation. Volcanic rocks in the Mount Galen area (fig. 1) that were thought by Reed (1961) to be part of the Cantwell Formation are now known to be much younger (Decker, 1975). Hornblende andesite flows and shallow intrusions on Polychrome Mountain (fig. 1) are also younger than the Teklanika Formation.

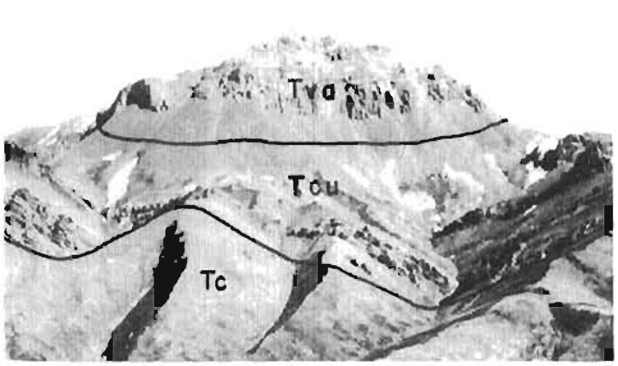

Figure 2. Looking at southwest side of Igloo Mountain. Tva, andesite and basalt flows; Tcu, upper conglomerate of Cantwell Formation; Tc, Cantwell Formation.

RELATED IGNEOUS ROCKS

Paleocene calc-alkaline volcanism in the central Alaska Range is only a small part of the extensive orogenesis and igneous activity that characterized the Canadian-Alaskan Cordillera during late Mesozoic and early Tertiary time (Lathram, 1973; Monger and others, 1972). In the Canadian Cordillera, extensive plutonism and volcanism occurred during uppermost Cretaceous, Paleocene, and Eocene time (Souther, 1967, Gabrielse, 1967).

In the western Aleutian Islands, major orogenesis accompanied by andesitic volcanism also took place during Late Cretaceous and early Tertiary time (Coats, 1962). In the eastern Aleutian Islands and the Alaska Peninsula, early Tertiary deformation was accompanied by andesitic volcanism and intrusion of granitic to quartz diorite batholiths (Burk, 1965).

In the northern Aleutian Range and southern and central Alaska Range, three episodes of intrusive activity during Jurassic, Late Cretaceous and early Tertiary, and mid-Tertiary time were accompanied by related volcanism (Reed and Lanphere, 1973). In the southern and central Alaska Range, Late Cretaceous and early Tertiary intrusions range mainly from quartz diorite to granite (Reed and Lanphere, 1973). The Teklanika Formation of the central Alaska Range is a series of calc-alkaline volcanic flows and tuff beds which are, perhaps, the surface expression of this Late Cretaceous—early Tertiary intrusive epoch.

VOLCANIC STRATIGRAPHY AND PETROLOGY

Within the study area the thickest known section of the Teklanika Formation underlies the ridge dividing the Calico Creek and the upper Teklanika River drainages (pl. 1). Other extensive exposures of the formation are found in the Cathedral-Igloo Mountains area, on the east side of Polychrome Mountain, and along the upper Toklat River. Coeval dikes, sills, and small stocks are scattered throughout this volcanic province. Complex faulting, overlying late Cenozoic sedimentary rocks, and extreme variation in volcanic stratigraphy make correlation between major areas of volcanic outcrop difficult. The stratigraphy of four representative areas will be described separately. The petrology of different parts of the formation is similar and will be discussed in one section (p. 7).

UPPER TEKLANIKA RIVER SEQUENCE

SUMMARY

This sequence forms the most complete known section of volcanic flows and is designated the type section of the Teklanika Formation (pl. 1, fig. 3). Six conformable units (units A-F) with a minimum thickness of approximately 3,750 meters compose the sequence. The base of the upper Teklanika River sequence is 6-1/2 kilometers south of Calico Creek along the upper Teklanika River. Here the sequence is in probable fault contact with the Cantwell Formation. The top of the sequence is 5 kilometers south of Calico Creek along the east side of the Teklanika River, where the upper unit in the sequence is unconformably overlain by Quaternary deposits.

UNIT A

The lower part of the basal unit of the upper Teklanika River sequence is a series of dark-gray porphyritic and aphanitic basalt flows that form rugged topography on both sides of the upper Teklanika River. Individual flows range from 20 to 40 meters thick and are commonly jointed and fractured. In hand specimen, the porphyritic flows contain fine- to medium-grained phenocrysts of pyroxene and hornblende, altered to chlorite and set in an altered groundmass containing abundant plagioclase. This series of basalt flows exhibits the highest degree of deuteric alteration of any rocks in the formation. The thickness of this series of flows is approximately 1,375 meters.

Overlying the series of basalt flows is an interval of interbedded mudstone, tuff, tuff breccia, and pillow basalt about 50 to 60 meters thick. These beds are present on both sides of the upper Teklanika River. The lowest bed in the interval is a 5-meter-thick dark-gray to black carbonaceous mudstone that contains pieces of wood and plant material. For 20 meters above the dark mudstone bed, thin mudstone beds 0.1 to 0.3 meters thick are interbedded with light-gray to white water-laid rhyolite tuff and tuff breccia and gray to black tuff beds. The top of the interval is composed of about 30 meters of gray-green pillow basalt.

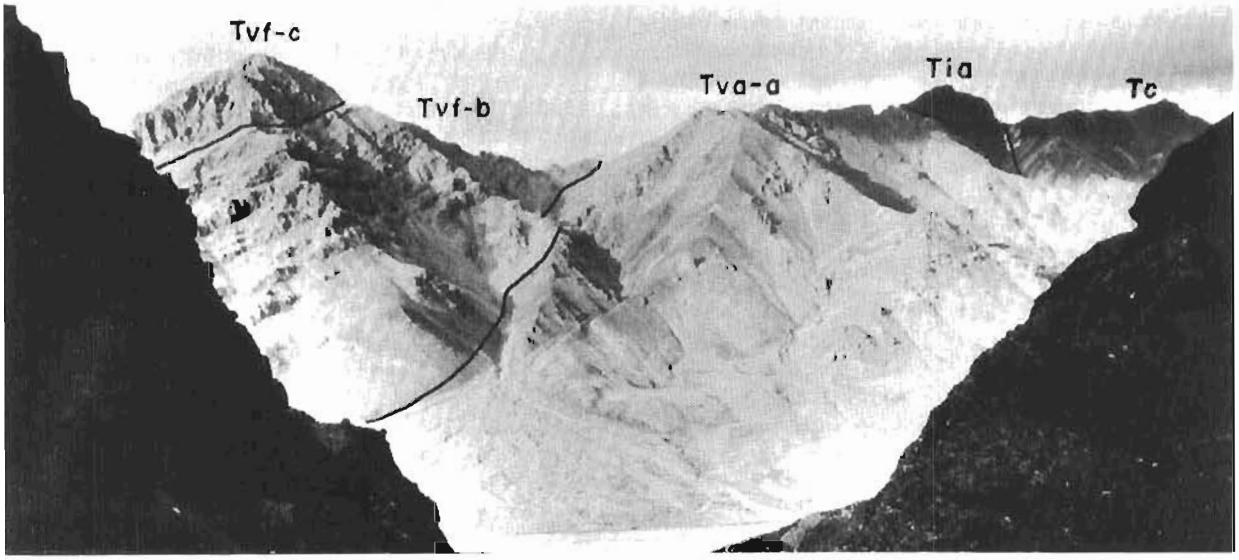

Figure 3. Lower part of upper Teklanika River sequence on east side of upper Teklanika River. Tva-a - unit A, Tvf-b - unit B, Tvf-c - unit C of upper Teklanika River sequence; Tc - Cantwell Formation, Tia - mafic intrusion.

