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# LATEST MESOZOIC AND CENOZOIC IGNEOUS ROCKS OF SOUTHEASTERN ALASKA--A SYNOPSIS

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## INTRODUCTION

The most important latest Mesozoic and Cenozoic, post-accretionary geologic features of southeastern Alaska are the magmatic activity that affected a large part of the region and the metamorphism and deformation that was interspersed with that activity. This report is a preliminary version of a report on this magmatism prepared for the Decade of North American Geology (DNAG) volume on Alaska. The magmatic activity is a continuation of the late Mesozoic igneous events that will be discussed in the DNAG volume by T.P. Miller. The metamorphic history will be discussed in the DNAG volume by C. Dusel-Bacon.

The post-accretionary geologic history starts with the accumulation of the Gravina belt overlap assemblage of rocks in Late Jurassic and Early Cretaceous time (Berg and others, 1972). The locally voluminous volcanic rocks within that assemblage are probably the extrusive equivalents of island-arc intrusive rocks that are preserved west of the Gravina belt over a large area in northern southeastern Alaska (Brew and Morrell, 1983). Neither those volcanics nor granitoids are discussed in this paper.

Previous syntheses concerned with the magmatic rocks of southeastern Alaska comprise a summary of post-Carboniferous volcanic activity (Brew, 1968), summaries of the distribution and general characteristics of the plutonic rocks (Brew and Morrell, 1980, 1983), a summary of the geochronologic data available (Wilson and Shew, 1982), and two reports concerned with the tectonic significance of major and trace element chemical data (Barker and Arth, 1984; Barker and others, 1986). Karl and Brew (1984) discussed migmatitic rocks associated with some of the intrusive rocks; that topic is not considered in this report. This present report summarizes a more lengthy and complete study on this same topic that is in preparation.

In this report, the latest Mesozoic and Cenozoic plutonic and volcanic rocks are grouped chronometrically; the same time divisions are to be used in the DNAG volume for the Cenozoic magmatic history of the remainder of Alaska by E. Moll-Stalcup. The divisions are approximate, and several of the belts described in the region include rocks whose radiometric ages fall somewhat outside of the defined limits. Within each chronometric group, extrusive and intrusive rocks are identified compositionally and are separated into geographic belts. The general approach is similar to that of Brew and Morrell (1983). Table 2 provides summary information on modal and chemical compositions, chronometric data, and emplacement/eruptive environment for each of the chronometric groups. The chemical classifications of the rocks are those of Shand (1951) and Irvine and Baragar (1971). Figure 1 shows the general geographic distribution of the rocks of different ages and is an index map for the descriptions in the table.

Igneous activity in southeastern Alaska ranges from early Paleozoic to Holocene in age but was most frequent in the late Mesozoic and Cenozoic. Currently available geochronologic data for southeastern Alaska are summarized in Figure 2, which shows the frequency distribution for 402 age determinations of all types of rocks from southeastern Alaska southeast of the Yakutat 1:250,000 scale quadrangle. The relative recency of magmatic activity in the region is obvious, as are the dominance of mid-Tertiary events and the absence of any real break between Mesozoic and Cenozoic events.

## DESCRIPTION OF THE TABLES

Table 1 links the major magmatic belts and areas of summary discussions in the text and of Figure 3 with the descriptions of the component belts and areas given in Table 2. The information presented in Tables 1 and 2 is derived from Brew (in press); that report contains more discussion of tectonic settings, emplacement situations, and extrusive activity than can be included here. Table 2 summarizes the data that support the conclusions of this report. However, the many intermediate inferences that relate the data to the conclusions are still unpublished.

Table 2 is divided into columns for: (1) Figure 1 reference, which is the letter designation on those maps for the specific area; (2) Area or belt name; (3) Major and minor lithic types, with the latter shown in parentheses, granitic rock names are from Streckeisen (1973); (4) Chemical classification and chemical compositional types present, based on calculations using the PETCAL 4 program (Bingler and others, 1976) as revised by R.D. Koch (written commun., 1985)); (5) $SiO_2$ range; (6) $SiO_2$ gap(s); (7) Reference to map and diagram figures in this report; most figures include a Streckeisen (1973) QAP (quartz-alkali feldspar-plagioclase feldspar) classification diagram for granitic rocks, a silica-variation diagram, an AFM (alkaline element oxide-iron oxide-magnesium oxide) diagram, and a small map showing the area containing the rocks described; (8) Age data; (9) Discussion or remarks, focussed mainly on the environment of pluton emplacement or volcanic extrusion; and (10) References to the sources of the data.

## EVOLUTION OF MAGMATIC BELTS AND AREAS

The tectonic settings and compositional variations recorded in the several Cenozoic magmatic belts of southeastern Alaska indicate that the belts have had a varied and complicated evolutionary history. The older part of the record, from latest Cretaceous through about early Oligocene time, reflects the two main collisional events that dominate the Cenozoic history of the region. The younger part of the record, from the late Oligocene on, is the result of less well understood events, ones that are probably related first to oblique subduction and then to extensional regimes associated with youngest Cenozoic strike-slip faulting.

The areas summarized in Tables 1 and 2 are grouped into nine major belts on Figure 3: the "great tonalite sill" belt is of latest Cretaceous and Paleocene age (75-55 Ma); the Coast Mountains belt is of early and middle Eocene age (55-45 Ma); the Fairweather-Baranof and Glacier Bay region belts are of middle and late Eocene and early Oligocene age (45-35 Ma), the Tkope-Portland Peninsula, Groundhog Basin-Cone Mountain, and southern southeastern Alaska dike swarm belts are of late Oligocene and Miocene age (35-5 Ma); and the Kruzof-Kupreanof and Behm Canal-Rudyerd Bay areas are of Pliocene and Quaternary age (5-0 Ma). Each of these belts is interpreted to record a specific magma-generating event (or series of events) and most have clear-cut chemical and(or) modal compositional features that support the definition of the belts.

## GREAT TONALITE SILL BELT

The oldest belt discussed here, the latest Cretaceous and Paleocene "great tonalite sill" belt (Skagway/Ketchikan-PrinceRupert (75-55 Ma) on Figure 3 and Tables 1 and 2), records only the youngest of a series of events that began in Early Cretaceous time in the "southeastern Alaska coincident zone" (Brew and Ford, 1985). Earlier volcanic and plutonic history will be discussed by T.P. Miller in the DNAG volume. The rocks of the tonalite sill belt are consistently calcalkalic and dominantly metaluminous, locally have a prominent silica gap at 63 to 68 percent, and fall in the tonalite-granodiorite-quartz monzodiorite-quartz diorite fields of Streckeisen (1973). These plutons have emplacement ages that range from 67 to 55 Ma. The sill rocks with Paleocene emplacement ages of around 60 Ma are included with the older tonalite sill family because of their closely similar ages and habits. They are mostly granodiorite and have higher silica contents than the slightly older rocks.

The plutons of the great tonalite sill belt are foliated and lineated tonalites that form a narrow belt that is over 900 km long and only 5 to 30 km wide.. They have been localized along a profound, straight, linear structural discontinuity within a convergent setting in which the northeast side was moving upwards relatively over the southwest side (D.H.W. Hutton, oral communs., 1985, 1986). This discontinuity can be interpreted as either a within-plate rift margin (Brew and Ford, 1983) or as the boundary between two exotic terranes (Monger and others, 1982, 1983). The linear zone of compression persisted at least from 70 Ma to 55 Ma, the tonalite period during which intrusions were emplaced. Metamorphism and major deformation occurred shortly before the emplacement of the intrusions.

The cause of the compression in this zone, whether it was originally a rift or an ocean between two different terranes, was the movement of the outboard Alexander terrane towards the northeast (Monger and others, 1982). This movement is interpreted to have preceded the convergence of the Chugach terrane against the westward margin of the Alexander terrane (Plafker and others, 1977; Johnson and Karl, 1985). The consistent composition of the magmas argues for a deep and equilibrated source, even though the preliminary data of Arth and others (1986) on strontium initial ratios indicate possible derivation from continental source materials. This latter possibility can be used to support a within-plate-rift origin of the structural discontinuity that localized the tonalite sill belt and the other nearby parallel features of the southeastern Alaska coincident zone (Brew and Ford, 1985).

## COAST MOUNTAINS BELT

The linear Coast Mountains belt along the International Boundary (Skagway/Ketchikan-Prince Rupert Coast Mountains belt (55-45 Ma) on Figure 3 and Tables 1 and 2) is over 1,000 km long and up to 90 km wide and consists of a large volume of early and middle Eocene plutons that are probably a result of the convergence and crustal thickening associated with the compressive event just described. These rocks are consistently calcalkalic, dominantly metaluminous north of the Sumdum area, and exclusively moderately peraluminous to the south. The overall range in silica content is 53 to 76 percent; the average silica content is about 67 percent to the north of the Sumdum area and 72 percent to the south. Modally, the rocks are dominantly sphene-hornblende-biotite granodiorite, granite, and tonalite. Available age determinations indicate that the plutons in the southern part of the Coast Mountains were emplaced between 55 and 45 Ma and those in the northern part from 54 to 49 Ma. The Coast Mountains belt of large composite plutons parallels the great tonalite sill belt, commonly within a few kilometers and in several places intrudes that belt.

The differences in age, structural habit, and composition of the rocks in this belt indicate a different origin from that of the great tonalite sill belt. The general absence of all structures but flow foliation, and the restricted thermal aureoles that are superposed on the earlier Barrovian-type metamorphism associated with the tonalite sill belt, indicate that these early and middle Eocene intrusions are post-tectonic and their emplacement followed the abrupt uplift that accompanied and closely followed intrusion of the sill belt.

The composition of the plutons in the Coast Mountains belt, their location in relation to the highly deformed and presumably thickened crust near the tonalite sill belt, and the time-lag relations all indicate that the Coast Mountains belt is the result of the thickening that occurred during the latest Cretaceous and early Tertiary collision discussed above. The change from metaluminous to moderately peraluminous composition from north to south is inferred to be related to the type of material conveyed to depth in the convergent zone. This may be a result of the greater thickness of older continental crust in the southern part of the Alexander terrane compared with the northern part.

## FAIRWEATHER-BARANOF BELT

Plutons of the Fairweather-Baranof belt and the Glacier Bay region (Fig. 3, Tables 1 and 2) were emplaced in the time span of late Eocene to early Oligocene (45-35 Ma). The Fairweather-Baranof belt is about 350 km long by 50 km wide and is parallel to the Coast Mountains belt approximately 200 km to its southwest. Emplacement ages of 49 to 39 Ma indicate that the Fairweather-Baranof belt is definitely younger than the Coast Mountains belt, although there is some overlap. Biotite-hornblende tonalite and granodiorite are the most common rock types in the southern part of the Fairweather-Baranof belt, and gabbronorite, pyroxenite, and other mafic and ultramafic rocks dominate the northern part. The granitic plutons are calcalkalic, mostly peraluminous, and have silica contents that range from 60 to 73 percent. The belt occurs largely within the Chugach terrane and is interpreted to have formed as a result of the convergence and accretion of the Chugach terrane. Metamorphic mineral ages suggest that the convergence occurred in Late Cretaceous time, though before the time of the main deformation and metamorphism associated with the great tonalite sill belt.

In this interpretation, the Coast Mountains and the Fairweather-Baranof belts are not quite synchronous and are not directly related; either could have formed independently. The Coast Mountains belt is one result of the closure of the Gravina basin because of northeastward movement of the Alexander terrane, whereas the Fairweather-Baranof belt is one result of the accretion of the Chugach terrane to the west side of the Alexander terrane.

## GLACIER BAY REGION

The Glacier Bay region (Fig. 3, Tables 1 and 2) is, in contrast to the magmatic belts described, a northeast-trending, nearly rectangular 80 km by 70 km area that slightly overlaps the northern part of the Fairweather-Baranof belt geographically and also in time, with ages ranging from about 42 to 30 Ma. The calcalkalic plutons are dominantly unfoliated to poorly foliated, metaluminous and moderately peraluminous biotite granite and alkali granite. Silica values range from 58 to 76 percent. This group of plutons is areally, compositionally, chemically, and structurally distinct from those in the Fairweather-Baranof belt, and their origin, although linked to the latter, must differ in some significant way. One possibility is that the plutons of the Glacier Bay region represent the silicic remnant of a magmatic system that produced the dominantly gabbroic plutons in the adjacent northern part of the Fairweather-Baranof belt, and that the emplacement of the silicic portion was displaced to the northeast by the previously emplaced less fractionated mafic and ultramafic bodies. Another possibility is that they are an early manifestation of the younger (35-5 Ma) Tkope-Portland Peninsula belt (discussed below), which is related to some obscure regime that occurred after Chugach-terrane accretion and before transform faulting.

## TKOPE-PORTLAND PENINSULA BELT

The Tkope-Portland Peninsula belt, the Groundhog Basin-Cone Mountain area, and the southern southeastern Alaska dike swarm (Fig. 3, Tables 1 and 2) were emplaced within the time span of and late Oligocene and Miocene (35-5 Ma). The three belts are clearly different from the collision-related belts just described; each has distinct petrological characteristics and represents different types of magma-generating events.

The Tkope-Portland Peninsula belt (Fig. 3, Tables 1 and 2) is the most prominent of the three belts or areas. It extends in a northwest-southeast direction for at least 560 km across all of southeastern Alaska, cutting across all tectonostratigraphic terranes, except the Chugach at an angle of about $15^{o}$. Both volcanic and plutonic rocks occur in the belt. The volcanic rocks are flows, tuff, and breccia of andesitic, basaltic, rhyolitic, and dacitic composition. All are calcalkalic, and silica contents range from 47 to 77 percent with a significant gap at 61 to 66 percent. Available age determinations indicate that the volcanics were erupted during the period from about 25 to 16 Ma. The granitics are both calcalkalic and alkalic. Granite and granite porphyry are the most common rock types at the ends of the belt; most are moderately peraluminous. Alkali granite, granite, quartz syenite, and alkali quartz syenite are common types in the central part. Leucogabbro and gabbro occur locally. The plutonic rocks have a silica range of 49 to 77 percent with significant gaps at 54 to 56 and at 61 to 65 percent. The plutons were emplaced from 35 to 19 Ma, with those at the northwest ends of the belt about 28 to 24 Ma, those in the center at 24 to 19 Ma, and those at the southeast end at 30 Ma and 27 to 24 Ma.

The length and continuity of the Tkope-Portland Peninsula belt suggest that it could be the result of a significant collisional event of unusual orientation. However, no other evidence supporting such an origin has been preserved, and thus it is considered unlikely. The composition of the plutons is unlike those in the other magmatic belts, probably because the magmas were generated at the base of or within the continental crust of the Alexander/Stikine terranes. The cause of the magmatic events is probably related to the change from convergence to oblique subduction to strike-slip movement between the Pacific and North American plates, but the actual mechanism that caused the long belt to form is not clear. The axis of the belt coincides with the orientation of the tension planes that would be associated with the onset of differential strike-slip movement along the continental margin. The slight change in orientation of the belt near its southeast end could be related to differences in the thickness of the crust.

## GROUNDHOG BASIN-CONE MOUNTAIN AREA

The Groundhog Basin-Cone Mountain area includes rhyolitic sills and biotite granite plugs in an area 10 km by 40 km (Fig. 3, Tables 1 and 2). Alkali granites may be present in the Cone Mountain area, but available data indicate that the rocks are calcalkalic and moderately peraluminous and have a silica content from 74 to 76 percent. The granites were intruded at about 16 Ma, definitely later than the rocks in the Tkope-Portland Peninsula belt. The plutons were intruded at a high crustal level under static conditions, but their relations to other belts and to possible localizing factors are obscure.

## SOUTHERN SOUTHEASTERN ALASKA DIKE SWARM

The southern southeastern Alaska dike swarm (Fig. 3, Tables 1 and 2) consists mostly of lamprophyres that occupy a significant part of a northeast-trending belt about 100 km wide and greater than 150 km long. Granitic and volcanic rocks are also present. The swarm overlaps the southeastern end of the Tkope-Portland Peninsula belt, and at least some of the dikes are closely related to the plutons there. The lamprophyres are alkalic, and most are classified as alkali-olivine rocks. The non-lamprophyres are calcalkalic and have a silica content ranging from 56 to 71 percent.

The age of intrusion of the lamprophyres is not well known; they cut plutons with ages of 27-24 Ma in the Tkope-Portland Peninsula belt but are not known to cut the plutons of the Groundhog Basin area with ages of 17-14 Ma. Souther (1970) interprets them as the deeper expression of the dated Miocene alkalic volcanic fields to the northeast in British Columbia. Those fields are inferred to be localized in belts of large-scale crustal extension related to continental-margin transcurrent faulting; the dikes follow joints that are perpendicular to the foliation and resulted from the relaxation of the major stresses that affected the Coast crystalline belt in earlier Tertiary time.

## KRUZOF-KUPREANOF AND BEHM CANAL-RUDYERD BAY AREAS

Two areas or belts of Pliocene and Quaternary volcanic rocks are shown on Figure 3 and described in Tables 1 and 2. The first, the Kruzof-Kupreanof area of Holocene rocks, appears as two segments separated at the Chatham Strait fault because it postdates the major offset that was removed in constructing the palinspastic base for the figure. This area consists of two widely spaced volcanic fields of similar age and chemical composition. Those fields, Edgecumbe and southern Kupreanof, contain tholeiitic basalt, and the Edgecumbe field also has calcalkalic younger flows and pyroclastic rocks.

Most, but not all, of the flows are interpreted to be postglacial. Together the two fields define an east-west-trending area similar in orientation to the east-west Holocene volcanic belts in the west-central British Columbia region; Souther (1970) relates the localization of the latter belts to large-scale crustal extension.

The second area of Pliocene and Quaternary volcanic rocks is the Behm Canal-Rudyerd Bay volcanic field, most of which occurs within the area covered by the southern southeastern Alaska dike swarm. The small Blue River-Unuk River volcanic field to the north (Fig. 1) is considered an outlier of the Behm Canal-Rudyerd Bay field. Both fields contain alkali olivine basalts and other alkalic rocks that are somewhat similar to the alkali to peralkaline basalts in the Mount Edziza field, which is located about 100 km to the north in Canada. Souther and Armstrong (1966), Souther (1970), and Souther and others (1984) relate the north-south orientation of the Mount Edziza field to large-scale crustal extension. It is likely that this area is an outlier of that large field.

## SUMMARY

The Cenozoic volcanic and plutonic rocks of southeastern Alaska record a progression of events that are related to the tectonics of the northeastern Pacific margin. The progression started with the collisional/convergent events related to the accretion of the Alexander terrane to the "Stikine" terrane; the progression continued with the events related to the accretion and subduction of the Chugach terrane on the west side of the Alexander. These events along the northeastern Pacific margin occurred in Late Cretaceous and early Tertiary time; they were followed by events related first to oblique subduction and then to transition to dominantly transcurrent movements. The progression ended with magmatic events localized along extensional zones that may be related either to present-day right-lateral crustal displacements in the northeastern Pacific region or to residual stresses that originated in the late stages of convergence. Figure 24 summarizes these time and space relations.

