CHEMISTRY, MINERALOGY, AND K-AR AGES OF IGNEOUS AND METAMORPHIC ROCKS OF THE MEDFRA QUADRANGLE, ALASKA

By

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This report discusses chemical analysis and potassium-argon (K-Ar) age determinations for the igneous and metamorphic rocks of the Medfra quadrangle. These chemical and isotopic studies were carried out as part of the Alaska Mineral Resources Assessment Program (AMRAP). A preliminary geologic map which provides detailed descriptions of the igneous and metamorphic units in the Medfra quadrangle has been released in open-file (Patton and others, 1980). A generalized version of the preliminary geologic map accompanies this report.

CHEMISTRY AND MINERALOGY OF THE IGNEOUS ROCKS

Representative samples of all the igneous rock units in the Medfra quadrangle were analyzed for major elements by X-ray fluorescence (XRF) in the laboratories of the U.S. Geological Survey in Menlo Park and Denver. Mineralogical studies by thin section petrography, modal grain counts, and X-ray diffraction were conducted by the senior author.

Most volcanic and plutonic rocks in the Medfra quadrangle are Late Cretaceous to early Tertiary in age. In addition, small bodies of gabbro and diabase of uncertain but probably older age are found in the east and northwest parts of the quadrangle.

Late Cretaceous-early Tertiary Igneous Rocks

Late Cretaceous-early Tertiary volcanic, hypabyssal, and plutonic rocks ranging in composition from mafic to felsic occur throughout the Medfra quadrangle. These rocks are divided into six map units: 1) mafic and intermediate lava flows of the Nowitna River area (TKn, TKnr), 2) volcano-plutonic complexes (TKc, TKcm), 3) granite (TKg), 4) monzonite (TKm), 5) felsic and intermediate sills, dikes, flows, and plugs of the Nixon Fork-upper Sulukna River area (TKv), and 6) felsic flows and domes of the Sischu Mountains (TKs). Despite the diversity of rock types and occurrences, chemical data for the entire quadrangle, when plotted on silica variation diagrams, show broad trends of major elements. CaO, MgO, FeO* (total Fe as FeO), TiO_2, and Al_2O_3 decrease, K_2O increases, and Na_2O remains about constant with increasing SiO_2 (Fig. 1). Where compositional variation and available data are sufficient to define trends, plots of data from individual centers show more linear trends and less scatter than plots of data from the entire quadrangle (Figs. I, II, and III, sheet 2). However, data from the volcano-plutonic complex (TKc, TKcm) and the volcanic rocks of Sischu Mountains (TKs) show considerably more scatter than data from other centers, probably due to rock alteration in these areas.

Although the entire Medfra calc-alkalic suite is K-rich, K_2O varies considerably from center to center (Figs. I, II, III). For example, at 56.5 percent SiO_2, K_2O averages 1.4 percent in plutonic rocks at Stone Mountain versus 3.2 percent in plutonic rocks at Von Frank Mountain. On the basis of

K_2O contents the Medfra suite can be divided, by an arbitrary line, into lower and higher K_2O groups. The plutonic rocks at Von Frank Mountain, Nixon Fork, and upper Sulukna are in the higher K_2O group; plutonic rocks at Stone Mountain, Sunshine Mountain, West Fork, Meadow Creek, and the Nowitna volcanic rocks are in the lower K_2O group. Samples from the volcano-plutonic complexes overlap the higher and lower K_2O fields, although most points plot in the higher K_2O field. Data from other centers are insufficient to characterize them on the basis of K_2O contents.

Other major elements that show geographic variation are CaO and Na_2O. CaO concentrations at a given SiO_2 content are slightly higher in the Nowitna volcanic rocks, and in plutonic rocks from Stone Mountain and Whirlwind Ridge, and relatively lower in plutonic rocks from Von Frank Mountain and Nixon Fork. CaO data on rocks from the volcano-plutonic complexes overlap the higher and lower CaO fields.

Plots of Na_2O vs. SiO_2 show more scatter than other major element plots, probably due in part to postdepositional alteration. In most areas Na_2O shows no clear separation from center to center. However, Na_2O is generally lower in the volcano-plutonic complexes than in rocks from other areas. Lower Na_2O in the complexes may be entirely due to postdepositional alteration but the constancy of the lower values suggest that it may be, in part, primary.

Most other major elements show little or no clear geographic variation. However, TiO_2 is slightly lower in rocks from Von Frank Mountain than in the Nowitna volcanic rocks and FeO* is slightly higher in rocks from the volcano-plutonic complexes than in rocks from other areas of the quadrangle.

On the basis of the chemical data we divide calc-alkalic rocks of the Medfra quadrangle into three groups: Group 1 consists of the Nowitna volcanic rocks and plutonic rocks at Stone Mountain, Sunshine Mountain, Meadow Creek, and West Fork; Group 2 consists of rocks at Von Frank Mountain and Nixon Fork; and Group 3 consists of the volcano-plutonic complexes. Other areas in the quadrangle have insufficient data to be clearly grouped. The first group has lower K_2O and higher CaO than the second group. The third group has lower Na_2O and higher FeO* than the first two groups.

The origin of these chemical groups is unknown. Most rocks in Group 1 are north and (or) west of the rocks in Group 2. Group 3 rocks lie in the southwest corner of the quadrangle. However, the location of the chemical groups does not coincide with known terrane boundaries or appear to reflect difference in the country rock.

<u>Volcanic rocks of the Nowitna River area (TKn)</u>

The volcanic rocks of the Nowitna River area (TKn) are composed of a pile at least 1,500 m thick of high-K andesite and subordinate basaltic andesite flows overlain by a few small rhyolite domes. The volcanic pile forms a gently folded northeast-trending syncline in the northwest part of the quadrangle. Flows are usually columnar jointed, 15 to 30 m thick, and have tops marked by highly vesicular and (or) red scoriaceous zones. The main body of the lava flows is gray to black, has lense-like flow banding, and weathers into platy or blocky rubble.