UNIT B

In this unit about 40 resistant flows of brown- and purple-weathering gray andesite, each 2 to 5 meters thick, alternate with beds of less resistant tuff and tuff breccia, 5 to 10 meters thick (fig. 3). The unit is about 400 meters thick.

UNIT C

This unit is composed of a rugged series of purple-weathering light-gray microcrystalline rhyolite flows 20 to 50 meters thick. The rhyolite flows are similar in lithology to flows in unit B, but differ in thickness and also lack interbedded tuff and tuff breccia. The unit is from 545 meters to 600 meters thick. West of the upper Teklanika River, units B and C merge into a composite unit with beds of tuff and tuff breccia scattered throughout.

UNIT D

This unit, composed of light-tan vesicular porphyro-aphanitic rhyolite flows 5 to 50 meters thick, is exposed on both the east and west sides of the upper Teklanika River. Interbeds of amygdaloidal olivine-augite basalt and andesite, 5 to 10 meters thick and locally displaying columnar jointing, are common in this unit. Scattered beds of rhyolite crystal tuff are also present. The unit is about 600 meters thick.

UNIT E

This unit contains a series of dark-brown-weathering dark-gray olivine-augite basalt and andesite flows, 5 to 40 meters thick. The tops of the flows are commonly amygdaloidal, with vesicles filled with calcite, chalcedony, or quartz. Interbeds of dark-gray agglomerate, containing clasts of mafic and intermediate volcanic rocks set in a dark-gray vesicular glassy groundmass, commonly overlie the flows. Beds of rhyolite tuff and tuff breccia 1 to 2 meters thick are intermittently interbedded with the basalt and andesite flows. Scattered flows of magnetite-rich basalt crop out east of the upper Teklanika River. The unit is from 430 to 670 meters thick.

UNIT F

This unit is composed of a thick flow of light-brown-weathering light-gray porphyritic rhyolite with sanidine phenocrysts. The base of the unit is marked by a 2-meter-thick black-and-white bed of obsidian. The unit has a minimum thickness of 60 meters and is unconformably overlain by Quaternary alluvial deposits.

VOLCANIC ROCKS OF CATHEDRAL AND IGLOO MOUNTAINS

A thick series of volcanic rocks caps Igloo Mountain, is exposed along Tattler Creek, and crops out over most of Cathedral Mountain (pl. 1). Two volcanic units are present: a lower andesite unit and an upper rhyolite unit. A major northeast-trending fault on Cathedral Mountain repeats the two units. Small intrusive dikes and sills are found intruding the extrusive rocks.

The andesite unit is present on both Cathedral and Igloo Mountains, where it conformably overlies the Cantwell Formation. On Igloo Mountain, about 12 brown-weathering gray aphanitic vesicular andesite flows are interbedded with minor laterally discontinuous tuff beds (fig. 2). The tuff beds are 0.5 to 1.0 meters thick, light green, and vesicular. On the northeast side of Igloo Mountain, a 2-meter-thick light-gray tuff bed marks the contact between the Teklanika and Cantwell Formations.

On the west side of Cathedral Mountain and in Tattler Creek, andesite and basalt flows are gray to black, aphanitic to fine grained, and vesicular. In this area, basalt flows are common in the lower portion of the unit. The andesite and basalt flows weather reddish brown and commonly exhibit columnar jointing. The contact with the underlying Cantwell Formation is marked by interbedded tuffaceous sedimentary rocks and volcanic flows, and is placed at the base of a 3-meter-thick light-colored tuff bed. The upper part of the andesite unit on Cathedral Mountain and along Tattler Creek contains interbedded dark-weathering rhyolite flows, similar to those in the overlying rhyolite unit. The thickness of the andesite unit ranges from 500 meters on Cathedral Mountain to 770 meters on Igloo Mountain.

A series of rhyolite flows and pyroclastic rocks overlies the andesite unit south of Tattler Creek and on Cathedral Mountain. The flows are siliceous microcrystalline to hyaline rocks from 3 to 25 meters thick. The flows south of Tattler Creek and on the northern and central parts of Cathedral Mountain are intruded by many small dikes and sills. Rhyolite crystal-lithic tuff and volcaniclastic lithic sandstone are found interbedded with the rhyolite flows on the central part of Cathedral Mountain. The minimum thickness of the rhyolite unit reaches 500 meters on Cathedral Mountain.

East of the Teklanika River and north of a major east-west-trending fault 3 kilometers south of the mouth of Calico Creek are two units that appear to be in fault contact with one another. The southern unit is made up of a variety of interbedded pyroclastic beds and rhyolite flows that are 50 to 60 meters thick. This unit has a minimum thickness of about 1,100 meters. Common lithologies observed include: andesitic lithic-crystal welded tuff, medium- to coarse-grained volcaniclastic lithic sandstone with tuff and feldspar fragments, porphyro-aphanitic rhyolite flows with altered microphenocrysts of sanidine, and other cryptocrystalline to microcrystalline flows with fine- to medium-grained plagioclase phenocrysts.

The northern unit along the lower part of Calico Creek includes at least 1,500 meters of augite basalt and pyroclastic rocks in beds 10 to 20 meters thick. The pyroclastic rocks are in part composed of crystal-lithic welded tuff, but the relative abundance of each rock type is unknown. The relationship of these two units to the volcanic rocks on Cathedral Mountain, or to the upper Teklanika sequence to the south, is unclear.

VOLCANIC ROCKS OF POLYCHROME MOUNTAIN

Two series of rhyolite flows sandwich a sequence of andesite flows on Polychrome Mountain (pl. 1). In both series, flows of porphyro-aphanitic flow-banded rhyolite contain interbeds of rhyolite crystal tuff and lithic welded tuff. Because scattered exposures of rhyolite are found between Polychrome Mountain and the rhyolite unit exposed along Tattler Creek, the rhyolite flows on Polychrome Mountain may be continuous with the upper rhyolite unit on Cathedral Mountain. The lower series of rhyolite flows forms an angular unconformity with the underlying Cantwell Formation and ranges in thickness from 0 to 350 meters (fig. 4). The upper series of rhyolite flows has a maximum exposed thickness of 750 meters.

Separating the two units of rhyolite flows is an andesite unit consisting of about 10 flows, each from 3 to 30 meters thick. The flows become thinner in the upper part of the unit. The flows are vesicular and bear geodes containing hematite, chalcedony, and calcite or quartz or both. The thickness of the unit ranges from 175 to 500 meters.

VOLCANIC ROCKS OF UPPER TOKLAT RIVER

Three to 5 kilometers south of Polychrome Mountain along the east branch of the Toklat River are two east-dipping volcanic units (pl. 1, fig. 5). The lower unit is composed of interbedded andesite and rhyolite flows that conformably(?) overlie the Cantwell Formation; the upper unit is predominantly rhyolite.