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**TABLE 1.**--Major latest Mesozoic and Cenozoic magmatic belts and areas of southeastern Alaska

| Major Area or Belt Name and Age Division | Components of the Major Area or Belt: Figure 1 and Table 2 Reference | Individual Area or Belt Name |
|---|---|---|
| Great tonalite sill belt (75-55 Ma) | EE | Bradfield Canal area |
| | FF | Ketchikan-Prince Rupert area |
| | GG | Juneau-Skagway area |
| | HH | Haines-Skagway area |
| | II | Juneau-Taku River area |
| | JJ | Sumdum area |
| | KK | Petersburg area |
| | LL | Bradfield Canal area |
| | MM | Ketchikan-Prince Rupert area |
| Coast Mountains belt (55-45 Ma) | AA | Haines-Skagway area |
| | BB | Juneau-Taku River area |
| | CC | Sumdum (Tracy Arm) area |
| | DD | Petersburg area |
| Fairweather-Baranof belt (45-35 Ma) | Y | Fairweather Range |
| | Z | Yakobi, Chichagof, and Baranof area |
| Glacier Bay region (45-35 Ma) | X | Glacier Bay region |
| Tkope-Portland Peninsula belt (35-5 Ma) | F | Tkope volcanic-plutonic belt |
| | J | William Henry Bay area |
| | K | Icy Strait volcanic-plutonic field |
| | M | Admiralty field |
| | N | Kuiu-Etolin volcanic-plutonic field |
| | P | Southern Etolin field |
| | S | Burroughs Bay area |
| | U | Ketchikan area |
| | V | Quartz Hill-Portland Peninsula area |
| Groundhog Basin-Cone Mountain (35-5 Ma) | O | Groundhog Basin area |
| | T | Cone Mountain area |
| Southern southeastern Alaska dike swarm (35-5 Ma) | W | Southern southeastern Alaska dike swarm |
| Kruzof-Kupreanof area (5-0 Ma) | A | Edgecumbe field |
| | B | Southern Kupreanof field |
| Behm Canal-Rudyerd Bay area (5-0 Ma) | C | Blue River-Unuk River field |
| | E | Behm Canal-Rudyerd Bay field |

TABLE 2.--Description of latest Mesozoic and Cenozoic magmatic rocks of southeastern Alaska.

| Figure 1 and Plate 1 Reference | Area or Belt Name | Major (and Minor) Lithic Types Present | Chemical Classification | $SiO_2$ Range | $SiO_2$ Gap(s) | Map and Diagrams on Fig. | Age Data | Discussion | References |
|---|---|---|---|---|---|---|---|---|---|
| PLIOCENE AND QUATERNARY ROCKS (5-0 Ma) | | | | | | | | | |
| A | Edgecumbe field | Basalt, basaltic andesite, andesite, dacite, (rhyolite) | Tholeiitic, calc-alkalic | 47-72 (non-tephra); 52-74 (tephra) | 62-69; 60-65 | 4, 5 (location) | Late Pleistocene and younger on K-Ar data (M.A. Lanphere, written commun., 1985) and microfossils (W.V. Sliter, written commun., 1985) | Basal tholeiitic basalt shield surmounted by calc-alkalic andesite cones and dacite plugs, basaltic to rhyolitic tephras all younger than 10,000 B.P. | Brew and others, 1969; Myers and others, 1984; Kosco, 1981; Riehle and Brew, 1984, unpub. data |
| B | Southern Kupreanof field | Olivine-bearing basalt | Mostly tholeiitic; aver. K content; some alkalic: sodic | 45-53 | | 5 | Younger than 300 ka on K-Ar data | Pahoehoe and aa flows, some plugs | Brew and others, 1984, 1985; Douglass and others, 1988 |
| C | Blue River-Unuk River field | Alkali olivine basalt | Mostly alkalic, sodic; some calc-alkalic: K-richs | 46-48 | | 5 | As young as 360±60 B.P. on radiocarbon | Valley-filling flows, small cinder cones | Elliott and others, 1981; Souther and others, 1984 |
| D | Tlevak Strait-Suemez field | Olivine basalt | Alkalic: sodic | 47 | | | No data | Pahohoe surfaces, valley-filling flows | Eberlein and Churkin, 1970; Eberlein and others, 1983; G.D. Eberlein, written commun., 1986 |
| E | Behm Canal-Rudyerd Bay field | Olivine basalt, basaltic breccia and tuff, andesite (trachyandesite) | Alkalic: mostly potassic | 43-61 | 46-59 | 5 | Possibly two periods: 5 Ma and 1 Ma-500 ka (Smith and Diggles, 1981) | Columnar flows, cinder cones | Wanek and Callahan, 1971; Berg and others, in press; Smith and others, 1977; Ouderkirk, 1982; Doyle, 1983; Souther and others, 1984 |
| LATE OLIGOCENE AND MIOCENE ROCKS (35-5 Ma) | | | | | | | | | |
| F | Tkope volcanic-plutonic belt | In Canada: granophyre, granite, quartz monzonite, granodiorite, quartz diorite gabbro. In U.S.: hornblende-biotite granite | Calcalkalic except for gabbros, which are on calc-alkalic-tholeiitic boundary | 49-77 | 51-69 | N.A. | 28-24 Ma on K-Ar, Rb-Sr, and fission track | Main expression is epizonal, composite Tkope River pluton in Canada; extension into U.S.A. consists of plugs, dikes, and small plutons | Jacobsen, 1979; Campbell and Dodds, 1983; D.A. Brew, unpub. data |

TABLE 2.--Description of latest Mesozoic and Cenozoic magmatic rocks of southeastern Alaska--Continued.

| Figure 1 and Plate 1 Reference | Area or Belt Name | Major (and Minor) Lithic Types Present | Chemical Classification | $SiO_2$ Range | $SiO_2$ Gap(s) | Map and Diagrams on Fig. | Age Data | Discussion | References |
|---|---|---|---|---|---|---|---|---|---|
| LATE OLIGOCENE AND MIOCENE ROCKS (35-5 Ma) (Continued) | | | | | | | | | |
| G | Haines area | Biotite quartz monzonite, locally miarolitic | No data | No data | No data | N.A. | No data | Age inferred from lithic similarity to Kuiu-Etolin belt plutons | Redman and others, 1984 |
| H | Fairweather Range | Garnet-muscovite-biotite granite and granodiorite | No data | No data | No data | N.A. | 5.9 Ma on biotite and 16.6 Ma on muscovite (M.A. Lanphere, written commun., 1978) | May belong with nearby early Oligocene and late Eocene bodies | Brew and others, 1978; D.A. Brew, unpub. data |
| I | Lituya Bay area | Tuffs, flows of andesite and basaltic andesite | Calcalkalic, K-poor, per Irvine and Baragar (1971) | 54 | N.A. | N.A. | Post-early Oligocene(?) to pre-middle Miocene (Miller, 1961) | Cenotaph volcanics unit of Miller (1961); non-marine | Plafker, 1971; G. Plafker, written commun., 1986 |
| J | William Henry Bay area | Biotite quartz monzonite, diorite | No data | No data | No data | N.A. | No data | Age inferred by Eakins (1975) on lithic grounds(?) | Eakins, 1975; Brew and Ford, 1985 (1986) |
| K | Icy Strait volcanic-plutonic belt | Hornblende gran-, ite, hornblende quartz monzonite; breccia, flows, and tuff of dacite, andesite, and basalt | Volcanic rocks, mostly tholeiitic, aver. K content; also calcalkalic, aver. K content; no data on granitoids | 47-72 | 61-68 | 6, 7 | Two episodes; 25 Ma and 16 Ma on whole-rock K-Ar (G.Plafker, written commun., 1986) | Linkage between plutons and volcanics is tenuous; REE diagram shows differentiated trend with higher $SiO_2$ rocks having negative Europium anomalies | Brew and Ford, 1985 (1986); D.A. Brew, unpub. data; G. Plafker, written commun., 1986; Fukuhara, 1986 |
| L | Gut Bay area | Hornblende-biotite granodiorite, tonalite, gabbro | No data | No data | No data | N.A. | 24.3 Ma on biotite; 24.9 Ma and 31.5 Ma on co-existing biotite and hornblende, respectively | Heterogeneous intrusion | Loney and others, 1975 |
| M | Admiralty field | Andesite and basalt flows, (rhyolite tuff and breccia) | Mostly tholeiitic per MacDonald and Katsura (1964), but calcalkalic (aver. K content) per Irvine and Baragar (1971) | 47-58 | N.A. | 6, 7 | Oligocene plant fossils (J.A. Wolfe, written commun., 1985) 27 Ma whole-rock K-Ar (G.Plafker, written commun., 1986) | 1,500-2,900 m thick; alteration common | Loney, 1964; Lathram and others, 1965; G. Plafker, written commun., 1986 |

**TABLE 2.**--Description of latest Mesozoic and Cenozoic magmatic rocks of southeastern Alaska-Continued

| Figure 1 and Plate 1 Reference | Area or Belt Name | Major (and Minor) Lithic Types Present | Chemical Classification | $SiO_2$ Range | $SiO_2$ Gap(s) | Map and Diagrams on Fig. | Age Data | Discussion | References |
|---|---|---|---|---|---|---|---|---|---|
| LATE OLIGOCENE AND MIOCENE ROCKS (35-5 Ma) (Continued) | | | | | | | | | |
| N | Kuiu-Etolin volcanic-plutonic belt | Basalt and andesite flows; rhyolite flows and tuffs, vent and and other breccias; alkali granite, granite, quartz syenite, (gabbro) | Volcanics mostly tholeiitic per MacDonald and Katsura (1964) and Miyashiro (1974), but calcalkalic, aver. and low K-content per Irvine and Baragar (1971). Granitics are mostly peraluminous and metaluminous, calcalkalic, K-poor or K-aver., and only a few are peralkaline or alkalic | (volcanics) 46-76 (granitoids) 49-77 | (volcanics) 61-65 (granitoids) 54-56, 61-65 | 8, 9, 10 | Volcanics 22-20 Ma on whole-rock K-Ar; granitoids 19-24 Ma (Douglass and others, 1987) | Heterogeneous volcanic and plutonic complex; gabbro and microgabbro low in section; siliceous volcaniclastic rocks associated with rhyolite; large, well-zoned granitoid body at east end of belt, basalts and andesites have no negative Europium anomaly, rhyolites a strong one, granitoids are in between | Brew and others, 1979, 1984; Hunt, 1984; Douglass and others, 1988 |
| O | Groundhog Basin area | Rhyolite, biotite granite | Peraluminous per Shand (1951); tholeiitic per Mac Donald and Katsura (1964), but calcalkalic, K-poor per Irvine and Baragar (1971) | 74-76 | | 10 | Sill 15 Ma on whole-rock K-Ar; plug 16 Ma on biotite K-Ar | Prominent rhyolite sill swarm apparently centered on granitic or felsic volcanic plugs | Brew and others, 1984; Douglass and others, 1988; R.P. Morrell. written commun., 1986 |
| P | Southern Etolin field | Basalt flows, andesite breccias | No data | No data | No data | N.A. | No data | May be outlier of Kuiu-Etolin volcanics | Berg and others, 1976; Eberlein and others, 1983 |
| Q | East-central Prince of Wales field | Basalt and rhyolite breccia and tuff | No data | No data | No data | N.A. | No data | Very poorly known small isolated occurrences | Eberlein and others, 1983 |
| R | Suemez field | Olivine basalt flows, basalt breccia, lapilli tuff, rhyolite and dacite flows | Peralkaline per Irvine and Baragar (1971); tholeiitic per MacDonald and Katsura (1964) | 72 | N.A. | N.A. | Associated with Tertiary(?) coal seams | Poorly known field, may be closely related to Tlevak field (D) | Eberlein and others, 1983; G.D. Eberlein, written commun., 1986 |

TABLE 2.--Description of latest Mesozoic and Cenozoic magmatic rocks of southeastern Alaska--Continued.

| Figure 1 and Plate 1 Reference | Area or Belt Name | Major (and Minor) Lithic Types Present | Chemical Classification | $SiO_2$ Range | $SiO_2$ Gap(s) | Map and Diagrams on Fig. | Age Data | Discussion | References |
|---|---|---|---|---|---|---|---|---|---|
| LATE OLIGOCENE AND MIOCENE ROCKS (5-35 Ma) (Continued) | | | | | | | | | |
| S | Burroughs Bay area | Biotite granite and biotite quartz monzonite | No data | No data | No data | N.A. | 23 Ma K-Ar on biotite+chlorite (Hudson and others, 1979) | Quartz porphyry stock and dike swarm; explored for molybdenum | Hudson and others, 1979b; Berg and others, in press; R.L. Elliott and R.D. Koch, written commun., 1986 |
| T | Cone Mountain area | Alkali-feldspar granite (rhyolite) | No data | No data | N.A. | N.A. | Miocene(?) reported by Koch and Elliott (1981) | May be similar to Groundhog Basin area (O) | Koch and Elliott, 1981; R.L. Elliott and R.D. Koch, written commun., 1986 |
| U | Ketchikan area | Olivine-bearing pyroxene leucogabbro (gabbro, quartz diorite, granodiorite) | No data | No data | N.A. | N.A. | 24 Ma K-Ar on biotite, 25 Ma K-Ar on hornblende (Smith and Diggles, 1981) | May be distant member of Quartz Hill-Portland Peninsula group of plutons | Koch and Elliott, 1984; Berg and others, 1987 |
| V | Quartz Hill-Portland Peninsula area | Olivine-hypersthene-augite gabbro, biotite granite, granite porphyry, biotite quartz monzonite | Granitoids: Peraluminous, calcalcalic; gabbro: metaluminous, tholeiitic | 47-78 | 48-73 | 11 | Two episodes based on K-Ar: one at 30 Ma and one between 27 and 24 Ma | Four plutons in crude, E-trending belt--one contains major molybdenite deposit (Quartz Hill); strongly fractionated REE patterns and large Europium anomalies for granitoids, Sr initial ratios 0.747 to 0.7051 (Arth and others, 1986) | Elliott and others, 1976; Hudson and others, 1979 |
| W | Southern southeastern Alaska dike swarm | Lamprophyres, granitoids, basalt, dacite | Lamprophyres: alkalic, sodic; others: calc-alkalic | 58-71 | N.A. | 11 | 7 Ma (Ouderkirk, 1982) | North-northeast striking swarm; probably deep expression of alkaline volcanic field to NE in British Columbia (Souther, 1970) | Smith, 1973; Elliott and others, 1976; Ouderkirk, 1982; Doyle, 1983 |

**TABLE 2.**--Description of latest Mesozoic and Cenozoic magmatic rocks of southeastern Alaska--Continued.

| Figure 1 and Plate 1 Reference | Area or Belt Name | Major (and Minor) Lithic Types Present | Chemical Classification | $SiO_2$ Range | $SiO_2$ Gap(s) | Map and Diagrams on Fig. | Age Data | Discussion | References |
|---|---|---|---|---|---|---|---|---|---|
| LATE AND MIDDLE EOCENE AND EARLY OLIGOCENE ROCKS (45-35 Ma) | | | | | | | | | |
| X | Glacier Bay region | Biotite granite; alkali granite | Per- and metaluminous dominantly calc-alkalic | 58-76 | 71-75 | 12 | 42 to 31 Ma on K-Ar (12 determinations, M.A. Lanphere, oral commun., 1967, 1968, 1980) | Plutonic rocks slightly younger than in following two areas (Y and Z); body at Muir Inlet is associated with a Cu-Mo deposit | MacKevett and others, 1971, 1974; Brew and others, 1978; Brew, unpub. data; Himmelberg and Loney, 1981; Plafker and MacKevett, 1970 |
| Y | Fairweather Range | Biotite granodiorite, biotite-hornblende quartz diorite and diorite; olivine gabbro, olivine norite, (olivine gabbronorite, anorthosite, wehrlite, dunite) | No data for granitoids, but similar rocks not far NW are peraluminous, calcalkalic; gabbroids are metaluminous, dominantly tholeitic | Granitoids: 72-73 Gabbroids: 39-51 | N.A. | N.A. | No data on granitoids; indirect dating of gabroids in that they are cut by felsic intrusives of above group (X) | This area and following area (Z) both contain a gabbroic and an intermediate to felsic suite; this area has dominant layered gabbros; area Z has dominant intermediate to felsic intrusives; La-Perouse layered gabbro is host of major magmatic Ni-Cu deposit | As above, plus Hudson and others, 1977; Loney and Himmelberg, 1983 |
| Z | Yakobi, Chichagof, and Baranof area | Garnet- or muscovite-bearing biotite-hornblende granodiorite and granite, biotite granodiorite, muscovite-hornblende-biotite tonalite, (hornblende quartz diorite) hornblende-pyroxene gabbronorite, hornblende pyroxenite, (quartz-bearing norite, leucogabbro) | Granitoids dominantly metaluminous, calc-alkalic--aver. K content; gabbroids metaluminous, calc-alkalic and tholeiitic, both aver. K content | Granitoids: 51-73 Gabbroids: 49-55 | Granitoids: 58-65 | 12, 13 | 43-40 Ma K-Ar on hornblende and biotite from tonalite on Yakobi (M.A. Lanphere, written commun., 1982; F.H. Wilson, written commun., 1985); 49 Ma K-Ar on biotite from granodiorite on Kruzof (Loney and others, 1967); 47-42 Ma K-Ar on biotite and hornblende from granodiorite and tonalite on Baranof (Loney and others, 1967) | See above; gabbronorite on Yakobi is host of Cu deposit; REE diagram shows relatively undifferentiated trends. Kruzof pluton has $^{87}Sr/^{86}Sr$ values of about 0.70535; (Myers and others, 1984) | Loney and others, 1975; Johnson and Karl, 1985; Callahan, 1970; Wanek and Callahan, 1969; Himmelberg and others, 1987 |

TABLE 2.--Description of latest Mesozoic and Cenozoic magmatic rocks of southeastern Alaska--Continued.