One and two pyroxene andesite is the most common rock type and can be divided into two textural groups--those with trachytic groundmasses and those with intersertal/intergranular groundmasses. Rocks with trachytic groundmasses usually have sparse phenocrysts, but phenocrysts may constitute up to 20 percent of the rock. Where present, phenocrysts consist of plagioclase, clinopyroxene, Fe-Ti oxide minerals, and orthopyroxene. Plagioclase phenocrysts are normally and oscillatory zoned and may have up to six repeats of the same composition in a single grain. In addition, many plagioclase grains contain compositionally zoned concentrations of glass inclusions. Some of the "trachytic" samples have brown streaky flow banding. Groundmasses are composed of abundant alined plagioclase microlites, scattered Fe-Ti oxide minerals, granular pyroxene, and K-feldspar. Intersertal/intergranular rocks are markedly porphyritic and some samples contain plagioclase phenocrysts up to 1 cm long. Phenocrysts in these rocks are approximately the same as in the trachytic group except for the absence of orthopyroxene in some of the intersertal/intergranular samples. The groundmass is composed of generally unoriented plagioclase microlites, granular pyroxene, and dark glass. Complete gradations exist between trachytic and intersertal/intergranular types and many highly porphyritic basalts have slightly alined plagioclase laths.

Rhyolite domes are composed of altered platy rhyolite that contains sparse quartz and altered feldspar phenocrysts in very fine grained devitrified groundmass.

Of seven chemical analyses on the Nowitna volcanic rocks, five are high-K andesites, one is a basaltic andesite, and one is a rhyolite. The mafic and intermediate rocks are chemically and mineralogically similar to, but less altered than, the high-K andesites from the volcano-plutonic complexes (TKc, TKcm). The rhyolitic sample is highly altered and contains about 85 percent SiO_2, 10 percent Al_2O_3, and 5 percent H_2O.

Mafic and intermediate volcano-plutonic complexes (TKc and TKcm)

Volcano-plutonic complexes, composed of high-K andesite flows, tuffs, and shallow hypabyssal rocks (TKc) intruded by small granitic stocks (TKcm), occur in the southwest part of the Medfra quadrangle at Page Mountain, Cloudy Mountain, and Alone benchmark. These complexes constitute the northern end of a belt of at least seven complexes that extends southwestward over 250 km from Page Mountain in the Medfra quadrangle to Horn Mountain in the Sleetemute quadrangle.

The complexes appear to be bounded by faults and are downdropped into the surrounding Cretaceous sedimentary rocks. At several well exposed localities at Cloudy and Page Mountains, columnar-jointed flows dip gently towards the center of the complexes. Volcanic rocks in the complexes are altered to hornfels in the vicinity of the granitic intrusions.

Alone benchmark has the smallest outcrop area of the three complexes and is very poorly exposed, but aeromagnetic data (Patton and others, 1981) show that the complex extends beneath the sediment-filled flatlands as a northeast-trending, oval body at least twice as large as its present outcrop area.

The most abundant rock type at Alone benchmark is dark porphyritic andesite, which consists of large (0.5-1.0 cm) euhedral plagioclase laths in a groundmass of sparse plagioclase needles, scattered opaque minerals, and abundant black glass. A small monzonite stock at the benchmark consists of chiefly plagioclase laths, poikilitic K-feldspar, and green to tan hornblende with subordinate biotite, Fe-Ti oxide minerals, clinopyroxene, and quartz.

Pyroxene andesite is also the most common rock type at Page and Cloudy Mountains, but rocks from these two complexes have more textural and mineralogical variation than rocks from Alone benchmark. Other rock types include biotite andesite, hornblende andesite, and minor dacite at Page Mountain, and olivine basalt, biotite andesite, hornblende andesite, and minor dacite at Cloudy Mountain. The granitic core at Page Mountain consists of B-type granite, granodiorite, and quartz monzonite, and at Cloudy Mountain of quartz monzonite and monzonite (fig. 3).

Although volcanic and plutonic rocks at Page and Cloudy Mountains are described and mapped separately, there is a complete textural range from medium-grained (1-3 mm) hypidiomorphic granular granitic rocks to medium-grained porphyritic hypabyssal rocks to medium- to fine-grained porphyritic holocrystalline, glassy, and tuffaceous volcanic rocks. In general, the plutonic rocks are slightly more felsic than the volcanic rocks.

Volcanic rocks at Page and Cloudy Mountains are mineralogically and chemically similar to volcanic rocks of the Nowitna River area (TKn), but more altered. They generally consist of plagioclase and clinopyroxene phenocrysts and subordinate biotite, hornblende, orthopyroxene, and Fe-Ti oxide phenocrysts. One sample from Cloudy Mountain has 5 percent olivine phenocrysts. Most of the volcanic and hypabyssal rocks contain 5 to 10 percent altered mafic minerals.

The plutonic rocks at Cloudy and Page Mountains are medium grained and range from porphyritic to hypidiomorphic granular. Plagioclase occurs as euhedral laths. K-feldspar occurs both as euhedral laths and large poikilitic grains enclosing plagioclase and other minerals. Mafic minerals include clinopyroxene, Fe-Ti oxide minerals, biotite, and rare amphibole. Quartz is found in the interstices and is usually less than 10 percent of the rock.

Although chemical data from the complexes fall along the same trends on major element variation diagrams as other Late Cretaceous-early Tertiary rocks from the Medfra quadrangle, the data generally are more scattered, probably due to postdepositional alteration.

Small granitic intrusions (TKcm) in the volcano-plutonic complexes at Page Mountain and Cloudy Mountain have REE contents (Moll, unpub. data) and K-Ar ages (table 2) similar to unaltered high-K andesitic volcanic rocks (TKc) from the same complex. These data suggest that the monzonites and high-K andesites are genetically related.

