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THE ANVIL PLUTONIC SUITE, FARO, YUKON TERRITORY

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ABSTRACT

The Anvil plutonic suite consists of three phases: a peraluminous muscovite-biotite granite (Mount Mye phase) and two metaluminous to peraluminous, hornblende-biotite granodiorite and minor granite intrusions (Orchay and Marjorie phases). The suite is massive or foliated, equigranular or seriate, and contains alkali feldspar megacrysts. Marjorie phase is characteristically porphyritic.

Geochemical trends are irregular for the suite and for individual phases. High K_2O , low-CaO, and low-MgO compositions typify the silicic, calc-alkaline suite. Hornblende-bearing phases contain less SiO_2 , K_2O , Rb, and more calcemic oxides, TiO_2 , Sr, Ba, and Y than the Mount Mye phase and are compositionally similar to coeval South Fork volcanics.

Isochrons from some of the Orchay phase whole-rock samples ($t = 99 \pm 2.5$ Ma; $^{87}Sr/^{86}Sr_i = 0.7161 \pm 0.0001$) and from whole-rocks and minerals of the Mount Mye phase ($t = 100 \pm 2$ Ma; $^{87}Sr/^{86}Sr_i = 0.7405 \pm 0.0001$) indicate they are coeval but not comagmatic, accounting for the lithologic, petrographic, and geochemical distinctions. Similar K-Ar isotopic ages (81-102 Ma) suggest rapid cooling and therefore high level emplacement. Together, the isotopic ages provide a minimum (youngest) age for the main deformation of the surrounding metasediments and a

ABSTRACT (cont'd)

maximum (oldest) age for movement along the Tintina Fault.

A petrographically and geochemically distinct sample from the Orchay phase yielded a Rb-Sr isochron age of 61 ± 1.5 Ma and an initial $^{87}\text{Sr}/^{86}\text{Sr}$ ratio of 0.7090 ± 0.0001 , implying intrusive activity in the Paleocene.

Field relations, lithology, petrography, geochronometry, and geochemistry suggest that the Orchay and Marjorie phases are plutonic equivalents of the South Fork volcanics. Similarity in plutonic style characterize the extensive mid-Cretaceous igneous event in southeast Yukon.

INTRODUCTION

Near Faro, Yukon Territory, Canada, the Anvil Range is partly underlain by the Anvil plutonic suite. The area is well known for important stratiform Pb-Zn-Ag-barite massive sulphide deposits of which Faro deposit is the best known and the only one being mined.

Mineralization occurs in Upper Proterozoic to Lower Paleozoic metasedimentary and metavolcanic rocks (Jennings et al. 1980; Carne and Cathro 1982; Jennings and Jilson, in preparation) which are the southwestern part of the North American miogeocline (Tempelman-Kluit 1972; Jennings et al. 1980; Gordey, 1983). The miogeocline is separated from the allochthonous Yukon-Tanana suspect terrane (Coney et al. 1980) by the Vangorda fault zone (Fig. 1), and all units were subsequently offset 450 km along the dextral Tintina transcurrent fault (Tempelman-Kluit 1977).

Upper Proterozoic to Mississippian rocks of the miogeocline were intruded by the Anvil (Tempelman-Kluit 1972) and Orchay batholiths of the Anvil plutonic suite. Timing of movement along the area's major faults is constrained by the suite's age because plutons intrude the Vangorda fault and are displaced along the Tintina fault. Nature of the western and central portions of the Anvil plutonic suite was established by reconnaissance mapping (Fig. 1), sampling for Rb-Sr isotopic dating, and preliminary petrography (Pigage) and by detailed petrography and geochemistry of the samples (Anderson). Tables 1-3 summarize major, minor and trace element compositions and Rb-Sr isotopic

data; Tables 4-6 list detailed modes, analyses, CIPW norms¹ and analytical methods and precision for chemical analyses.

The results permit comparisons with the coeval South Fork volcanics to the east (e.g., Wood 1981; Wood and Armstrong 1982), the mid-Cretaceous Selwyn plutonic suite (e.g., Anderson 1982, 1983) to the northeast and with genetic and tectonic pluton classifications.

GEOLOGIC SETTING

The geologic framework for the area (Roddick and Green 1961a, b; Tempelman-Kluit 1972) has been refined by detailed mapping of the metasedimentary and metavolcanic country rocks of the Anvil plutonic suite by Jennings et al. (1980) and Gordey (1983). The suite forms the core of a northwest-trending structural culmination called the Anvil Arch (Tempelman-Kluit 1972). Surrounding metasediments contain evidence for at least five phases of deformation with Buchan-type metamorphism (of Miyashiro (1961)) accompanying the first two. Metamorphic grade falls to lower greenschist facies away from the Anvil batholith. The second phase foliation in the metasediments dominates. Doming that forms the Anvil Arch is related to the third (or later) deformation (D. Jennings, personal communication 1982).

¹Tables 4-6 are available, at a nominal charge, from the Depository of Unpublished Data, National Science Library, National Research Council of Canada, Ottawa, Canada K1A 0S2.

The suite is probably syn- to post-kinematic. Anvil batholith contacts with metasedimentary country rock are typically sharp and concordant with phase two foliation. The plutonic suite clearly crosscuts stratigraphy and structure in map pattern; however, normal faults mark the contact locally, with the intrusions in the footwall.

In pelitic schist adjacent to the intrusions, the typical assemblage andalusite-staurolite-garnet-biotite-muscovite-quartz-plagioclase with local fibrolite and cordierite indicates high level emplacement for the suite. Absence of kyanite restricts pressure to less than 400 MPa (4 kb; Holdaway 1971) and therefore, stratigraphic cover to less than about 13 km during emplacement. Absence of muscovite as a liquidus phase (see petrography) supports low pressure at emplacement (Anderson and Rowley 1981; Clarke 1981).

East of the Anvil and Orchay batholiths, deformed Paleozoic and Mesozoic sedimentary rocks of the miogeocline are unconformably overlain by the mid-Cretaceous South Fork volcanics (Roddick and Green 1961a, b; Wood 1981). The extensive, dark, massive volcanics are (hornblende-) biotite-quartz phyrlic dacite, crystal-lithic lapilli tuff, and minor calc-alkaline andesite, dacitic ashflow tuff, and basaltic andesite. Well-exposed, unfaulted contacts with basement rocks are uncommon (Roddick and Green 1961b). Wood and Roddick and Green considered that the South Fork volcanics were extruded across terrain of variable, moderate relief, underlain in part

by a mid-Cretaceous biotite quartz monzonite pluton. Small, massive and highly altered biotite-hornblende porphyry granodiorite stocks or plugs in porphyritic dacite are likely. the hypabyssal link between the volcanics and comagmatic hornblende-bearing plutonic phases.

ANVIL PLUTONIC SUITE

Screens of metasedimentary rock separate granite to granodiorite bodies which form the three major phases of the Anvil plutonic suite (Fig. 1). The abundance of pendants suggests that the intrusion's roof is presently exposed.

The Mount Mye phase is an extensive, heterogeneous, hypidiomorphic-granular biotite-muscovite granite northeast of the Faro deposit (Figs. 1 and 2). Outcrop-scale variations in biotite and coarse grained muscovite abundance are characteristic.

The Orchay phase is biotite + hornblende granodiorite and granite northwest and southeast of the Mount Mye phase (Figs. 1 and 2) and resembles it texturally. Contact relations between the Mount Mye and Orchay phases are unknown.

The Marjorie phase, a large porphyritic biotite-hornblende granite intrusion characterized by anhedral, smoky grey quartz phenocrysts, forms the suite's southeastern part (Figs. 1 and 2). It intrudes the metasedimentary rocks and the Mount Mye phase as porphyritic quartz monzonite dykes and in map pattern appears to crosscut the Orchay phase. It was considered to be a subvolcanic equivalent of the mid-Cretaceous South Fork

volcanics by Roddick and Green (1961a, b; their unit 13), but neither this nor an unconformity between South Fork volcanics and a biotite quartz monzonite (Wood 1981) could be confirmed because of poor exposure of field relations.

Phases in the suite range from equigranular to seriate, megacrystic to porphyritic, and massive to foliated. Mount Mye and Orchay phases are locally strongly to weakly foliated, but the Marjorie phase is consistently massive. Foliation in the Mount Mye phase is a deformation texture defined by interstitial mica aggregates coplanar with elongate, fine-grained, recrystallized quartz aggregates which enclose feldspar porphyroclasts.

Northeast-trending, pale green, hypabyssal hornblende diorite dykes up to 100 metres thick intrude the Mount Mye phase, and near the Faro deposit are in turn intruded by the Marjorie phase (D. Jennings, personal communication 1982), corroborating other interphase intrusive relations.

PETROGRAPHY

Mineral abundance, texture, composition, and alteration assemblages distinguish the phases in the Anvil plutonic suite and permit further subdivision of the Orchay phase.

Mount Mye Phase:

Euhedral or subhedral apatite, zircon, biotite, plagioclase, muscovite (in sample 8586B), allanite, and anhedral quartz, alkali feldspar, and tourmaline (in approximate

crystallization order) form the main constituents of the seriate and megacrystic Mount Mye granite (Fig. 2). Chlorite and muscovite alteration products of biotite and minor, fine-grained sericitic alteration of plagioclase are uncommon. Myrmekite is more common in the Mount Mye phase than in the hornblende-bearing phases. Common quartz subgrains, scattered bent micas, and mortar texture are evidence of the strain in massive and foliated Mount Mye samples.

Coexisting biotite and muscovite characterize the Mount Mye phase. Biotite is characterized by its moderate absorption, reddish brown pleochroism (α' = pale orange brown or yellow; β = γ' = orange or reddish brown), and common, round, fine-grained zircon (or monazite?) inclusions with associated radiation-damage haloes. Apatite inclusions in biotite are uncommon. Plutonic biotite is petrographically identical with biotite in the country rock schist.

Coarse muscovite has at least two distinctive textures and is distinctive of the Mount Mye phase. Commonly, it forms anhedral or subhedral aggregates or grains locally intergrown with biotite or in plagioclase cores. Raggedness and paragenesis of this muscovite suggest that it is not a primary liquidus phase. However, it is not a retrograde mineral and probably formed as a high temperature reaction product of earlier aluminous minerals. Rarely (e.g., sample 8586B), muscovite is locally coarser grained than accompanying biotite, is not preferentially associated with any particular mineral, and forms euhedral, separate grains.

Scattered fibrolite sprays may occur with the clusters of anhedral muscovite. One sample (AR10a) is distinguished by rare clots of fine-grained randomly oriented white mica which may mark sites of original peraluminous minerals (garnet or cordierite?). Garnet is observed locally in the aplitic Mount Mye phase.

