Calc-alkaline plutonism along the Pacific rim of southern Alaska

by

Travis Hudson

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Abstract

Field, petrology, and age data on southern Alaska plutonic rocks now enable the delineation of eight calc-alkaline plutonic belts. These belts of plutons or batholithic complexes are curvilinear to linear and trend parallel or subparallel to the continental margin. The belts represent the principal loci of emplacement for plutons of specific ages and although there is spatial or temporal overlap in some cases, they are more commonly spatially and temporally distinct. Intermediate lithologies such as quartz diorite, tonalite, and granodiorite dominate in most of the belts but granodiorite and granite characterize one. The belts are of Mesozoic or Cenozoic age and plutonism began in six of them at about 195, 175, 120, 75, 60, and 40 m.y. ago; age relations in two are poorly known. Recognition of the belts is important for future studies of regional geology, tectonism, and magmatism along the Pacific rim of southern Alaska.

Introduction

Southern Alaska is a part of the Pacific rim that is now the site of major plate convergence and may have been so during earlier intervals of the Mesozoic and Cenozoic (Plafker, 1969, 1972, p. 921). Calc-alkaline plutonism has played a major role in the evolution of this continental margin but data necessary for a relatively complete overview have only recently become available. These data enable the delineation of eight major calc-alkaline plutonic belts in southern Alaska. This paper outlines the distribution of these belts and summarizes available data concerning their geologic settings, petrologic characteristics, and age relations.

Southern Alaska (fig. 1) is here considered to include the Aleutian and Alaska Ranges, all mainland areas to the south, all Gulf of Alaska islands, the St. Elias Mountains and adjacent coastal belt, and the Haines-Glacier Bay-Chichagof Island area of southeast Alaska. Contiguous parts of Canada between the eastern Alaska Range and the Haines area are also included. The north boundary of this 500,000 km^2 region approximately coincides with the Denali fault system from about longitude 153°W. eastward to Chatham Strait and with the north flank of the Aleutian and Alaska Ranges west of longitude 153°W.

This region of complex Phanerozoic geology is divisable into several geologic terranes (generalized in fig. 1) composed primarily of marine sedimentary and volcanic rocks. The terranes were developed and aggregated through processes of sedimentation, magmatism, and tectonism that accompanied episodes of plate subduction and transform

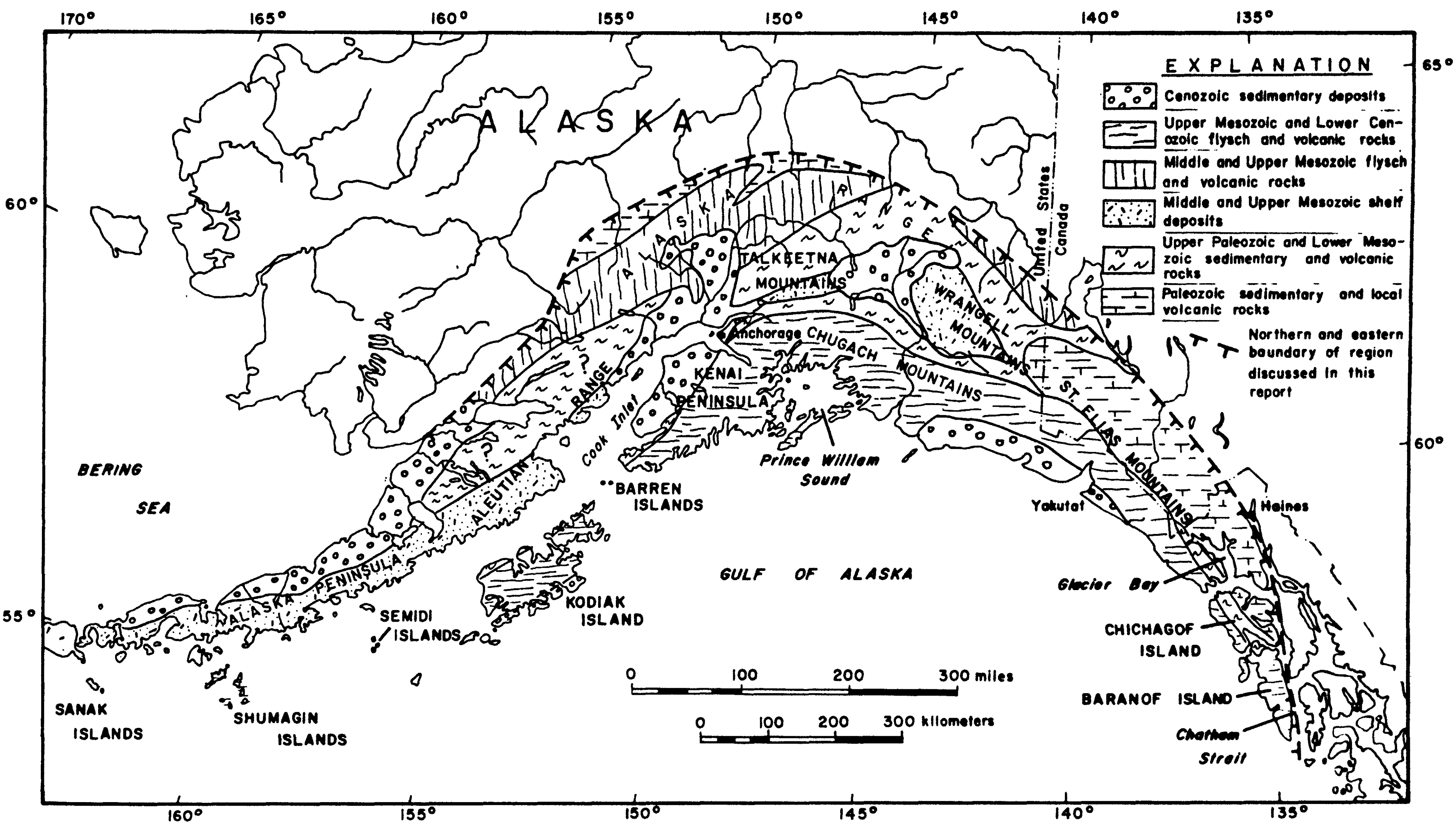

Figure 1. Index map and generalized geologic terranes of southern Alaska (Modified from Beikman, 1978).

faulting. They include tectonostratigraphic sequences that may be only partly related to the evolution of presently nearby parts of the North American craton (Jones and others, 1972, 1976, 1977). Some plutonic belts are restricted to particular geologic terranes but others are not.

Petrologic nomenclature throughout the paper corresponds to that suggested by the International Union of Geological Sciences' Subcommission on the Systematics of Igneous Rocks (Geotimes, October 1973). Correlation of stratigraphic and absolute ages follows the time scale of Van Eysinga (1975). All radiometric ages used in this report have been determined by the potassium-argon (K-Ar) method, and single-mineral K-Ar ages are considered to be minimum ages.

Plutonic Belts

A plutonic belt is a region in which plutonic rocks of specific ages are known or are reasonably expected to occur. Belts of different ages may be spatially distinct or overlap. They represent the loci of principal pluton emplacement and do not necessarily include all plutons of specific ages (Kistler, 1974, p. 409). On the basis of available information, eight Mesozoic and Cenozoic calc-alkaline plutonic belts can be delineated in southern Alaska. The distribution, geologic setting, petrologic characteristics, and age relations of each belt are summarized below. The belts are informally named after geographic areas or places near their present definable limits.