The lower andesite-rhyolite unit is 1,350 meters thick and contains alternating andesite and rhyolite flows from 5 to 20 meters thick. The andesite flows are highly vesicular and often contain geodes. Some of the rhyolite flows may be devitrified welded rhyolite tuff with microphenocrysts of quartz, sanidine, and biotite.

East of and above the andesite-rhyolite unit is a series of porphyro-aphanitic rhyolite flows. This unit has a thickness of at least 555 meters. Scattered exposures suggest that these flows merge with rhyolite units in the upper Teklanika River area.

INTRUSIVE ROCKS

Most of the intrusive rocks in the area are mafic and intermediate sills, dikes, and small plutonic bodies (pl. 1). Intruding unit A of the upper Teklanika sequence is a small mafic plug. On Cathedral Mountain about 0.5 kilometers east of the mouth of Tattler Creek is a fine- to medium-grained quartz-bearing diorite; a diabase plug and a series of fine-grained augite diabase sills

Figure 4. Looking north at eastern part of Polychrome Mountain. Tva - andesite and basalt flows, Tvf - rhyolite flows, Tc - Cantwell Formation.

Figure 5. Looking south at east-dipping andesite and rhyolite flows on east side of upper Toklat River.

are exposed along the east side of the mountain (fig. 6).

A small fine- to medium-grained quartz-bearing diorite plug covering 0.15 square kilometers is found on Polychrome Mountain along the Denali Highway, and an east-west-trending diabase dike is exposed for 3 kilometers on the north side of the mountain. Numerous mafic dikes and sills, ranging from 1 to 10 meters thick, are found throughout the Cantwell and Teklanika Formations. They are generally aphanitic and often exhibit a directive fabric due to flow.

Felsic intrusive rocks are less common than mafic intrusive rocks in the region, but rhyolite to quartz latite dikes, sills, and small plugs crop out throughout the area of the Teklanika Formation. A 25-meter-thick porphyro-aphanitic rhyolite dike cuts unit A on the east side of the upper Teklanika River. On the western side of Polychrome Mountain, a rhyolite sill 14 meters thick has intruded the Cantwell Formation. Three hypabyssal porphyro-aphanitic rhyodacite to quartz latite plugs are present near the mouth of Tattler Creek.

Most of these intrusive rocks were probably feeders to the volcanic rocks of the Teklanika Formation. The intrusions are widely scattered, suggesting that the stratigraphically heterogeneous Teklanika Formation was formed around many centers of eruption.

PETROLOGY

FELSIC FLOWS AND INTRUSIONS

Most of the felsic volcanic flows are porphyritic rhyolites (table 1). The rocks have a microcrystalline to hyaline groundmass and a faint planar fabric caused by either segregation of mafic and siliceous minerals or by the alignment of feldspars.

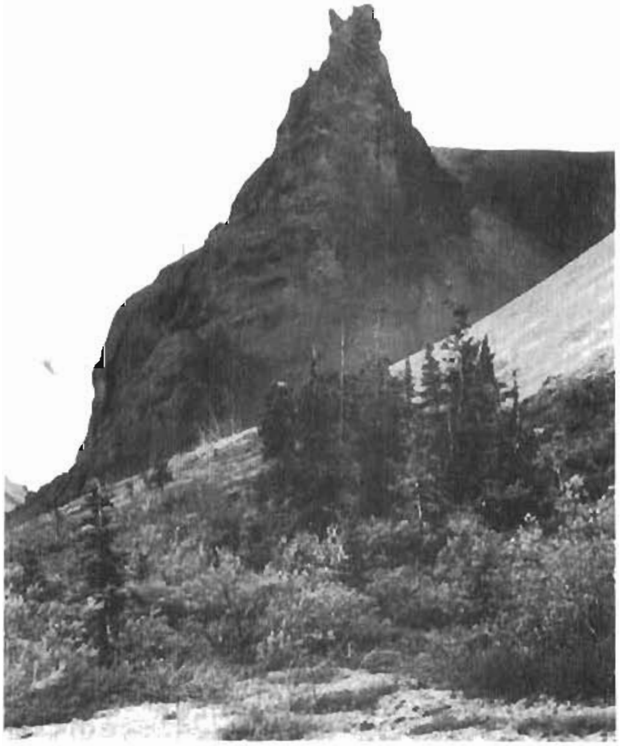

Figure 6. Diabase plug on east side of Cathedral Mountain.

In the rhyolite flows, high sanidine ($2V=0.40^{\circ}$) occurs as euhedral to subhedral phenocrysts and microphenocrysts (fig. 7), and may contain simple Carlsbad

Table 1. *Modes of selected rhyolite flows and felsic intrusions (based on 300 points counted per thin section and estimation of groundmass composition)—in percent.*

	Rock No.[1]	Location[2]	Quartz	Sanidine	Glass	Plagioclase	Biotite	Iron oxide	Trace accessory minerals[3]	Limonite	Alteration minerals[4]
Rhyolite flows	DE14-1	Te	53.5[5]	40.6	- -	- -	- -	Tr	z	3.9	2.4
	(1)										
	EA14-29a	Te	5.0	34.0	- -	6.7	- -	- -	- -	34.7	19.7
	EA14-29b	Te	22.2	41.0	- -	6.1	- -	11.2	- -	15.6	13.8
	EA14-32	Te	2.3	80.7	- -	- -	- -	10.5	- -	6.6	- -
	RE15-10	Te	- -	- -	- -	- -	- -	11.7	z	5.1	1.3
	74WG-9	Te	- -	- -	- -	- -	- -	6.9	z	24.3	- -
	(2)										
	SL13-53	CI	25.0	46.0	- -	0.3	- -	13.0	- -	16.0	- -
	(3)										
	M73-17	CI	7.6	67.6	- -	- -	- -	8.7	- -	16.5	- -
	M73-20	CI	27.0	54.4	- -	0.7	- -	5.3	- -	12.6	- -
	M73-21B	CI	33.3[5]	7.7	54.0	- -	- -	1.0	- -	1.9	1.9
	TKB2-1	P	30.0	53.2	- -	- -	- -	1.7	z	15.1	- -
	TKB2-7	P	30.0	44.0	- -	- -	- -	Tr	a	25.0	- -
	(4)										
	TKB2-53	P	1.2	1.5	89.6	- -	- -	2.1	- -	5.5	- -
	EH3-39	P	7.0	65.4	- -	- -	- -	- -	z	27.2	- -
	DT73-4	P	- -	3.5	91.9	- -	- -	5.0	z	- -	Tr
	M73-41A	To	27.0	67.3	- -	- -	- -	0.3	z	2.7	2.7
	M73-41B	To	26.7	51.9	- -	1.6	- -	4.9	a	13.4	1.3
Felsic intrusions	74WG-2B	Te	84.7[5]	0.7	- -	- -	- -	- -	- -	8.7	6.3
	SL13-29	CI	3.9	73.8	- -	10.5	6.8	- -	- -	- -	5.0
	DT73-7	CI	24.6	33.9	- -	34.6	5.3	- -	g	- -	1.6
	(5)										
	M73-4	CI	20.0	35.6	- -	36.9	1.3	- -	z, a, s	- -	2.0
	74GF-30	CI	40.0	20.7	- -	42.3	11.7	- -	z, a, s, g	- -	- -
	RD6-12	P	7.6	55.5	- -	- -	0.6		- -	12.4	24.9