Granite (TKg)

In the central and eastern parts of the Medfra quadrangle granite stocks occur in the Telida and Sunshine Mountains, and in the Meadow Creek, West Fork, and upper Sulukna River drainages. The granite bodies are chemically and mineralogically homogeneous, and the SiO_2 content within a single body does not vary more than a few percent.

Granite at Sunshine Mountains consists of white to light-gray medium-grained B-type granite composed predominantly of plagioclase, K-feldspar, and quartz. It generally contains 6-10 percent biotite, and very minor Fe-Ti oxide minerals, hornblende, apatite, sphene, and zircon. The texture is hypidiomorphic granular.

Two intrusive bodies located about 7 km east of the Sunshine Mountains in the Meadow Creek drainage are chemically similar to the Sunshine Mountains granite, but are porphyritic hypabyssal rocks instead of plutonic rocks. Meadow Creek hypabyssal rocks contain about 30 to 40 percent phenocrysts of zoned plagioclase, sanidine, quartz, hornblende, and biotite. The groundmass consists of interlocking quartz and feldspar crystals averaging 0.07-0.10 mm in diameter.

The pluton in the West Fork drainage is very poorly exposed; outcrops are confined to scattered large boulders partly buried in deep brush on a hillside. It appears to consist chiefly of very coarse grained porphyritic B-type granite. The rock contains sparse but very large K-feldspar crystals up to 3 cm long, smoky quartz crystals that average 1 cm long, and zoned plagioclase crystals 1.0-1.5 cm long. K-feldspar, plagioclase, and quartz also occur as finer medium-grained "groundmass" crystals. The rock also has about 10 percent partially chloritized biotite and 1-2 percent Fe-Ti oxide minerals.

The pluton in the Telida Mountains is A-type granite. It consists of coarse 1-cm-long euhedral K-spar crystals and medium-grained anhedral K-spar, euhedral plagioclase, anhedral smoky quartz, and 2-8 percent mafic minerals, most of which is biotite.

A small stock of granite and syenite is intruded into lower Paleozoic carbonate rocks in the upper Sulukna River drainage. The contact between the stock and the carbonates contains abundant magnetite, diopside, tremolite, and clinohumite. Throckmorton and Patton (1978) described a small magnetite body (11,600 m^3) in the contact zone. The granite and syenite both consist of subhedral to anhedral zoned plagioclase, orthoclase, and quartz. Some of the large K-feldspar crystals have stringy perthitic exsolution. Mafic minerals in the granite include biotite, green hornblende, and colorless clinopyroxene. The chief mafic mineral in the syenite is pale-green clinopyroxene which occurs chiefly along grain boundaries and in veins. The skarn deposits surrounding the igneous body have abundant pale-green diopside and the clinopyroxene in the syenite may be due to reaction with the carbonate rocks rather than primary igneous clinopyroxene. This idea is supported by the mapping of Throckmorton and Patton (1978) which shows that the stock is chiefly B-type granite and that the syenite probably represents a hybrid border phase.

<u>Monzonite (TKm)</u>

A number of plutons composed chiefly of monzonite, quartz monzonite, monzodiorite, and quartz monzodiorite occur in the Medfra quadrangle (fig. 4). The plutons at Von Frank and Stone Mountains also contain small bodies of monzogabbro and gabbro. Monzonite, monzodiorite, quartz monzonite, and quartz monzodiorite generally contain 25 to 40 percent mafic minerals and 60 to 70 percent gray or white plagioclase and K-feldspar. K-feldspar usually occurs as large crystals subophitically or ophitically enclosing plagioclase laths and mafic minerals. The most common mafic minerals are biotite, hornblende, orthopyroxene, clinopyroxene, and Fe-Ti oxide minerals. Monzogabbros contain olivine, orthopyroxene, clinopyroxene, and more than 10 percent K-feldspar. Gabbros contain orthopyroxene and clinopyroxene plus or minus olivine.

Volcanic and hypabyssal rocks of the Nixon Fork-Sulukna River area (TKv)

Numerous small dikes, sills, and plugs along with a small volcanic flow occur in the central part of the quadrangle between the Nixon Fork Mine and the upper Sulukna River. At Mystery Mountains the unit consists of a number of parallel northwest-trending sills and small plugs of highly altered rhyolite, dacite, and trachyandesite. The sills and plugs are hydrothermally altered and commonly contain secondary sericite, calcite, chlorite, tourmaline, and muscovite. Large areas of hydrothermal breccia, composed of fragments of altered volcanic rocks and sedimentary hornfels cemented by tourmaline, crop out on the southwest flank of Mystery Mountains (T. 23 S., R. 22 E.). West of Cottonwood Creek volcanic rocks crop out as an oblong body of a green to greenish-gray altered and vesicular trachyandesite lava. West of Shepherd Creek, the unit is composed of small rhyolite and dacite hypabyssal plugs and domes.

Hypabyssal rhyolites consist of 3-10 percent phenocrysts of quartz, plagioclase, biotite, and rare sanidine in a groundmass of quartz and feldspar. Dacites contain plagioclase, hornblende, and biotite phenocrysts in a quartz and feldspar groundmass. Trachyandesites contain about 10 percent plagioclase and altered mafic minerals phenocrysts in a groundmass of subparallel plagioclase laths.