Oligoclase (An₂₅₋₃₁) is subhedral with poorly preserved albite and Carlsbad-albite twins and oscillatory and normal zoning. Rare apatite, finer grained plagioclase, and biotite inclusions are locally arranged about plagioclase cores. Subhedral to anhedral, clear alkali feldspar is megacrystic, microperthitic, and twins along the Carlsbad twin and uncommonly, microcline twin laws. Apatite, plagioclase, biotite, quartz, and muscovite inclusions are common and arranged concentrically about alkali feldspar interiors in a few places.

Euhedral allanite and anhedral tourmaline appear late in the crystallization sequence. Allanite, commonly euhedral and strongly zoned, also forms fracture-filling veinlets in quartz. Tourmaline (ϵ = pale yellow, ω = yellowish or bluish green) is interstitial with respect to quartz and alkali feldspar.

Orchay and Marjorie Phases:

Constituent minerals in the granodiorite and granite of the Orchay and Marjorie phases are (in approximate crystallization order): euhedral or subhedral apatite, zircon, plagioclase, clinopyroxene (in sample AR2), hornblende, and biotite, and subhedral or anhedral and interstitial quartz, alkali feldspar,

allanite, and tourmaline (Fig. 2). Myrmekite is unimportant compared to the Mount Mye phase. Hornblende-bearing phases are little deformed; strain features are restricted to undulatory extinction in quartz. Porphyritic Marjorie phase differs texturally from seriate Orchay phase but the two phases are mineralogically identical.

Ferromagnesians are distinguished by strong absorption (hornblende: α' = pale brown; β = deep olive or brownish green; γ' = grass green; and biotite: α' = pale brown; β = γ' = dark chocolate brown) and scattered apatite, zircon, plagioclase, and rare allanite and quartz inclusions. Pleochroism in hornblende is locally patchy, especially in grain cores. Hornblende in sample AR2 has common clinopyroxene cores and scattered, possibly primary, subhedral magnetite. Epidote, chlorite, and titanite alteration of hornblende and biotite are more common than in the Mount Mye phase.

Plagioclase is subhedral and encloses apatite, zircon, and rare hornblende; quartz and alkali feldspar are anhedral and interstitial. Andesine is common (An_{34} - An_{53}) and labradorite rare. Normal and oscillatory zoning account for compositional variation of about An_5 within grains. Irregular cores are common in plagioclase of the hornblende-bearing phases (abundant in sample AR2); they appear to be more calcic and are altered in preference to rims. Sericite and sausserite alteration of plagioclase cores are more common than in the Mount Mye phase.

Quartz enclosed by alkali feldspar is subhedral; it is euhedral where it forms phenocrysts in the Marjorie phase.

Locally, quartz also forms optically continuous inclusions in apparently earlier formed minerals. Alkali feldspar is turbid, microperthitic, and exhibits Carlsbad twins. In scattered, subhedral alkali feldspar megacrysts, concentric zoning may be outlined by fine-grained plagioclase, biotite, hornblende, and quartz inclusion trains.

Subhedral or euhedral, commonly zoned allanite is associated with radial fractures in enclosing quartz and fracture-fillings in plagioclase and quartz. Brown tourmaline is interstitial to quartz and alkali feldspar.

Hornblende Diorite Dykes

Hornblende diorite dykes have large (2 centimeter) dark green hornblende phenocrysts and smaller plagioclase phenocrysts (partly rimmed by anhedral alkali feldspar) in an aphanitic, pale green matrix of intergrown plagioclase, chlorite, opaque minerals, and minor quartz. Dyke alteration, featuring replacement of hornblende phenocrysts by chlorite-epidote aggregates and plagioclase by sausserite, is widespread.

GEOCHEMISTRY

Major, minor, and trace element compositions for samples from the Anvil plutonic suite and South Fork volcanics permit intraphase, interphase, and volcanic-plutonic comparisons. Geochemical data are summarized in Table 1 and presented in Figure 3.

Major and minor element concentrations in the plutonic rocks are similar to those in other low-CaO, low-MgO, high K₂O calc-alkaline granitoids (e.g., Turekian and Wedepohl 1961; Ewart 1979; White and Chappell 1983; Table 1 and Figs. 3(a), (b) and (c)). Trends on Harker variation diagrams are irregular for many oxides for the suite and constituent phases (Fig. 3(c)).

Hornblende-bearing samples have a slightly greater compositional spectrum than the Mount Mye phase and are distinguished by higher mafic oxide contents (e.g., TiO₂ (Fig. 3(i)), total iron and MgO (Fig. 3(c)), MnO, CaO (Fig. 3(d))), and lower silic oxide contents (e.g., SiO₂ (Figs. 3(a) and (c)) and K₂O (Figs. 3(d) and (h))). The Marjorie and Orchard phase compositions are similar but one Orchard phase sample (AR2) is more basic and mafic. Sample 43D, a biotite quartz monzonite associated with the South Fork volcanics, is compositionally close to the Orchard and Marjorie phases. In Figure 3, it plots between compositions for the volcanics and the Mount Mye phase. Aplitic sample compositions (AR17 and 9087B) from Orchard and Mount Mye phases are nearly identical.

Hornblende-bearing phases and volcanics are characterized by lower differentiation index (D.I. < 80 weight per cent; Thorton and Tuttle 1960), lesser normative corundum contents (< 1.13 weight per cent) or normative diopside, and smaller Shand index ($A/CNK = \text{molar } Al_2O_3 / (CaO + Na_2O + K_2O) < 1.08$) compared with the Mount Mye phase (D.I. > 81 weight per cent; normative corundum > 2.49 weight per cent and $A/CNK = 1.17-1.30$; see Figs. 3(f) and (g)).

Trace elements also distinguish the various granites and volcanics (Table 1). Higher Sr, Ba, La, Y contents and K/Rb and Ba/Rb ratios, and lower Rb, Rb/Sr and K/Ba for most Orchard and Marjorie phase samples (and sample 43D) separate them from of the Mount Mye phase samples (e.g., Fig. 3(e)). AR2 is distinguished from other Orchard samples by higher Ba/Rb and Cr, Ni, and V contents and lower Rb/Sr and K/Ba.

As noted by Wood (1981) and Wood and Armstrong (1982) and shown in Figures 3(a), (b), (c), and (h), the K-rich, subalkaline South Fork volcanics are characterized by some calc-alkaline affinities and moderately regular compositional variation. Higher CaO, total iron, and MgO and lower Al₂O₃ and alkali contents distinguish the volcanics from classic calc-alkaline suites. The volcanics are compositionally similar but not identical to the hornblende-bearing granitoids rather than to the Mount Mye phase. South Fork volcanics share many trace element characteristics with the hornblende-bearing granitoids, but are distinguished from both granite types in the suite by higher Cr, Ni, V, and Ba/Rb and lower Rb/Sr and K/Ba.

General compositional fields for plutons with and without hornblende in the Selwyn plutonic suite (Anderson 1983; Anderson et al. 1983; Sinclair, in press) are included for comparison in some variation diagrams of Figure 3. Compositional overlap of the respective bipartite subdivisions of each suite is obvious and indicates a similar geochemical signature for mid-Cretaceous plutonism in southeastern Yukon. No analog for the highly evolved, lithophile-element-enriched, hornblende-free siliceous plutons of the Selwyn plutonic suite associated with tungsten

skarns are known in the Anvil plutonic suite (e.g., Fig. 3(a), (e), and (f); Anderson 1983; Anderson et al. 1983; Sinclair, in press).

Some of the geochemical criteria (i.e., compositional spectrum, A/CNK values, and normative corundum contents, and TiO₂-Zr variations (Figs. 3(c), (f), (g), and (i)), and petrographic features suggest I-type affinities for the Orchard and Marjorie phases and an S-type character for the Mount Mye phase (White and Chappell 1983). Other criteria, such as Na₂O-K₂O (Fig. 3(h)), Fe₂O₃-FeO variations, and trace element abundances (e.g., Cr, Ni) separate the granites in the suite but do not compare with classic I- or S-type granitoids.

GEOCHRONOMETRY

K-Ar ISOTOPIC AGES

Previously determined K-Ar isotopic ages for the Anvil plutonic suite and surrounding schist in the study area and in the Orchard Lakes area indicate cooling ages between 81-104 Ma (Wanless et al. 1967, 1970, 1972, 1973; Wood and Armstrong 1982; see Fig. 1).

Four K-Ar isotopic ages for biotite or hornblende phenocrysts from three units in the South Fork volcanics east of the study area show an age range similar to that of the granitic rocks, (from 94-102 Ma; Wood and Armstrong 1982). Previously determined K-Ar isotopic ages of 100 and 117 Ma for porphyritic dacite (Lowdon et al. 1963, p. 27) are discredited because no

estimate of atmospheric ^{40}Ar contamination was made during analysis.

Rb-Sr ISOTOPIC RESULTS

Previous Rb-Sr isotopic studies in the area (Wood 1981; Wood and Armstrong 1982) are limited to work on whole-rocks and mineral-separates from the South Fork volcanics and an associated biotite quartz monzonite pluton east of the study area. Whole-rock and plagioclase and biotite mineral-separates from two samples yielded isochron ages of 89.2 ± 1.9 Ma ($^{87}\text{Sr}/^{86}\text{Sr}_i = 0.7278 \pm 0.0001$) for the pluton and 84.2 ± 1.7 Ma ($^{87}\text{Sr}/^{86}\text{Sr}_i = 0.7170 \pm 0.0001$) for a hornblende-biotite andesite tuff. The 5-10 million year difference between the older K-Ar and younger Rb-Sr isochron isotopic ages for a given sample was attributed to low grade metamorphism or incipient weathering of the biotite in each case. An enigmatic whole-rock isochron age of 135.5 ± 9.8 Ma ($^{87}\text{Sr}/^{86}\text{Sr}_i = 0.7160 \pm 0.0002$) for six samples from the South Fork volcanics probably reflects heterogeneous distribution of the $^{87}\text{Sr}/^{86}\text{Sr}$ initial ratio throughout the magma resulting from proportionately greater contamination of siliceous magma by sialic crustal strontium (see Fig. 5).

Representative samples of the three phases in the Anvil plutonic suite were selected for isotopic studies. Sample locations are indicated in Figure 1 and listed in Table 2. Analytical results, calculated ages, and initial ratios for twelve whole-rock samples and eleven mineral-separates are listed in Tables 2 and 3 and plotted in Figures 4 and 5.

Analytical techniques, errors, and regression methods are outlined in Appendix I.

The Mount Mye phase yielded a very radiogenic suite of samples with measured $^{87}\text{Sr}/^{86}\text{Sr}$ ratios greater than 0.74. Whole-rock samples show an exceptional scatter of $^{87}\text{Sr}/^{86}\text{Sr}$. Combined whole-rock and mineral-separate results for one sample (9088) produced an excellent isochron with an apparent crystallization age of 100 ± 2 Ma and an initial $^{87}\text{Sr}/^{86}\text{Sr}$ ratio of 0.7405 ± 0.0001 (Table 3 and Figs. 4 and 5). Whole-rock 9087B plots on this isochron, but other whole-rock Mount Mye samples plot off it.