Kodiak-Kenai belt

The Kodiak-Kenai belt (fig. 2) trends northeastward for 300 km along the west coast of the Kodiak Archipelago (Connelly and Moore, 1977), through the Barren Islands (Cowan and Boss, 1978), to the southern Kenai Peninsula (Carden and others, 1977; Donald L. Turner, personal commun., 1978). Extensions of the belt along trend are likely, especially to the northeast to areas along the north flank of the Chugach Mountains.

The plutons intrude a diverse assemblage of sedimentary and metamorphic rocks that are part of a complicated upper Paleozoic and lower Mesozoic terrane that parallels the continental margin throughout southern Alaska and is structurally bound to the south by the Border Ranges fault (Plafker, 1969; MacKevett and Plafker, 1974; Plafker and others, 1976). Plutons are elongate parallel to regional trends and locally fault-bounded. Intrusive contacts are sharp to migmatitic, and diking and thermal metamorphism of nearby country rocks are locally well developed. Petrologic data are scarce but hornblende (± biotite) diorite and quartz diorite apparently are characteristic lithologies; some chemical data have been reported by Hill and Morris (1977).

Plutons were emplaced in the belt during the Early Jurassic and possibly Late Triassic; some intrude Upper Triassic (Norian) sedimentary rocks (including volcanogenic sandstone and tuff) and single-mineral (hornblende) K-Ar ages range from 184 to 193 m.y. (fig. 2).

Aleutian Range-Talkeetna Mountains belt

The Aleutian Range-Talkeetna Mountains belt contains plutons that are almost continuously exposed in a narrow and linear, northeast-

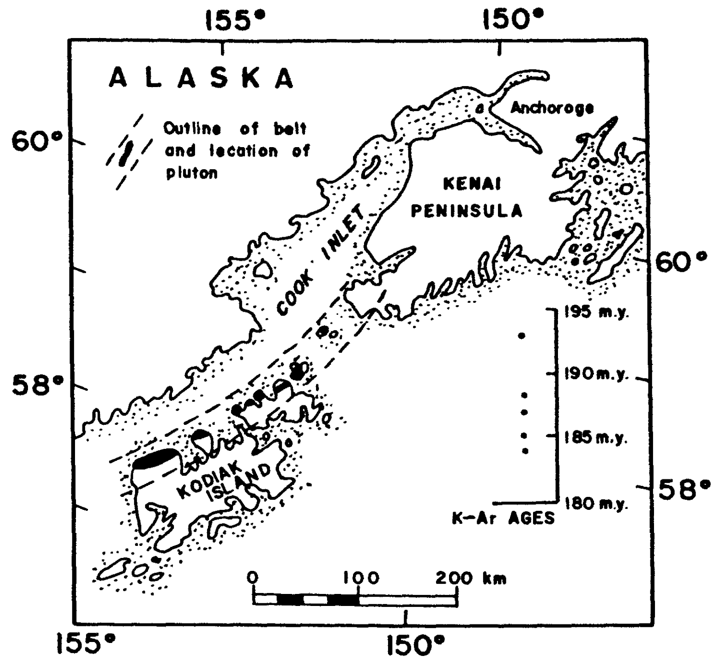

Figure 2. Distribution of plutons and summary of K-Ar ages (hornblende) for the Kodiak-Kenai plutonic belt.

trending belt that appears to comprise two separate segments (fig. 3). The southern segment is exposed from near Becharof Lake on the Alaska Peninsula northeast 500 km to near Tyonek on the west side of Cook Inlet (Reed and Lanphere, 1972). Reed and Lanphere (1973, p. 2593) suggested that this segment may extend unexposed for an additional 480 km or more to the southwest of Becharof Lake. The shorter (about 150 km) but similar northern segment is exposed in the Talkeetna Mountains where Jurassic plutonic rocks make up the eastern one-third of the Talkeetna Mountains batholithic complex (Csejtey and others, 1978).

The northern and southern segments are both locally emplaced against Lower Jurassic sedimentary and volcanic rocks to the east and are in turn locally intruded by Upper Cretaceous-lower Tertiary plutonic rocks to the west. Triassic or older metamorphic rocks form roof pendants and parts of complex border zones and the southern segment is fault bounded for long distances along its east margin. Individual plutons are generally concordant to regional trends and contacts are sharp to gradational with migmatitic and inclusion-rich zones locally developed. Foliated biotite hornblende quartz diorite, tonalite, trondhjemite, and granodiorite dominate in the belt but gabbro, diorite, and some monzonitic rocks are present (fig. 3).

Plutons of the belt locally intrude Lower Jurassic (Sinemurian to Toarcian) marine sedimentary and volcanic rocks of the Talkeetna Formation and boulders derived from the plutonic belt are present in the Upper Jurassic (lower Oxfordian) Naknek Formation (Grantz and others,