Volcanic rocks of Sischu Mountains (TKs)

Siliceous volcanic rocks at Sischu Mountain form a thick, poorly exposed, broadly folded, northeast-trending syncline that is fault bounded on the southeast side. Weathered rhyolite and dacite flows and domes, with minor felsic tuffs and andesite dikes, are the predominant rock types. Most rhyolite and dacite is light gray to purplish red and has lenselike flow banding. The rocks are altered, and in many original phenocryst and groundmass minerals are replaced or recrystallized. These extremely altered rocks, termed felsites, are composed of 76 to 85 percent SiO_2, 10-15 percent Al_2O_3, and about 5 percent H_2O. The mineralogy consists of 0.1 mm indistinct low-birefringent crystals of quartz, feldspar, and probable kaolinite. Relatively fresh samples have less than 76 percent SiO_2 and about 7-8 percent total alkalis. They consist of less than 10 percent phenocrysts of quartz, sanidine, and plagioclase. Most also have altered mafic pseudomorphs after biotite(?) and a small amount of Fe-Ti oxide mineral phenocrysts. The groundmass consists of fine interlocking grains of quartz, feldspar, Fe-Ti oxide minerals, biotite, and rare pale-blue fluorite. One sample has a partially glassy groundmass.

Igneous rocks of uncertain age

Small bodies of gabbro and diabase (KDg) are widespread throughout the east and northwest parts of the Medfra quadrangle. In the eastern part they intrude lower Paleozoic carbonate units (DOsl and DOld), lower Paleozoic and Precambrian chert and phyllite (Pzc) and quartzite, grit, and argillite (Pzp€q) units. In the northwest part of the quadrangle they crop out in rocks with oceanic-island arc affinities in the chert and limestone unit (TPMc) and in the cherty tuff, crystal and lithic tuffs, and volcanic breccia unit (J₮t). Few data are available on the gabbro and diabase due to poor exposure and rock alteration, and their age and correlation are uncertain. In the eastern part of the quadrangle they intrude lower Paleozoic strata and therefore cannot be older than Devonian. In the northwestern part of the quadrangle, poor exposures preclude a clear understanding of the relationship between these bodies and the upper Paleozoic-lower Mesozoic oceanic-island arc rocks. The gabbros and diabases may be part of the oceanic-island arc terrane or they may be later intrusions as young as Cretaceous.

In the northwest part of the quadrangle, two samples of diabase (nos. 37 and 38) were collected within 10 km of each other along a strong positive magnetic anomaly that trends northeast (Patton, Cady, and Moll, 1981). Rocks from both sample localities are medium-grained porphyritic diabases that have 20-25 percent phenocrysts and intersertal/intergranular textures. They are composed of plagioclase laths, tan or pale-green clinopyroxene, minor magnetite, and less than 1 percent minor interstitial quartz. A chemical analysis of one of the samples (no. 38, map; table 1) shows that the rocks are low-TiO_2 (less than 1 percent) tholeiites.

Two additional diabase samples (nos. 36 and 39) were collected along the northern border of the quadrangle. Sample 39 is a coarse-grained olivine gabbro that has a subophitic texture and contains 5 percent olivine, plagioclase, clinopyroxene, and Fe-Ti oxide minerals. The rock can be classified as either an olivine tholeiite or a high-Al gabbro (Al_2O_3 greater than 17 percent, moderate TiO_2, low K_2O). Sample 36 is chemically similar to the Late Cretaceous-early Tertiary calc-alkalic volcanic rocks throughout the Medfra quadrangle and is petrographically distinct from the three previously described gabbro samples (37, 38, and 39) in that it contains brown-gold hornblende instead of pyroxene. This rock is a fine-grained hypidiomorphic granular diabase composed of chiefly plagioclase, 20 to 30 percent hornblende, and 3 to 4 percent Fe-Ti oxide minerals.

K-Ar AGES

K-Ar ages and analytical data are summarized and described in four groups:

(1) Pelitic schists (Pzp€p) and associated rocks of the northern Kuskokwim Mountains in the north-central part of the quadrangle; (2) sheared grit, quartzite, and quartz-mica schist (Pzp€s) in the Slow Fork Hills in the southeast corner of the quadrangle; (3) small gabbro and diabase bodies (KDg) in the northwestern part of the quadrangle; and (4) Late Cretaceous-early Tertiary volcanic and plutonic rocks (TKn, TKc, TKg, TKm, TKcm, TKv, TKs).

Methods

Whole-rock samples and mineral concentrates were prepared by crushing, grinding, and sieving rock samples, and by standard electrostatic, magnetic, and heavy liquid procedures (Peterson, 1978) at the U.S. Geological Survey, Menlo Park, California, by C. L. Connor, E. J. Moll, M. L. Silberman, and C. E. Schwab, and at the laboratories of Kruger Enterprises, Cambridge, Mass., or Teledyne Isotopes, Westwood, N. J. Whole-rock and mineral concentrates were split and analyzed separately for potassium and argon. Potassium was analyzed by a lithium metaborate flame photometry technique (Ingamells, 1970) at the U.S. Geological Survey, Menlo Park. Argon was analyzed by standard techniques of isotope dilution and mass spectrometry (Dalrymple and Lanphere, 1969) at the U.S. Geological Survey, Menlo Park, by C. L. Connor, M. L. Silberman, and L. B. Gray, or at the laboratories of Kruger Enterprises and Teledyne Isotopes. The constants used in the age calculations are listed with the tabulated data. The plus-minus figures represent analytical uncertainty, at one standard deviation, and are based on analyses of the uncertainties of both the argon and potassium analytical procedures.

Schists in the north-central part of the quadrangle

A broad schist terrane crops out in the north-central part of the Medfra quadrangle. The schists are divided into three map units: felsic metavolcanic rocks (Pzp€v), calc schists (Pzp€c), and pelitic schists (Pzp€p). Although stratigraphic relationships are uncertain, the metavolcanic rocks and calc schists appear to overlie the pelitic schists. Stratigraphic evidence suggests that the schist terrane is at least pre-Permian and probably pre-Ordovician (Patton and Dutro, 1979).