| Figure 1 and Plate 1 Reference | Area or Belt Name | Major (and Minor) Lithic Types Present | Chemical Classification | $SiO_2$ Range | $SiO_2$ Gap(s) | Map and Diagrams on Fig. | Age Data | Discussion | References |
|---|---|---|---|---|---|---|---|---|---|
| EARLY AND MIDDLE EOCENE ROCKS (55-45 Ma) | | | | | | | | | |
| AA | Haines-Skagway area | K-feldspar porphyritic hornblende quartz monzodiorite, K-feldspar porphyritic hornblende-biotite quartz monzonite and granite, hornblende-biotite tonalite and granodiorite, biotite granite | Tonalite To W dominantly peraluminous (8:3), rest metaluminous, calcalkalic, aver. and high K content; granodiorite and granite to E equally peraluminous and metaluminous, calcalkalic, low K content | 53-77 | N.A. | 14, 15A | Tonalite and granodiorite 54 Ma on Pb/U on zircon, 52 Ma on K-Ar on biotite; granite 52-51 Ma on Pb/U on zircon to E, 48 Ma to W (Barker and others, 1986) | Assignment of rocks north of Haines based on lithic similarity to rocks to E and S; if assignment is correct, then this is the only known occurrence of an early Eocene body W. of the "tonalite sill" family of plutons. Tonalite and granodiorite near Skagway REE diagram shows moderate to steep negative slopes and small negative Eu anomalies, granites have flat slopes and distinct negative anomalies. Initial Sr ratios range from 0.70485 to 0.70770 | Margaritz and Taylor, 1976; Redman and others, 1984; Lambert, 1974; Christie, 1957, 1959; Barker and others, 1986; D.A. Brew and A.B. Ford, unpub. data |
| BB | Juneau-Taku River area | Homogeneous sphene-bearing biotite-hornblende granodiorite, tonalite, and granite; K-spar porphyritic hornblende-biotite granite, quartz monzodiorite, and granodiorite | Dominantly (2:1) metaluminous, rest peraluminous, calcalkalic--aver. K content | 60-76 | N.A. | 15B, 16 | Published K-Ar of 53-50 Ma (Forbes and Engels, 1970) and Pb/U on zircon of 50 Ma (Gehrels and others, 1984) supported by abundant unpub. K-Ar data (J.G. Smith, written communs., 1976-1986; F.H. Wilson, written communs., 1985, 1986 | Very large composite pluton; K-spar, porphyritic phase restricted to near InterNational Boundary; associated with volcanic rocks of Sloko Group in same area (Souther, 1971) | Brew and Ford, 1986; Souther, 1971; D.A. Brew and A.B. Ford, unpub. data. |
| CC | Sumdum (Tracy Arm) area | Sphene-hornblende biotite granodiorite and granite, sphene-biotite-hornblende granodiorite, hornblende granodiorite; locally porphyritic | Dominantly (2:1) metaluminous, rest peraluminous, calcalkalic--aver. K-content | 59-75 | N.A. | 17 | 54-49 Ma K-Ar on numerous biotite and hornblende samples (J.G. Smith, written communs., 1976-1986) | Southeastward continuation of very large composite pluton of Juneau-Taku River area | Brew and Grybeck, 1984; D.A. Brew and A.B. Ford, unpub. data |

TABLE 2.--Description of latest Mesozoic and Cenozoic magmatic rocks of southeastern Alaska--Continued.

| Figure 1 and Plate 1 Reference | Area or Belt Name | Major (and Minor) Lithic Types Present | Chemical Classification | $SiO_2$ Range | $SiO_2$ Gap(s) | Map and Diagrams on Fig. | Age Data | Discussion | References |
|---|---|---|---|---|---|---|---|---|---|
| EARLY AND MIDDLE EOCENE ROCKS (55-45 Ma) (Continued) | | | | | | | | | |
| DD | Petersburg area | Locally K-spar porphyritic sphene-bearing biotite-hornblende granodiorite, tonalite, and granite | Dominantly peraluminous, calcalkalic--aver. K content | 64-75 | N.A. | 17, 18 | 52-49 Ma K-Ar on biotite and hornblende (Douglass and others, 1987) | Large discrete pluton with complicated border phases | Brew and others, 1984; Webster, 1984; Douglass and others, 1988 |
| EE | Bradfield Canal area | Locally K-spar porphyritic sphene-bearing biotite-hornblende granodiorite and granite, leucocratic quartz monzonite, alkali granite | Peraluminous, calcalkalic--aver. K-content and K-poor | 54-75 | 55-65 | 19 | 53-46 Ma on K-Ar from three different intrusive phases (Smith, 1977) | Several intrusive episodes probably represented | Koch and Elliott, 1981; Smith, 1977; R.D. Koch and R.L. Elliott, oral commun., 1986 |
| FF | Ketchikan-Prince Rupert area | Locally K-spar porphyritic sphene-bearing biotite-hornblende granodiorite, granite, and tonalite | Peraluminous dominant over metaluminous 2:1; calcalkalic--aver. K-content | 58-72 | 60-65 | 19 | 55-45 Ma on K-Ar from biotite and hornblende (Smith and Diggles, 1981) | Major bodies are continuations of those in Bradfield Canal area; probably several close-spaced intrusive episodes represented; strongly fractionated REE patterns with small negative Eu anomalies; Sr initial ratios 0.7046-0.7061; area connects to SE in British Columbia with Ponder pluton (Hutchison, 1982) and Mo-bearing Alice Arm intrusions (Woodcock and Carter, 1976; Christopher and Carter, 1976) | Berg and others, in press; Smith, 1977; Smith and others, 1977; Woodcock and Carter, 1976; Hutchison, 1982; Arth and others, 1986 |

**TABLE 2.**--Description of latest Mesozoic and Cenozoic magmatic rocks of southeastern Alaska--Continued.

| Figure 1 and Plate 1 Reference | Area or Belt Name | Major (and Minor) Lithic Types Present | Chemical Classification | $SiO_2$ Range | $SiO_2$ Gap(s) | Map and Diagrams on Fig. | Age Data | Discussion | References |
|---|---|---|---|---|---|---|---|---|---|
| PALEOCENE ROCKS (65-55 Ma) | | | | | | | | | |
| GG | Juneau-Skagway area | Foliated hornblende granodiorite and tonalite; biotite-hornblende granodiorite | Equal peraluminous and metaluminous; calcalkalic--aver. K-content, some K-rich | 57-76 | N.A. | 20 | 60 Ma on zircon (Gehrels and others, 1984) is supported by unpublished zircon zircon age (G.R. Tilton, written commun., 1986) and K-Ar ages (F.H. Wilson, written communs., 1985, 1986) | Structurally more complicated than above (45-55 Ma) suite modally and chemically in between the above suite and that below (65-75 Ma); plutons are generally stubby sills | Brew and Ford, 1986 |
| LATEST CRETACEOUS ROCKS (75-65 Ma) | | | | | | | | | |
| HH | Haines-Skagway area | In Canada: Locally Foliated K-spar porphyritic biotite-hornblende granite<br>In U.S.: well- to slightly foliated locally lineated sphene-hornblende biotite tonalite (hornblende quartz diorite, biotite-hornblende-granodiorite) | In Canada: Peraluminous, calcalkalic--aver. K-content and some K-poor<br>In U.S.: Equal pera- and metaluminous, calcalkalic--aver. K-content and some K-rich | In Canada 67-73<br>In U.S.: 57-73 | N.A.<br>N.A. | 21, 22A | In Canada: U-Pb age of 72 Ma on zircon;<br>In U.S.: U-Pb ages of 67-68 on zircons (Barker and others, 1986) | Pluton in Canada is unlike others in this suite structurally and modally;it has Sr initial ratio of 0.70615; the plutons in the U.S. are part of the "Great tonalite sill" family. REE diagram shows steep slopes with no or small negative Eu anomalies | Barker and others, 1986, Redman and others, 1984; D.A. Brew and A.B. Ford, unpub. data |
| II | Juneau-Taku River area | Very well foliated, locally well lineated, locally sphene-bearing biotite-hornblende and hornblende-biotite tonalite, quartz diorite, and granodiorite | Very dominantly metaluminous, calcalkalic - aver. K-content slightly more common than K-rich | 51-71 | N.A. | 21 | Pb/U age of 67 Ma on zircon (Gehrels and others, 1984); unpub. K-Ar ages on biotite and hornblende suggest range may be 56-67 Ma (F.H. Wilson, written communs., 1985, 1986) | "Great tonalite sill" family consists of a single NW-digitating pluton to the NW and a group of narrow digitating plutons to the SE | Brew and Ford, 1986; Ford and Brew, 1981; D.A. Brew and A.B. Ford, unpub. data |

**TABLE 2.**--Description of latest Mesozoic and Cenozoic magmatic rocks of southeastern Alaska--Continued.

| Figure 1 and Plate 1 Reference | Area or Belt Name | Major (and Minor) Lithic Types Present | Chemical Classification | $SiO_2$ Range | $SiO_2$ Gap(s) | Map and Diagrams on Fig. | Age Data | Discussion | References |
|---|---|---|---|---|---|---|---|---|---|
| LATEST CRETACEOUS ROCKS (75-65 Ma) - CONTINUED | | | | | | | | | |
| JJ | Sumdum area | Generally well-foliated, locally well-lineated biotite-hornblende quartz diorite and tonalite, (biotite-hornblende granodiorite and quartz monzonite) | Meta- to peraluminous ratio 2.5:1; calc-alkalic - aver. K-content and K-rich equally abundant | 58-68 | 64-67? | 23 | K-Ar ages range from 66 Ma on hornblende to 50 Ma (J.G. Smith, written communs., 1977, 1978, 1986) Pb/U of 64 Ma reported by Gehrels and others (1984) | "Great tonalite sill" family consists of one narrow but continuous pluton plus several small sills of somewhat uncertain affinity | Brew and Grybeck, 1984; D.A. Brew and A.B. Ford, unpub. data |
| KK | Petersburg area | Generally well-foliated, locally well-lineated biotite-hornblende and hornblende-biotite tonalite, quartz diorite (granodiorite) | Meta- to peraluminous ratio is 10.5:1; calcalkalic - dominantly K-rich, some aver. K-content | 54-67 | 63-66? | 22B, 23 | No reliable ages available | "Great tonalite sill" family consists of four large homogeneous bodies; migmatite unit between two of them | Brew and others, 1984; Douglass and others, 1988 |
| LL | Bradfield Canal area | Granodiorite and quartz diorite | No data | No data | No data | N.A. | No data | "Great tonalite sill" family consists of continuations from the Petersburg area (LL) that digitate or otherwise die out to the SE | Koch and Elliott, 1981; R.L. Elliott and R.D. Koch, oral commun., 1986 |

**TABLE 2.**--Description of latest Mesozoic and Cenozoic magmatic rocks of southeastern Alaska--Continued.

| Figure 1 and Plate 1 Reference | Area or Belt Name | Major (and Minor) Lithic Types Present | Chemical Classification | $SiO_2$ Range | $SiO_2$ Gap(s) | Map and Diagrams on Fig. | Age Data | Discussion | References |
|---|---|---|---|---|---|---|---|---|---|
| LATEST CRETACEOUS ROCKS (75-65 Ma) - CONTINUED | | | | | | | | | |
| MM | Ketchikan-Prince Rupert area | Foliated biotite-hornblende quartz diorite and tonalite, granodiorite | Meta- to peraluminous ratio 5:1; calcalkalic - aver. K-content and K-rich in equal amounts | 56-62 | N.A. | 23 | 58 to 55 Ma on zircon (Berg and others, 1987) | Extension of "Great tonalite sill" family into British Columbia is Quotoon pluton; in the U.S. adjacent to International Boundary that single homogeneous body resembles the family further N, but intervening area (to Bradfield Canal (LL)) is a poorly understood zone 25 Km wide with several narrow sills; Arth and others (1986) report mildly fractionated REE patterns with small negative Eu anomalies and Sr initial ratios of 0.7063-0.7064 | Berg and others, in press; Smith and others, 1977; Hutchison, 1982; Arth and others, 1986 |

## ILLUSTRATIONS

Oligocene and Miocene age from the Kuiu-Etolin volcanic-plutonic belt. A, Basalts and andesites; B, Rhyolites (dots) and granitic rocks (circles). Data source: D.A. Brew (unpub. data, 1985).

**FIGURE 10.** Location map and composition diagrams for plutonic rocks of late Oligocene and Miocene age from A, the Kuiu-Etolin volcanic-plutonic belt (N) and Groundhog Basin area (O). B, AFM diagram (Irvine and Baragar, 1971); C, Silica-variation diagram; D, general plutonic rock classification diagram (Streckeisen, 1973): AF, alkali-feldspar granite; AQ, alkali-feldspar quartz syenite; AS, alkali-feldspar syenite; DI, diorite; GR, granite; GD, granodiorite; MD, monzodiorite; MO, monzonite; QD, quartz diorite; QO, quartz monzodiorite; QM, quartz monzonite; QS, quartz syenite; SY, syenite; AM, quartz monzonite; QS, quartz syenite; SY, syenite; TO, tonalite. Data sources: Douglass and others (1988), and Hunt (1984).

**FIGURE 11.** Location map and composition diagrams for plutonic rocks of late Oligocene and Miocene age from A, the Quartz Hill/Portland Peninsula area (V). B, AFM diagram (Irvine and Baragar, 1971); C, Silica-variation diagram; D, general plutonic rock classification diagram (Strekeisen, 1973): AF, alkali-feldspar granite; AQ, alkali-feldspar quartz syenite; AS, alkali-feldspar syenite; DI, diorite; GR, granite; GD, granodiorite; MD, monzondiorite; MO, monzonite; QD, quartz diorite; QO, quartz monzodiorite; QM, quartz monzonite; QS, quartz syenite; SY, syenite; TO, tonalite. Data sources: Smith and others (1977); Hudson and others (1979).

**FIGURE 12.** Location map and composition diagrams for granitic and gabbroic rocks of Miocene and late Eocene and early Oligocene age from A, the Glacier Bay region (X) and the Yakobi, Chichagof, and Baranof area (Z). B, AFM diagram (Irvine and Baragar, 1971); C, Silica-variation diagram; D, general plutonic rock classification diagram (Streckeisen, 1973): AF, alkali-feldspar granite; AQ, alkali-feldspar quartz syenite; AS, alkali-feldspar syenite; DI, diorite; GR, granite; GD, granodiorite; MD, monzondiorite; MO, monzonite; QD, quartz diorite; MO, quartz monzodiorite; QM, quartz monzonite; QS, quartz syenite; SY, syenite; TO, tonalite. Data sources: Himmelberg and Loney (1987), and Brew (unpub. data) for all but Baranof area; Wanek and Callahan (1969) and Callahan (1978) for Baranof area.

**FIGURE 13.** Chondrite-normalized rare-earth-element diagram for rocks of middle and late Eocene and early Oligocene age from the Yakobi Island area. Data source: Himmelberg and others (1987).

**FIGURE 14.** Location map and composition diagrams for granitic rocks of early and middle Eocene age from A, the Haines-Skagway area (AA). B, AFM diagram (Irvine and Baragar, 1971; C, Silica-variation diagram; D, general plutonic rock classification diagram (Streckeisen, 1973): AF, alkali-feldspar granite; AQ, alkali-feldspar quartz syenite; AS, alkali-feldspar syenite; DI, diorite, GR, granite; GD, granodiorite; MD, monzondiorite; MO, monzonite; QD, quartz diorite; QO, quartz monzodiorite; QM, quartz monzonite; QS, quartz syenite; SY, syenite; TO, tonalite; $FeO^*$ indicates total Fe as FeO. Data source: Barker and others (1986).

**FIGURE 15.** Chondrite-normalized rare-earth-element diagrams for granitic rocks of early and middle Eocene age. A, Haines-Skagway area; data source: Barker and others (1986); B, Juneau-Taku River area; data source: D.A. Brew and A.B. Ford (unpub. data, 1985).

**FIGURE 16.** Location map and composition diagrams for granitic rocks of early and middle Eocene age from A, the Juneau-Taku River area (BB). B, AFM diagram (Irvine and Baragar, 1971); C, Silica-variation diagram; D, general plutonic rock classification diagram (Streckeisen, 1973): AF, Alkali-feldspar granite; AQ, alkali-feldspar quartz syenite; AS, alkali-feldspar syenite; DI, diorite; GR, granite; GD, granodiorite; MD, monzondiorite; MO, monzonite; QD, quartz diorite; QO, quartz monzodiorite; QM, quartz monzonite; QS, quartz syenite; SY, syenite; TO, tonalite. Data source: D.A. Brew and A.B. Ford (unpub. data, 1985).

**FIGURE 17.** Location map and composition diagrams for granitic rocks of early and middle Eocene age from A, the Sumdum (CC) and Petersburg (DD) areas. B, AFM diagram (Irvine and Baragar, 1971); C, Silica-variation diagram; D, general plutonic rock classification diagram (Streckeisen, 1973): AF, alkali-feldspar granite; AQ, alkali-feldspar quartz syenite; AS, alkali-feldspar syenite; DI, diorite; GR, granite; GD, granodiorite; MD, monzondiorite; MO, monzonite; QD, quartz diorite; QO, quartz monzodiorite; QM, quartz monzonite; QS, quartz syenite; SY, syenite; TO, tonalite. Data sources: D.A. Brew and A.B. Ford (unpub. data, 1985) for Sumdum; Douglass and others (1988) for Petersburg.

**FIGURE 18.** Chondrite-normalized rare-earth element diagram for granitic rocks of early and middle Eocene age from the Petersburg area. Data source: D.A. Brew (unpub. data 1985).

**FIGURE 19.** Location map and composition diagrams for granitic rocks of early and middle Eocene age from A, Bradfield Canal (EE) and Ketchikan (FF) areas. B, AFM diagram (Irvine and Baragar, 1971); C, Silica-variation diagram; D, general plutonic rock classification diagram (Streckeisen, 1973): AF, alkali-feldspar granite; AQ, alkali-feldspar quartz syenite; AS, alkali-feldspar syenite; DI, diorite; GR, granite; GD, granodiorite; MD, monzondiorite; MO, monzonite; QD, quartz diorite; QO, quartz monzodiorite; QM, quartz monzonite; QS, quartz syenite; SY, syenite; TO, Tonalite. Data sources: Webster (1984) and Smith (1977) for Bradfield Canal area; Smith (1977) for Ketchikan-Prince Rupert area.

**FIGURE 20.** Location map and composition diagrams for granitic rocks of Paleocene age from A, the Juneau-Skagway area (GG). B, AFM diagram (Irvine and Baragar (1971); C, Silica-variation diagram; D, general plutonic rock classification diagram (Streckeisen, 1973): AF, alkali-feldspar granite; AQ, alkali-feldspar quartz syenite; AS, alkali-feldspar syenite; DI, diorite; GR, granite; GD, granodiorite; MD, monzondiorite; MO, monzonite; QD, quartz diorite; QO, quartz monzodiorite; QM, quartz monzonite; QS, quartz syenite; SY, syenite; TO, tonalite. Data source: D.A. Brew and A.B. Ford (unpub. data, 1985).

**FIGURE 21.** Location map and composition diagrams for granitic rocks of latest Cretaceous age from A, the Haines-Skagway (HH) and Juneau-Taku River (II) areas. B, AFM diagram (Irvine and Baragar, 1971); C, Silica-variation diagram; D, general plutonic rock classification diagram (Streckeisen, 1973): AF, alkali-feldspar granite; AQ, alkali-feldspar quartz syenite; AS, alkali-feldspar syenite; DI, diorite; GR, granite, GD, granodiorite; MD, monzondiorite; MO, monzonite; QD, quartz diorite; QO, quartz monzodiorite; QM, quartz monzonite; QS, quartz d=syenite; SY, syenite; TO, tonalite. Data sources: D.A. Brew and A.B. Ford (unpub. data, 1985) and Barker and others (1986).

**FIGURE 22.** Chondrite-normalized rare-earth element diagrams for granitic rocks of latest Cretaceous age. A, Haines-Skagway area (data from Barker and others, 1986); B, Petersburg area (D.A. Brew, unpub. data, 1985).