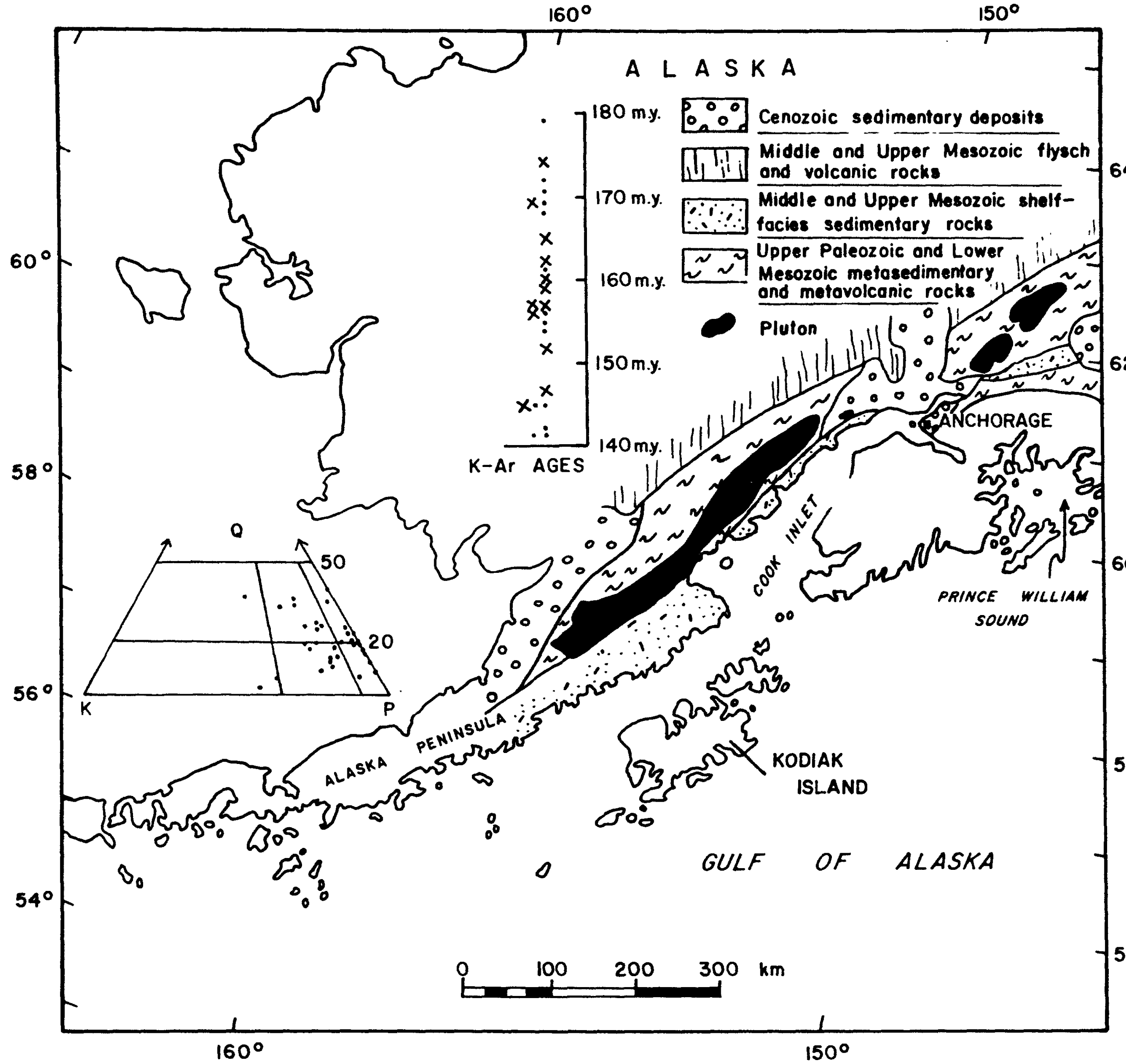

Figure 3. Distribution of plutons and nearby geologic terranes, summary of modal data (Reed and Lanphere, 1973), and summary of K-Ar ages (•, single mineral; x, concordant mineral pair) for the Aleutian Range-Talkeetna Mountains plutonic belt.

1963; Detterman and others, 1965). K-Ar ages (fig. 3) from the southern segment (Reed and Lanphere, 1972, 1973) range from 142 to 179 m.y. with concordant mineral pairs being between 155 and 175 million years. In the northern segment, the range of K-Ar ages is similar (142-173 m.y., Grantz and others, 1963; Turner and Smith, 1974; Csejtey and others, 1978) and although dated mineral pairs are mostly discordant they do include the youngest concordant age in the belt (145 m.y.). The field and K-Ar data show that the age of plutonism in the Alaska Peninsula-Talkeetna Mountains belt is Middle and Late Jurassic.

Tonsina-Chichagof belt

The Tonsina-Chichagof belt (fig. 4) includes all plutons of known or probable Jurassic age located in or along the north side of the eastern Chugach and St. Elias Mountains as well as Jurassic plutons of Chichagof Island. The belt extends southeastward for about 800 km from near Tonsina at the north side of the Chugach Mountains (Beikman, Holloway, and MacKevett, 1977), through parts of the Wrangell and St. Elias Mountains (Campbell and Dodds, 1978; Hudson and others, 1977) probably through parts of Glacier Bay National Monument, to western Chichagof Island (Loney and others, 1975). Spatial continuity and temporal correlation of at least parts of this belt with Jurassic belts to the west is possible but cannot be demonstrated at present.

Plutons of the Tonsina-Chichagof belt are mostly emplaced in greenschist to amphibolite facies, upper Paleozoic and lower Mesozoic metasedimentary and metavolcanic rocks that form the upper plate of the Border Ranges fault (MacKevett and Plafker, 1974; Plafker and

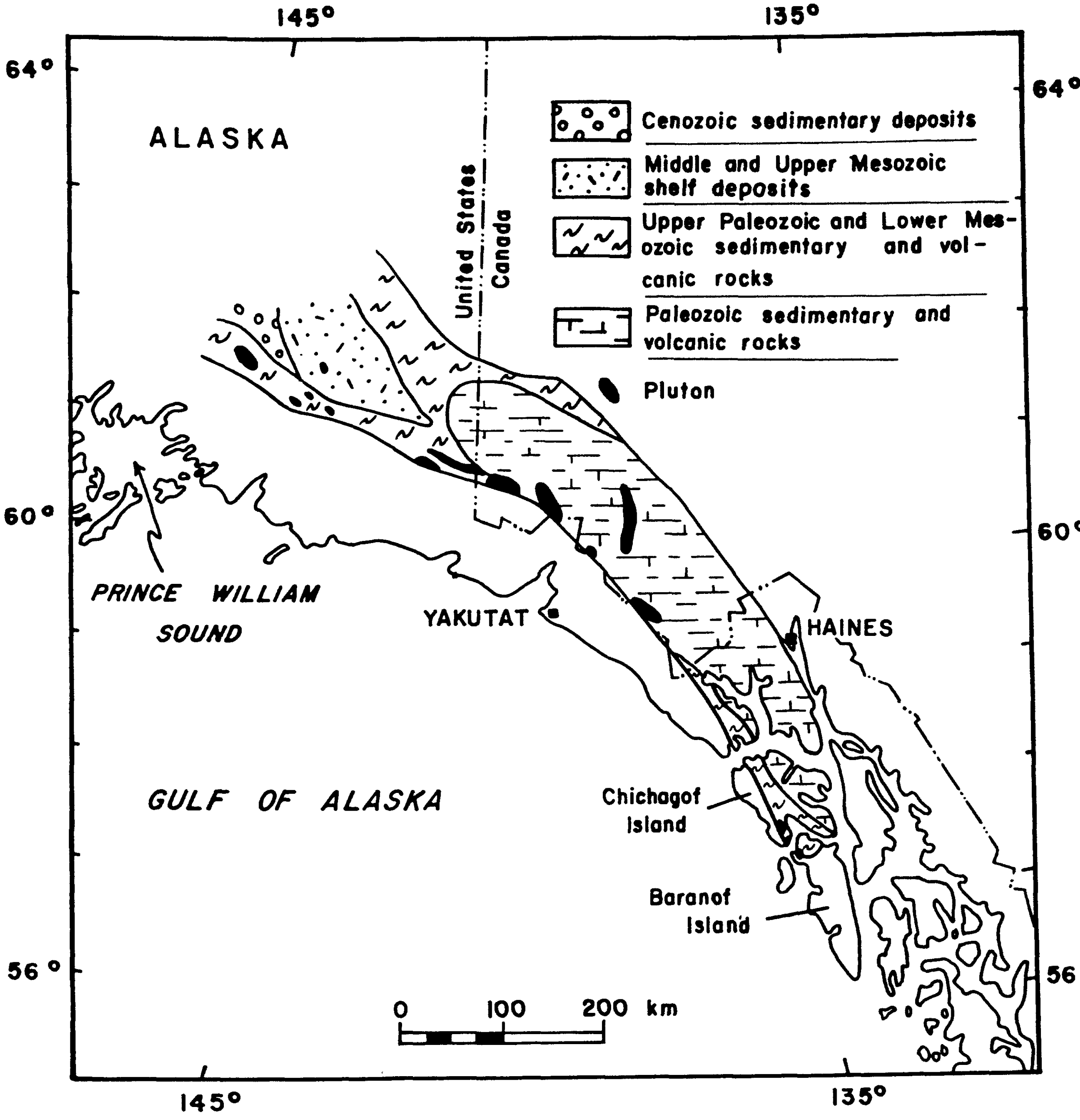

Figure 4. Distribution of plutons and host geologic terranes for the Tonsina-Chichagof plutonic belt.

others, 1976) but also intrude older Paleozoic rocks in parts of the St. Elias Mountains (Campbell and Dodds, 1978) and probably in Glacier Bay National Monument (fig. 4). The plutons are commonly elongate parallel to regional trends and have sharp to migmatitic and gradational boundaries. Foliated biotite hornblende quartz diorite, tonalite, and granodiorite are characteristic of the belt.