[1] (1) = Geochemical analysis number; refers to preceding sample
[2] Te = Upper Teklanika sequence
CI = Cathedral-Igloo Mountain area
P = Polychrome Mountain area
To = Upper Toklat River area
Tr = Trace amount
[3] z = Zircon
a = Apatite
s = Sphene
g = Garnet
[4] Primarily calcite, sericite, and kaolinite
[5] Includes tridymite

twins. Plagioclase (An content not optically determinable) is found as a minor subhedral microphenocryst which may be surrounded by cumulophyric sanidine. Quartz rarely occurs as phenocrysts, but is common as a late interstitial constituent. Tridymite and cristobalite commonly fill vesicles. Iron oxide minerals are abundant. Microcrystalline (0.01 to 0.2 mm) minerals include subhedral to euhedral sanidine and interstitial quartz, and primary spherulites of microcrystalline quartz, sanidine, and cristobalite surrounded by limonite are common (fig. 8). Plagioclase is occasionally present in the groundmass. Zircon and rarely apatite occur in trace amounts. Secondary minerals include kaolinite, calcite, and biotite; kaolinite, wholly or in part, commonly replaces groundmass and sanidine phenocrysts.

Petrology and texture of nearby felsic intrusive rocks strongly suggest they are related to the rhyolite flows (table 1). The rhyolite dike in unit A of the upper Teklanika sequence and the rhyolite sill on the west side of Polychrome Mountain are hypidiomorphic and holocrystalline. Phenocrysts of anhedral fine-grained quartz, fine-grained biotite, and fine- to medium-grained anhedral to euhedral high sanidine occur in a groundmass of sanidine, quartz, and limonite. Biotite commonly has a reaction rim containing magnetite, and deuteric alteration of sanidine phenocrysts and groundmass to sericite and kaolinite is common. The rhyolite dike and sill are similar in texture and mineralogy to the rhyolite flows in the Teklanika Formation.

Three small hypabyssal quartz latite plugs near the mouth of Tattler Creek may either be related to volcanic flows or represent a separate igneous event. In these rocks, fine- to medium-grained subhedral labradorite phenocrysts and fine- to medium-grained subhedral sanidine phenocrysts are set in a microcrystalline to fine-grained groundmass of sanidine, quartz, and biotite. Apatite, zircon, and sphene are common accessory minerals. Trace amounts of anhedral garnet are found in the plugs. If these rocks are derived from the same magma as nearby flows, they probably are the result of a mixing of andesite and rhyolite magmas.

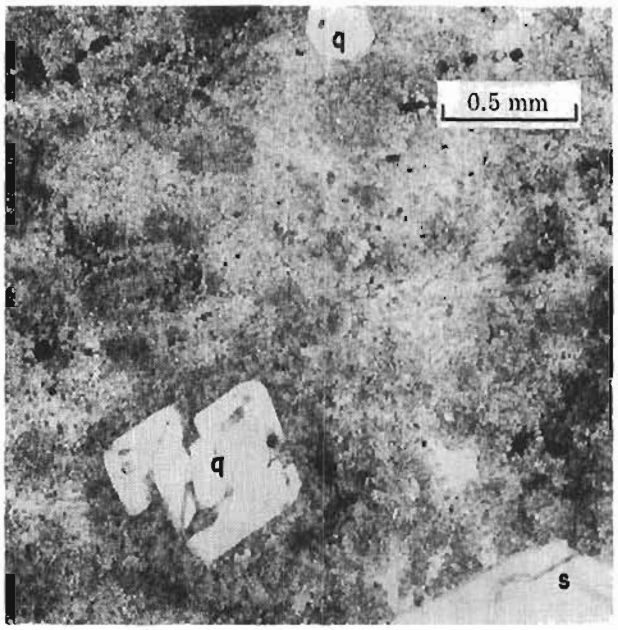

Figure 7. Photomicrograph of rhyolite flow from unit F of upper Teklanika sequence. Phenocrysts of quartz and sanidine are set in a quartz-cristobalite-sanidine groundmass. Cristobalite forms the dark halo around the resorbed quartz phenocryst. q quartz, s - sanidine. Plane polarized light.

PYROCLASTIC ROCKS

Pyroclastic rocks are most commonly found interbedded with felsic flows and rarely with mafic flows. They are dominantly a combination of andesite to rhyolite vitric, lithic, and crystal welded tuffs. Some graded volcaniclastic sandstone beds containing tuffaceous fragments suggest deposition in a quiet aquatic environment.

Welded tuffs contain either crystals or lithic fragments, or both, in a devitrified groundmass of shards and pumice fragments (figs. 9 and 10). Crystal fragments include high sanidine (2V=30-35°), calcic plagioclase (An $_{36-74}$) and rarely, quartz. Sanidine and plagioclase are commonly found in the same rock. Opaque oxides are common accessory minerals in the groundmass. Glass shards have been contorted and flattened, and range from 0.1 to 0.5 mm in length. The shards commonly display axialitic or spherulitic textures due to devitrification to cristobalite. A wide variety of cognate lithic fragments are derived from flows or tuffaceous rocks; they range from 0.05 to 0.08 mm in length.

MAFIC AND INTERMEDIATE FLOWS AND INTRUSIONS

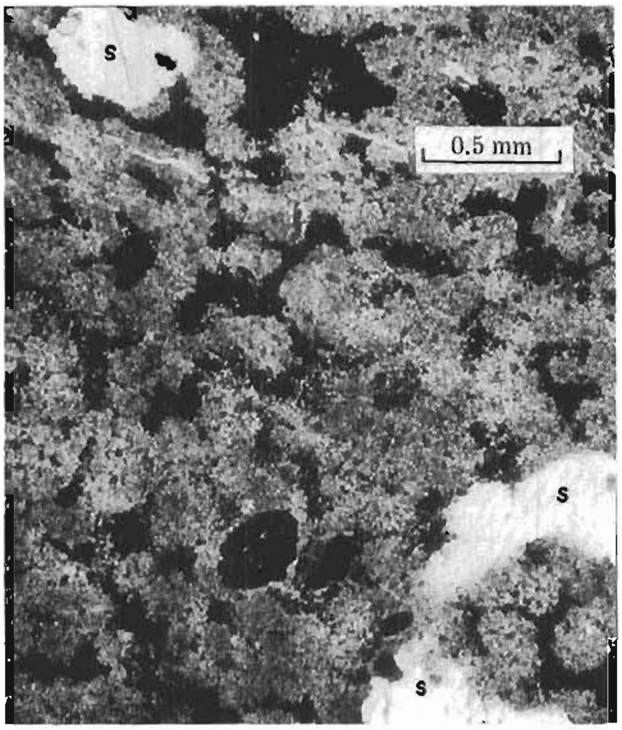

Figure 8. Photomicrograph of rhyolite flow from Cathedral Mountain. Groundmass of quartz-feldspar spherulites and limonite exhibits faint flow foliation. s - sanidine phenocryst. Plane polarized light.