Orchay phase samples are less radiogenic than Mount Mye samples with whole-rock $^{87}\text{Sr}/^{86}\text{Sr}$ ratios considerably scattered about a value 0.72. Isochron WR1, calculated using only whole-rock data from the Orchay batholith (Figs. 1 and 5 and Table 3), yielded an apparent age of intrusion of 99 ± 2.5 Ma with an initial $^{87}\text{Sr}/^{86}\text{Sr}$ ratio of 0.7161 ± 0.0001 . Sample AR4 also plots on this isochron, but not sample AR7.

Sample AR2 was initially considered to be part of the Orchay phase on lithologic and petrographic grounds. It differs from other Orchay phase samples geochemically and is isotopically unique. A younger, mineral-separate plus whole-rock isochron age of 61 ± 1.5 Ma, and a significantly lower $^{87}\text{Sr}/^{86}\text{Sr}$ initial ratio of 0.7090 ± 0.0001 was obtained (Figs. 4 and 5) from the sample.

Biotite contamination in sample AR2's hornblende separate led to an ambiguous interpretation of the M1 isochron because the hornblende analysis rests on a mixing line between pure

hornblende and biotite endmembers. However, a similarly young, isochron age results if only the whole-rock and feldspar data are used to calculate an age. Consequently the young age is believed to mark an intrusive event and not an isotopic resetting of the biotite.

One sample (AR16) was collected from the Marjorie phase of the suite. It is isotopically as well as geochemically indistinguishable from Orchay phase whole-rocks (Fig. 5).

A biotite quartz monzonite (sample 43D) associated with the South Fork volcanics, has a geochemical composition between that of the Orchay and Mount Mye phases. Its correlation with the Anvil plutonic suite phases is uncertain. Whole-rock plus mineral separate Rb-Sr isotopic data reported for it (Wood and Armstrong 1982) plots between the results for the Orchay-Marjorie phases and Mount Mye phase in this study (Fig. 5).

The Marjorie phase has been considered a subvolcanic equivalent of the South Fork volcanics. The Rb-Sr isotopic data for six whole-rock samples from the volcanics (Wood and Armstrong 1982), are plotted on Figure 5 and in themselves yielded an enigmatic Early Cretaceous isochron age (discussed above). They plot close to the data cluster for the Orchay and Marjorie phases and, in some cases, also on the independently calculated whole-rock isochron for samples AR14, AR15, and AR17 from the Orchay phase.

DISCUSSION

Anvil plutonic suite can be split into coeval mid-Cretaceous (81-102 Ma) phases on the basis of essential hornblende or muscovite. Phases are also distinguished by structural grain, phenocryst or megacryst assemblage, and interphase intrusive relations. Petrography and major and trace element geochemistry confirm the twofold division. They point out intraphase distinctions (e.g., between sample AR2 and other Orchay phase samples) and interphase similarities (e.g., between the Marjorie and Orchay phases). Regionally, there is a transition in composition within the suite from hornblende-bearing phases to a biotite quartz monzonite east of the study area (Wood and Armstrong 1982) to the muscovite- and biotite-bearing Mount Mye phase. These comparisons are supported by detailed Rb-Sr isotopic geochemistry for selected samples.

Crystallization (Rb-Sr isochron) and cooling (K-Ar mineral) isotopic ages for two of the three phases overlap around 100 Ma. Concordance of the two isotopic systems suggests that crystallization of the phases was coeval and was followed by rapid cooling. The structural setting indicates that shallow intrusion of the suite was contemporaneous with, or slightly younger than phase two deformation and syn- to postkinematic metamorphism. The isotopic ages therefore provide a minimum age (100 Ma) for the deformation and a maximum age for later movement along the Tintina Fault (Tempelman-Kluit 1972).

The South Fork volcanics yielded K-Ar isotopic ages the same as those for the Anvil plutonic suite (Wood and Armstrong 1982). Phenocryst petrography, whole-rock geochemistry, and $^{87}\text{Sr}/^{86}\text{Sr}$ isotopic ratios for the volcanics strongly resemble those for the Orchard and Marjorie phases (Fig. 5). Together with the proximity of the suite to the volcanics and the hornblende porphyry granodiorite stocks and hornblende diorite dykes, the data support Roddick and Green's (1961a, b) suggestion that part of the suite represents the plutonic equivalent of the South Fork volcanics.

Later intrusion is indicated by the 61 ± 1.5 Ma isotopic age obtained for the petrographically and geochemically distinctive sample AR2. The age is unlikely to be a metamorphic or post-emplacement homogenization date because the $^{87}\text{Sr}/^{86}\text{Sr}$ initial ratio of 0.7090 ± 0.0001 is lower than initial ratios for all other phases of the suite. Probably this sample represents a dyke or intrusive stock which was emplaced during the Paleocene.

Southwest of the Tintina fault (150-175 km south and southeast of the study area) similar, anomalously young K-Ar isotopic ages were determined for part of the Quiet Lake batholith (70.1 ± 2.6 Ma; Wanless et al. 1979, p. 29) and Black River batholith (53.9 ± 1.3 and 46.9 ± 2.6 Ma; Stevens et al. 1982, p. 21).

Two of the three coeval phases in the Anvil plutonic suite can be distinguished isotopically. The Mount Mye phase is very radiogenic with a high $^{87}\text{Sr}/^{86}\text{Sr}$ initial ratio (0.7405 ± 0.0001) whereas the Orchard phase is less radiogenic but is still

characterized by a high initial ratio (0.7161 ± 0.0001). The initial $^{87}\text{Sr}/^{86}\text{Sr}$ ratio for the Mount Mye phase is consistent with its more peraluminous mafic mineralogy and geochemistry. The Marjorie and Orchard phases are isotopically indistinguishable.

High $^{87}\text{Sr}/^{86}\text{Sr}$ initial ratios characterize assimilation and/or anatexis of radiogenic sialic crust during magma genesis (Faure and Powell 1972; Faure 1977; Pitcher 1979). In the western North American Cordillera, contamination of upper mantle magmas by Precambrian crust is indicated by a northeastward initial ratio increase beyond 0.706 (Armstrong et al. 1977; Armstrong 1979). Mesozoic to Tertiary, syn- to post-tectonic, S-type granitoids are commonly associated with areas of Phanerozoic, medium to high grade metamorphism northeast of the 0.706 line in the northwestern United States cordillera (Miller and Bradfish 1980).

Sr initial ratio and $^{87}\text{Rb}/^{86}\text{Sr}$ values are well correlated ($r = 0.98$) for the mid-Cretaceous Anvil plutonic suite (Orchard phase sample AR14 or 15, Mount Mye phase sample 9088, Marjorie phase sample 43D (from Wood and Armstrong 1982)) and the South Fork volcanics (sample 33B (from Wood and Armstrong 1982)). The correlation and resultant "isochron age" of 1.28 ± 0.24 Ga (MSWD = 18.7) from a best fit line through the data suggest a minimum age for the radiogenic crustal reservoir which provided the distinctive Sr isotopic signature for the suites or for its last isotopic homogenization (perhaps as old as 1.9 Ga?; Godwin et al. 1982). Inclusion of whole rock data for Tertiary sample AR2 leads to an older "age" (1.38 ± 0.20 Ga), smaller MSWD (15.3) and slightly better correlation (0.99),

but its comparatively low Rb/Sr isotopic ratio does not permit a unique interpretation regarding the nature of crustal Rb-Sr systematics between the 100 Ma and 61 Ma melting events. Sub-primordial initial ratios in both cases (0.688 ± 0.006 and 0.685 ± 0.005 respectively) for the Proterozoic crustal reservoir at the time of homogenization seem unlikely.

The Anvil plutonic suite, compared with granitoid classifications developed in detailed studies of diverse granitoid suites (e.g., Chappell and White 1974; White and Chappell 1983; Pitcher 1979, 1982), possesses mixed attributes and a unique plutonic style. It was emplaced syn- to posttectonically into a complex, polydeformed, and metamorphosed terrane which possibly resulted from an arc-continent collision (Templeman-Kluit 1979). Its setting is Hercynotype and the phases have similar, restricted granite and granodiorite compositions as typical Hercynotype granitoids (cf. Cobbing and Mallick 1983). Nonetheless, hornblende-bearing phases of the suite appear to be spatially, temporally, and geochemically linked to coeval, compositionally more diverse volcanics, typical of igneous suites in Andinotype settings.

Petrographically and geochemically, Orchay and Marjorie phases resemble granitoids of igneous protolith (I-type) and the Mount Mye phase of granitoids of sedimentary protolith (S-type). The high $^{87}\text{Sr}/^{86}\text{Sr}$ initial ratio for the Mount Mye phase corresponds well with its peraluminous mineralogy and geochemistry. Although lower than the Mount Mye phase, I-type Orchay and Marjorie phases also yield high initial ratios. Extensive involvement of Precambrian, radiogenic continental crust as protolith and/or contaminant is required in the genesis

of hornblende-bearing Orchay and Marjorie phases and the mica-bearing Mount Mye phase.

The field, lithological, petrographic, geochemical, and isotopic subdivision of the Anvil plutonic suite resembles a twofold subdivision of the Selwyn plutonic suite in the southeastern Selwyn Mountains proposed by Anderson (1983) and Anderson et al. (1983 and in preparation). More detailed field, geochemical, and isotopic study may establish the extent of the granite types and refine the granitoid classifications, developed elsewhere, to account for diverse granite types generated from and intruded into radiogenic, sialic crust.

CONCLUSIONS

The Anvil plutonic suite is a high level intrusive complex with three important plutonic phases (of I- and S-type affinities) and two periods of intrusion. Crystallization and rapid cooling of the extensive phases occurred around 100 Ma. Rb-Sr isotopic dating of one sample suggests that late intrusion occurred about 61 Ma ago. Geochronometry, field relations and Hercynotype structural setting provide a minimum (youngest) age for juxtaposition of the Yukon-Tanana suspect terrane onto the North American miogeocline along the Vangorda fault zone (predating emplacement of the suite), and a maximum (oldest) age for movement along the Tintina Fault (postdating emplacement). Marked isotopic heterogeneity and high initial ratios which characterize the suite ($^{87}\text{Sr}/^{86}\text{Sr}_i = 0.7090-0.7405$ for the metaluminous, hornblende-bearing Orchay and Marjorie phases and the peraluminous Mount Mye phase) indicate that genesis of the

suite involved Precambrian sialic crust. Petrographic, geochemical, and isotopic similarities between the hornblende-bearing plutons and South Fork volcanics (Wood and Armstrong 1982) forge a spatial, temporal, and geochemical link between mid-Cretaceous plutonism and volcanism.

ACKNOWLEDGEMENTS.