Age relations in the belt are incompletely known. Plutons locally intrude Upper Triassic sedimentary rocks and are unconformably overlain by Lower Cretaceous sedimentary rocks. Biotite from a granodiorite clast in the Kotsina Conglomerate (Middle or Late Jurassic) is dated at 157 ± 6 m.y. and a microdiorite dike intruding this conglomerate is dated at 142 ± 5 m.y. (Grantz and others, 1966). Jurassic K-Ar ages from the belt range upward to 164 m.y. and two mineral pairs have yielded concordant ages at about 140 and 151 m.y. (R. B. Campbell, written commun., 1977; Loney and others, 1975). The age data show that a major Jurassic plutonic event (mostly Late? Jurassic) occured in eastern southern Alaska.

Nutzotin-Chichagof belt

The Nutzotin-Chichagof belt (fig. 5) consists of northern and southern segments that differ in some general field and petrologic characteristics. The northern segment extends from near the intersection of the Denali and Totshunda faults in the Nutzotin Mountains (Richter and others, 1975) 475 km southeast to near lower Dezadeash Lake in Yukon Territory, Canada (Campbell and Dodds, 1978). The southern segment extends 375 km south from near Mush Lake in Yukon Territory

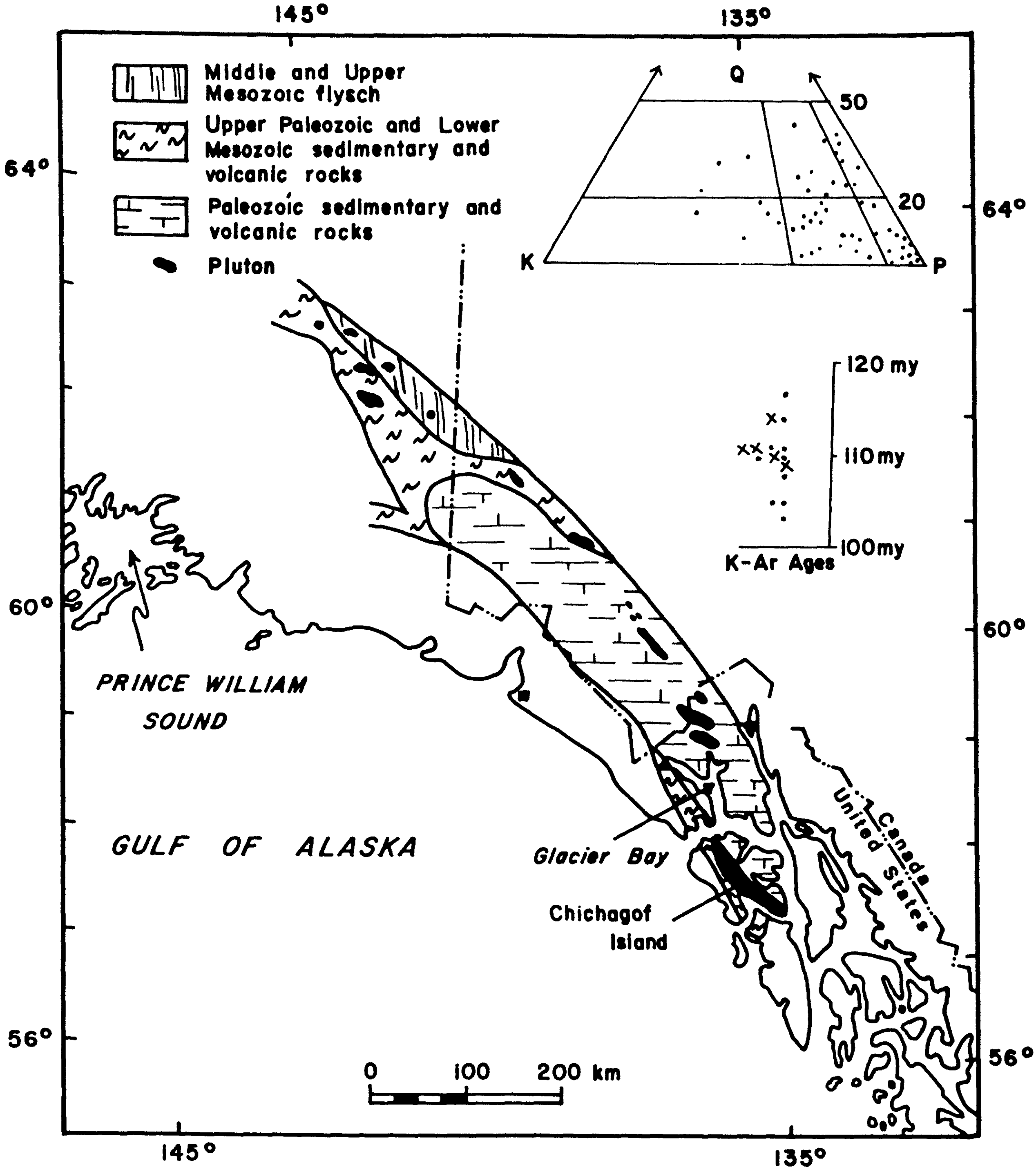

Figure 5. Distribution of plutons and host geologic terranes, summary of modal data (Alaska plutons in northern segment only, Richter and others, 1975), and summary of K-Ar ages (., single mineral; x, concordant mineral pair) for the Nutzotin-Chichagof plutonic belt.

(Campbell and Dodds, 1978), through British Columbia (Watson, 1948), through parts of Glacier Bay National Monument and the Haines area (MacKevett and others, 1971; MacKevett, Robertson, and Winkler, 1974), to Chichagof Island (Loney and others, 1975).

Plutons of the northern segment commonly intrude Upper Jurassic and Lower Cretaceous flyschoid rocks of the Nutzotin Mountains sequence (Richter, 1976), and correlative rocks of the Dezadeash Formation in Canada (Eisbacher, 1976). They locally intrude upper Paleozoic and Triassic sedimentary and volcanic rocks that flank the Upper Jurassic and Lower Cretaceous flysch terrane to the west (Richter, 1976; Campbell and Dodds, 1978). These plutons are generally widely spaced, isolated intrusive complexes that are irregularly shaped and have sharp discordant contacts. Thermal aureoles are commonly well developed. In Alaska, the plutons are commonly composite, are petrologically variable, and display zonal relations; gabbro, diorite, quartz monzodiorite, quartz diorite, tonalite, granodiorite and granite are present (fig. 5). Some plutons are associated with porphyry-type copper and molybdenum mineralization.

Plutons of the southern segment intrude diverse Paleozoic metasedimentary and metavolcanic rocks. Contact relations vary from sharply discordant to gradational, migmatitic, and concordant. Many plutons are elongate and grossly conformable to regional structure. They are apparently more uniform petrologically than those to the north and characteristically contain foliated biotite and hornblende-bearing dioritic to tonalitic rocks. Granodiorite is also present.