Mafic flows range from olivine basalt to andesite, but most flows are andesites (table 2). These rocks are hypidiomorphic and holocrystalline (figs. 11 and 12). Plagioclase (An $_{42-60}$) is generally subhedral, tabular, and twinned, and exhibits resorbed crystal outlines. Complex zoning, with calcic plagioclase cores, is common. Minor interstitial sanidine is occasionally present. Augite (2V=30-40°) is commonly ophitic, anhedral, and fine to medium grained. Olivine (Fo $_{60-65}$) is a common fine-grained constituent and occasionally forms medium-grained phenocrysts. Alteration of the olivine to serpentine and iddingsite is ubiquitous. Ilmenite and magnetite are usually present, and apatite and zircon are frequent accessory minerals. A few basalt and andesite flows on Cathedral Mountain exhibit a directive fabric due to the orientation of the plagioclase crystals. Dense magnetite-rich (36-39%) basalt flows are a minor part of unit E in the upper Teklanika sequence. These rocks also contain fine-grained plagioclase, olivine, and augite. Secondary minerals observed in the basalt and andesite flows are chiefly sericite, calcite, and biotite.

Numerous mafic and intermediate sills, dikes, and small plutons cut both the Teklanika Formation and the nearby Cantwell Formation. On the southwest side of Cathedral Mountain, a small fine- to medium-grained quartz-bearing diorite plug contains subhedral tabular andesine and medium-grained subhedral sanidine (2V=35°). Augite is the only primary mafic silicate present, and hydrothermal alteration has introduced

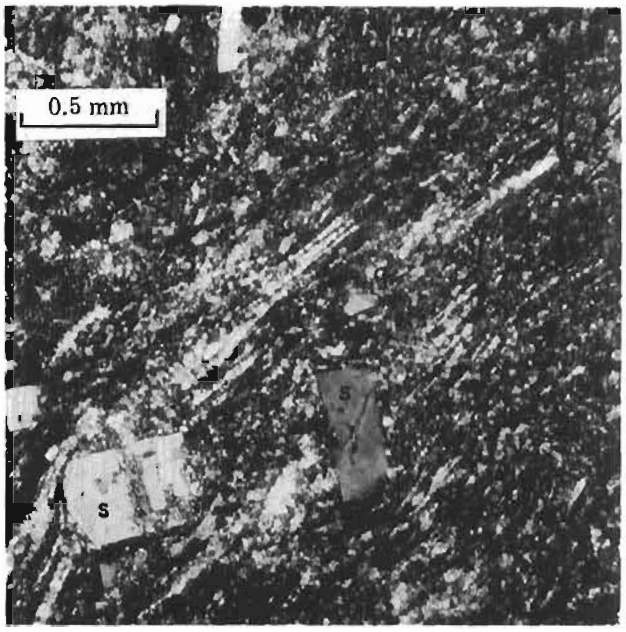

Figure 9. Photomicrograph of devitrified welded tuff from Cathedral Mountain displaying highly compressed shards and sanidine crystal fragments. s - sanidine, q - quartz. Crossed nicols.

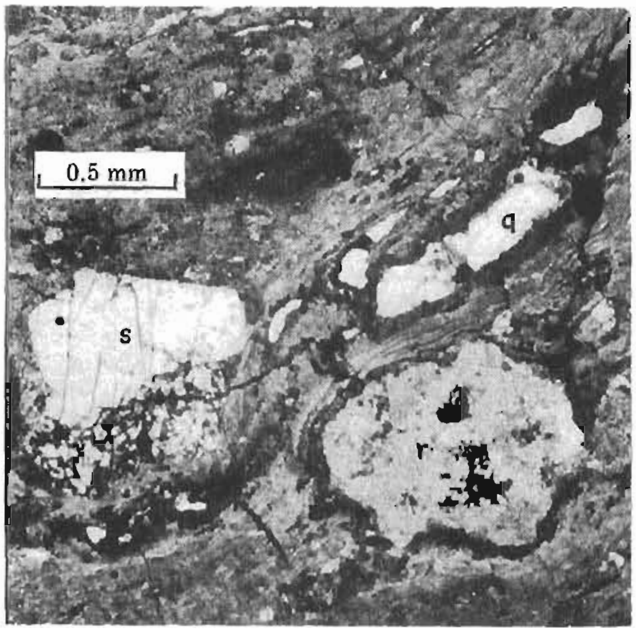

Figure 10. Photomicrograph of devitrified welded tuff along lower Calico Creek. Extreme compression and stretching has nearly eliminated shard texture. r - rhyolite rock fragment, s - sanidine fragment, q - quartz. Plane polarized light.

calcite and biotite.

On the east side of Cathedral Mountain are a fine-grained hypidiomorphic and holocrystalline diabase plug and numerous sills. The plug and sills contain subhedral labradorite, anhedral augite, and ilmenite. Magnetite and apatite are very fine-grained accessories, and secondary biotite has been hydrothermally introduced.

A quartz diorite plug on Polychrome Mountain is holocrystalline, fine to medium grained, inequigranular, and hypidiomorphic. The plug contains medium-grained subhedral andesine (An $_{38-44}$), interstitial alkali feldspar (surrounding the plagioclase grains), anhedral olivine (Fo $_{45-50}$), anhedral medium-grained augite, and subhedral to euhedral quartz. Apatite is fine grained, euhedral, equant to prismatic, and makes up 2 to 4 percent of the plug. Accessory minerals include magnetite, ilmenite, hematite, zircon, and garnet.

An east-west-trending olivine-hornblende gabbro dike crops out on the northern edge of Polychrome Mountain. It contains fine- to medium-grained subhedral tabular labradorite. Hornblende is completely replaced by magnetite, leaving relict fine- to medium-grained subhedral to euhedral hornblende outlines. Augite is subhedral to euhedral, cumulophyric, and zoned. Olivine is both fine grained and anhedral and medium-grained, euhedral, and zoned.

Many other andesite and basalt dikes cut the volcanic flows and the Cantwell Formation. The dikes are dark gray, aphanitic, and equigranular. Plagioclase accounts for about 70 percent of the rocks, with the rest being mainly limonite and opaque oxides. The dikes are commonly partially altered to calcite, sericite, and chlorite. Both geologic setting and petrology suggest that the andesite and basalt dikes and sills, together with the other mafic and intermediate intrusions discussed, have direct extrusive equivalents.

GEOCHEMISTRY

Chemical data from 11 samples suggest that the Teklanika Formation forms a calc-alkaline volcanic suite as is commonly found in continental margin volcanic belts (Green and Ringwood, 1968; Jakes and White, 1972). This conclusion is based on the chemical classification of Irvine and Baragar (1971), whereby volcanic rocks are classified into three main types: subalkaline, alkaline, and peralkaline, with subalkaline rocks being subdivided into a tholeiitic basalt series and a calc-alkali series. Chemical analyses and CIPW norm values for the 11 samples are given in table 3. Four of the samples were modally classified as rhyolite, four as andesites, and one as a basalt; one sample is from a quartz-latite plug and one is from a quartz-bearing diorite pluton. A chemical classification of the nine volcanic samples analyzed according to the method of Irvine and Barager (1971) is given in figure 13.