Four K-Ar ages (table 2) from the pelitic schist unit (Pzp€p) in the Medfra quadrangle range from 274 to 514 m.y. and are strongly discordant. To the north in adjoining parts of the Ruby quadrangle nine additional K-Ar ages from micas and amphiboles yielded ages ranging from 254 m.y. to 921 m.y. (Silberman and others, 1979; M. L. Silberman and R. M. Chapman, unpub. data). Three of the samples from the northern Medfra quadrangle (nos. 41, 42, 43) occur near a small body of felsic volcanic rocks (TKs), but show no obvious correlation between age and proximity to the present exposures of volcanic rocks. The ages of micas from the schist unit appear to correlate roughly with grain size as the coarsest grained micas yield the oldest ages. K-Ar ages from this terrane are interpreted as minimum figures. Argon loss, resulting from regional metamorphism, has probably affected most of the samples. A preliminary isochron analysis, using the methods of Shafigullah and Damon (1974), on the entire set of K-Ar data, including the samples from the schist in the southern Ruby quadrangle, suggests that the resetting may have occurred during the middle Permian. Late Cretaceous-early Tertiary igneous activity has evidently not significantly affected the K-Ar ages of the schist as none of the samples, even those containing very fine grained micas, have been reset to the younger ages (Silberman and others, 1979). Although the available K-Ar ages clarify neither the age of the protolith nor the age of metamorphism, two of the ages from the Ruby quadrangle--921 m.y. from biotite from a sheared diorite, and 663 m.y. from muscovite from a mylonite schist (Silberman and others, 1979)--support the pre-Ordovician age suggested by stratigraphic evidence (Patton and Dutro, 1979).

Schists of the Slow Forks Hills

A greenschist metamorphic assemblage of sheared grit, quartzite, and quartz-mica schist (Pzp€s) underlies the Slow Fork Hills in the southeastern corner of the Medfra quadrangle and in adjoining parts of the Mt. McKinley quadrangle. This assemblage is interpreted to be the metamorphic equivalents of the quartzite, grit, and argillite unit (Pzp€q) in the Telida Mountains. The age of these metamorphic rocks is uncertain because no fossils were found either in the Telida Mountain grit unit (Pzp€q) or in the Slow Fork Hills metagrit unit (Pzp€s). The Telida Mountain rocks have been assigned an early Paleozoic to Precambrian age based on a probable correlation with similar rocks in the Livengood, Kantishna River, and Fairbanks quadrangles (Patton and others, 1980). If the metagrits of the Slow Fork Hills are the metamorphic equivalents of the grits of Telida Mountain, the Slow Fork rocks are also early Paleozoic to Precambrian in age.

The three K-Ar ages obtained from the sheared grit and quartz-mica schists do not provide diagnostic age for the protolith or age of metamorphism. Muscovite from two samples of metagrit yields ages of 108 $\pm$ 5 m.y. and 276 $\pm$ 8 m.y. (samples 44 and 45, table 2) and green amphibole from a metagabbro that crops out in metagrits and metaquartzites in the adjacent Mt. McKinley quadrangle (sample 46, table 2) gave an age of 421 $\pm$ 21 m.y. The two older ages, 421 and 276 m.y., are interpreted to be minimum figures, probably resulting from argon loss during regional metamorphism of unknown age. The 108-m.y.-old age came from an area where a positive magnetic anomaly occurs--similar to those associated with small gabbroic stocks (KDg) elsewhere in the quadrangle (Patton, Cady, and Moll, 1981). We suggest that this young age reflects argon loss during intrusion of a gabbro body about 108 m.y. ago beneath this area of the Slow Fork Hills.

Gabbro and diabase bodies in the northwestern part of the quadrangle

Four K-Ar ages from small gabbro bodies that crop out in the northwestern part of the quadrangle range from 85 to 267 m.y. The two oldest ages, 267 and 176 m.y. (nos. 37 and 38), are from low-TiO_2 tholeiites collected within 10 km of each other. These two samples were believed to be in sequence with the unit of cherty tuff, crystal and lithic tuffs, and volcanic breccia (JꞦt), but the isotopic age data suggest that they may be different ages.

A sample of olivine gabbro (no. 39), collected near the northern border of the quadrangle, gives a whole-rock age of 98 m.y. and appears to represent a Cretaceous intrusive event.

A sample of diorite/gabbro (no. 36) that was collected near the northern border of the quadrangle in a small upfaulted(?) block of the tuff-breccia unit (J₨t) gives a hornblende age of 85 m.y. Because of its calc-alkalic rather than tholeiitic affinity, this intrusive body is probably not related to the other dated gabbro bodies described. It may represent an older, subvolcanic phase of the nearby volcanic rock of the Nowitna River area (TKn), or it may represent a much older rock whose age was reset by argon loss during the Late Cretaceous-early Tertiary thermal event.

Poor exposures of the gabbro bodies and the possibility of partial resetting by postcrystallization thermal events preclude an unequivocal interpretation of their ages, but isotopic and chemical data suggest that they represent several ages of mafic igneous activity.

Late Cretaceous-early Tertiary volcanic and plutonic rocks

Late Cretaceous-early Tertiary volcanic and plutonic rocks occur throughout the Medfra quadrangle and comprise a wide range of rock types and occurrences. However, despite the diversity of rock types, occurrences, and dated material, samples from all six map units (TKn, TKc, TKg, TKm, TKv, TKs) give K/Ar ages in the range 59 to 71 m.y.

At the Nixon Fork Mine area and at Mystery Mountains, hydrothermally altered rocks yield ages of 69.1 and 63 m.y. ago, which suggest that hydrothermal alteration and mineralization was associated with at least some of the igneous activity. At Mystery Mountains, copper and tin anomalies occur in altered dacite porphyry (TKv) and in sedimentary hornfels adjacent to the intrusive porphyries (Ksu and Ksc). Chloritized biotite from weakly altered dacite porphyry at Mystery Mountains (no. 27) gave an age of 63 m.y. At the Nixon Fork Mine area, contact metasomatic gold-bearing skarn deposits (Herreid, 1966) occur in metamorphosed limestones (DOld) adjacent to quartz monzonite (TKm). Quartz porphyry intrusions, too small to be shown on the map, are associated with the quartz monzonite. A sample of altered and mineralized porphyry from an open-pit at the Nixon Fork Mine gave a hydrothermal muscovite age of 69.1 $\pm$ 2.1 m.y. (no. 32), the same age within analytical uncertainty as our date on biotite from an unaltered quartz monzonite sample (no. 21) and Reed and Miller's (1971) previously published K-Ar age of 68.6 $\pm$ 2 m.y. on the pluton.