In the northern segment, the Alaska plutons locally intrude sedimentary and volcanic rocks of the Lower Cretaceous (Valanginian? to Barremian) Chisana Formation and were apparently the source of granitic cobbles incorporated in Upper(?) Cretaceous continental sedimentary rocks (Richter, 1976). K-Ar ages (fig. 5) in the northern segment range from 105 to 117 m.y., with four biotite-hornblende mineral pairs yielding concordant dates between 111 and 114 m.y. (Richter and others, 1975; R. B. Campbell, written commun., 1977). K-Ar ages in the southern segment include several from the Haines area that range from 105 to 119 m.y. and include two concordant biotite-hornblende pairs at about 107 m.y. and 110 m.y. (MacKevett and others, 1974). Single mineral K-Ar ages reported from Chichagof Island range from 103 to 114 m.y. (Loney and others, 1975). The age data throughout the belt indicate the time of plutonism was late Early Cretaceous; between about 105 and 120 m.y. ago.

Alaska Range-Talkeetna Mountains belt

The Alaska Range-Talkeetna Mountains belt (fig. 6) is about 700 km long and extends from near Nonvianuk Lake in the Aleutian Range, northeast through the southern Alaska Range (Reed and Lanphere, 1969, 1972, 1973) and the Talkeetna Mountains (Csejtey and others, 1978), to the central Alaska Range (Smith and Lanphere, 1971; Turner and Smith, 1974). The belt as now exposed is broader than any other; it is about 100 km wide in the southern Alaska Range and about 175 km wide between the Talkeetna Mountains and the central Alaska Range.

The southeastern parts of the belt contain elongate, somewhat

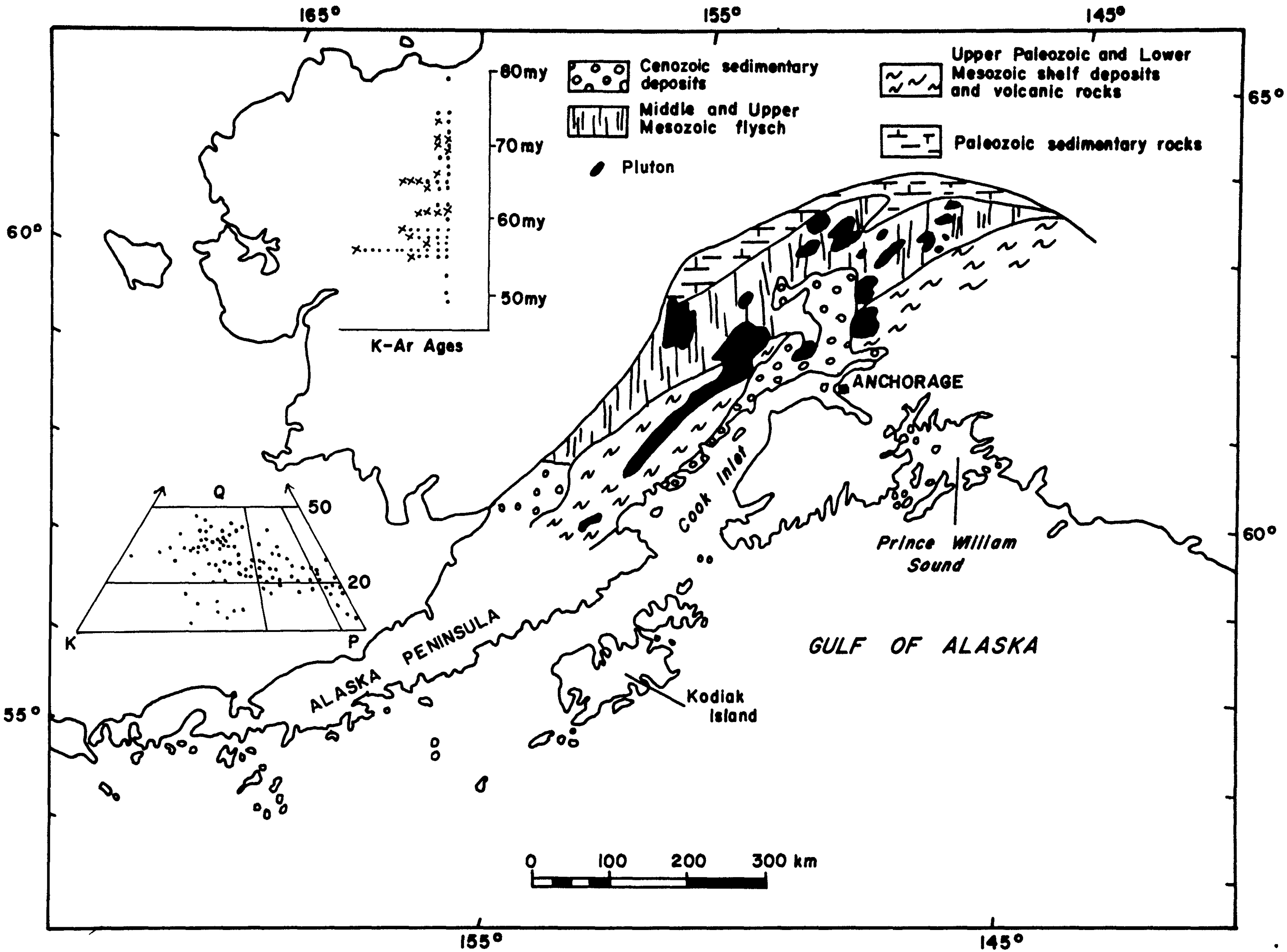

Figure 6. Distribution of plutons and host geologic terranes, summary of modal data (Reed and Lanphere, 1973; Reed and Nelson, 1977), and summary of K-Ar ages (·, single mineral; x concordant mineral pair) for the Alaska Range-Talkeetna Mountains plutonic belt.

continuous and regionally concordant batholithic complexes that intrude Mesozoic and upper Paleozoic metamorphic rocks as well as plutons of the Aleutian Range-Talkeetna Mountains belt. These batholithic complexes are dominantly foliated biotite hornblende quartz diorite, tonalite, and granodiorite. The northwestern parts of the belt contain many irregular plutons, scattered through the central Alaska Range, that sharply and discordantly intrude a wide variety of Mesozoic and Paleozoic sedimentary, volcanic, and metamorphic rocks (fig. 6). They mostly contain granodiorite and granite.

The age of the plutonism in the belt is well established by K-Ar dating. K-Ar ages range from 50 to 74 m.y. (fig. 6) and include concordant mineral pairs between 50 and 73 m.y. (Reed and Lanphere, 1972, 1973; Csejtey and others, 1978; Smith and Lanphere, 1971; Turner and Smith, 1974). The K-Ar data alone do not discriminate separate plutonic episodes but the more mafic rock suites (quartz diorite to tonalite) are $\geq$ 62 m.y. old (Reed and Lanphere, 1973, p. 2599) and are found mainly in the southeastern parts of the belt. Most plutons were emplaced during the Late Cretaceous and Paleocene.

Yakutat-Chichagof belt

Plutons of the Yakutat-Chichagof belt (fig. 7) have only recently been recognized on a regional scale (Hudson, Plafker, and Lanphere, 1977, p. 169) and only preliminary data are available concerning them; their age and field relations are poorly known. They have been identified over a distance of about 300 km in the eastern Gulf of Alaska near Yakutat, in the Lituya Bay area, and on Chichagof Island.