D. Jennings and G. Jilson (Cyprus Anvil Mining Corporation) suggested and encouraged this project. They also shared their extensive knowledge of field relations in the Anvil area. R.L. Armstrong kindly provided samples from D. Wood's thesis area for further analysis in the Geological Survey of Canada laboratories. Isotopic dating work was funded jointly by Cyprus Anvil Mining Corporation and by an NSERC operating grant to R.L. Armstrong. Other analytical work was performed in part under the auspices of Project 790044, Geological Survey of Canada, during Anderson's tenure of a NSERC Visiting Fellowship in Canadian Government Laboratories. K.L. Scott completed the Rb-Sr analytical work. Pigage thanks Cyprus Anvil Mining Corporation and Dome Petroleum for permission to publish this information. B. Vanlier patiently and accurately typed the initial manuscript. Careful reviews by R.L. Armstrong, C. Brooks, L.P. Grent, Z.E. Peterman, J.A. Roddick, and D.K. Tempelman-Kluit improved earlier versions of it.

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TABLES

- Table 1. Summary of chemical composition for Anvil plutonic suite and South Fork volcanics.
- Table 2. Rb-Sr data for samples of the Anvil plutonic suite.
- Table 3. Calculated initial ratios and isotopic ages for whole-rock and mineral separate Rb-Sr data.

TABLE 1. SUMMARY OF CHEMICAL COMPOSITION FOR SAMPLES OF THE ANVIL RANGE PLUTONIC SUITE AND SOUTH FORK VOLCANICS

(a) Major Elements (in weight per cent)

SAMPLES PHASE ^a (No. of Samples)	AR2	AVERAGE COMPOSITION		AVERAGE COMPOSITION		AR16	AR17	9087B	AVERAGE COMPOSITION		43D
	O?	ORCHAY PHASE		MOUNT MYE PHASE		J	Oap	Map	SOUTH FORK VOLCANICS		SF
		Average ($\pm 1 \sigma$)		Average ($\pm 1 \sigma$)					Average ($\pm 1 \sigma$)		
		(4)		(4)		(1)	(1)	(1)	(6)		(1)
OXIDE											
SiO ₂	65.5	70.1	(1.7)	71.4	(1.3)	69.3	75.7	74.5	65.6	(4.26)	67.4
Al ₂ O ₃	15.1	14.2	(0.8)	14.7	(0.2)	14.2	12.8	13.6	15.0	(0.69)	15.2
TiO ₂	0.69	0.39	(0.06)	0.32	(0.11)	0.38	0.06	0.07	0.56	(0.17)	0.58
Fe ₂ O ₃	4.4	0.2	(0.2)	0.6	(1.1)	0.2	0.8	0.0	1.4	(2.6)	0.5
FeO	0.0	3.0	(0.4)	1.4	(1.3)	3.3	0.0	0.7	3.5	(1.9)	2.9
MnO	0.07	0.08	(0.01)	0.03	(0.01)	0.05	0.03	0.05	0.09	(0.02)	0.07
MgO	2.17	0.90	(0.20)	0.68	(0.25)	0.86	0.09	0.13	1.57	(0.78)	1.53
CaO	3.60	2.96	(0.65)	1.48	(0.26)	3.01	0.89	0.86	4.22	(0.91)	2.84
Na ₂ O	2.9	2.2	(0.3)	2.3	(0.3)	2.2	2.9	2.5	2.7	(0.4)	2.3
K ₂ O	4.13	3.94	(0.19)	4.86	(0.26)	3.79	4.99	5.01	2.85	(0.66)	4.46
P ₂ O ₅	0.21	0.10	(0.02)	0.14	(0.03)	0.08	0.02	0.16	0.12	(0.02)	0.18
H ₂ O	0.4	0.8	(0.3)	0.7	(0.1)	1.2	0.2	0.5	1.7	(0.7)	1.3
CO ₂	0.1	0.1	(0.1)	0.1	(0.1)	0.1	0.1	0.2	0.8	(1.0)	0.1
Cl	0.04	0.01	(0.01)	0.0		0.01	0.03	0.00	0.02	(0.03)	0.01
F	0.08	0.06	(0.01)	0.08	(0.02)	0.05	0.00	0.03	0.05	(0.01)	0.07
S	0.00	0.01	(0.01)	0.01	(0.01)	0.0	0.00	0.00	0.01	(0.01)	0.01
TOTAL	<u>99.39</u>	(99.05)		(98.80)		<u>98.73</u>	<u>98.61</u>	<u>98.31</u>	(100.19)		<u>99.45</u>

TABLE 1. SUMMARY OF CHEMICAL COMPOSITION FOR SAMPLES OF THE ANVIL PLUTONIC SUITE AND SOUTH FORK VOLCANICS (cont'd)

(b) Trace Element Content (in parts per million)

SAMPLES	AR2	AVERAGE COMPOSITION		AVERAGE COMPOSITION		AR16	AR17	9087B	AVERAGE COMPOSITION		43D
PHASE ^a	07	ORCHAY PHASE		MOUNT MYE PHASE		J	Oap	Map	SOUTH FORK VOLCANICS		SF
(No. of Samples)	(1)	Average ($\pm 1 \sigma$)		Average ($\pm 1 \sigma$)		(1)	(1)	(1)	Average ($\pm 1 \sigma$)		(1)
		(4)		(4)					(6)		
Rb	200	180	(33)	270	(17)	150	330	300	110	(33)	210
Sr	350	200	(29)	160	(44)	200	49	67	240	(59)	220
Ba	920	820	(260)	530	(190)	1100	56	180	1100	(300)	720
Zr	230	150	(19)	160	(47)	180	30	70	150	(25)	190
Be	2.4	2.8	(0.9)	4.7	(1.4)	b.d. ^a	4.4	23	3.1	(0.5)	4.1
B	23	20	(4)	33	(8)	16	27	210	23	(6.9)	23
Co	16	7.8	(0.6)	10	(1)	7.5	7.3	b.d.	12	(3.1)	11
Cr	57	12	(6.5)	13	(6)	14	5.4	5.5	29	(11)	22
Ni	26	b.d.		b.d.		b.d.	b.d.	b.d.	20	(6)	10
V	69	36	(13)	38	(11)	44	18	22	79	(27)	74
Cu	21	8.3	(2.6)	9.2	(2.3)	11	9.7	6.5	22	(8)	19
Zn	60	90	(5)	80	(10)	80	10	40			
La	67	83	(58)	46	(9)	47	b.d.	b.d.	86	(12)	84
Yb	b.d.	2.9	(0.6)	2.9	(0.8)	2.7	7.3	4.6	3.2	(1.4)	b.d.
Y	26	31	(4)	23	(1)	37	43	26	34	(4)	30
Rb/Sr ^b	0.465	0.765	(0.190)	1.48	(0.54)	0.613	5.62	4.31	0.413	(0.169)	0.767
K/Ba	37	44	(16)	91	(49)	29	740	240	23	(8)	51
K/Rb ^b	186	208	(27)	173	(8)	219	113	149	225	(26)	187
Ba/Rb ^b	5.0	5.4	(2.4)	2.2	(0.9)	7.6	0.15	0.63	11	(6.0)	3.6

a. b.d. = below detection limits of analytical method. Other abbreviations are: J = Marjorie phase; O = Orçay phase; Oap = aplite in Orçay phase; Map = aplite in Mount Mye phase; SF = biotite quartz monzonite associated with South Fork volcanics (see Wood and Armstrong (1982) for location).

b. Rb, Sr values from Table 4.

TABLE 2. Rb-Sr data for all analyzed samples

Sample	Intrusive Phase ⁺	Latitude(N)	Longitude(W)	Material	Sr(ppm)	Rb(ppm)	⁸⁷ Rb/ ⁸⁶ Sr	⁸⁷ Sr/ ⁸⁶ Sr
AR2	O?	62°28.1'	133°51.2'	rock	396	184	1.342	0.7102
				plagioclase -1	347	56	0.464	0.7095
				plagioclase -2*	370	116	0.905	0.7096
				plagioclase -3*	494	244	1.428	0.7103
				hornblende**	34	142	12.17	0.7190
				biotite	13	938	209	0.8950
AR4	O	62°33.5'	133°45.8'	rock	205	177	2.495	0.7195
AR7	O	62°35.0'	133°34.4'	rock	192	189	2.850	0.7181
AR14	O	62°07.3'	132°42.4'	rock	229	133	1.687	0.7184
AR15	O	62°17.7'	132°38.6'	rock	244	142	1.687	0.7185
AR17	O ap	62°05.0'	132°15.6'	rock	65	365	16.38	0.7391
AR16	J	62°07.1'	132°15.6'	rock	235	144	1.775	0.7196
AR10A	M	62°23.5'	133°18.4'	rock	192	229	3.45	0.7429
J586B	M	62°22.0'	133°08.6'	rock	165	253	4.46	0.7506
9087B	M ap	62°19.2'	133°13.0'	rock	66	285	12.54	0.7583
9088	M	62°18.5'	133°11.5'	rock	219	215	2.85	0.7446
				plagioclase -1	129	17	0.383	0.7413
				plagioclase -2	285	49	0.498	0.7412
				plagioclase -3*	348	303	2.53	0.7437
				K-feldspar	367	446	3.53	0.7458
				muscovite	28	511	53.1	0.8162
				biotite	21	989	140.5	0.9416
9501A	M	62°16.6'	133°07.6'	rock	116	256	6.41	0.7576

+ M-Mount Mye, O-Orchay, J-Marjorie, ap-aplitic

* contains K-feldspar

** contains biotite

NOTE: Analytical errors: Rb-Sr ratio, 2%(1σ); ⁸⁷Sr/⁸⁶Sr, 0.0002(1σ). See appendix for

analytical methods.

TABLE 3. CALCULATED INITIAL RATIOS ($^{87}\text{Sr}/^{86}\text{Sr}_i$) AND ISOTOPIC AGES FOR WHOLE-ROCK AND MINERAL-SEPARATE Rb-Sr DATA

<u>Samples used in</u> <u>Calculation</u>	$\frac{^{87}\text{Sr}}{^{86}\text{Sr}_i}$ ($\pm 1\sigma$)	<u>Apparent Age (Ma)</u> ($\pm 1\sigma$)	<u>MSWD</u>
----------------------------------------------	----------------------------------------------------------------	-----------------------------------------------	-------------

Whole Rock Isochron:

ORCHAY PHASE

<u>WR1:</u>			
AR14, AR15, AR17	0.7161 ± 0.0001	99 ± 2.5	0.21

Mineral Separate-Whole Rock Isochrons:

ORCHAY(?) PHASE

<u>M1:</u>			
AR2 biotite,			
AR2 hornblende,			
AR2 plagioclase-1,			
AR2 plagioclase-2,	0.7090 ± 0.0001	61 ± 1.5	1.94
AR2 plagioclase-3,			
AR2 whole-rock			

TABLE 3. CALCULATED INITIAL RATIOS ($^{87}\text{Sr}/^{86}\text{Sr}_i$) AND ISOTOPIC AGES FOR WHOLE-ROCK AND MINERAL-SEPARATE Rb-Sr DATA (cont'd)

<u>Samples used in</u>	<u>$^{87}\text{Sr}/^{86}\text{Sr}_i$</u>	<u>Apparent Age (Ma)</u>	<u>MSWD</u>
<u>Calculation</u>	(<u>$\pm 1\sigma$</u>)	(<u>$\pm 1\sigma$</u>)	

Mineral Separate-Whole Rock Isochrons (cont'd):

MOUNT MYE PHASE

M2:

9088 biotite,			
9088 muscovite,			
9088 plagioclase-1,			
9088 plagioclase-2,	0.7405 ± 0.0001	100 ± 2	1.83
9088 plagioclase-3,			
9088 K-feldspar,			
9088 whole-rock			

NOTE: $\lambda_{\text{Rb}} = 1.42 \times 10^{-11} \text{ y}^{-1}$. Apparent age and initial ratio calculated using YORK I model (York 1967).