Chemically, the volcanic rocks of the Teklanika Formation are subalkaline, as suggested by the presence of normative quartz, and hypersthene and by their position on the alkalies-silica diagram (fig. 14). Furthermore, an AFM plot (fig. 15), which shows a lack of

Table 2. *Modes of selected andesite and basalt flows and mafic and intermediate intrusions (based on 300 point count)—in percent.*

	Rock No.[1]	Location[2]	Quartz	Sanidine	Plagioclase	Hornblende	Augite	Olivine	Iron oxides	Accessory minerals[3]	Serpentine	Iddingsite	Limonite	Other alteration minerals[4]
Andesite and basalt flows	DE14-2	Te	--	--	43.3	--	0.7	2.7	39.3	0.3 a	--	--	--	13.7
	DE14-6	Te	--	--	61.3	--	10.9	3.0	8.2	0.7 a	1.7	--	7.6	6.6
	EA14-36	Te	--	--	40.8	--	17.7	--	6.4	--	--	34.7	--	0.3
	CC15-5	Te	--	--	41.5	--	5.3	11.4	37.1	Tr z	--	0.6	--	4.0
	CC15-6	Te	--	--	57.5	--	16.6	3.8	4.5	0.3 a	2.9	10.9	--	3.5
	RE15-30	Te	--	--	20.0	--	--	--	--	--	--	--	--	80.0
	RE15-38 (6)	Te	Tr	--	59.5	--	17.9	--	7.0	--	--	--	--	16.5
	74WG-4A	Te	--	--	61.7	--	20.0	6.3	2.5	0.9 a	5.4	1.6	--	1.6
	74WG-4B	Te	--	--	56.6	--	11.0	1.0	3.0	Tr a	12.0	3.6	Tr	12.6
	74WG-6 (7)	Te	--	--	52.3	--	15.4	4.4	6.0	--	14.1	3.7	--	4.7
	74WG-14	Te	--	--	62.3	--	13.0	5.3	1.6	0.7 a	15.0	--	--	2.0
	JR12-43	CI	--	--	54.8	--	--	--	12.5	--	--	--	--	32.8
	RJ13-48	CI	--	0.3	55.4	--	--	--	0.3	Tr a	--	--	29.8	13.8
	RJ13-51	CI	--	--	46.6	--	12.3	32.6	8.0	Tr a	--	--	--	0.7
	SL13-44A (8)	CI	--	--	59.6	--	20.1	0.6	2.1	0.6 a	--	14.5	--	2.5
	SL13-44B	CI	0.6	--	58.2	--	17.7	14.3	4.5	1.2 a	--	--	3.0	0.3
	DT73-9 (9)	CI	--	--	63.3	--	--	--	8.0	0.3 a	--	--	5.0	23.2
	M73-14	CI	--	--	49.4	--	--	--	8.9	--	--	--	--	41.8
	TKB2-33 (10)	P	--	--	50.7	--	17.4	--	5.3	1.3 a	--	--	--	25.8
	TKB2-57	P	--	--	61.4	--	8.2	--	5.3	1.0 a	--	--	--	24.1
	M73-36B	P	--	--	56.2	--	8.4	--	0.6	--	--	--	4.1	30.6
	EH5-2A	To	--	--	55.8	--	--	--	0.9	--	--	--	4.1	2.2
	EH5-2B	To	--	--	7.6	--	--	--	7.6	--	--	--	1.3	82.4
Mafic and intermediate intrusions	SL13-6	CI	5.9	6.9	62.4	--	7.2	--	0.7	Tr a	--	--	--	17.0
	SL13-37	CI	--	--	70.2	--	10.4	--	2.9	0.3 a	0.6	--	--	15.6
	DT73-5	CI	2.9	--	55.6	--	--	--	4.2	--	--	--	--	37.4
	M73-21A	CI	0.3	--	64.7	Tr	9.0	2.7	2.9	0.3 a	1.3	--	--	18.0
	M73-23	CI	5.5	--	67.4	--	8.5	--	3.3	0.3 a	--	--	--	15.0
	TBK2-12	P	3.0	6.1	52.1	--	6.7	1.8	3.6	Tr g, 3.7 a, Tr z	--	5.8	--	17.1
	TKB2-35	P	2.6	8.4	57.3	--	7.8	0.3	4.8	1.6 a	--	5.2	--	12.3
	EH3-1	P	--	--	45.6	--	15.2	2.6	30.4	0.3 a	1.6	--	--	4.2
	EH3-11	P	--	--	63.9	--	0.3	0.3	18.4	--	--	--	--	17.1
	SJ4-34	P	--	--	68.2	--	6.2	1.3	5.3	0.3 a	8.9	1.6	--	8.2
	DT73-1 (11)	P	2.7	3.7	58.3	--	8.7	0.3	3.7	2.3 a	--	16.0	--	4.3
	M73-38	P	--	--	44.6	12.1	5.4	1.6	22.9	--	--	--	--	13.3

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[1] (7) Geochemical analysis number.

[2] Te = Upper Teklanika sequence
CI = Cathedral-Igloo Mountain area
P = Polychrome Mountain area
To = Upper Toklat River area

[3] z = Zircon
a = Apatite
s = Sphene
g = Garnet
Tr = Trace

[4] Primarily calcite, chlorite, and kaolinite.

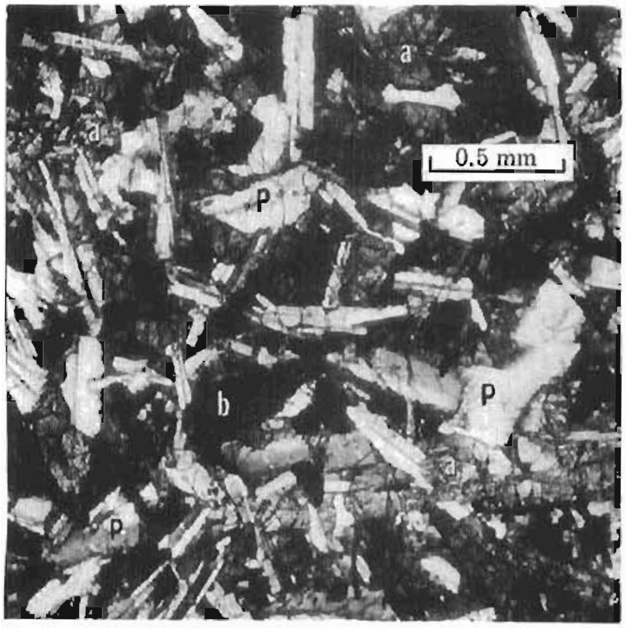

Figure 11. Photomicrograph of andesite flow from Polychrome Mountain. p - plagioclase, a - augite, b - biotite. Crossed nicols.

Figure 12. Photomicrograph of andesite flow from unit E of upper Teklanika sequence. p - plagioclase, a - augite, o - olivine altering to serpentine and iddingsite. Crossed nicols.

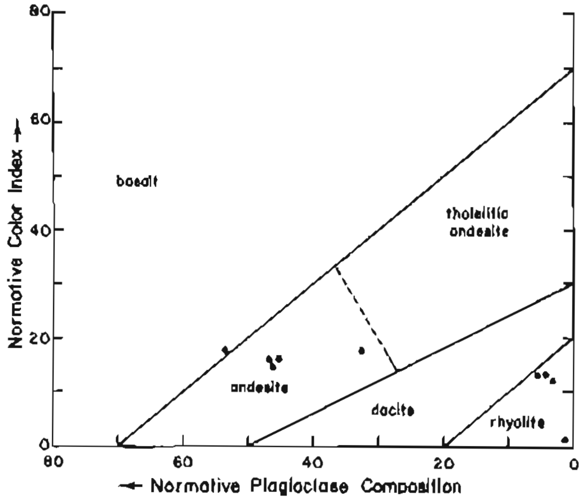

Figure 13. Chemical classification of nine volcanic rocks from Teklanika Formation after Irvine and Baragar, 1971.