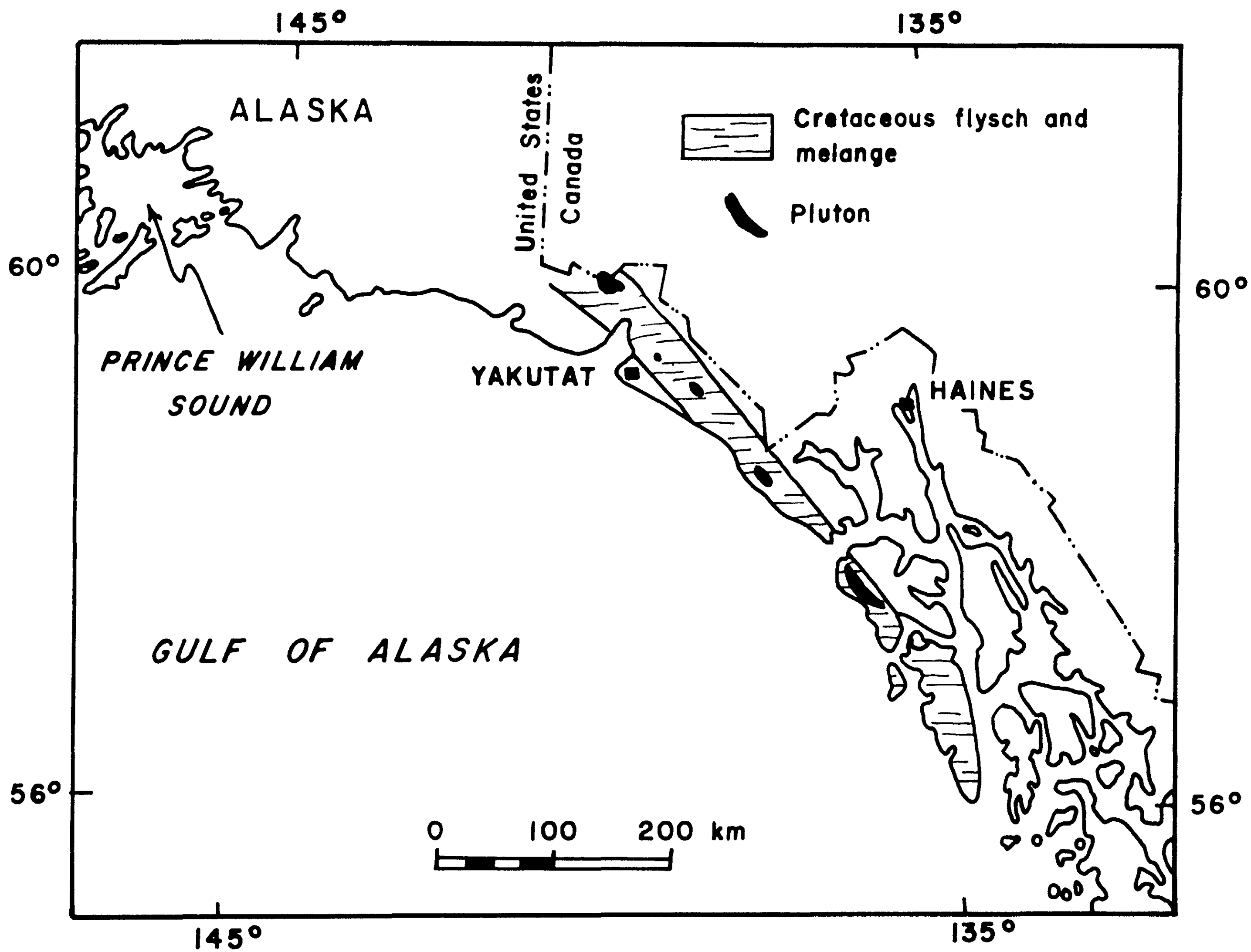

Figure 7. Distribution of plutons and host geologic terranes of the Yakutat-Chichagof plutonic belt.

The plutons form small stocks and larger elongate bodies enclosed in Cretaceous flyschoid rocks of the eastern Gulf of Alaska continental margin (Plafker and others, 1977). They contain foliated biotite hornblende quartz diorite and tonalite that is characteristically sheared and altered. Alteration consists of extensive saussuritization, sericitization, and prehnite veining and replacement of biotite. In some places the enclosing rocks are thermally metamorphosed (Hudson, Plafker, and Lanphere, 1977, p. 165), and on the basis of these relations, the belt is provisionally considered to be Cretaceous or Tertiary in age.

One small Jurassic pluton in the Yakutat area is apparently incorporated as an exotic block in melange of the coastal flysch belt (Hudson, Plafker, and Lanphere, 1977). This relation suggests the possibility that some of the plutons in the Yakutat-Chichagof belt may also be allochthonous and older than their enclosing rocks.

Sanak-Baranof belt

The Sanak-Baranof belt (fig. 8) is over 2,000 km long and parallel to the continental margin throughout the Gulf of Alaska region (Hudson, Plafker, and Lanphere, 1977, p. 169-170). It is defined by a series of discrete plutons that are present on Sanak Island (Moore, 1974), the Shumagin Islands (Grantz, 1963; Moore, 1974), the Semidi Islands (Burk, 1965), on central Kodiak Island (Moore, 1967), the Kenai Peninsula (Tysdal and Case, 1979), in the eastern Chugach Mountains (T. Hudson and G. Plafker, unpubl. data; Hudson, Plafker, and Peterman, 1977), the eastern Gulf of Alaska (Hudson, Plafker, and Lanphere, 1977), and on western Chichagof and Baranof Islands (Loney and others, 1975).