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- Table 4. Modal composition of the Anvil plutonic suite
- Table 5. Composition of the Anvil Range plutonic suite and
 South Fork volcanics
- a) Major elements (in weight per cent)
 - b) Trace element content (in parts per million)
 - c) Analytical techniques and precision for
 chemical analyses
- Table 6. CIPW normative minerals for the Anvil plutonic suite
 and South Fork volcanics (in weight per cent)

TABLE 4. MODAL COMPOSITION OF THE ANVIL PLUTONIC SUITE

Analytical Techniques for Modal Analyses:

Twelve samples of the Anvil plutonic suite were studied by standard petrographic techniques including flat stage determination of plagioclase composition and point counting for modal abundances (1000-1088 points per thin section except for sample AR7 where 2067 points were counted).

SAMPLES	AR2	AR4	AR7	AR14	AR15	AR16	AR17	AR10A	8586B	9087B	9088	9501A
INTRUSIVE PHASE^a	0?	0	0	0	0	J	Oap	M	M	Map	M	M
TEXTURE												
Grain Size	medium	coarse	coarse	medium	medium	coarse	fine	coarse	fine	medium	medium	medium
Foliation	no	no	no	no	no	no	no	no	no	no	no	no
Megacrystic	no	yes	yes	no	no	yes	no	yes	no	no	yes	yes
PRIMARY OR PHENOCRYST MINERALOGY												
Quartz	18.7	23.9	39.0	31.0	23.1	7.9	38.1	31.9	30.4	32.1	29.2	30.3
Alkali Felds.	21.8	23.9	10.0	26.8	18.8	2.7	27.0	23.1	26.9	32.4	26.4	28.8
Plagioclase	42.8	40.8	36.5	29.1	43.1	26.8	34.2	30.0	28.2	22.3	31.0	29.8
Clinopyroxene	1.0											
Hornblende	4.6			3.0	1.6	1.5						
Biotite	9.5	7.4	10.4	7.2	5.4	11.1	0.7	9.1	9.4	1.3	8.5	3.3
Muscovite								4.3	4.6	11.6	4.1	5.1
Opagues	1.2											
Apatite	0.3	Tr. ^a	0.1	Tr	Tr	0.1		0.3	0.2	Tr	0.3	0.4
Zircon	Tr	Tr	Tr		Tr	0.1		Tr	Tr	Tr	Tr	Tr
Allanite	Tr	0.3	0.1	Tr	Tr	0.2	Tr		0.1			
Tourmaline	0.1									Tr		Tr
PLAGIOCLASE COMPOSITION												
	An36-50	An36-50	An34-38	An42-53	n.d. ^a	An43-45	An26-35	An29-31	An25-27	An25-29	n.d.	n.d.

TABLE 4. MODAL COMPOSITION OF THE ANVIL PLUTONIC SUITE (cont'd)

SAMPLES	AR2	AR4	AR7	AR14	AR15	AR16	AR17	AR10A	8586B	9087B	9088	9501A
INTRUSIVE PHASE ^a 0?	0	0	0	0	0	J	Oap	M	M	Map	M	M
SECONDARY OR GROUNDMASS MINERALOGY												
Myrmekite	0.1	0.1	Tr					0.2	0.1	0.3	0.5	2.3
Sericite/Sauss.	1.6	3.1	1.1	3.4	0.3			0.1	Tr	Tr		
Epidote	0.6	0.1	0.2	0.6	0.1							
Chlorite	1.4	0.6	1.6	3.9	0.8			0.8				
Titanite	Tr	Tr	Tr	0.1								
Opagues				Tr				0.2	0.1		Tr	
Quartz						16.5						
Alkali Felds.						12.1						
Plagioclase						18.4						
Hornblende						0.1						
Biotite						1.2						
Apatite						0.1						
Zircon						Tr						
Allanite						Tr						

a. Abbreviations are: n.d. = no determinations possible; 0 = Orchay phase; Oap = aplite in Orchay phase; J = Marjorie phase; M = Mount Mye phase; Map = aplite in Mount Mye phase; Tr = trace amount.

TABLE 5. COMPOSITION OF THE ANVIL RANGE PLUTONIC SUITE AND SOUTH FORK VOLCANICS

Table 5a. Major Elements (in weight per cent)

SAMPLES	AR2	AR4	AR7	AR14	AR15	AR16	AR17	AR10A	8586B	9087B	9088	9501A
INTRUSIVE PHASE ^a	O?	O	O	O	O	J	Oap	M	M	Map	M	M
OXIDE												
SiO ₂	65.5	70.9	72.1	69.2	68.2	69.3	75.7	70.6	71.0	74.5	70.7	73.3
Al ₂ O ₃	15.1	13.8	13.3	14.7	15.1	14.2	12.8	14.8	14.6	13.6	14.9	14.6
TiO ₂	0.69	0.34	0.35	0.40	0.46	0.38	0.06	0.41	0.36	0.07	0.35	0.16
Fe ₂ O ₃	4.4	0.5	0.1	0.1	0.1	0.2	0.8	0.0	0.1	0.0	2.3	0.1
FeO	0.0	2.5	2.8	3.1	3.5	3.3	0.0	2.9	1.9	0.7	0.0	0.9
MnO	0.07	0.08	0.08	0.07	0.07	0.05	0.03	0.04	0.03	0.05	0.04	0.02
MgO	2.17	0.66	0.81	1.08	1.04	0.86	0.09	0.90	0.84	0.13	0.64	0.35
CaO	3.60	2.34	2.46	3.58	3.45	3.01	0.89	1.69	1.32	0.86	1.71	1.19
Na ₂ O	2.9	2.1	2.2	1.8	2.5	2.2	2.9	2.1	2.2	2.5	2.8	2.2
K ₂ O	4.13	4.18	4.00	3.82	3.77	3.79	4.99	4.79	4.80	5.01	4.62	5.22
P ₂ O ₅	0.21	0.08	0.10	0.10	0.12	0.08	0.02	0.17	0.13	0.16	0.11	0.13
H ₂ O	0.4	0.8	0.5	0.8	1.2	1.2	0.2	0.8	0.8	0.5	0.6	0.6
CO ₂	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.1	0.0
Cl	0.04	0.00	0.01	0.00	0.01	0.01	0.03	0.00	0.00	0.00	0.00	0.00
F	0.08	0.06	0.06	0.05	0.05	0.05	0.00	0.09	0.09	0.03	0.07	0.05
S	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00
TOTAL	<u>99.39</u>	<u>98.55</u>	<u>98.98</u>	<u>98.90</u>	<u>99.66</u>	<u>98.73</u>	<u>98.61</u>	<u>99.40</u>	<u>98.38</u>	<u>98.31</u>	<u>98.94</u>	<u>98.82</u>

TABLE 5. CHEMICAL COMPOSITION OF THE ANVIL PLUTONIC SUITE AND SOUTH FORK VOLCANICS (cont'd)

Table 5b. Trace Element Content (in parts per million)

SAMPLES	AR2	AR4	AR7	AR14	AR15	AR16	AR17	AR10A	8586B	9087B	9088	9501A
INTRUSIVE PHASE ^a O?		0	0	0	0	J	Oap	M	M	Map	M	M
Rb	200	200	220	150	160	150	330	270	270	300	240	280
Sr	350	170	170	220	220	200	49	190	140	67	190	100
Ba	920	720	520	950	1100	1100	56	730	560	180	540	270
Zr	230	140	140	150	180	180	30	160	170	70	200	90
Be	2.4	3.4	2.1	b.d. ^a	b.d.	b.d.	4.4	2.6	5.8	23	4.9	5.5
B	23	23	16	b.d.	22	16	27	25	41	210	b.d.	32
Co	16	8.2	b.d.	7.2	8.1	7.5	7.3	9.1	10	b.d.	b.d.	b.d.
Cr	57	9.3	6.4	15	21	14	5.4	17	17	5.5	14	5.2
Ni	26	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.
V	69	32	19	47	46	44	18	44	45	22	40	21
Cu	21	7.9	5.8	7.6	12	11	9.7	12	10	6.5	8.2	6.6
Zn	60	80	90	90	90	80	10	70	90	40	60	80
La	67	47	b.d.	150	52	47	b.d.	42	45	b.d.	58	37
Yb	b.d.	3.0	3.5	b.d.	2.3	2.7	7.3	2.3	2.6	4.6	2.5	4.1
Y	26	32	26	30	36	37	43	21	24	26	22	23
Rb/Sr ^b	0.465	0.863	0.984	0.581	0.633	0.613	5.62	1.19	1.53	4.31	0.982	2.21
K/Ba	37	48	64	33	29	29	740	55	73	240	72	160
K/Rb ^b	186	196	176	238	220	219	113	176	162	149	182	173
Ba/Rb ^b	5.0	4.1	2.8	7.1	7.7	7.6	0.15	3.2	2.2	0.63	2.5	1.1

a. Abbreviations are: b.d. = below detection limits of analytical method; O = Orchay phase; Oap = aplite in Orchay phase; J = Marjorie phase; M = Mount Mye phase; Map = aplite in Mount Mye phase; Tr = trace amount.

b. Rb, Sr values from Table 3.