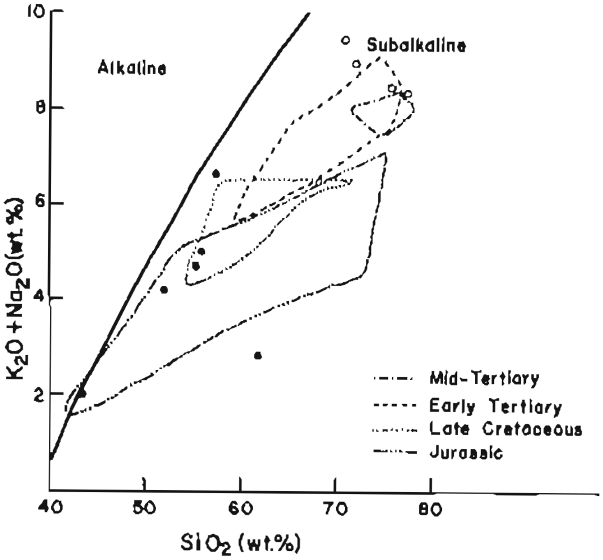

Figure 14. Alkalies-silica diagram with nine volcanic rocks from Teklanika Formation plotted (solid circles - andesite and basalt; open circles - rhyolite). Solid line separates alkaline and subalkaline rocks after Irvine and Baragar, 1971. Broken lines enclose chemical trends of plutonic rocks from Alaska-Aleutian Range batholith from Reed and Lanphere, 1973.

iron enrichment for low alkali values, and a plot of Al_2O_3 versus normative plagioclase (fig. 16) strongly suggest that the rocks are part of a calc-alkali series rather than a tholeiitic basalt series, although the Al_2O_3 content of basalts and andesites is somewhat transitional between the two series. The presence of modal augite, quartz, and phenocrysts of pyroxene, olivine, and plagioclase are also consistent with mineral phases commonly found in calc-alkaline basalts and andesites (Hyndman, 1972).

Because of the generally siliceous nature, low Na-K ratio, lack of iron enrichment, and trace amounts of

Table 3. *Geochemical analyses (rapid rock technique by Skyline Labs, Wheatridge, CO) and CIPW norm calculations—in percent.*

	Sample[1]										
Oxides	1	2	3	4	5	6	7	8	9	10	11
SiO_2	77.49	72.06	71.03	76.04	71.66	61.99	55.37	55.93	57.49	52.15	53.27
TiO_2	0.21	0.34	0.37	0.11	0.43	1.01	2.20	1.97	1.93	2.40	2.86
Al_2O_3	12.68	13.91	13.81	12.51	15.04	15.53	15.05	15.17	15.85	16.76	16.63
Fe_2O_3	0.73	4.09	4.57	2.44	0.79	0.79	1.26	0.94	3.75	4.27	5.41
FeO	0.10	0.05	0.18	0.12	1.77	5.44	6.90	6.81	5.89	4.38	4.45
MnO	0.02	0.09	0.09	0.02	0.03	0.16	0.11	0.10	0.19	0.14	0.15
MgO	0.29	0.12	0.09	0.15	1.15	5.77	5.23	4.96	1.93	5.83	2.55
CaO	0.33	0.49	0.45	0.22	2.60	6.44	8.68	8.67	6.00	9.58	8.27
Na_2O	2.66	3.28	3.56	3.26	3.63	2.33	2.93	2.89	3.22	2.82	3.71
K_2O	5.63	5.63	5.89	5.19	2.80	0.48	1.78	2.07	3.43	1.36	2.02
P_2O_5	0.03	0.02	0.03	0.02	0.15	0.10	0.55	0.54	0.37	0.36	0.74
Norms											
Quartz	37.35	28.84	25.48	34.73	31.79	24.60	4.36	3.17	9.89	2.18	4.59
Orthoclase	33.72	33.76	35.29	31.11	16.52	2.76	10.50	12.26	20.50	8.05	12.10
Albite	24.23	29.85	32.37	29.67	32.54	20.52	26.29	26.08	29.21	25.40	33.87
Anorthite	0.86	1.70	1.46	0.36	6.66	16.91	22.70	22.45	18.94	29.32	23.20
Corundum	2.00	2.02	1.17	1.57	3.91	5.21	----	----	----	----	----
Diopside	----	----	----	----	----	----	5.14	6.38	1.87	6.21	5.19
Hypersthene											
en[2]	0.80	0.32	0.23	0.40	3.15	15.62	14.44	13.75	5.39	16.20	7.14
fs[3]	----	----	----	----	1.62	6.58	6.92	7.35	4.16	0.68	----
Olivene	----	----	----	----	----	----	----	----	----	----	----
Magnetite	----	----	----	0.07	0.82	0.81	1.31	0.99	3.97	4.49	4.79
Ilmenite	0.16	0.19	0.40	0.14	0.59	1.38	3.06	2.75	2.72	3.36	4.05
Apatite	0.04	0.02	0.04	0.02	0.30	0.20	1.14	1.13	0.77	0.75	1.56
Calcite	0.26	0.26	0.26	0.26	2.10	5.50	1.59	0.52	1.65	0.27	0.27
Hematite	0.51	2.90	3.23	1.68	----	----	----	----	----	----	0.64
Rutile	0.06	0.14	----	----	----	----	----	----	----	----	----

[1] Geochemical analysis number (see tables 1 and 2).
[2] Enstatite
[3] Ferrosilite

Table 4. *Analytical data for K-Ar age determinations.*

Sample	Rock type	Mineral dated	K_2O (weight percent)	Sample weight (gm)	$^{40}Ar_{rad}$ (moles/gm) X 10^{-11}	$\frac{^{40}Ar_{rad}}{^{40}K}$ X 10^{-2}	$\frac{^{40}Ar_{rad}}{^{40}Ar_{total}}$	Age ± 2σ (m.y.)
DT-73-9	andesite	plagioclase	0.600, 0.610	4.4935	24.73	0.3600	0.812	60.6 Min.
DT-73-1	quartz diorite	plagioclase	0.320, 0.317	3.6977	2.74	0.3400	0.661	57.2 ±3.4
74 WG-14	basalt	whole rock	2.30, 2.30	1.9480	14.36	0.2472	0.480	41.8 Min.

Constants used in age calculations:

$\lambda_{\varepsilon} = 0.585 \times 10^{-10}/yr$
$\lambda_{\beta} = 4.72 \times 10^{-10}/yr$
K^{40}/K total = 1.19×10^{-4} mole/mole

garnet, the Teklanika Formation may have been produced by eclogite-controlled fractionation at a depth greater than 100 kilometers (Ringwood, 1974). The bimodal character of the formation may be caused by contemporaneous fractionation in the mantle of hydrous parental material into two contrasting magmas as suggested by Yoder (1973).