Small intrusive bodies (TKcm) in the volcano-plutonic complexes at Page Mountain (no. 8, table 1) and Cloudy Mountain (no. 9, table 1) yield the same K-Ar ages, within analytical uncertainty, as unaltered andesitic volcanic rocks (TKc) (Page Mountain, no. 4; Cloudy Mountain, no. 6, table 1), suggesting that the intrusive and volcanic rocks in these complexes are consanguineous. The intrusive bodies are probably late stage differentiates of the magmas that produced the more mafic volcanic rocks, as suggested by Silberman and others (1979).

Figure 4 graphically summarizes the K-Ar ages for Late Cretaceous-early Tertiary rocks from table 2. Concordant mineral pair ages from several samples of Late Cretaceous-early Tertiary igneous rocks (nos. 4, 6, 17, 18, table 2) indicate that this igneous episode is well documented by the K-Ar data. The overlapping ages and calc-alkaline nature of the plutonic, hypabyssal, and volcanic rocks suggest that the hypabyssal and plutonic rocks represent subsurface magmas related to the same magmatic episode that produced the volcanic rocks.

Volcanic and plutonic rocks in the age range 59-75 m.y. occur in much of western Alaska in a vast region stretching from the Arctic Circle south to Hagemeister Island and west to St. Matthew and St. Lawrence Islands (Moll and Patton, 1981). Their ages and distribution show that igneous activity was widespread throughout much of western Alaska in Late Cretaceous-early Tertiary time. An earlier 80- to 110-m.y.-old (Silberman and others, 1979) calc-alkalic igneous episode was restricted to an area north of the Medfra quadrangle between the Brooks Range and the Yukon River. Most of these older rocks are plutonic and many have considerably larger outcrop areas than the Late Cretaceous-early Tertiary plutonic and volcanic bodies.

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KEY TO PLUTON LOCALITIES

A	Cripple Creek Mountains
B	West Fork
C	Sunshine Mountains
D	Meadow Creek
E	Nixon Fork
F	Whirlwind Ridge
G	Von Frank Mountain
H	Shepherd Creek
I	Upper Sulukna River
J	Stone Mountain
K	Telida Mountains
L	Appel Mountain
M	Cloudy Mountain
N	Alone benchmark
O	Page Mountain