**FIGURE 23.** Location map and composition diagrams from granitic rocks of latest Cretaceous age from A, the Sumdum (JJ), Petersburg (KK), and Ketchikan-Prince Rupert (MM) areas. B, AFM diagram (Irvine and Baragar, 1971); C, Silica-variation diagram; D, general plutonic rock classification diagram (Streckeisen, 1973): AF, alkali-feldspar granite; AQ, alkali-feldspar quartz syenite; AS, alkali-feldspar quartz syenite; AS, alkali-feldspar syenite; DI, diorite; GR, granite; GD, granodiorite; MD, monzondiorite; MO, monzonite; QD, quartz diorite; QO, quartz monzodiorite; QM, quartz monzonite; QS, quartz syenite; SY, syenite; TO, tonalite. Data sources: D.A. Brew and A.B. Ford (unpub. data, 1985) and Brew and Grybeck (1984) for Sumdum; Douglass and others (1988) for Petersburg; and Smith (1977) for Ketchikan-Prince Rupert.

**FIGURE 24.** Time space diagram summarizing latest Mesozoic and Cenozoic magmatism in southeastern Alaska.

## TABLES

**TABLE 1.** Major latest Mesozoic and Cenozoic magmatic belts and areas of southeastern Alaska.

**TABLE 2.** Description of latest Mesozoic and Cenozoic magmatic rocks of southeastern Alaska. See text for discussion.

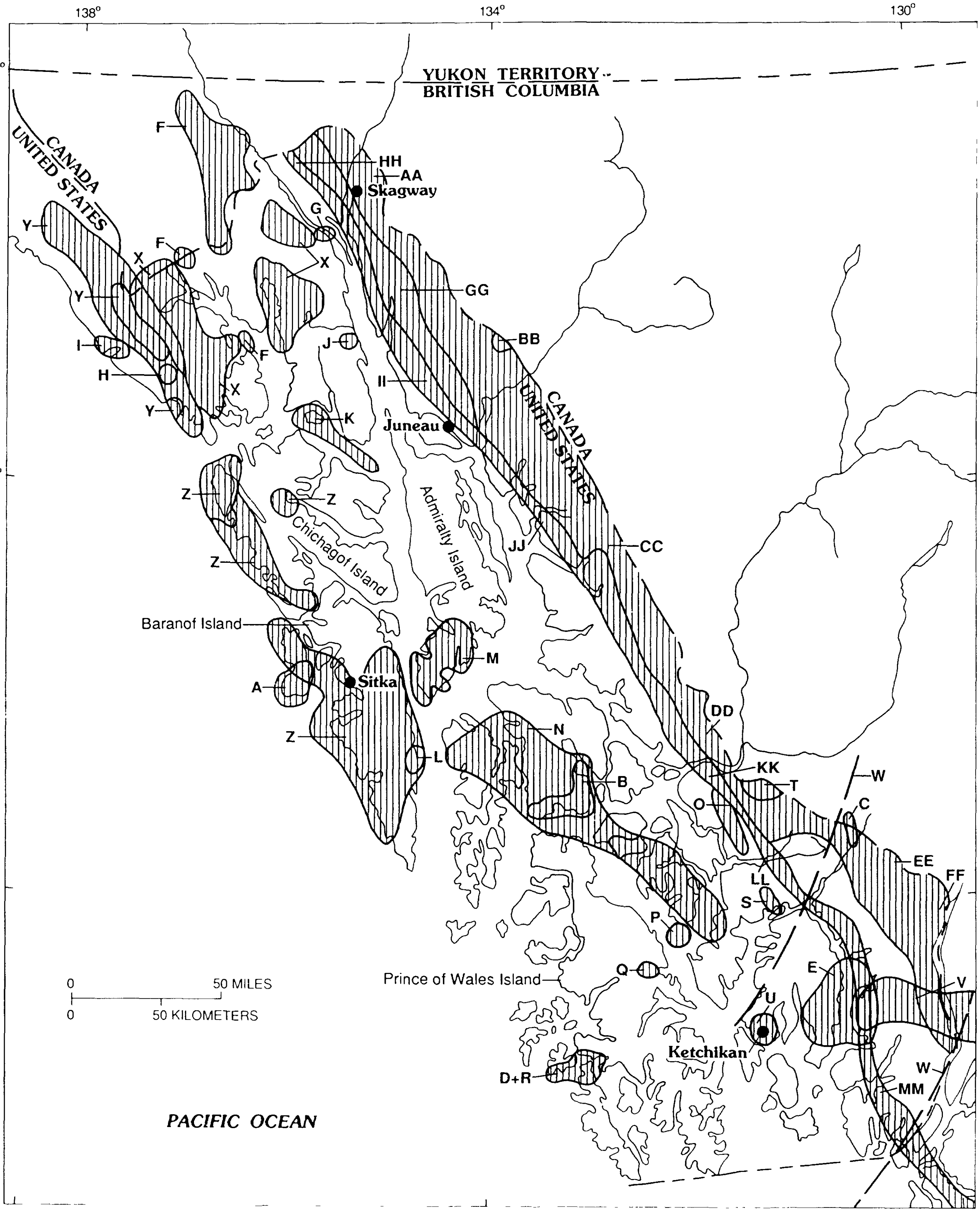
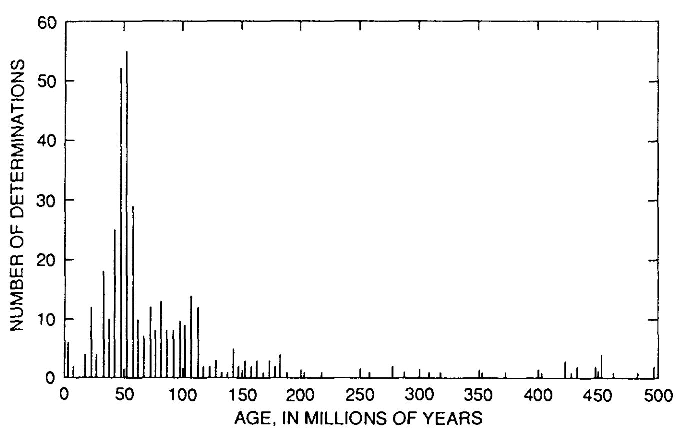

138°
134°
130°
60°
58°
56°
YUKON TERRITORY
BRITISH COLUMBIA
CANADA
UNITED STATES
Skagway
Juneau
Sitka
Ketchikan
Chichagof Island
Admiralty Island
Baranof Island
Prince of Wales Island
PACIFIC OCEAN
0 50 MILES
0 50 KILOMETERS
A
B
C
D+R
E
F
G
H
I
J
K
L
M
N
O
P
Q
S
T
U
V
W
X
Y
Z
AA
BB
CC
DD
EE
FF
GG
HH
II
JJ
KK
LL
MM

FIGURE 1.



NUMBER OF DETERMINATIONS
60
50
40
30
20
10
0
0
50
100
150
200
250
300
350
400
450
500
AGE, IN MILLIONS OF YEARS


FIGURE 2.

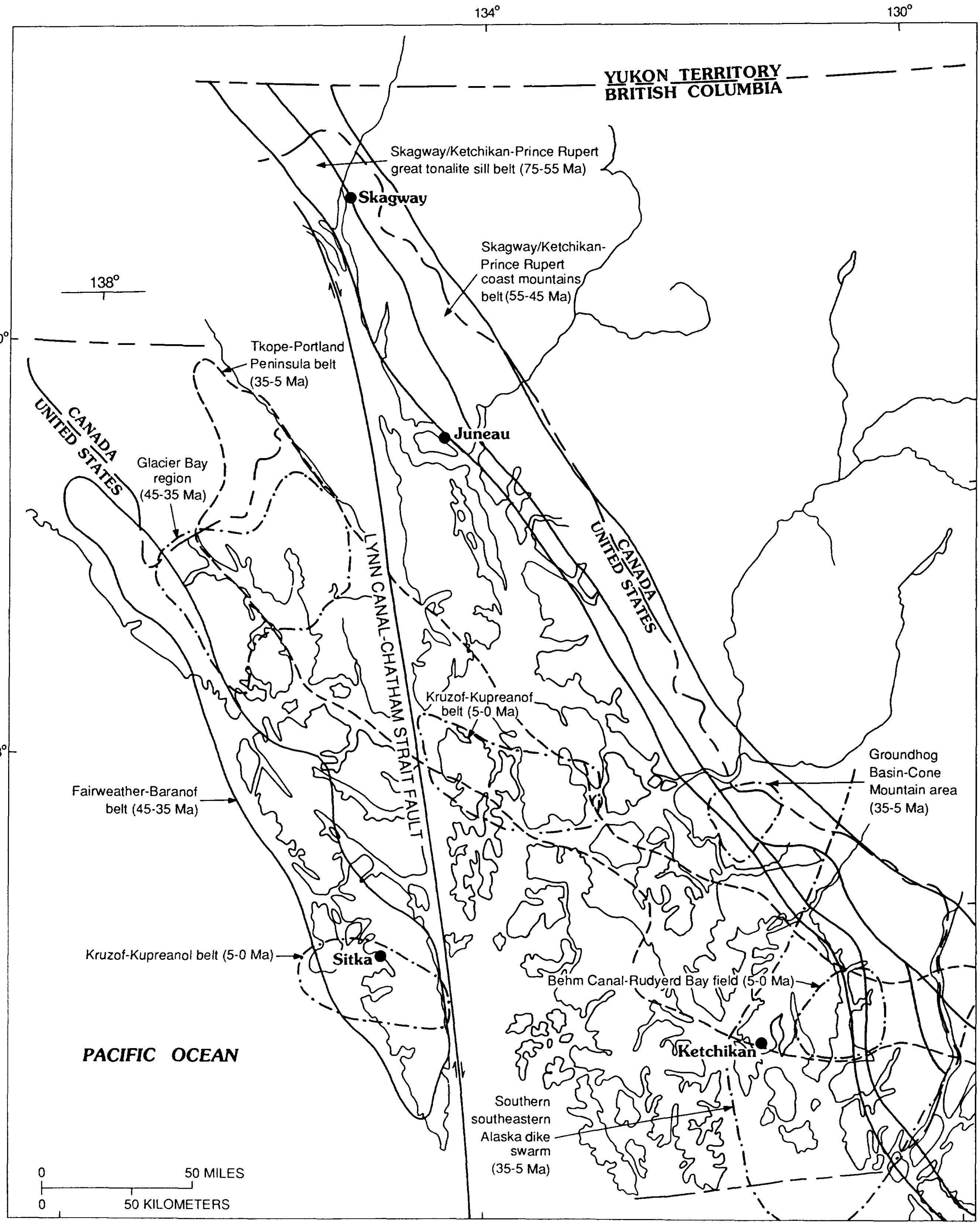

134°
130°
YUKON TERRITORY
BRITISH COLUMBIA
Skagway/Ketchikan-Prince Rupert great tonalite sill belt (75-55 Ma)
Skagway
Skagway/Ketchikan-Prince Rupert coast mountains belt (55-45 Ma)
138°
60°
Tkope-Portland Peninsula belt (35-5 Ma)
CANADA
UNITED STATES
Glacier Bay region (45-35 Ma)
Juneau
LYNN CANAL-CHATHAM STRAIT FAULT
CANADA
UNITED STATES
Kruzof-Kupreanof belt (5-0 Ma)
58°
Groundhog Basin-Cone Mountain area (35-5 Ma)
Fairweather-Baranof belt (45-35 Ma)
Kruzof-Kupreanol belt (5-0 Ma)
Sitka
Behm Canal-Rudyerd Bay field (5-0 Ma)
PACIFIC OCEAN
Ketchikan
Southern southeastern Alaska dike swarm (35-5 Ma)
0
50 MILES
0
50 KILOMETERS

FIGURE 3.

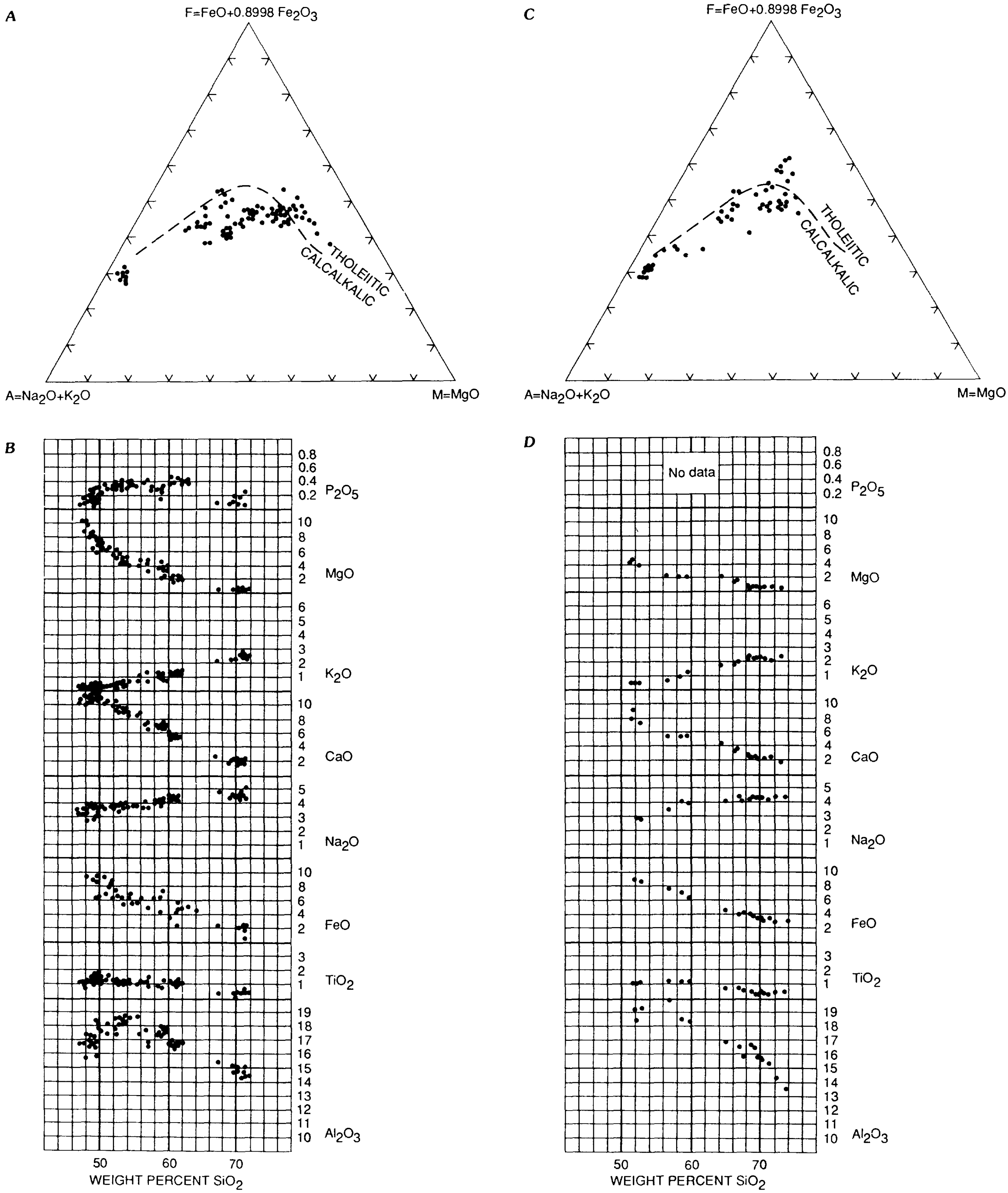
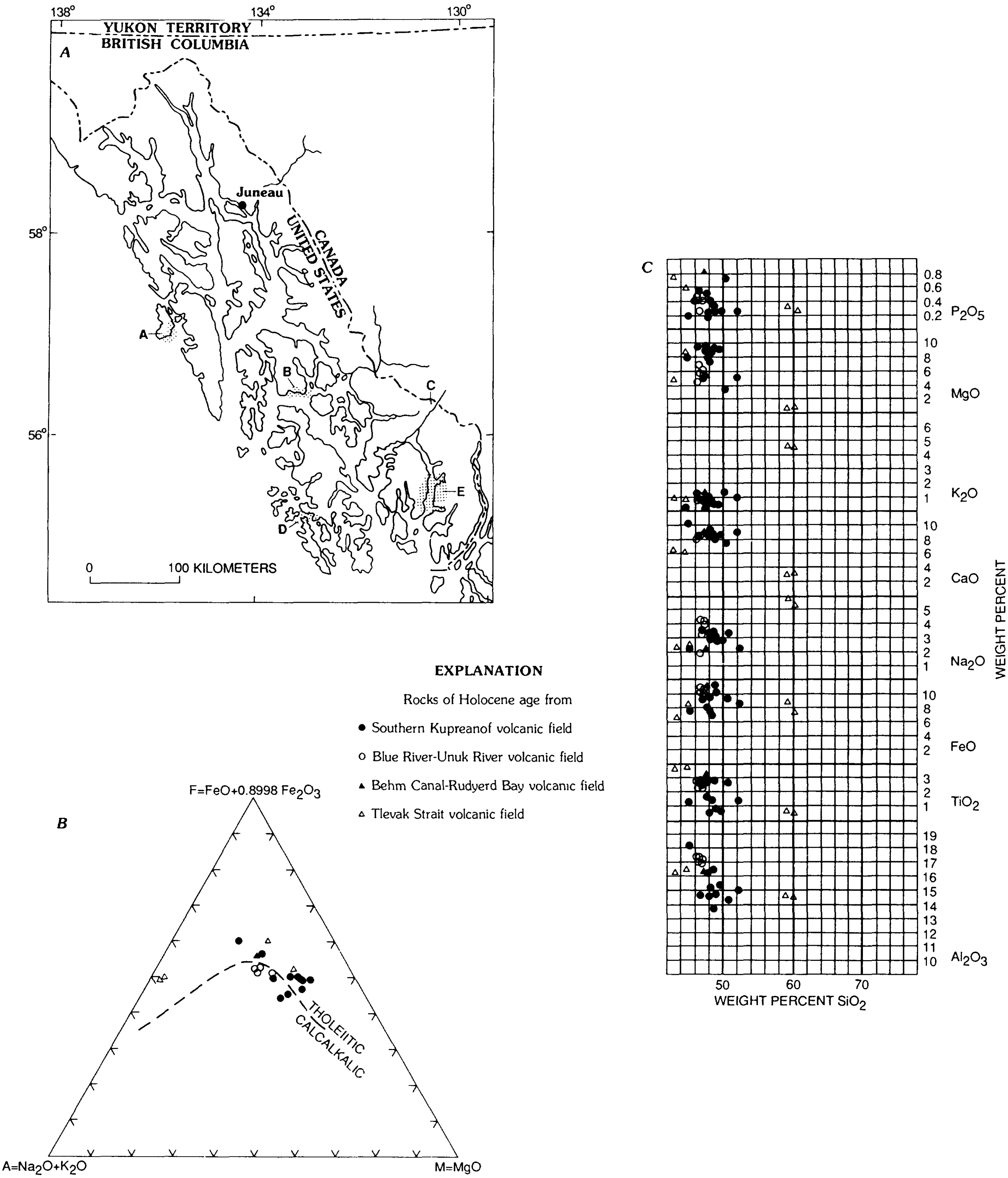

A
F=FeO+0.8998 Fe2O3
THOLEIITIC
CALCALKALIC
A=Na2O+K2O
M=MgO
B
0.8
0.6
0.4
0.2
P2O5
MgO
K2O
CaO
Na2O
FeO
TiO2
Al2O3
50
60
70
WEIGHT PERCENT SiO2
C
F=FeO+0.8998 Fe2O3
THOLEIITIC
CALCALKALIC
A=Na2O+K2O
M=MgO
D
No data
P2O5
MgO
K2O
CaO
Na2O
FeO
TiO2
Al2O3
50
60
70
WEIGHT PERCENT SiO2

FIGURE 4.