TABLE 6. CIPW NORMATIVE MINERALS FOR THE ANVIL PLUTONIC SUITE AND SOUTH FORK VOLCANICS (in weight per cent)

SAMPLES	AR2	AR4	AR7	AR14	AR15	AR16	AR17	AR10A	8586B	9087B	9088	9501A
INTRUSIVE PHASE ^a	0	0	0	0	0	J	Oap	M	M	Map	M	M
qz	22.86	36.11	36.30	33.49	28.51	32.92	38.41	33.96	35.78	39.58	33.03	37.90
or	24.71	25.33	24.04	23.05	22.66	23.00	30.00	28.75	29.15	30.34	27.81	31.42
ab	24.84	18.22	18.93	15.55	21.52	19.12	24.97	18.05	19.13	21.68	24.13	18.96
an	16.18	11.36	11.74	17.46	16.61	14.79	4.36	7.39	5.85	3.30	7.91	5.15
c		1.80	1.14	1.36	0.94	1.23	1.08	3.55	3.80	2.96	2.49	3.54
di												
hy	5.47	5.52	6.74	7.93	8.45	7.70	0.23	7.05	5.07	1.63	1.62	2.26
ol												
mt		0.74	0.15	0.15	0.15	0.30			0.15			0.15
hm	4.45						0.81				2.34	
il	0.15	0.66	0.68	0.78	0.89	0.74	0.07	0.79	0.70	0.14	0.09	0.31
ap	0.50	0.19	0.24	0.24	0.28	0.19	0.05	0.40	0.31	0.38	0.26	0.31
ru	0.47						0.03				0.31	
sp	0.36											
py		0.06	0.06					0.06	0.06			
D.I. ^b	72.40	79.66	79.27	72.08	72.69	75.04	93.38	80.76	84.05	91.60	84.98	88.29

a. Abbreviations are: O = Orchay phase; Oap = aplite in Orchay phase; J = Marjorie phase; M = Mount Mye phase; Map = aplite in Mount Mye phase.

b. D.I. = differentiation index (weight per cent normative quartz + albite + alkali feldspar; Thorton and Tuttle, 1960).

FIGURES

Figure 1. Location of study area and geological map of the Anvil plutonic suite. Sample location for previously determined K-Ar isotopic ages, and petrographic, geochemical and Rb-Sr sample locations are shown. Location of Faro deposit indicated by open circle. Previously determined K-Ar isotopic ages shown as triangles (errors are $\pm 2 \sigma$, m = muscovite, b = biotite; Wanless et al. 1967, 1970, 1972, 1973) are consistent with new IUGS decay constants (Steiger and Jäger, 1977).

Figure 2. Streckeisen's (1973) granitoid classification and modal proportions for quartz, alkali feldspar and plagioclase for Orchay phase (open circle), sample AR2 (encircled cross), aplitic Orchay phase (solid circle), Marjorie phase (open square), Mount Mye phase (open diamond), aplitic Mount Mye phase (solid diamond) of the Anvil plutonic suite. Modal fields for Selwyn plutonic suite shown by ruled patterns (see Figure 3(a) for legend).

Figure 3. Geochemical variation diagrams for the Anvil plutonic suite, South Fork volcanics and

FIGURES (cont'd)

Figure 3
(cont'd)

compositional fields for the Selwyn plutonic suite. Symbols given in diagram (a) and patterns in diagram (g). Compositional fields for I-type (dotted line) and S-type (dashed line) granitic rocks in the Kosciusko Batholith given in Figures 3(h) and (i) are after Hine et al. (1978).

- (a) Total alkali - silica variation diagram and alkaline - subalkaline classification after Irvine and Baragar (1971).
- (b) Calc-alkaline affinity for the mid-Cretaceous igneous suites in AFM ternary diagram (classification after Irvine and Baragar (1971)).
- (c) Harker variation diagrams for mid-Cretaceous plutons and volcanics.
- (d) Na_2 - K_2O - CaO ternary diagram.
- (e) Ba - Rb - Sr ternary diagram for Anvil and Selwyn plutonic suites. Note comparative Rb enrichment in two mica-bearing plutons associated with tungsten skarns in Selwyn plutonic

FIGURES (cont'd)

Figure 3(e)
(cont'd)

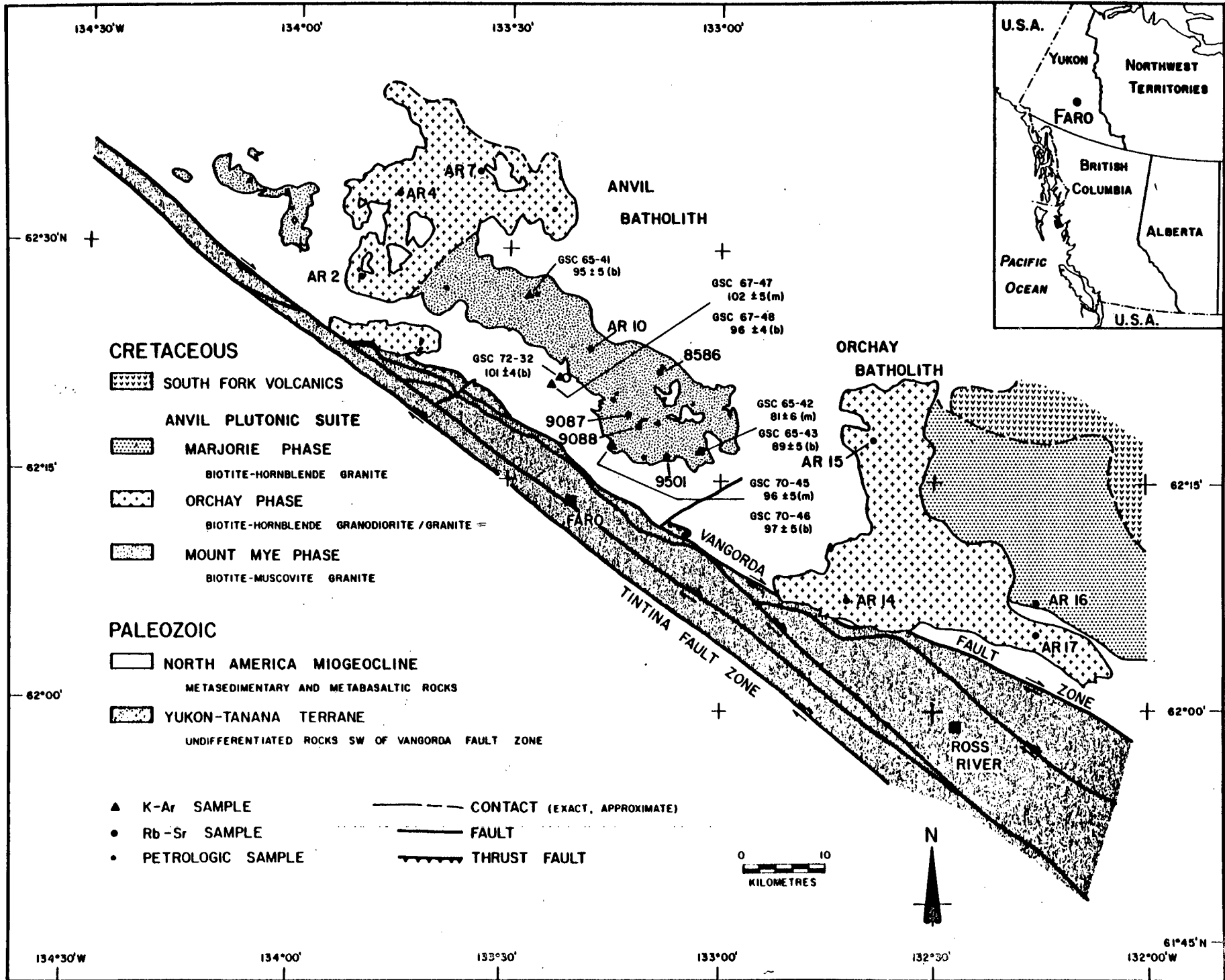
suite (cf. Sinclair, in press).

- (f) Normative minerals - silica diagram and subdivision of plutons with hornblende and plutons with muscovite and biotite.
- (g) Shand index (molar $\text{Al}_2\text{O}_3 / (\text{CaO} + \text{Na}_2\text{O} + \text{K}_2\text{O})$) histogram for mid-Cretaceous igneous suites.
- (h) $\text{Na}_2\text{O} - \text{K}_2\text{O}$ variation diagram and compositional field for I- and S-type granitoids.
- (i) $\text{TiO}_2 - \text{Zr}$ variation diagram and compositional field for I- and S-type granitoids.

Figure 4. Isochron diagram for isochrons of Table 3. Whole-rock (circles) and mineral-separate (solid triangles) analyses from Table 2 are also shown.

Figure 5. Detail of area shown in Figure 4; includes isotopic analyses of whole-rock (solid circles) and mineral-separate (solid triangles) samples from Anvil plutonic suite, whole-rock samples from South Fork volcanics (open circles; Wood and Armstrong, 1982) and a whole-rock and mineral-separate from biotite quartz monzonite (sample 43D, open squares; Wood and Armstrong, 1982).

Figure 1



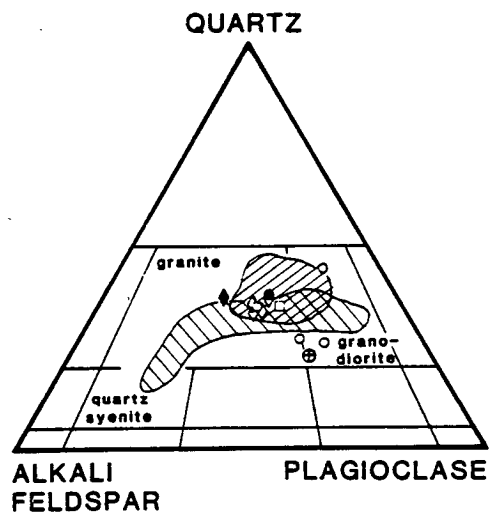
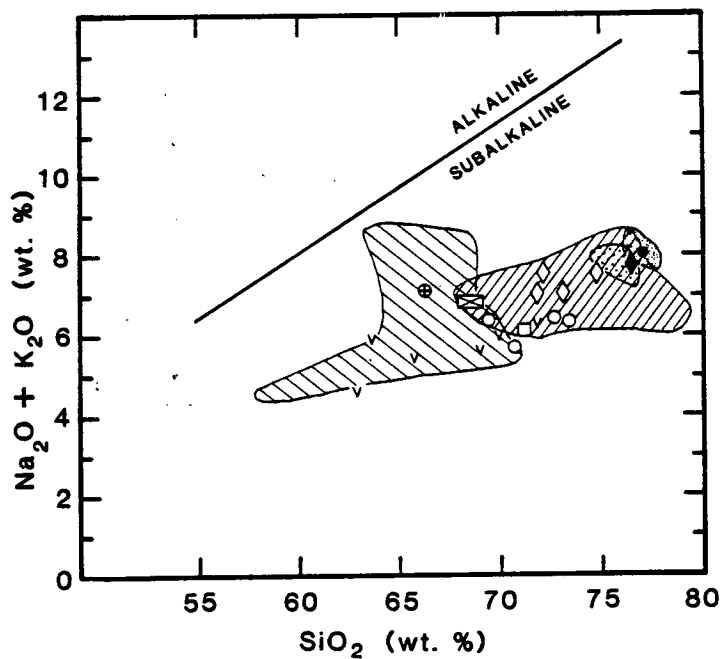


Figure 2

Figure 3 (a)

(a)



SYMBOLS

∇ SOUTH FORK VOLCANICS

⊠ Bi Qz Monzonite (sample 43D)