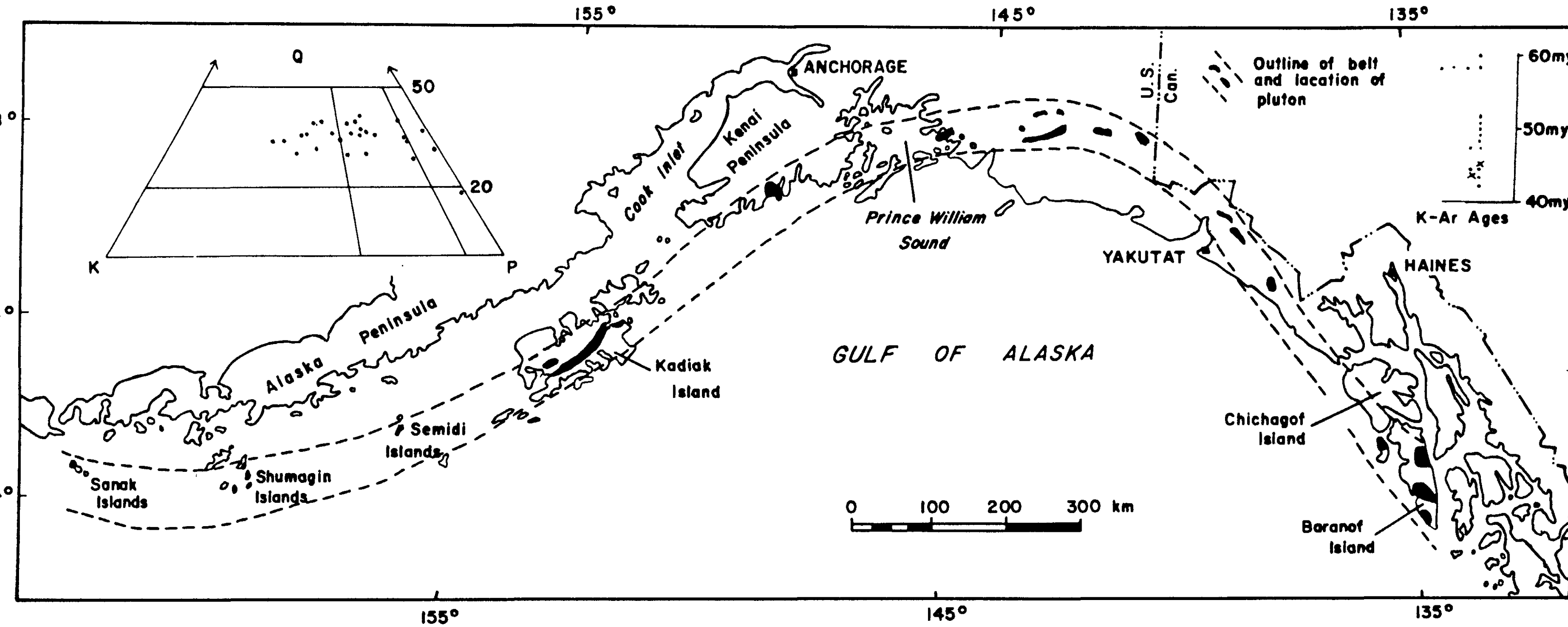

Figure 8. Distribution of plutons, summary of modal data (Hudson, Plafker, and Lanphere, 1977, and Hudson, unpubl. data), and summary of K-Ar ages (•, single mineral; x concordant mineral pair) for the Sanak-Baranof plutonic belt. All plutons are located wtihin an Upper Mesozoic (Cretaceous) and Lower Cenozoic flysch terrane (Fig. 1).

Plutons throughout the belt intrude an upper Mesozoic and lower Tertiary accretionary prism of flyschoid rocks (Plafker and others, 1977) that lies between the Border Ranges fault (MacKevett and Plafker, 1974; Plafker and others, 1976) and the present continental margin. They include stocks and larger bodies and although many are elongate and grossly conformable to regional structural trends, they commonly have sharp and locally discordant contacts. Distinct thermal aureoles are well developed adjacent to many plutons but migmatitic and gradational contact zones are associated with some more deeply eroded plutons. The plutons characteristically contain biotite granodiorite and granite but include some biotite tonalite (fig. 8). Hornblende is absent except in certain marginal zones that have complex contact relations with mafic volcanic rocks. Some white mica and garnet are present.

The plutons intrude strongly deformed Cretaceous and Paleocene rocks; K-Ar ages are almost all between 47 and 60 m.y. (fig. 8). Prince William Sound apparently divides the belt between a slightly older 58-60 m.y. western segment (Moore, 1974; Kienle and Turner, 1976; Karlstrom and Ball, 1969, p. 29; Tysdal and Case, 1979) and a younger 47-52 m.y. eastern segment (Plafker and Lanphere, 1974; Hudson, Plafker and Lanphere, 1977; Loney and others, 1975). One pluton on Baranof Island that is probably part of the belt is apparently about 43 m.y. old. The available data indicate that plutonism was approximately synchronous during the early Eocene (47-51 m.y.) in the eastern segment and during the late Paleocene (58-60 m.y.) in the western segment.

Alaska Range belt

Plutons of the Alaska Range belt (fig. 9) are scattered through the southern and central Alaska Range in a curvilinear trend at least 600 km long from Lake Clark northeastward to the vicinity of the Richardson Highway (Reed and Lanphere, 1969, 1972, 1973; Turner and Smith, 1974). The belt extends southeastward from Lake Clark to the Aleutian Peninsula, but plutons in this part have been identified only near Nonvianuk Lake (Reed and Lanphere, 1973, p. 2603-2604). The Alaska Range belt spatially overlaps the central and northern parts of the Late Cretaceous to early Tertiary Alaska Range-Talkeetna Mountains belt.

Country rocks of the Alaska Range belt include extensive areas of Mesozoic flysch and volcanic rocks as well as Paleozoic carbonate and clastic rocks. Plutons form a large elongate intrusive complex (the Merrill Pass sequence, Reed and Lanphere, 1973, p. 2601-2603) and many smaller isolated and irregular bodies. Many of the plutons are epizonal or hypabyssal and some are spatially associated with probable cogenetic subaerial volcanic rocks. Lithologic variation is well developed in the belt, and rocks range from biotite-hornblende quartz diorite to muscovite-bearing granite (fig. 9).

Age relations within the Alaska Range belt have been determined primarily by K-Ar dating; the K-Ar ages range from 25 to 41 m.y. with concordant mineral pairs between 26 and 38 m.y. (fig. 9). These ages are probably a good measure of the emplacement ages in the belt and establish it as Oligocene--the youngest major plutonic belt now identifiable in southern Alaska.