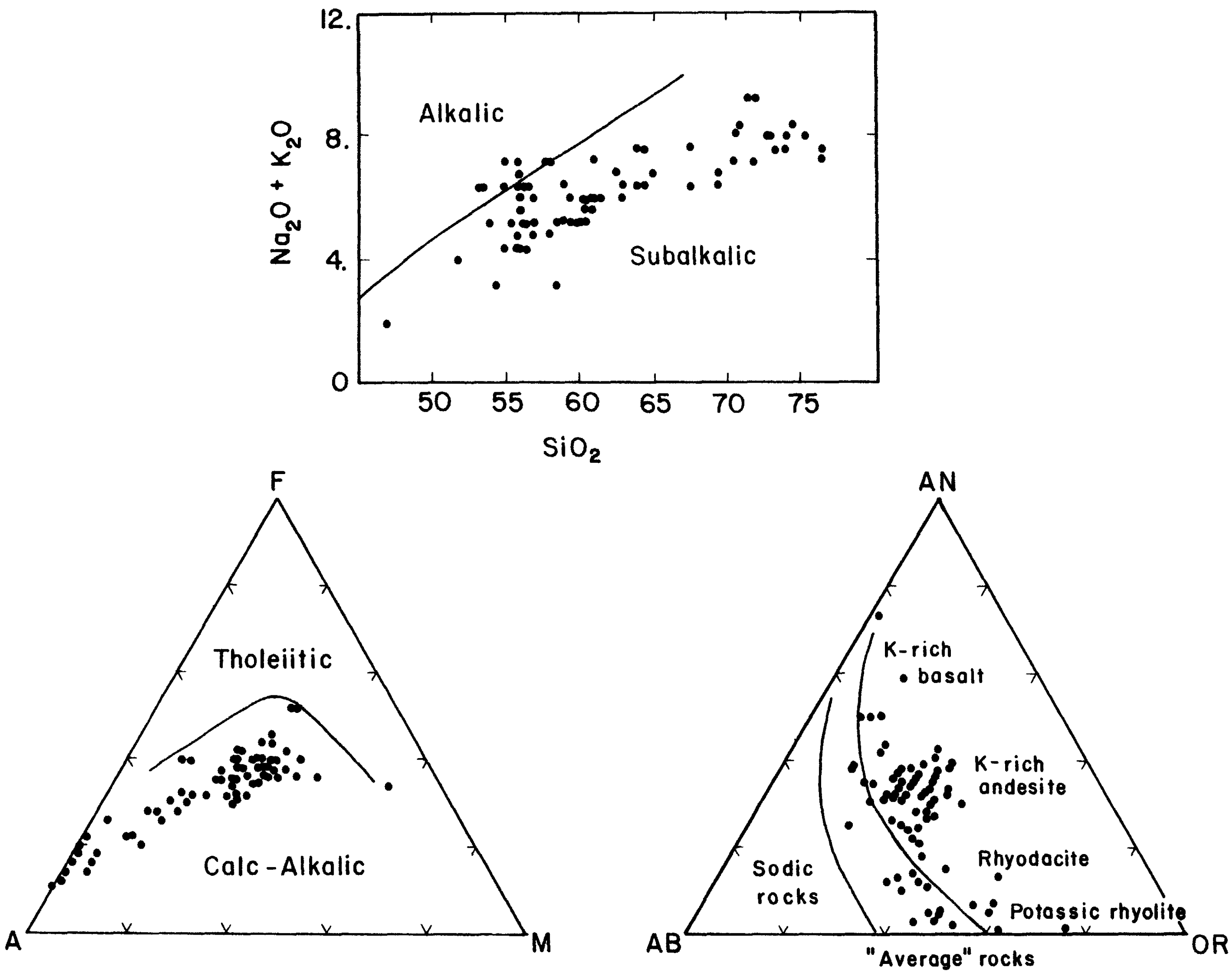

Figure 1. Late Cretaceous-early Tertiary volcanic, hypabyssal, and plutonic rocks of the Medfra quadrangle plotted on three classification diagrams from Irvine and Baragar (1971): AFM ($A = K_2O + Na_2O$; $F = FeO + MnO + 0.9\ Fe_2O_3$; $M = MgO$) total alkalis vs. SiO_2 and AB-AN-OR diagrams (weight percent CIPW norms). According to the classification diagrams, the suite is high-K calc-alkalic.

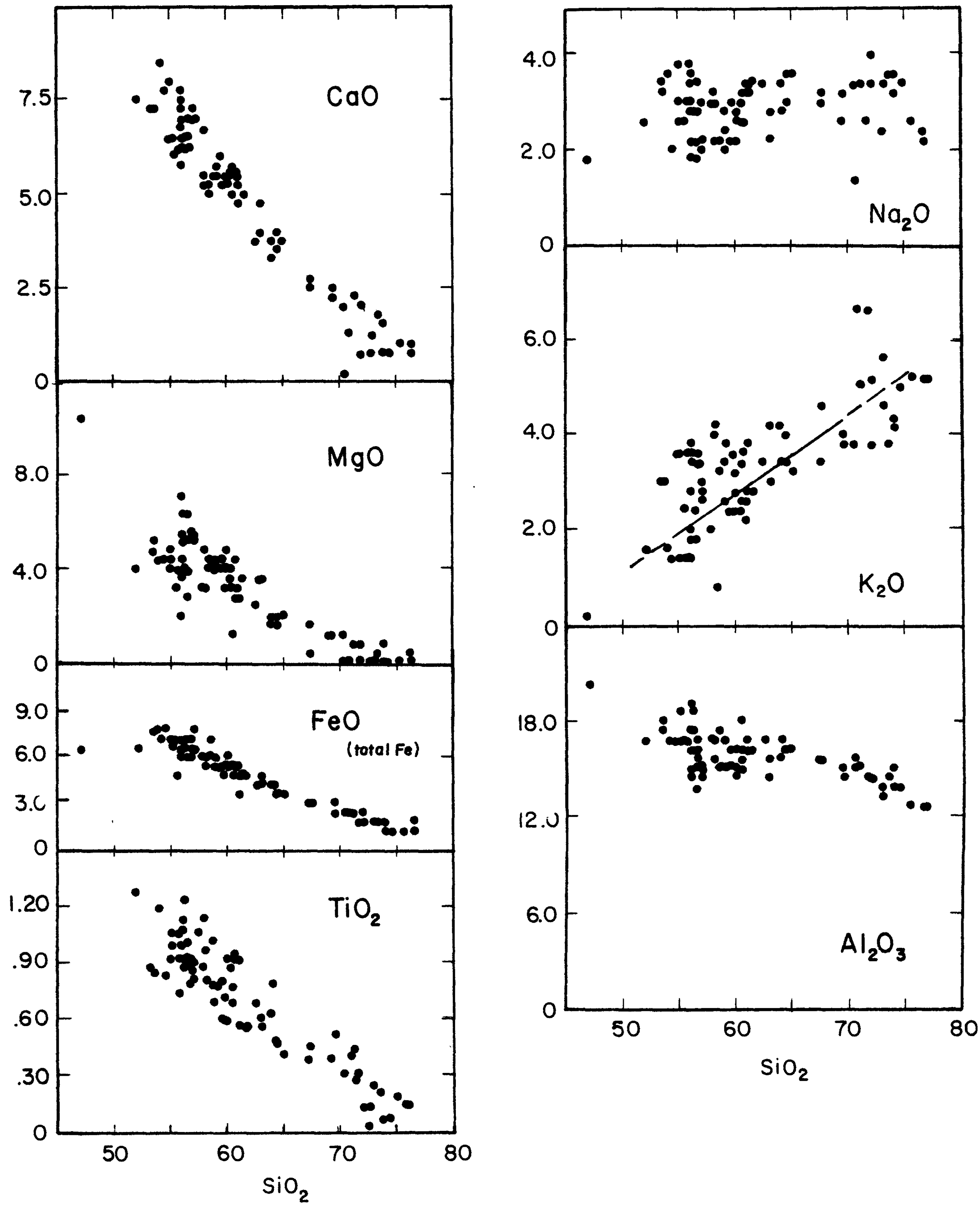

Figure 2. Major-element variation with SiO_2 content for Late Cretaceous-early Tertiary volcanic, hypabyssal, and plutonic rocks from the Medfra quadrangle.