ANVIL PLUTONIC SUITE

○ Orchard Phase

⊕ Orchard Phase (sample AR2)

● aplitic Orchard Phase

□ Marjorie Phase

◇ Mount Mye Phase

◆ aplitic Mount Mye Phase

SELWYN PLUTONIC SUITE

▨ hornblende-bearing plutons

▩ aplites in hb-bearing plutons

▧ plutons without hornblende

▩ aplites in plutons without hb

Figure 3(b)

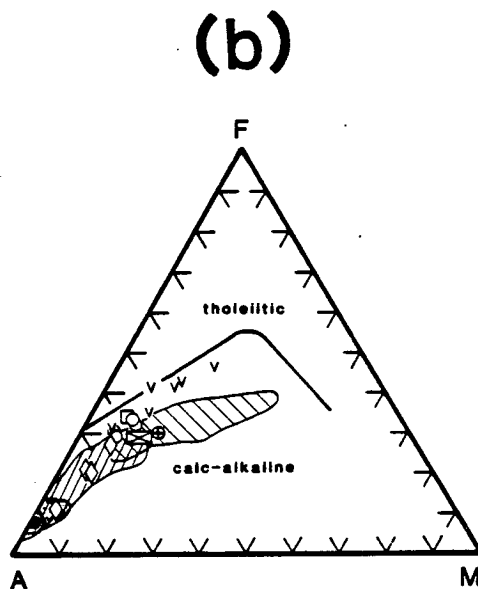


Figure 3(c)

(c)

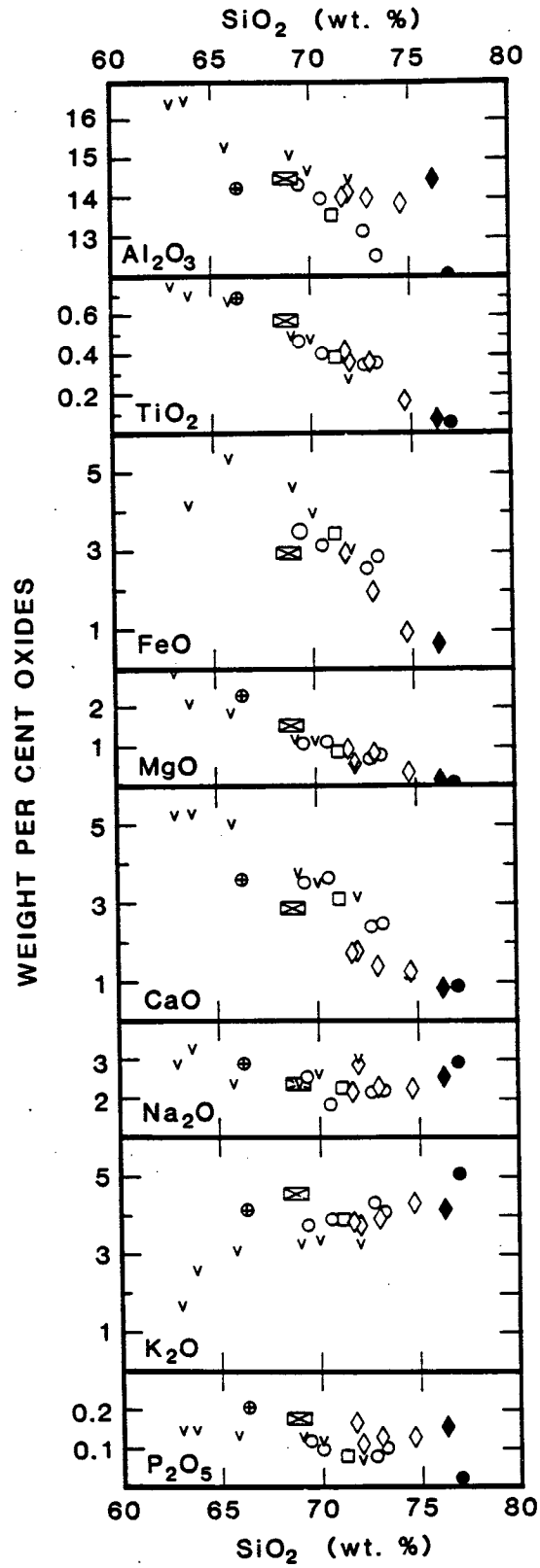


Figure 3(d)

(d)

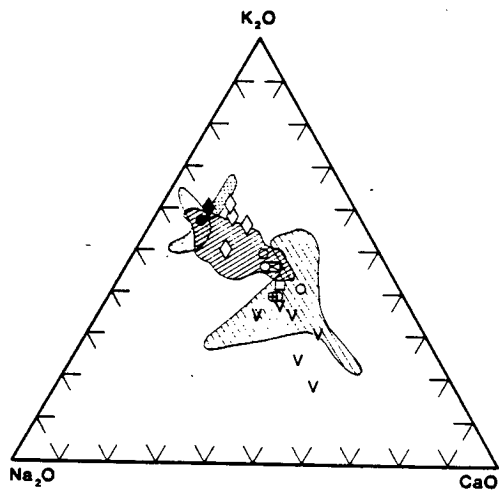


Figure 3(e)

(e)

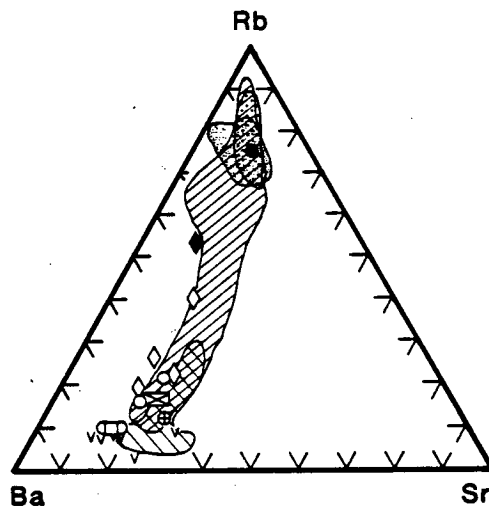


Figure 3(f)

(f)

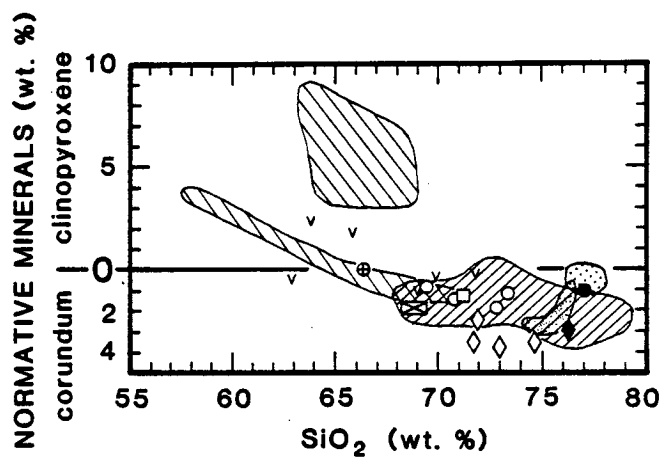


Figure 3(g)

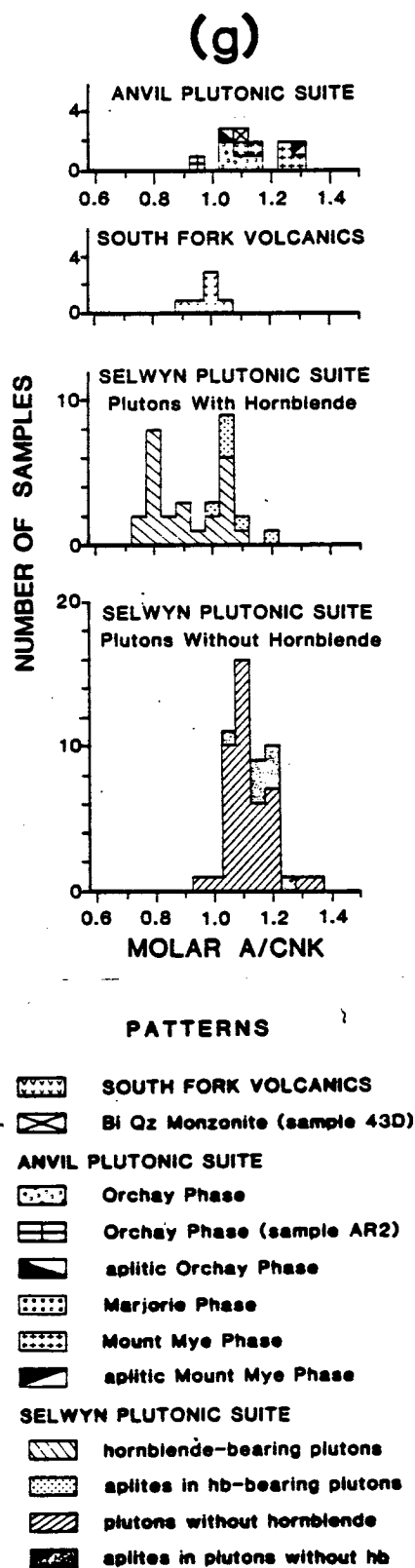


Figure 3(h)

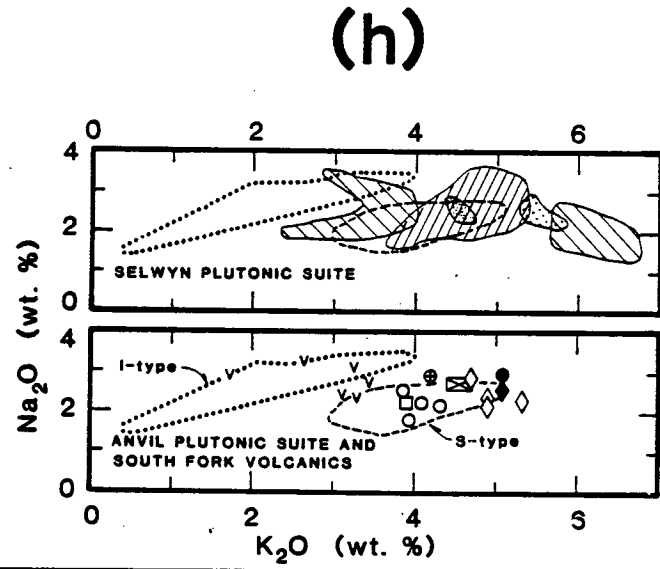


Figure 3(i)