A
138°
134°
130°
YUKON TERRITORY
BRITISH COLUMBIA
Juneau
CANADA
UNITED STATES
58°
56°
A
B
C
D
E
0
100 KILOMETERS
B
F=FeO+0.8998 Fe2O3
THOLEIITIC
CALCALKALIC
A=Na2O+K2O
M=MgO
EXPLANATION
Rocks of Holocene age from
● Southern Kupreanof volcanic field
○ Blue River-Unuk River volcanic field
▲ Behm Canal-Rudyerd Bay volcanic field
△ Tlevak Strait volcanic field
C
P2O5
MgO
K2O
CaO
Na2O
FeO
TiO2
Al2O3
WEIGHT PERCENT
50
60
70
WEIGHT PERCENT SiO2


FIGURE 5.

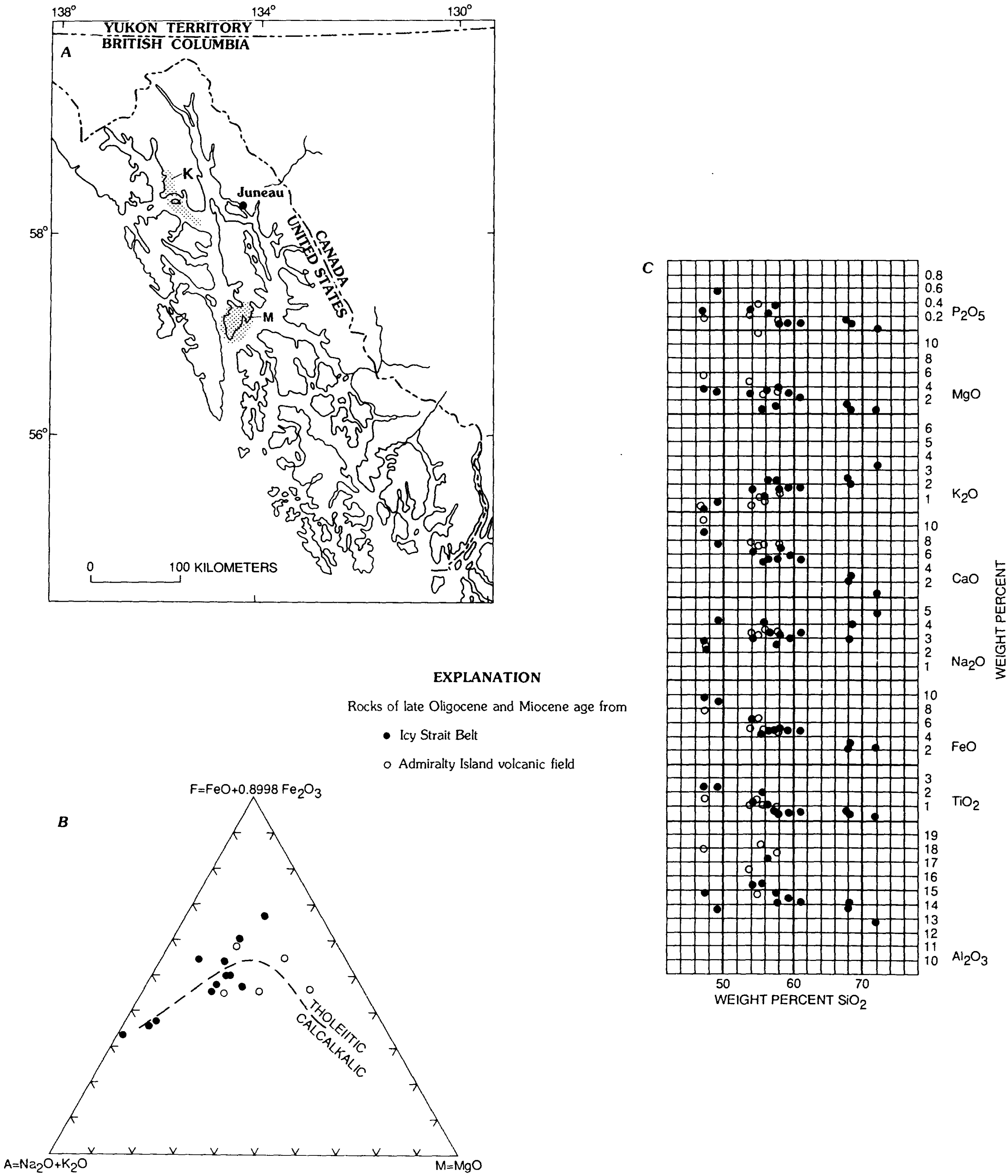
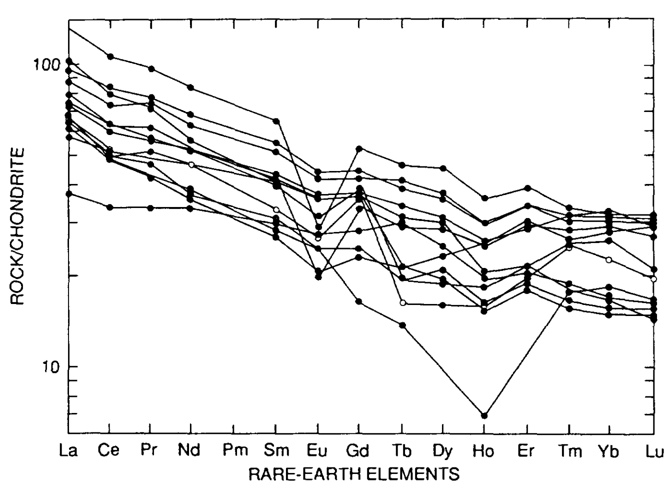
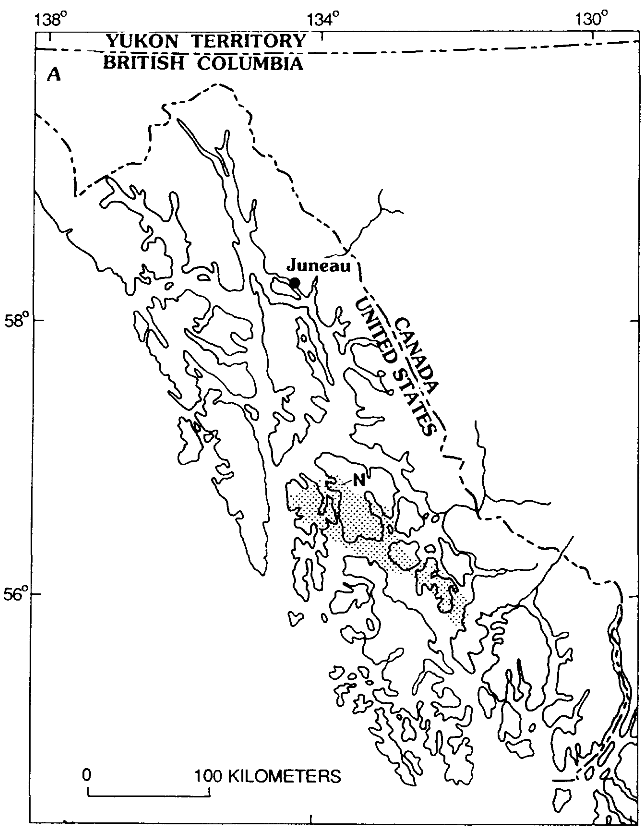

A
138°
134°
130°
YUKON TERRITORY
BRITISH COLUMBIA
K
Juneau
M
CANADA
UNITED STATES
58°
56°
0
100 KILOMETERS
B
F=FeO+0.8998 Fe2O3
A=Na2O+K2O
M=MgO
THOLEIITIC
CALCALKALIC
C
P2O5
MgO
K2O
CaO
Na2O
FeO
TiO2
Al2O3
WEIGHT PERCENT
WEIGHT PERCENT SiO2
50
60
70
EXPLANATION
Rocks of late Oligocene and Miocene age from
● Icy Strait Belt
○ Admiralty Island volcanic field

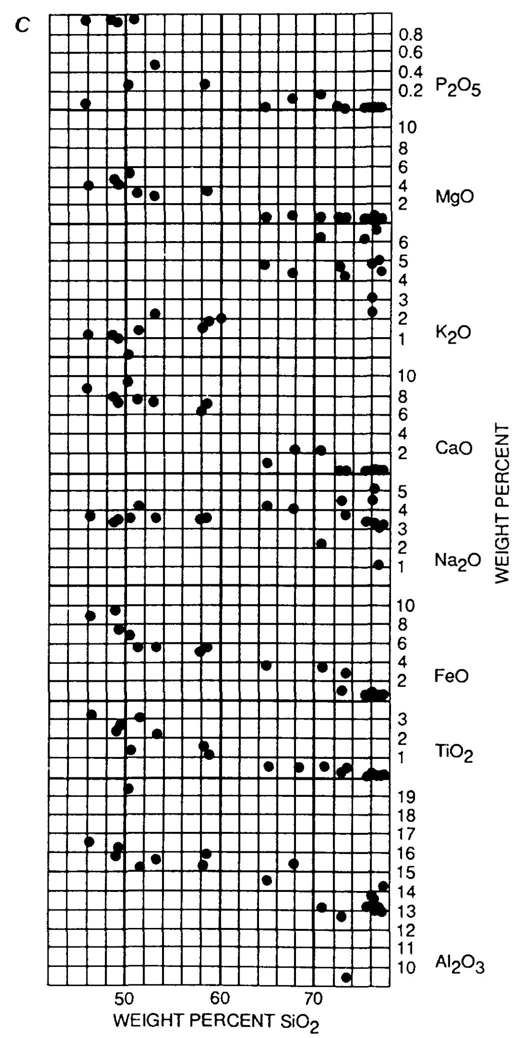
FIGURE 6.



100
10
ROCK/CHONDRITE
La Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Tm Yb Lu
RARE-EARTH ELEMENTS


FIGURE 7.


138°
134°
130°
YUKON TERRITORY
BRITISH COLUMBIA
A
Juneau
CANADA
UNITED STATES
N
58°
56°
0
100 KILOMETERS


C
0.8
0.6
0.4
0.2
P2O5
10
8
6
4
2
MgO
6
5
4
3
2
1
K2O
10
8
6
4
2
CaO
5
4
3
2
1
Na2O
10
8
6
4
2
FeO
3
2
1
TiO2
19
18
17
16
15
14
13
12
11
10
Al2O3
WEIGHT PERCENT
50
60
70
WEIGHT PERCENT SiO2

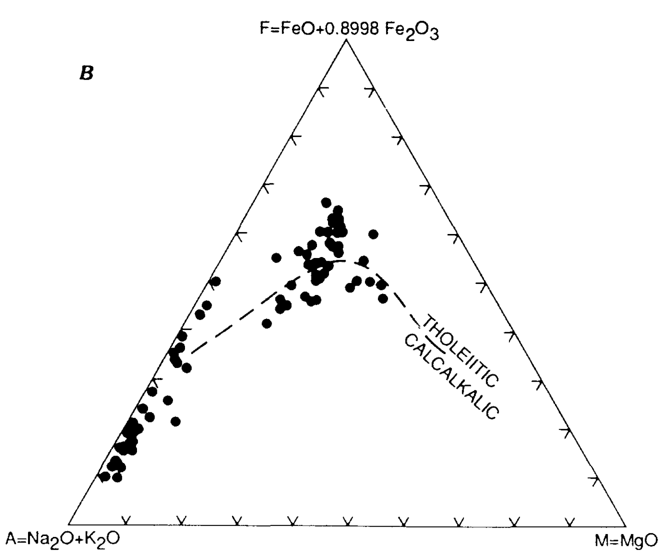

F=FeO+0.8998 Fe2O3
B
THOLEIITIC
CALCALKALIC
A=Na2O+K2O
M=MgO

FIGURE 8.

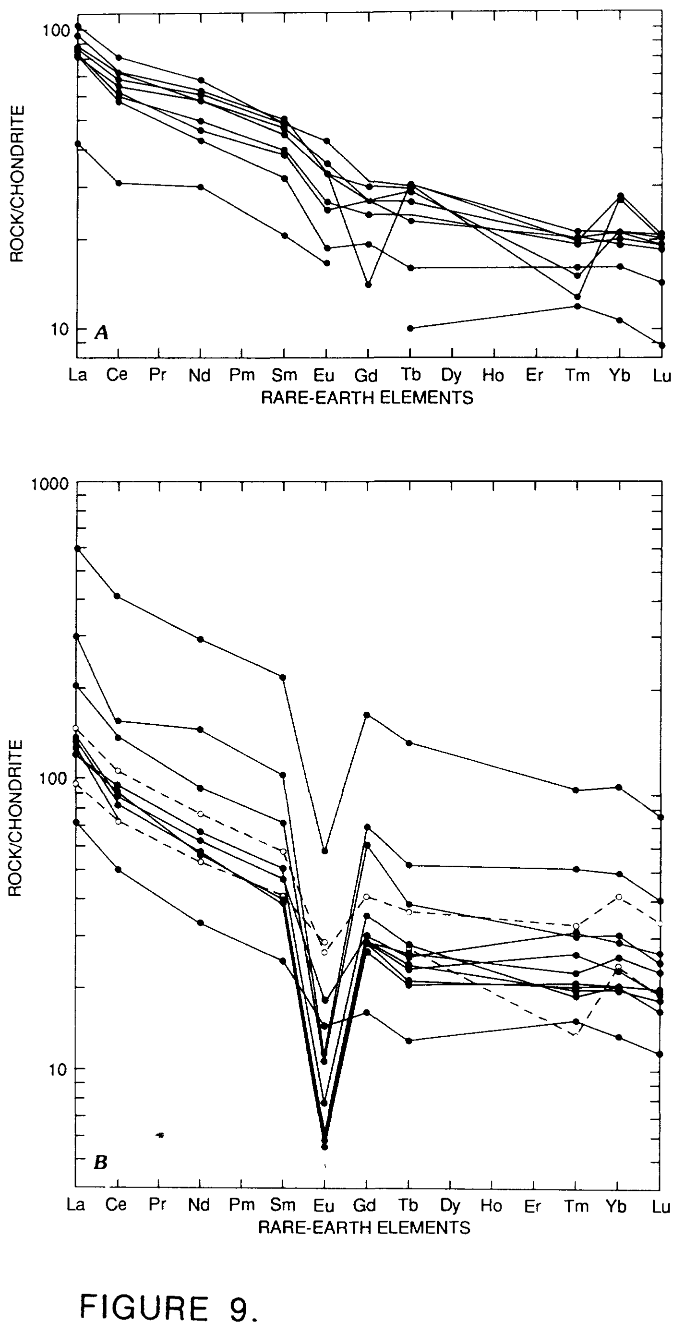
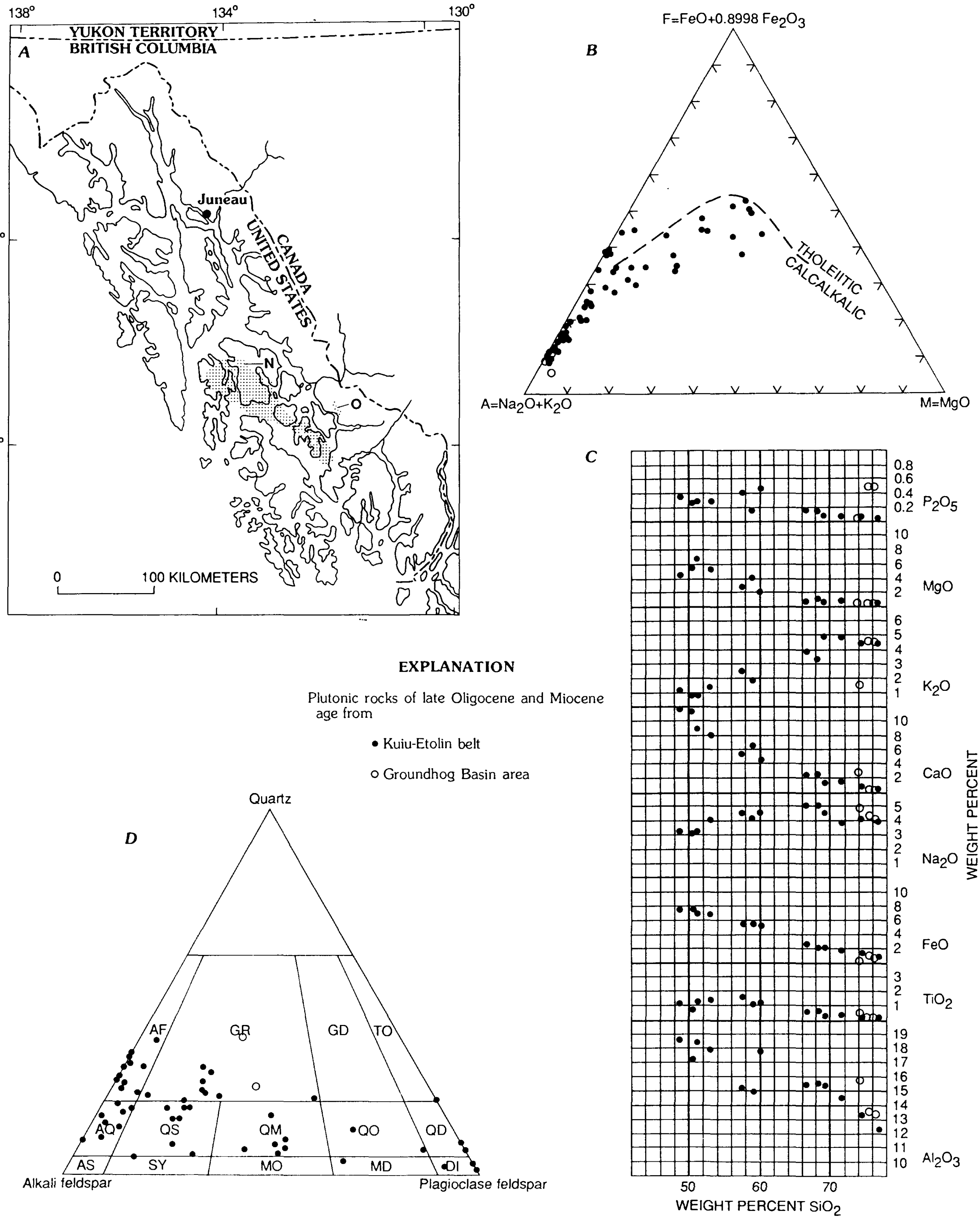
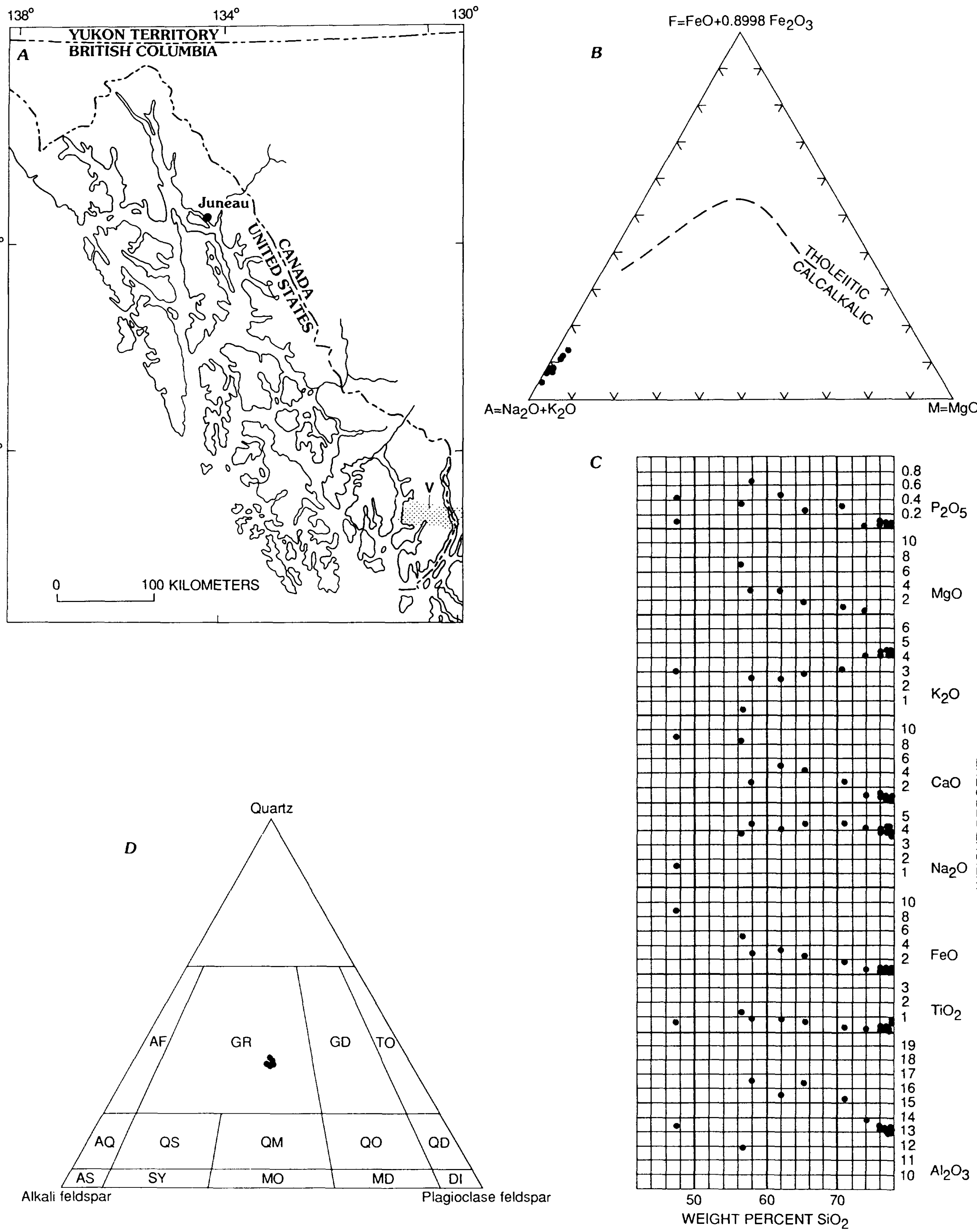