Figure 14 also reproduces the chemical trends of 139

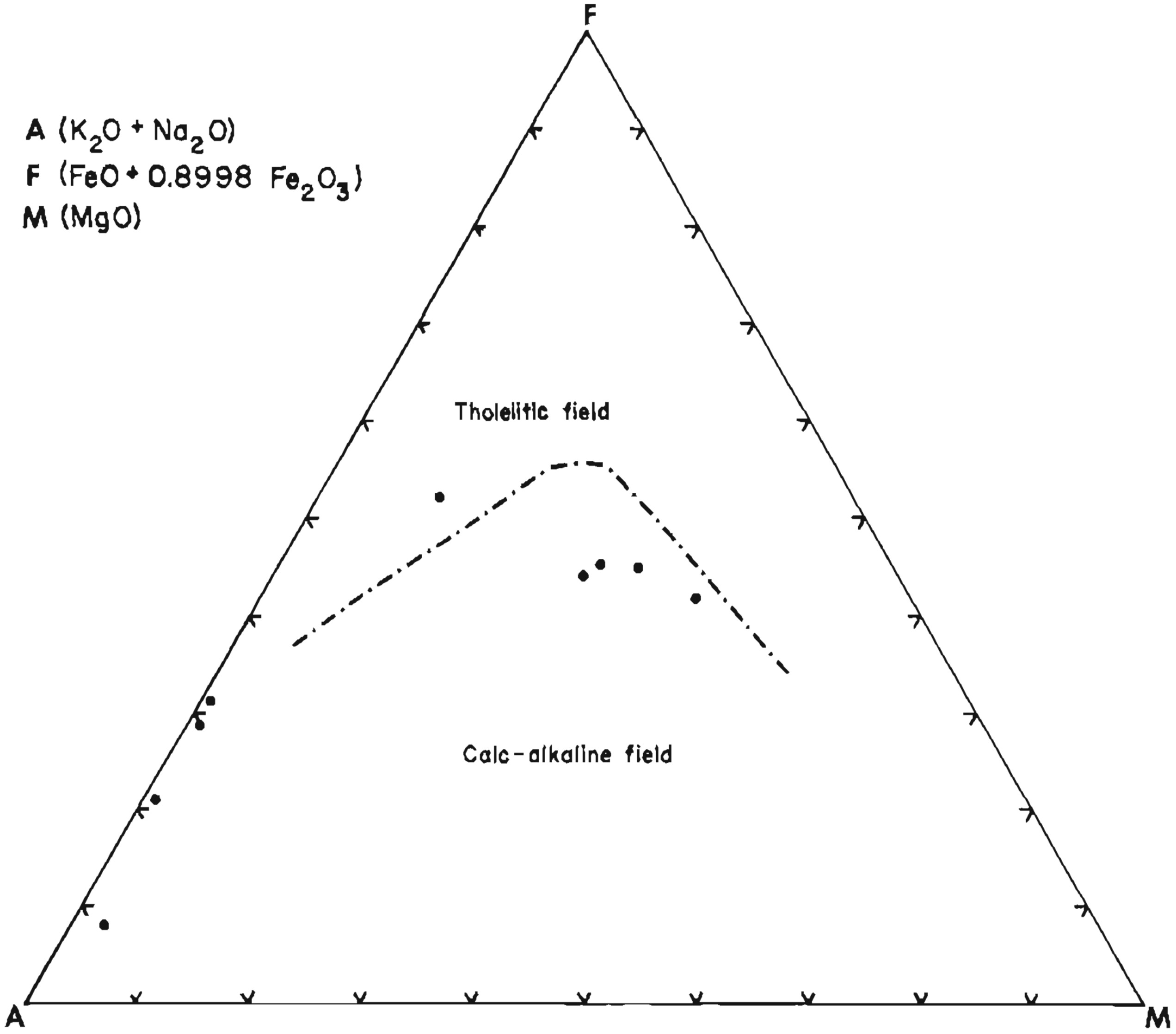

Figure 15. AFM diagram with nine volcanic rocks from Teklanika Formation plotted. Broken line separates tholeiitic and calc-alkaline rocks after Irvine and Baragar, 1971.

plutonic rock samples from the Alaska-Aleutian Range batholith published by Reed and Lanphere (1973). The diagram vaguely suggests that the rhyolite flows of the Paleocene Teklanika Formation may be cogenetic with early Tertiary granitic rocks of equivalent age in south-central Alaska, although more petrologic and chemical studies are needed.

GEOCHRONOLOGY

Radiometric ages of two volcanic and one related plutonic rock were determined by the potassium-argon method (analytical data reported in table 4; see Turner and others, 1973, for discussion of analytical method used). Plagioclase from the andesite flow on Cathedral Mountain (DT-73-9) yielded a minimum age of 60.6 m.y. A whole-rock sample from a basalt flow in the upper East Fork drainage yielded a minimum age of 41.8 m.y. These two dates must be considered minimum ages because incipient alteration is likely to have caused postcrystallization argon loss. Plagioclase from the quartz-diorite plug on Polychrome Mountain (DT-73-1) yielded an age of 57.2 ± 3.4 m.y.

Five whole-rock potassium-argon ages from the Teklanika Formation to the east (Hickman, 1974) range from 49.5 ± 2.1 m.y. to 59.3 ± 2.7 m.y. Alteration is reported from these rocks also, and their ages must be considered minimum ages for Teklanika Formation volcanism.

All these dates suggest that eruption of the Teklanika Formation took place during Paleocene time. Because the Teklanika Formation is closely associated in time and space with the underlying Cantwell Formation, the radiometric ages give a minimum age for the deposition of the Cantwell Formation as well. The age dates agree with paleobotanical dating of the Cantwell Formation (Wolfe and Wahrhaftig, 1970; Wolfe, 1972), which indicates that the formation is Paleocene in age; they also agree with a maximum age of the Cantwell Formation to the east of 95 m.y. (Wahrhaftig and others, 1975). Thus, a closely spaced series of events, beginning with deposition of the Cantwell Formation and ending with orogeny and its associated calc-alkaline volcanism (Gilbert, 1975), occurred during Paleocene time in the central Alaska range.

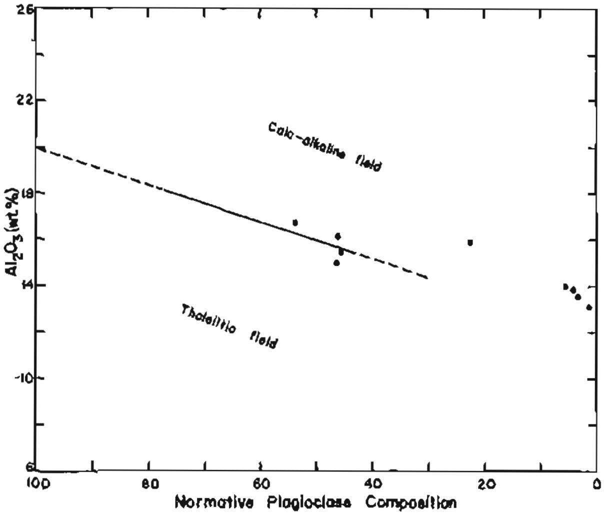

Figure 16. Al_2O_3 - Normative plagioclase diagram with nine volcanic rocks from Teklanika Formation plotted. Solid and broken line separates calc-alkaline and tholeiitic rocks after Irvine and Baragar, 1971.

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