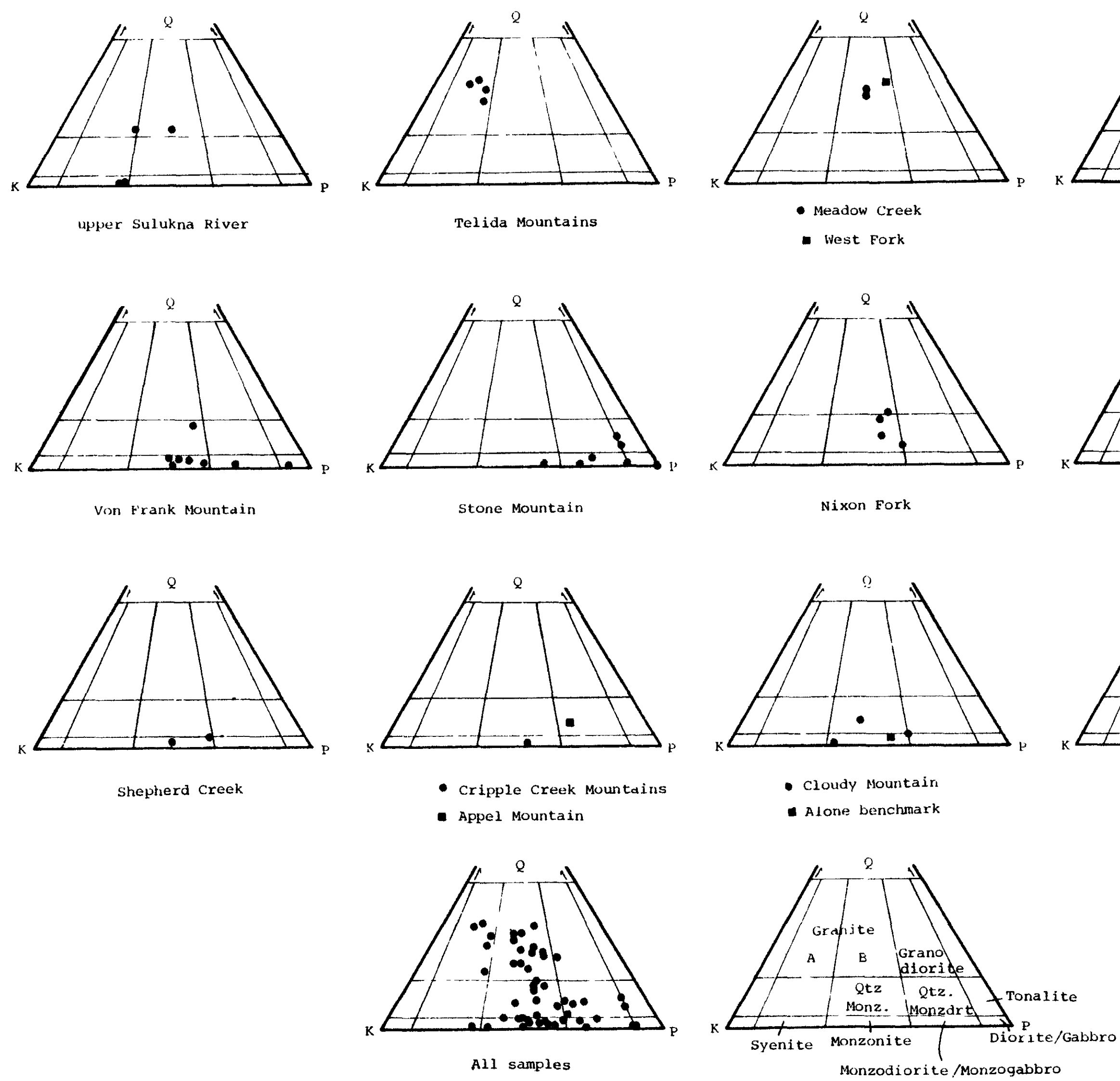

Figure 3. Point count data for plutonic rocks in the Medfra quadrangle plotted on a quartz-potassium feldspar-plagioclase (Q-K-P) ternary diagram. Each point represents 800-1100 points counted on stained slabs with the exception of Telida Mountains (650-700 points), upper Sulukna River (350-550 points), and Page Mountain (150-200 points on stained thin sections). Modal classification modified after Streckeisen (1973). In this classification scheme the granite field is divided into A and B types on the basis of K-feldspar-plagioclase ratios.

Figure 4. Histogram showing the distribution of 30 K-Ar ages for the six Late Cretaceous-early Tertiary volcanic, hypabyssal, and plutonic map units. The igneous activity peaked 65 to 70 m.y. before present.

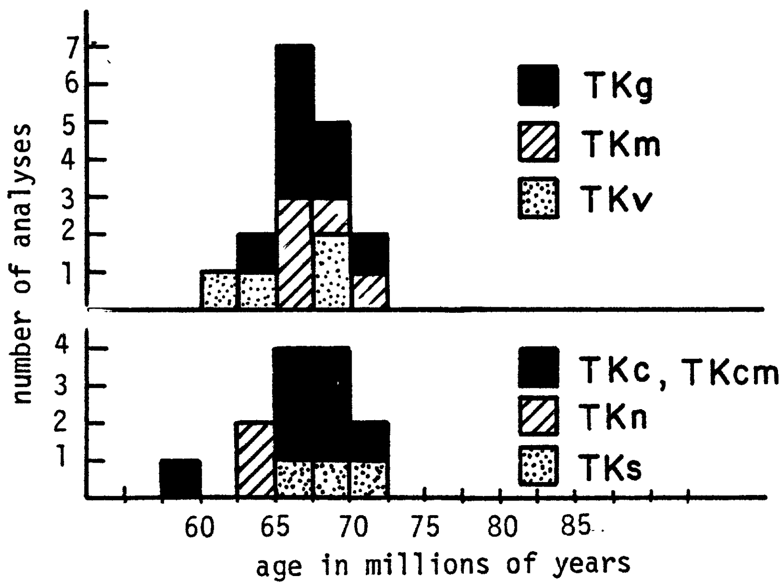

Figure 5. Histogram showing the distribution of K-Ar ages for units older than Late Cretaceous-early Tertiary. All three dated units--Sheared grit, quartz-mica schist (PzpCs); pelitic schist (PzpCp); and gabbros (KDg)--give strongly discordant K-Ar ages.