100
10
A
ROCK/CHONDRITE
La Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Tm Yb Lu
RARE-EARTH ELEMENTS
1000
100
10
B
ROCK/CHONDRITE
La Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Tm Yb Lu
RARE-EARTH ELEMENTS

FIGURE 9.



138°
134°
130°
58°
56°
YUKON TERRITORY
BRITISH COLUMBIA
A
Juneau
CANADA
UNITED STATES
N
O
0
100 KILOMETERS
B
F=FeO+0.8998 Fe2O3
A=Na2O+K2O
M=MgO
THOLEIITIC
CALCALKALIC
C
P2O5
MgO
K2O
CaO
Na2O
FeO
TiO2
Al2O3
WEIGHT PERCENT
WEIGHT PERCENT SiO2
50
60
70
EXPLANATION
Plutonic rocks of late Oligocene and Miocene age from
• Kuiu-Etolin belt
o Groundhog Basin area
D
Quartz
AF
GR
GD
TO
AQ
QS
QM
QO
QD
AS
SY
MO
MD
DI
Alkali feldspar
Plagioclase feldspar


FIGURE 10.



138°
134°
130°
YUKON TERRITORY
BRITISH COLUMBIA
A
Juneau
CANADA
UNITED STATES
58°
56°
V
0
100 KILOMETERS
B
F=FeO+0.8998 Fe2O3
THOLEIITIC
CALCALKALIC
A=Na2O+K2O
M=MgO
C
P2O5
MgO
K2O
CaO
Na2O
FeO
TiO2
Al2O3
WEIGHT PERCENT
50
60
70
WEIGHT PERCENT SiO2
D
Quartz
AF
GR
GD
TO
AQ
QS
QM
QO
QD
AS
SY
MO
MD
DI
Alkali feldspar
Plagioclase feldspar


FIGURE 11.

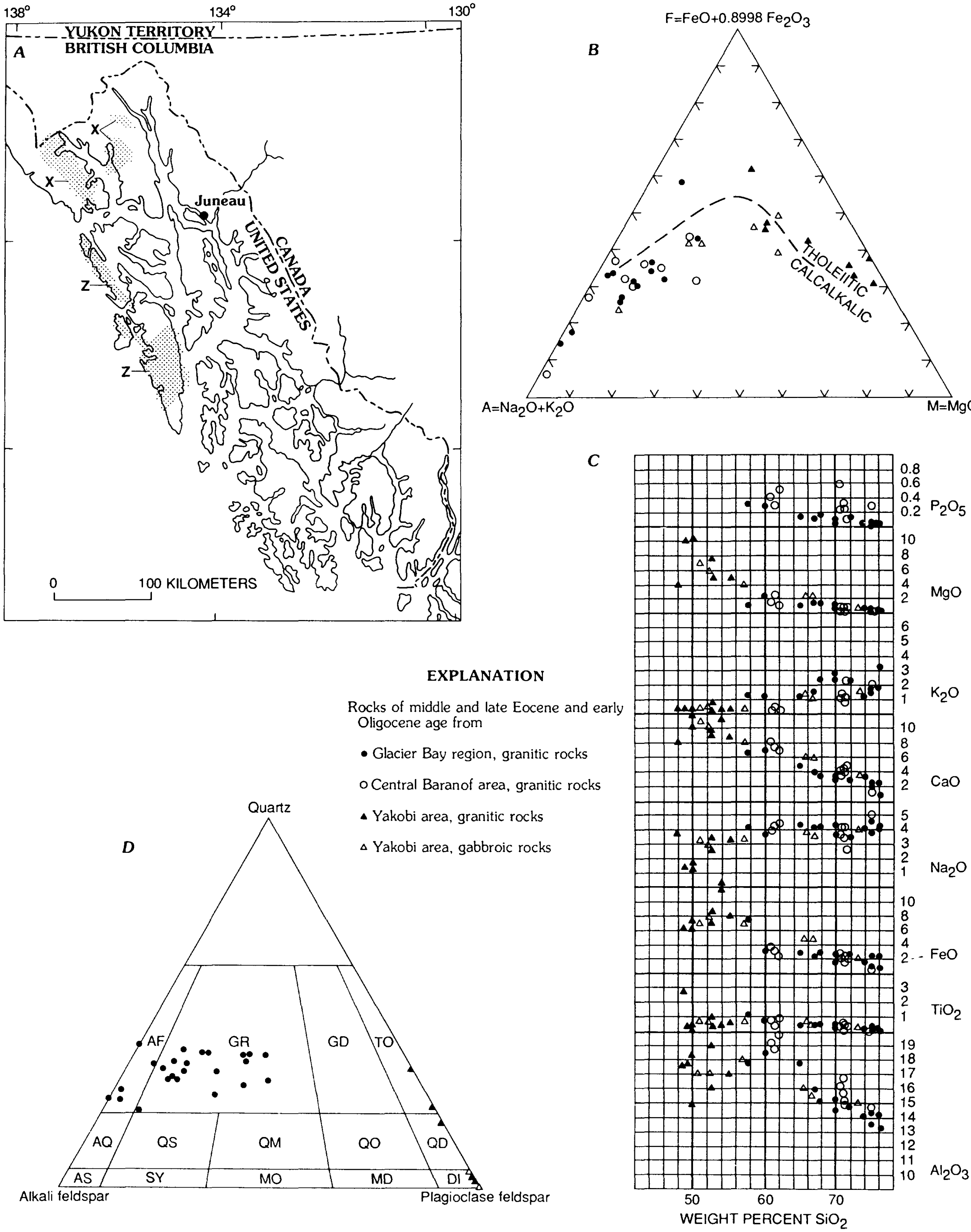

138°
134°
130°
YUKON TERRITORY
BRITISH COLUMBIA
A
X
X
Juneau
CANADA
UNITED STATES
58°
Z
Z
56°
0
100 KILOMETERS
B
F=FeO+0.8998 Fe2O3
THOLEIITIC
CALCALKALIC
A=Na2O+K2O
M=MgO
C
P2O5
MgO
K2O
CaO
Na2O
FeO
TiO2
Al2O3
WEIGHT PERCENT
WEIGHT PERCENT SiO2
50
60
70
EXPLANATION
Rocks of middle and late Eocene and early Oligocene age from
• Glacier Bay region, granitic rocks
○ Central Baranof area, granitic rocks
▲ Yakobi area, granitic rocks
△ Yakobi area, gabbroic rocks
D
Quartz
AF
GR
GD
TO
AQ
QS
QM
QO
QD
AS
SY
MO
MD
DI
Alkali feldspar
Plagioclase feldspar

FIGURE 12.

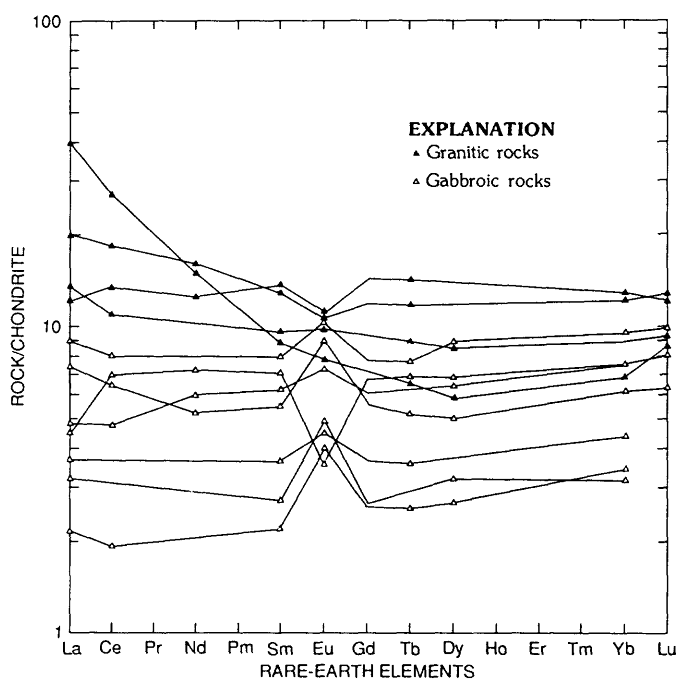
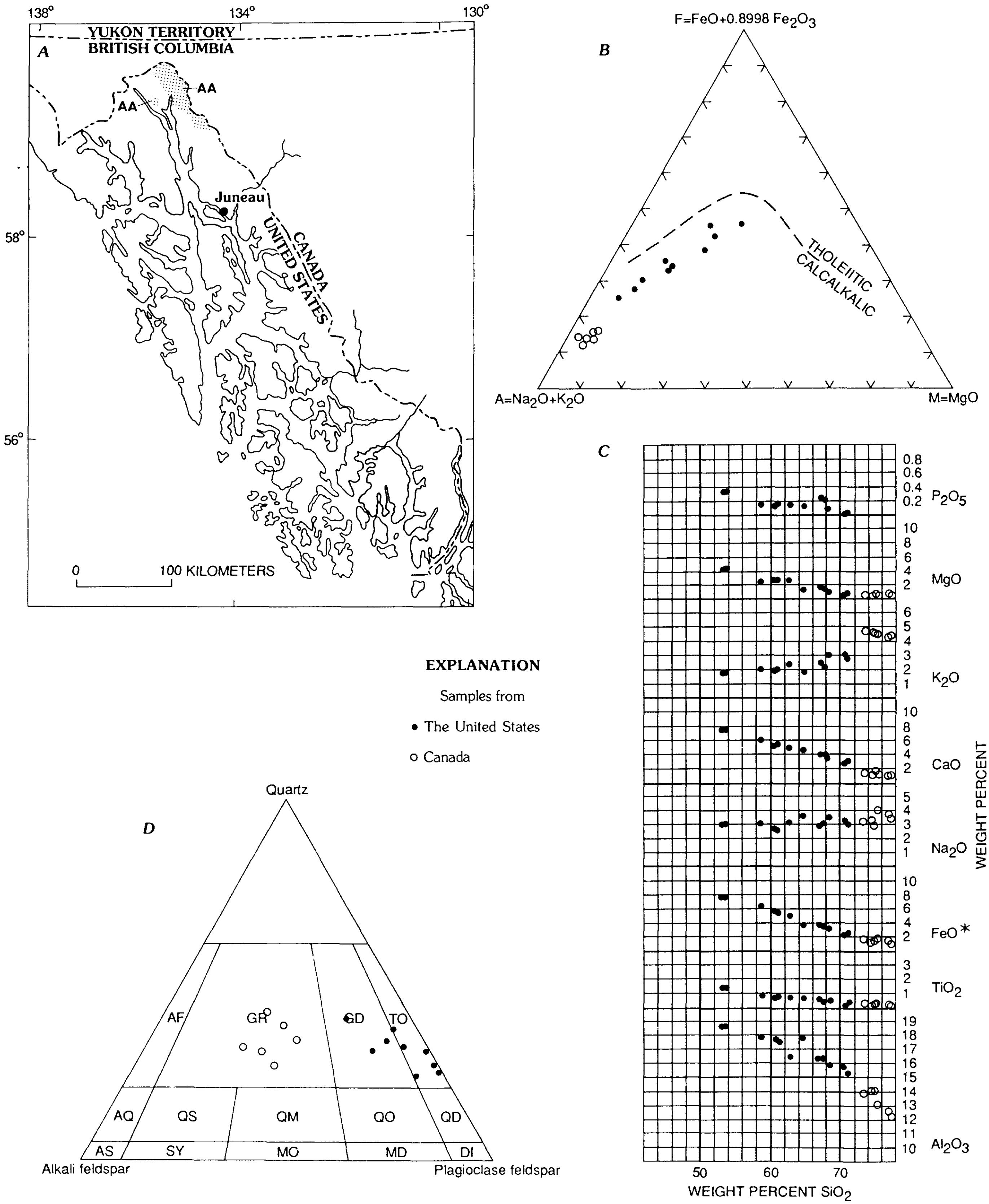

EXPLANATION
Granitic rocks
Gabbroic rocks
100
10
1
ROCK/CHONDRITE
La Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Tm Yb Lu
RARE-EARTH ELEMENTS

FIGURE 13.



A
138°
134°
130°
58°
56°
YUKON TERRITORY
BRITISH COLUMBIA
AA
Juneau
CANADA
UNITED STATES
0
100 KILOMETERS
B
F=FeO+0.8998 Fe2O3
A=Na2O+K2O
M=MgO
THOLEIITIC
CALCALKALIC
C
P2O5
MgO
K2O
CaO
Na2O
FeO*
TiO2
Al2O3
WEIGHT PERCENT
50
60
70
WEIGHT PERCENT SiO2
EXPLANATION
Samples from
• The United States
○ Canada
D
Quartz
AF
GR
GD
TO
AQ
QS
QM
QO
QD
AS
SY
MO
MD
DI
Alkali feldspar
Plagioclase feldspar


FIGURE 14.

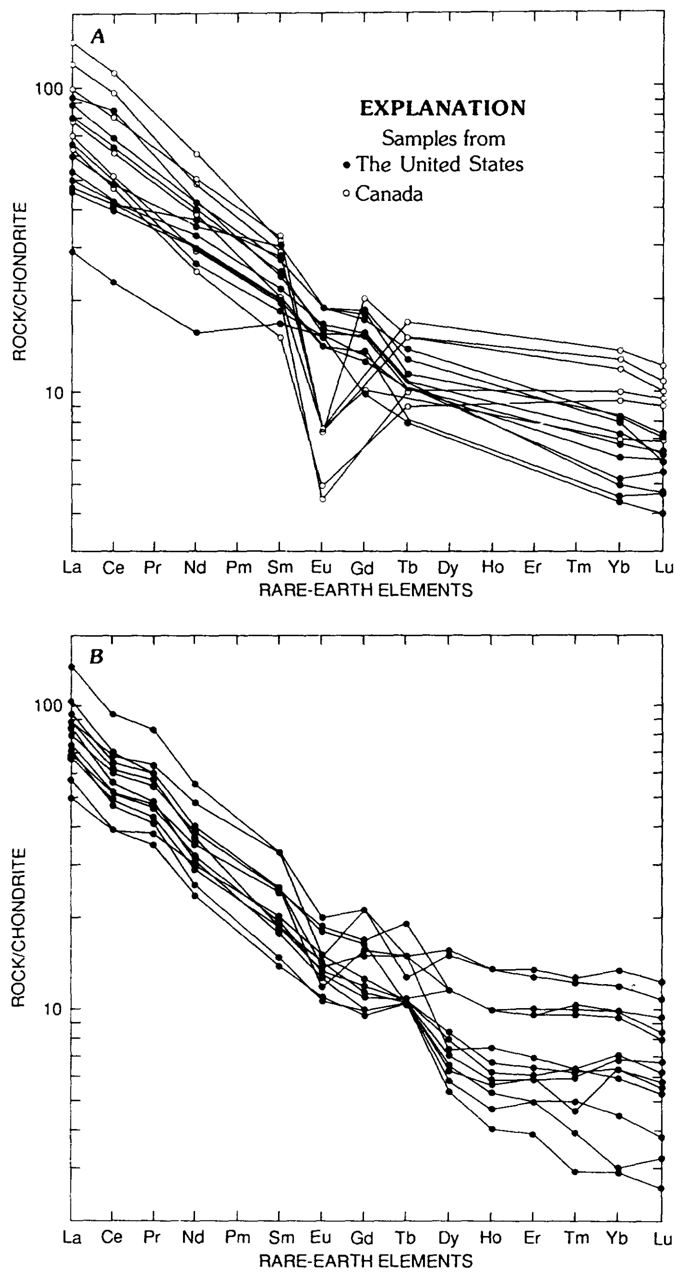

A
EXPLANATION
Samples from
• The United States
◦ Canada
ROCK/CHONDRITE
100
10
La Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Tm Yb Lu
RARE-EARTH ELEMENTS
B
ROCK/CHONDRITE
100
10
La Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Tm Yb Lu
RARE-EARTH ELEMENTS

FIGURE 15.