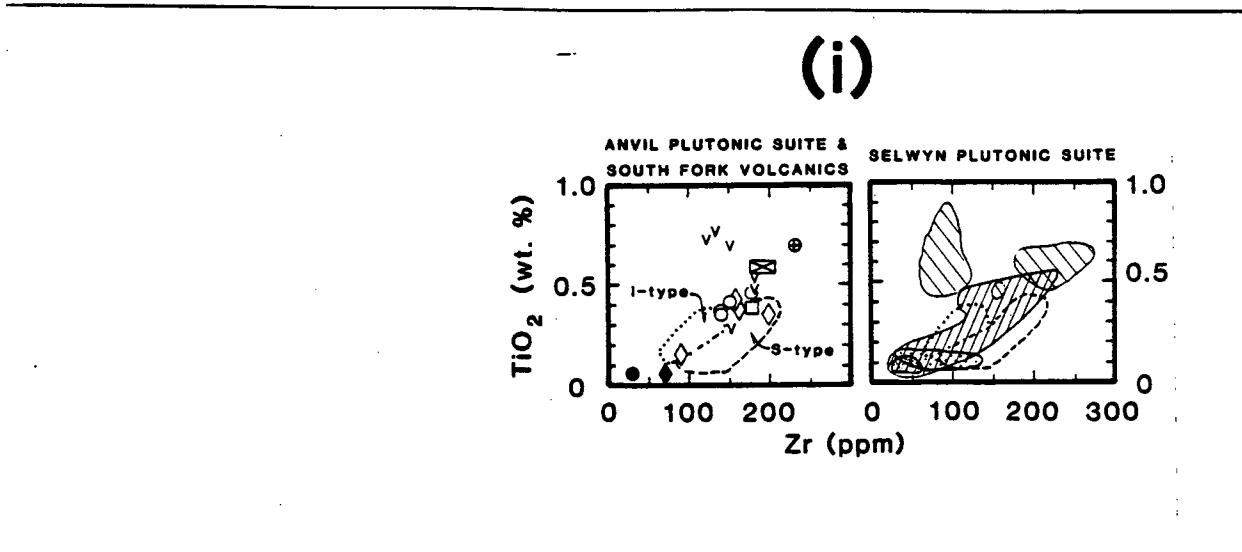
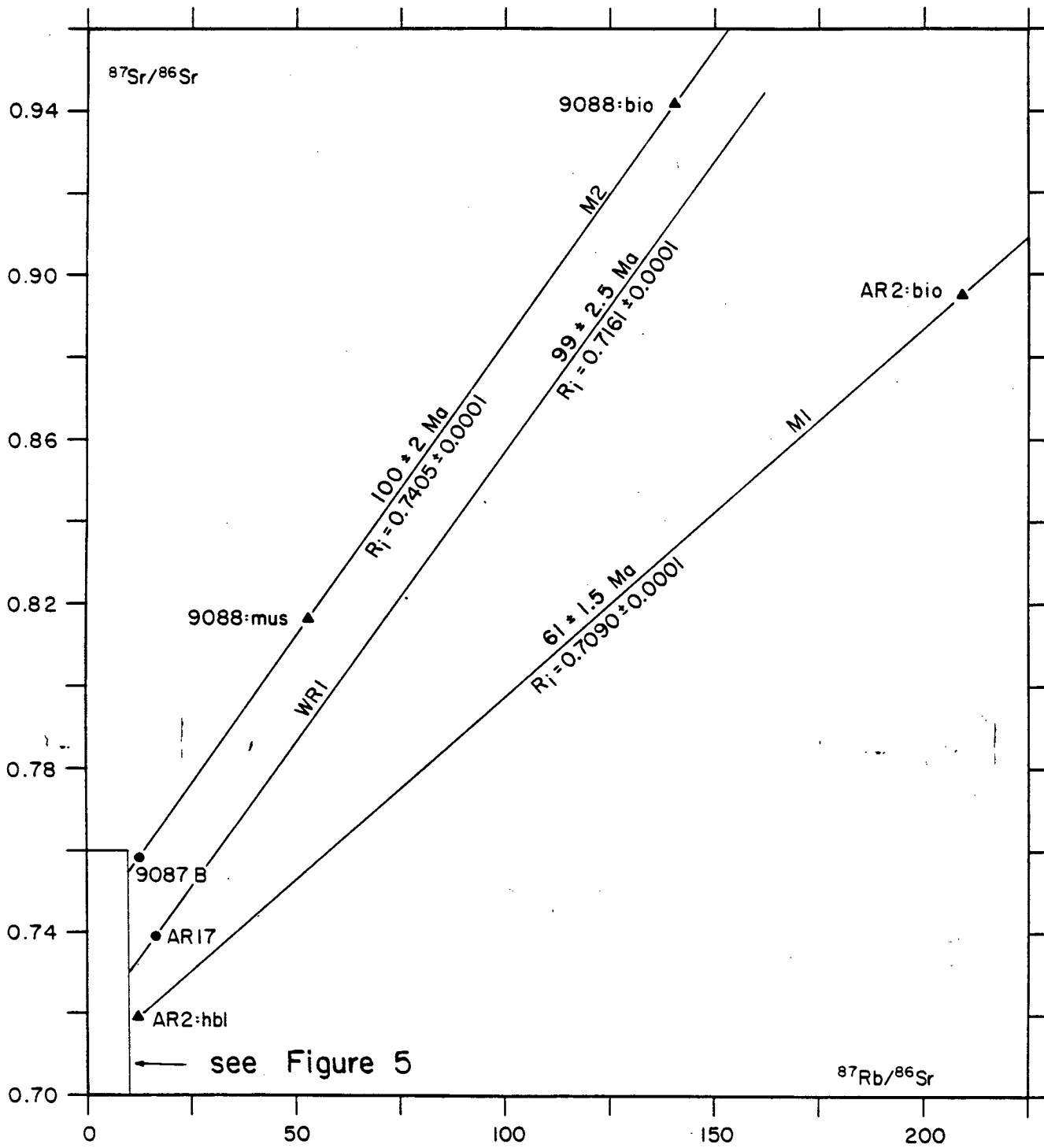


Figure 4



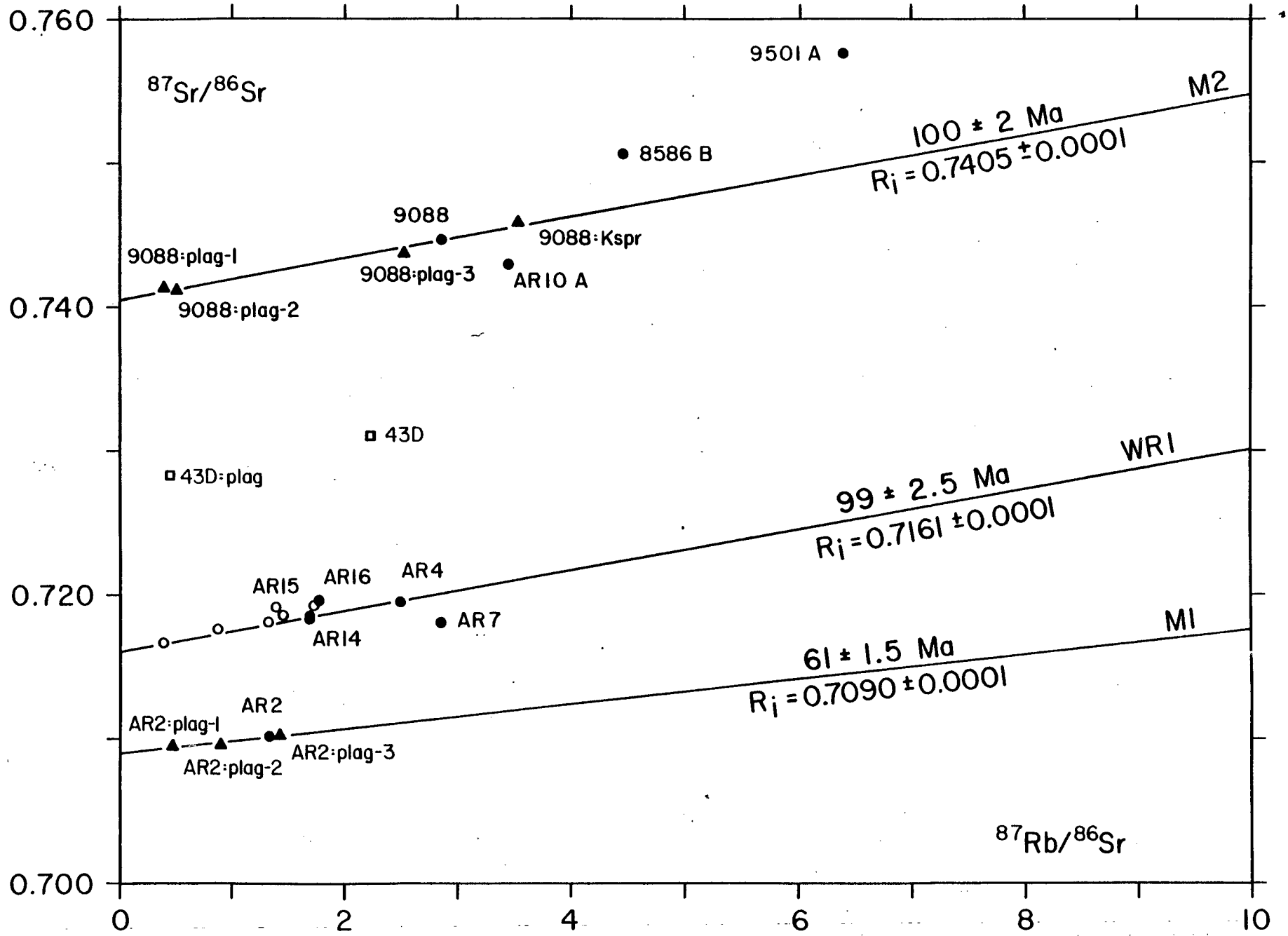


Figure 5

APPENDIX I. ANALYTICAL TECHNIQUES AND PRECISION

Rb-Sr Isotopic Analyses:

Rb and Sr concentrations were determined by replicate analysis of pressed powder pellets using X-ray fluorescence. U.S. Geological Survey rock standards were used for calibration; mass absorption coefficients were obtained from Mo K Compton scattering measurements. Rb/Sr ratios have a precision of 2% (1σ) and concentrations a precision of 5% (1σ). Sr isotopic composition was measured on unspiked samples prepared using standard ion exchange techniques. Data from the mass spectrometer, V.G. Isomass 54R, was acquired and processed by a Hewlet-Packard 85 computer. Experimental data have been normalized to a $^{86}\text{Sr}/^{88}\text{Sr}$ ratio of 0.1194 and adjusted so that the NBS standard SrCO_3 (SRM987) gives a $^{87}\text{Sr}/^{86}\text{Sr}$ ratio of 0.71020 ± 2 and the Eimer and Amend Sr a ratio of 0.70800 ± 2 . The precision of a single $^{87}\text{Sr}/^{86}\text{Sr}$ ratio is 0.00010 (1σ) or better. Rb-Sr dates are based on a Rb decay constant of $1.42 \times 10^{-11}\text{y}^{-1}$. All isochrons and errors were calculated using the York I regression model (York 1967). Calculated statistical error indices (MSWD; Brooks et al. 1972) for all regressions presented herein indicate that the experimental data can be interpreted as isochrons.