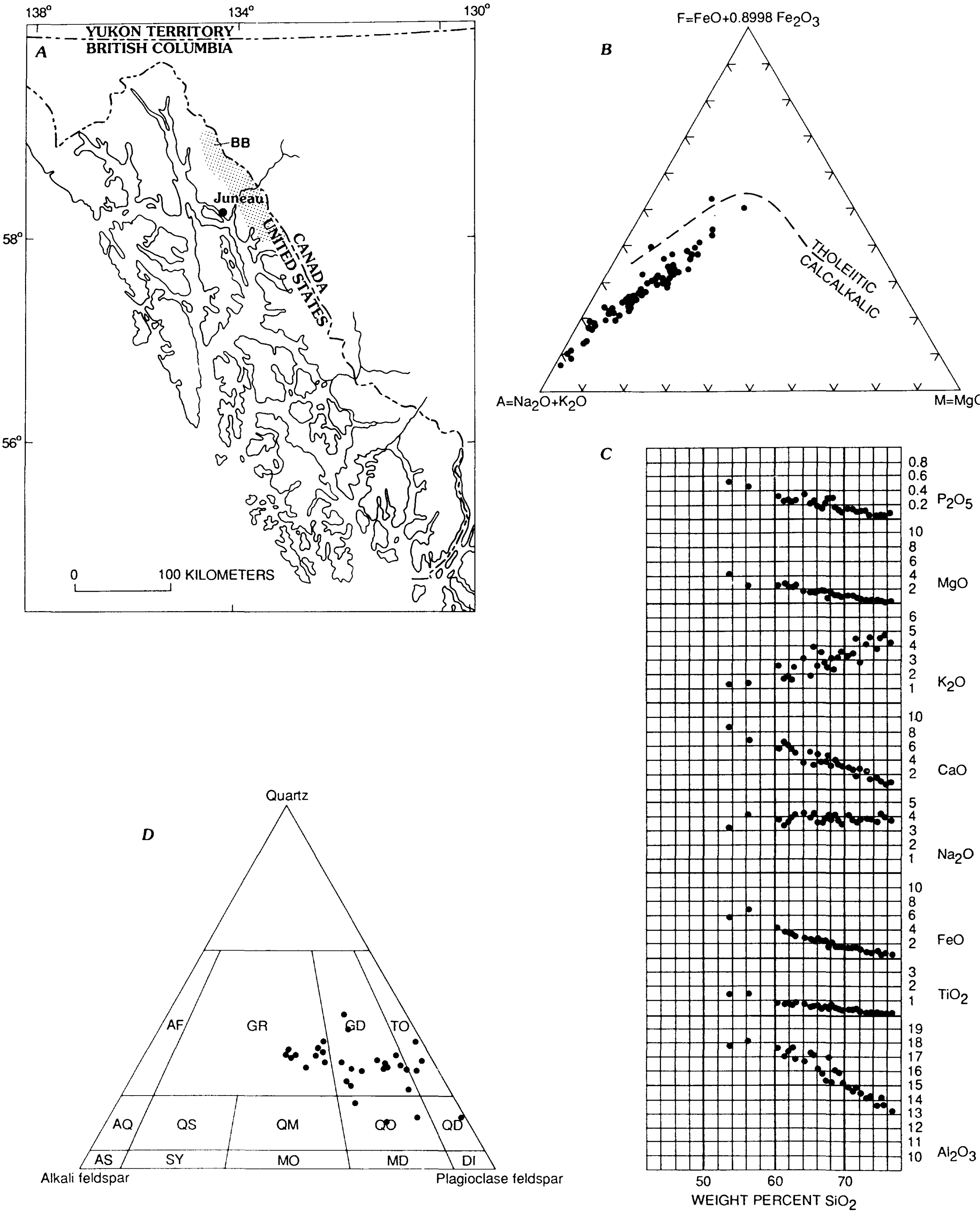
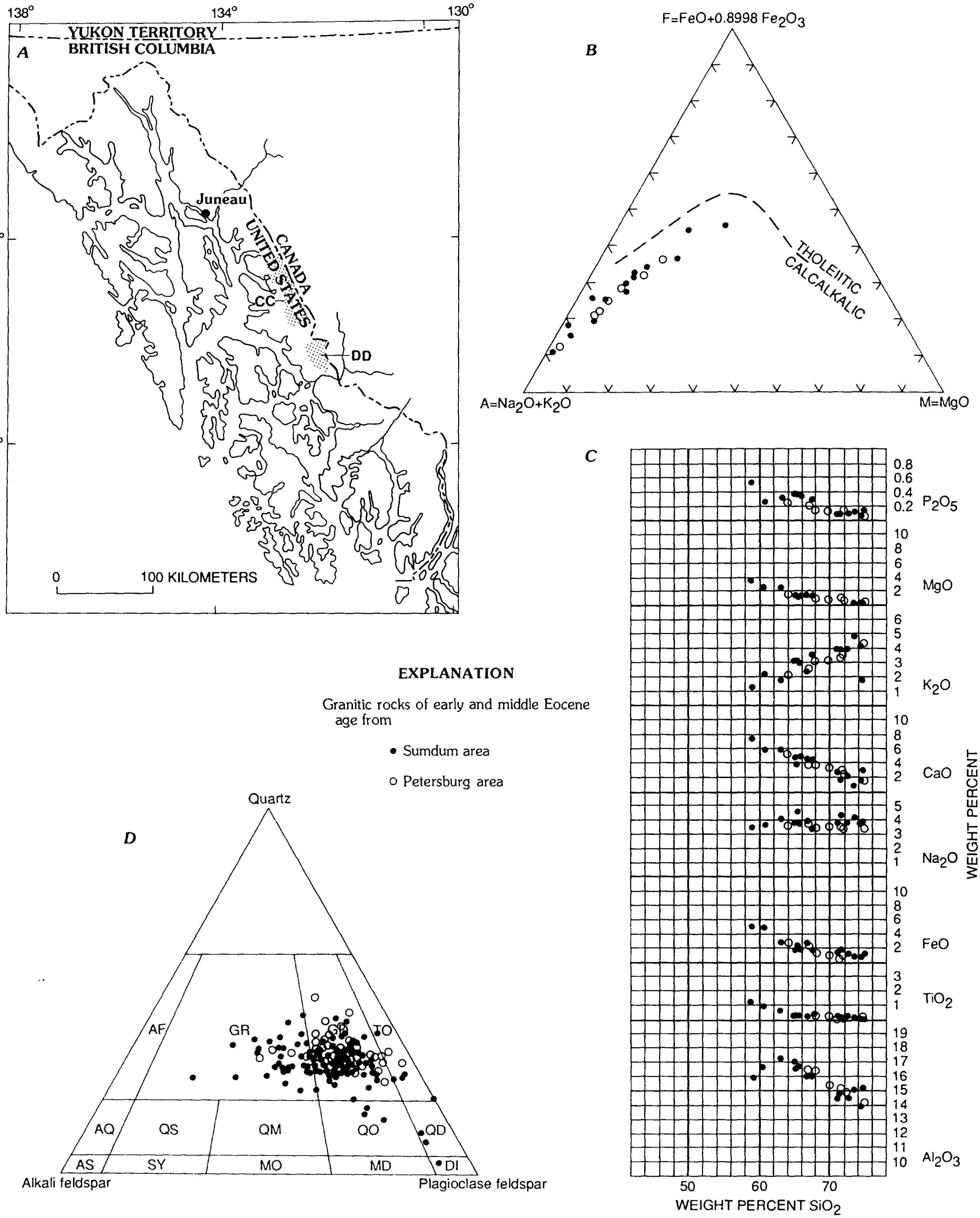

A
138°
134°
130°
YUKON TERRITORY
BRITISH COLUMBIA
BB
Juneau
CANADA
UNITED STATES
58°
56°
0
100 KILOMETERS
B
F=FeO+0.8998 $Fe_2O_3$
A=$Na_2O$+$K_2O$
M=MgO
THOLEIITIC
CALCALKALIC
C
$P_2O_5$
MgO
$K_2O$
CaO
$Na_2O$
FeO
$TiO_2$
$Al_2O_3$
WEIGHT PERCENT
50
60
70
WEIGHT PERCENT $SiO_2$
D
Quartz
AF
GR
GD
TO
AQ
QS
QM
QO
QD
AS
SY
MO
MD
DI
Alkali feldspar
Plagioclase feldspar

FIGURE 16.



138°
134°
130°
YUKON TERRITORY
BRITISH COLUMBIA
A
Juneau
CANADA
UNITED STATES
58°
56°
CC
DD
0
100 KILOMETERS
B
F=FeO+0.8998 Fe2O3
A=Na2O+K2O
M=MgO
THOLEIITIC
CALCALKALIC
C
0.8
0.6
0.4
0.2
P2O5
MgO
K2O
CaO
Na2O
FeO
TiO2
Al2O3
WEIGHT PERCENT
50
60
70
WEIGHT PERCENT SiO2
EXPLANATION
Granitic rocks of early and middle Eocene age from
● Sumdum area
○ Petersburg area
D
Quartz
AF
GR
TO
AQ
QS
QM
QO
QD
AS
SY
MO
MD
DI
Alkali feldspar
Plagioclase feldspar


FIGURE 17.

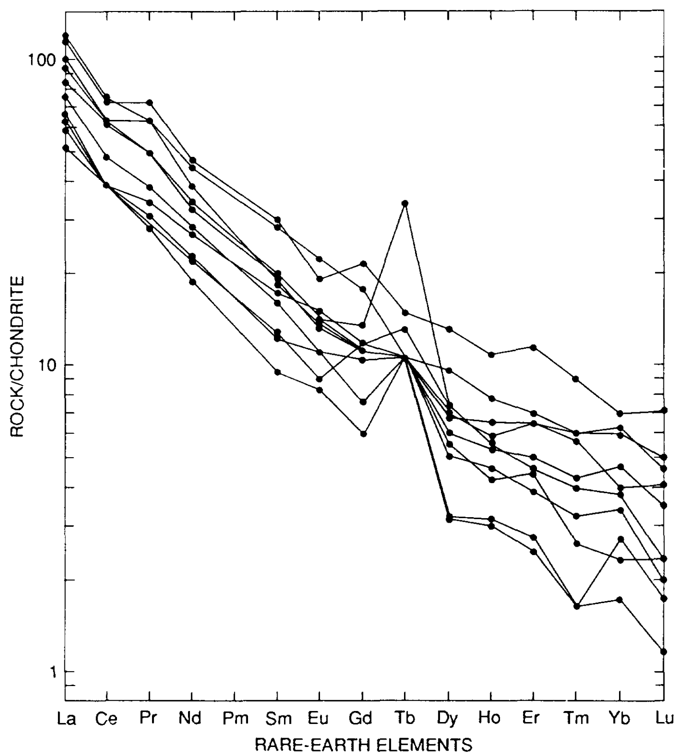
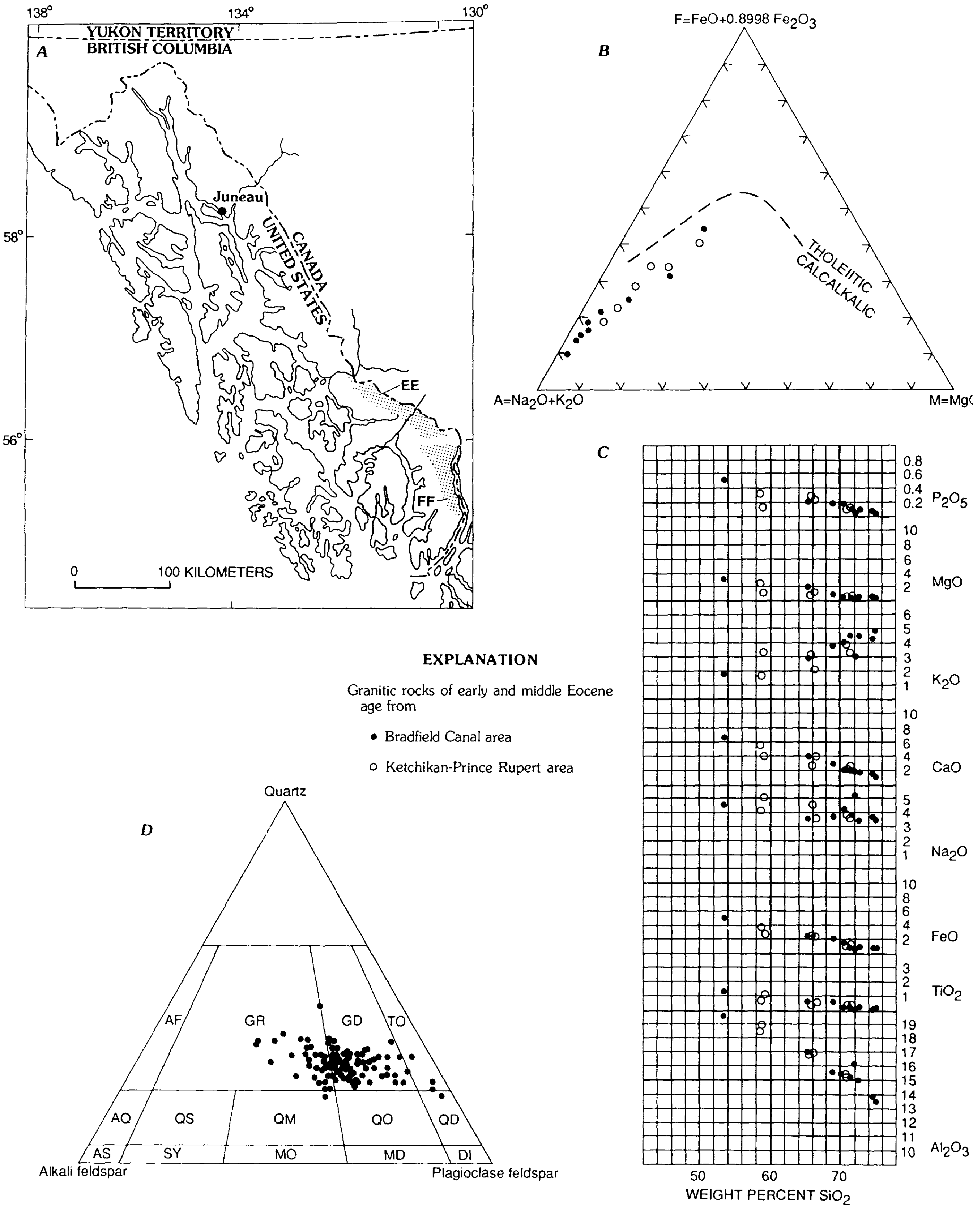
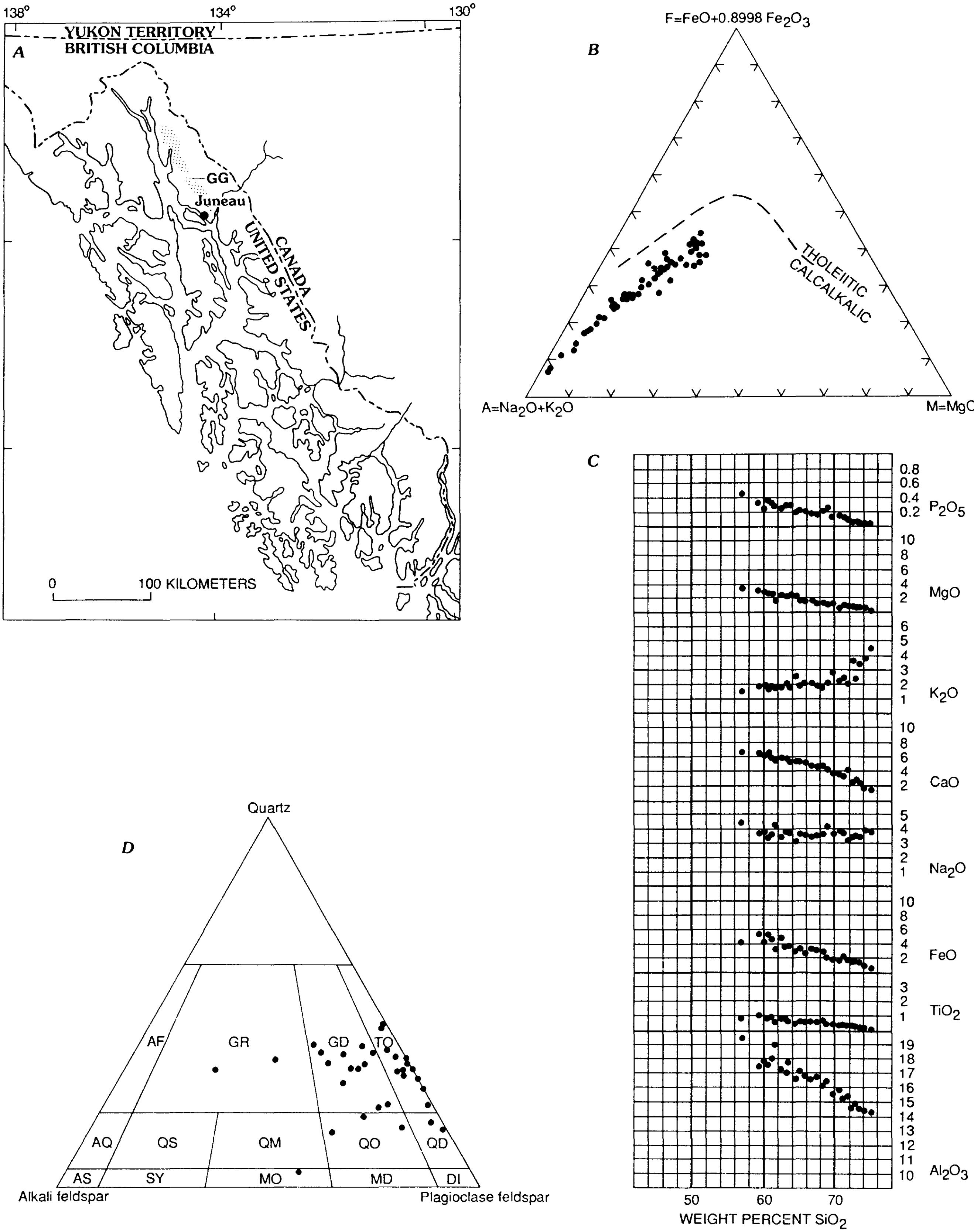

100
10
1
ROCK/CHONDRITE
La Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Tm Yb Lu
RARE-EARTH ELEMENTS

FIGURE 18.



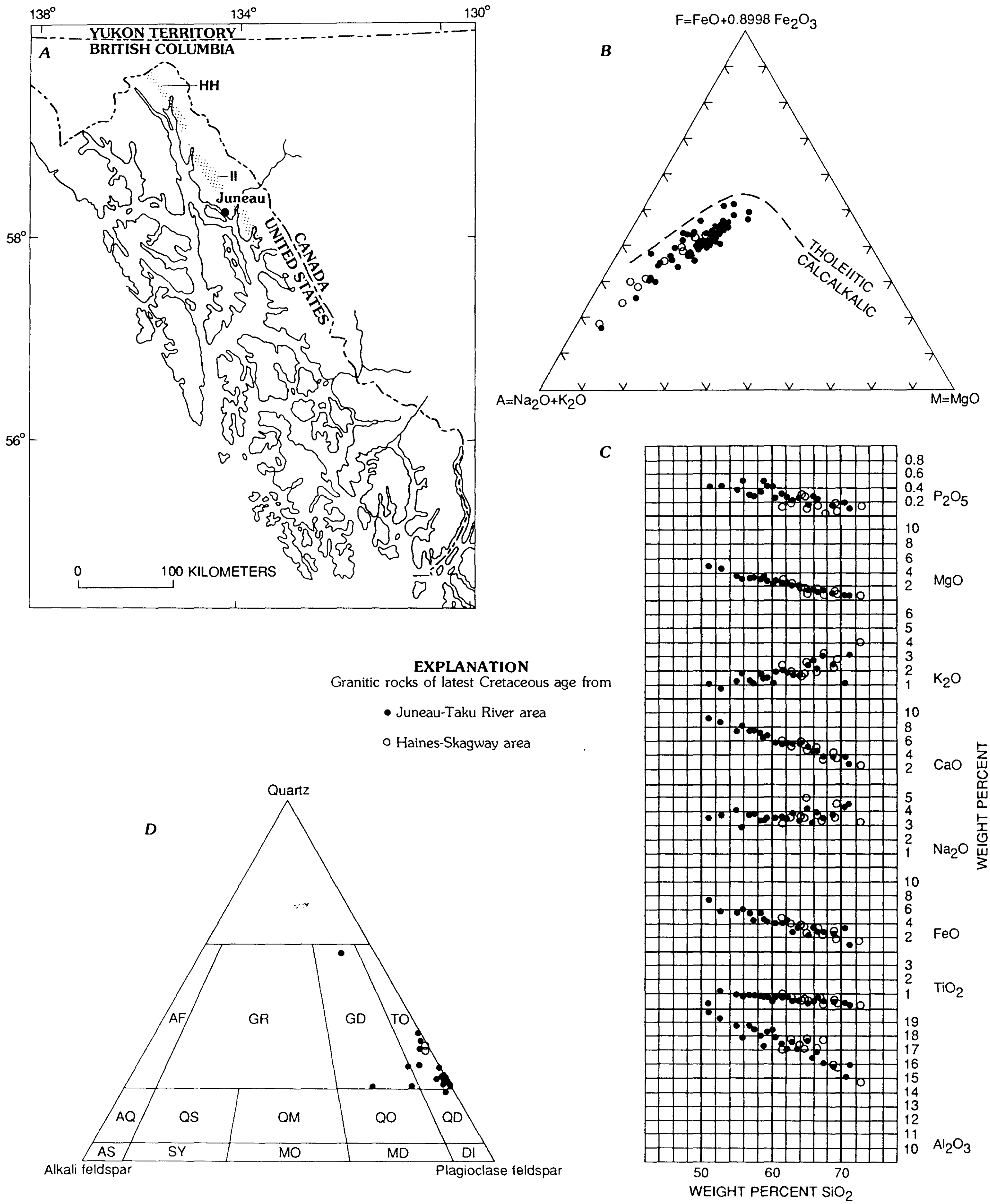
138°
134°
130°
YUKON TERRITORY
BRITISH COLUMBIA
A
Juneau
58°
56°
CANADA
UNITED STATES
EE
FF
0
100 KILOMETERS
B
F=FeO+0.8998 Fe2O3
THOLEIITIC
CALCALKALIC
A=Na2O+K2O
M=MgO
C
P2O5
MgO
K2O
CaO
Na2O
FeO
TiO2
Al2O3
WEIGHT PERCENT
WEIGHT PERCENT SiO2
50
60
70
EXPLANATION
Granitic rocks of early and middle Eocene age from
Bradfield Canal area
Ketchikan-Prince Rupert area
D
Quartz
AF
GR
GD
TO
AQ
QS
QM
QO
QD
AS
SY
MO
MD
DI
Alkali feldspar
Plagioclase feldspar


FIGURE 19.



138°
134°
130°
YUKON TERRITORY
BRITISH COLUMBIA
A
GG
Juneau
CANADA
UNITED STATES
58°
56°
0
100 KILOMETERS
F=FeO+0.8998 Fe2O3
B
THOLEIITIC
CALCALKALIC
A=Na2O+K2O
M=MgO
C
P2O5
MgO
K2O
CaO
Na2O
FeO
TiO2
Al2O3
WEIGHT PERCENT
50
60
70
WEIGHT PERCENT SiO2
Quartz
D
AF
GR
GD
TO
AQ
QS
QM
QO
QD
AS
SY
MO
MD
DI
Alkali feldspar
Plagioclase feldspar


FIGURE 20.



138°
134°
130°
YUKON TERRITORY
BRITISH COLUMBIA
A
HH
II
Juneau
CANADA
UNITED STATES
58°
56°
0
100 KILOMETERS
B
F=FeO+0.8998 Fe2O3
THOLEIITIC
CALCALKALIC
A=Na2O+K2O
M=MgO
C
P2O5
MgO
K2O
CaO
Na2O
FeO
TiO2
Al2O3
WEIGHT PERCENT
50
60
70
WEIGHT PERCENT SiO2
EXPLANATION
Granitic rocks of latest Cretaceous age from
• Juneau-Taku River area
○ Haines-Skagway area
D
Quartz
AF
GR
GD
TO
AQ
QS
QM
QO
QD
AS
SY
MO
MD
DI
Alkali feldspar
Plagioclase feldspar


FIGURE 21.

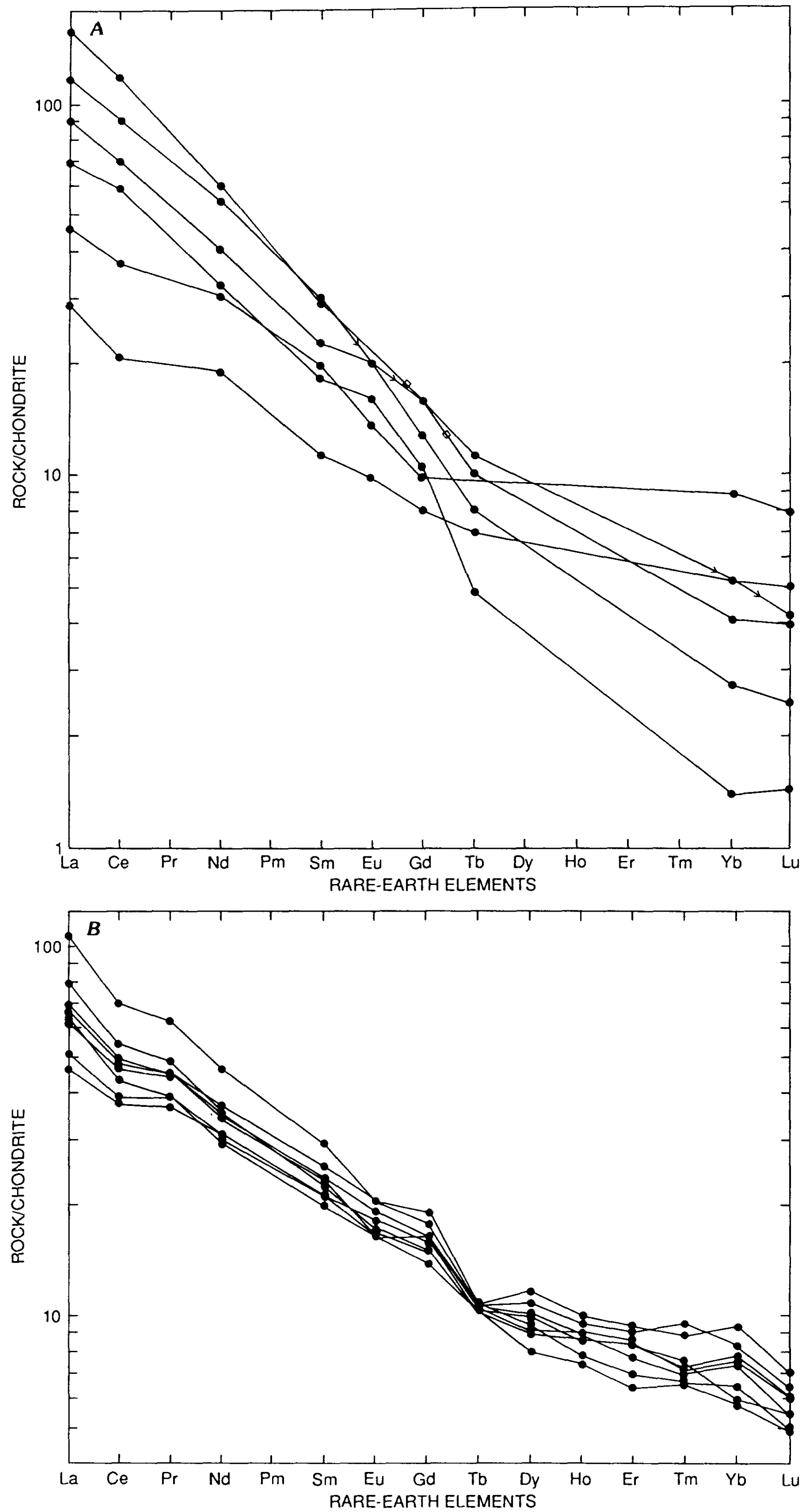

A
B
100
10
1
ROCK/CHONDRITE
La Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Tm Yb Lu
RARE-EARTH ELEMENTS

FIGURE 22.

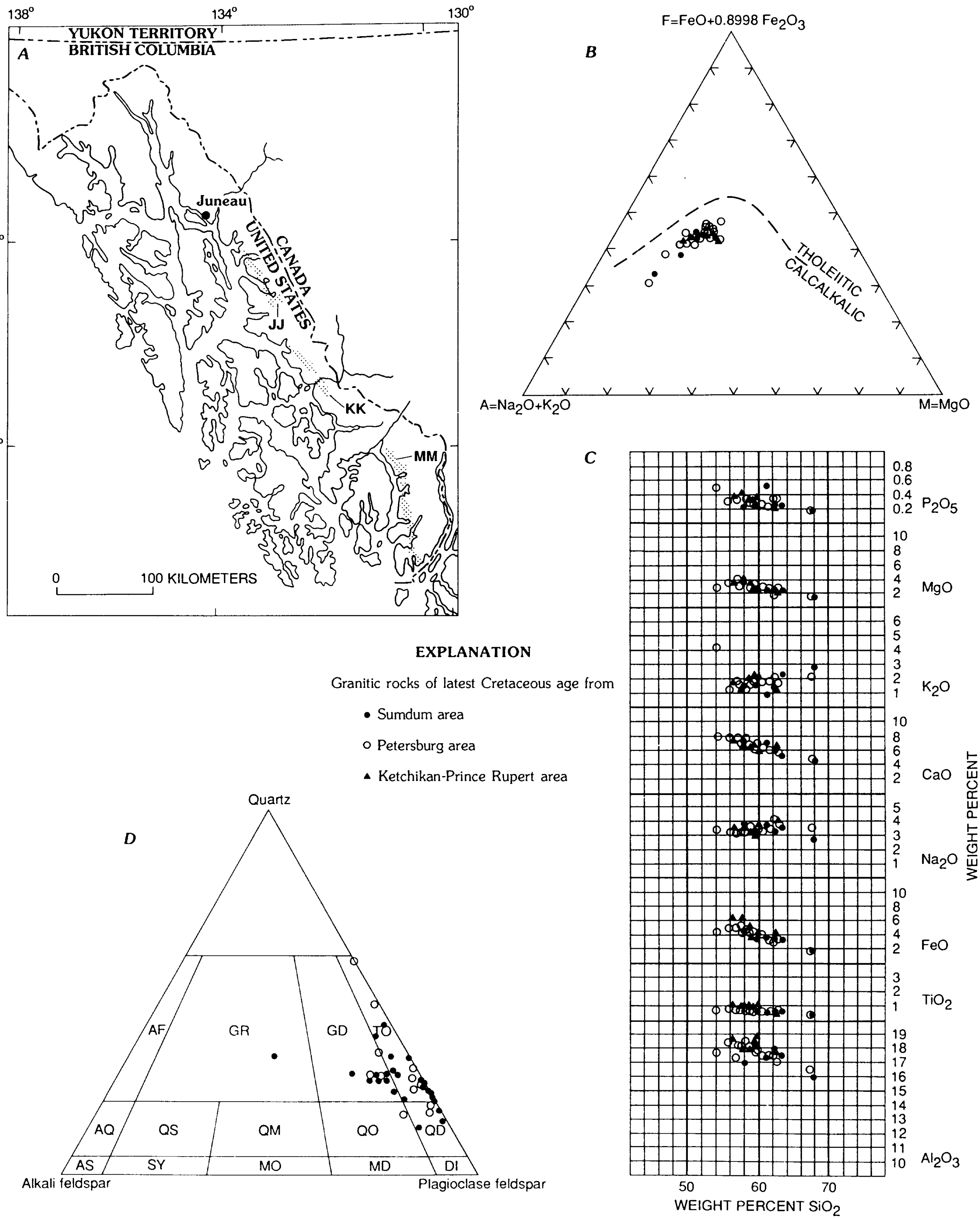
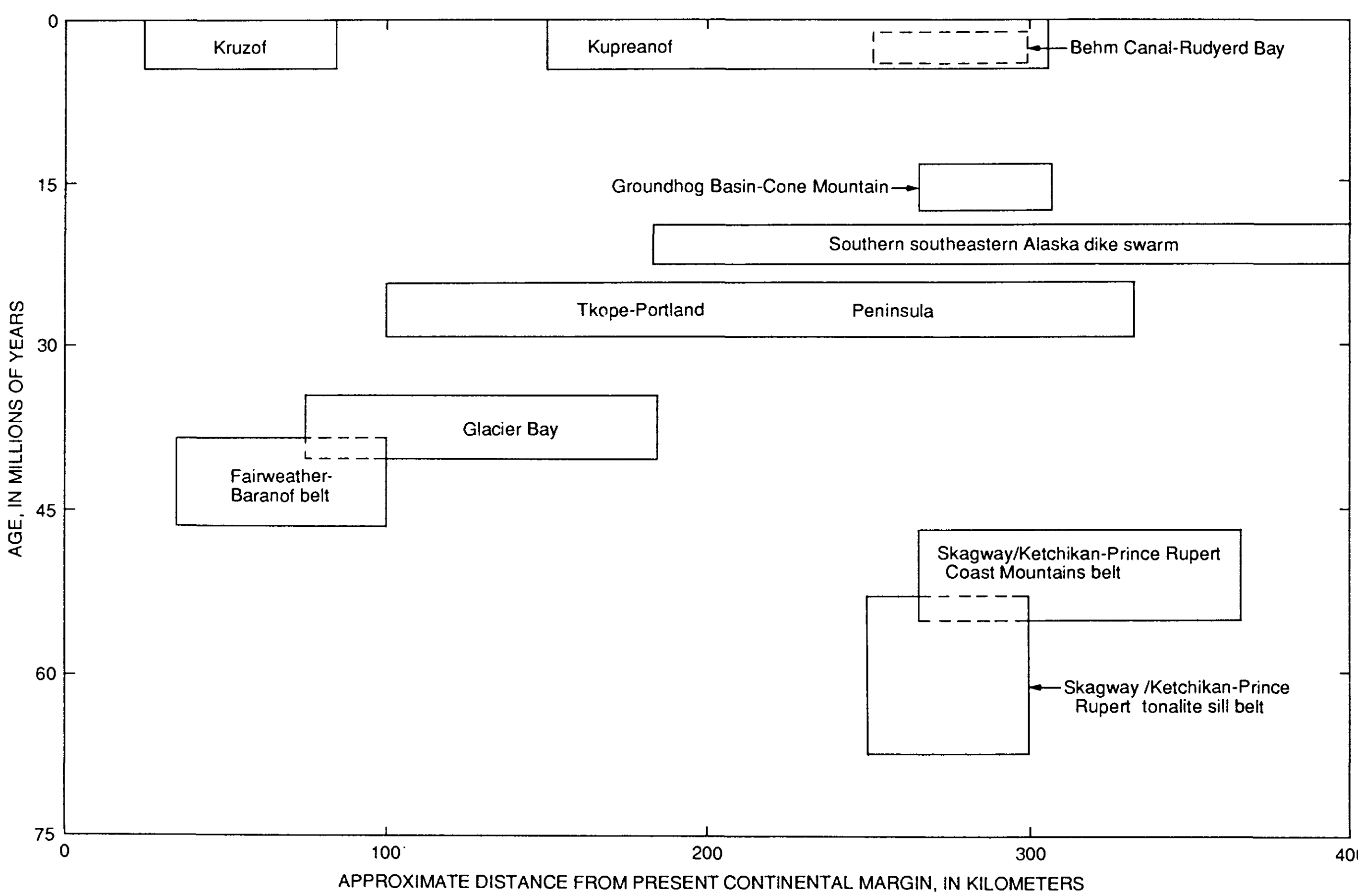

A
138°
134°
130°
58°
56°
YUKON TERRITORY
BRITISH COLUMBIA
Juneau
CANADA
UNITED STATES
JJ
KK
MM
0
100 KILOMETERS
B
F=FeO+0.8998 Fe2O3
A=Na2O+K2O
M=MgO
THOLEIITIC
CALCALKALIC
C
P2O5
MgO
K2O
CaO
Na2O
FeO
TiO2
Al2O3
WEIGHT PERCENT
WEIGHT PERCENT SiO2
50
60
70
EXPLANATION
Granitic rocks of latest Cretaceous age from
• Sumdum area
○ Petersburg area
▲ Ketchikan-Prince Rupert area
D
Quartz
AF
GR
GD
TO
AQ
QS
QM
QO
QD
AS
SY
MO
MD
DI
Alkali feldspar
Plagioclase feldspar

FIGURE 23.



Kruzof
Kupreanof
Behm Canal-Rudyerd Bay
Groundhog Basin-Cone Mountain
Southern southeastern Alaska dike swarm
Tkope-Portland
Peninsula
Glacier Bay
Fairweather-
Baranof belt
Skagway/Ketchikan-Prince Rupert
Coast Mountains belt
Skagway /Ketchikan-Prince
Rupert tonalite sill belt
AGE, IN MILLIONS OF YEARS
0
15
30
45
60
75
0
100
200
300
400
APPROXIMATE DISTANCE FROM PRESENT CONTINENTAL MARGIN, IN KILOMETERS


FIGURE 24.