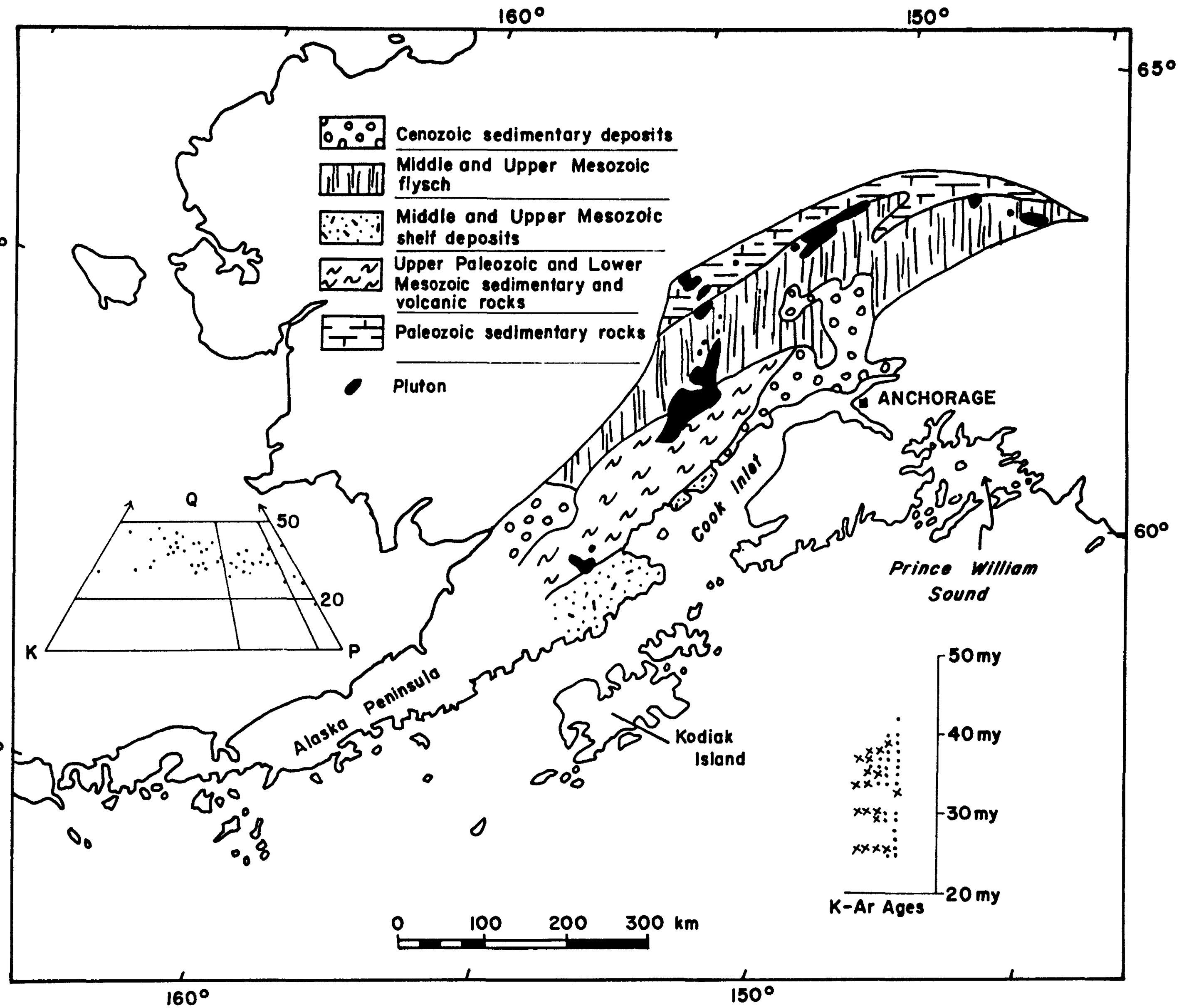

Figure 9. Distribution of plutons and host geologic terranes, summary of modal data (Reed and Lanphere, 1973), and summary of K-Ar ages (·, single mineral; x, concordant mineral pair) for the Alaska Range plutonic belt.

Other Plutonic Rocks

The eight plutonic belts include the great bulk of plutonic rocks in southern Alaska but others that are of local and possibly regional significance include: (1) upper Paleozoic rocks ranging from diorite to granite that form several plutons in the Wrangell-St. Elias Mountains (Hudson and others, 1977; Campbell and Dodds, 1978); (2) undated layered gabbro complexes in the St. Elias Mountains (Rossman, 1963; Plafker and MacKevett, 1970); (3) scattered granitic rocks in the Aleutian and Alaska Ranges that yield mid-Cretaceous K-Ar ages (Reed and Lanphere, 1972; Turner and Smith, 1974) but for which field and age relations are incompletely known (many granitic plutons in the central and eastern Alaska Range north of the area discussed in this report are mid-Cretaceous, Richter and others, 1975); and (4) Tertiary intrusive rocks that are spottily distributed but widespread in southern Alaska and mostly undated. They include many small plutons and dikes of early Miocene age in the Yakutat-St. Elias area (Hudson and others, 1977) and Oligocene plutons in the Prince William Sound area (Lanphere, 1966).

Summary

The available data on southern Alaska plutonic rocks show that plutonism was widespread but characterized by specific loci of emplacement for plutons of specific ages. These loci define eight plutonic belts that together represent most of the plutonic rocks in southern Alaska. The plutonic belts are defined by curvilinear to linear trends of exposed plutons or batholithic complexes that are now broadly parallel to subparallel to the continental margin. The lengths of the belts, based on known exposures and in all cases minimum lengths, range from 300 to 2,000 km but most are between 650 and 850 km. Approximate widths of the belts range from 15 to 175 km but most are between 30 and 100 km. Many of the belts are spatially distinct but overlap of a younger belt on an older one is known in the Alaska Range, the Yakutat-St. Elias area, and probably the Glacier Bay-Haines-Chichagof area of southeast Alaska.

Petrologically the plutonic belts are predominantly intermediate in composition--quartz diorite, tonalite, and granodiorite are by far the most abundant rock types. Gabbro and monzonitic rocks are locally a part of some intermediate-composition belts and granite is an important part of the belts in the Alaska Range. Granodiorite and granite dominate in the early Tertiary Sanak-Baranof belt--a belt that is petrologically distinct in this respect.

Plutonism in southern Alaska is mostly of Mesozoic and Cenozoic age. Most of the belts are temporally distinct, but there is known overlap in ages between the belts containing Late Jurassic and early Tertiary plutons (fig. 10). The timing of pluton emplacement in six of the belts is moderately well known and plutonism apparently began in them at about 195, 175, 120, 75, 60, and 40 m.y. ago; the intrusive episodes were as short as about 10 m.y. and as long as about 30 m.y.

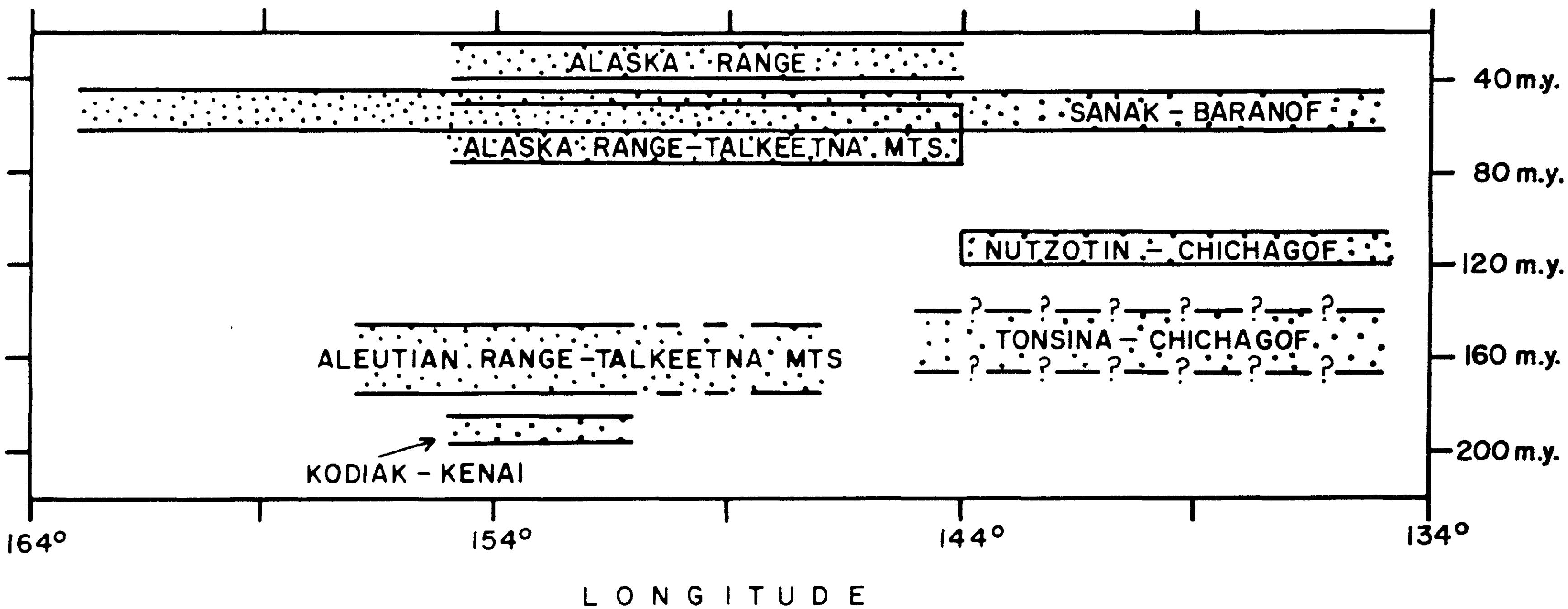

Figure 10. Diagrammatic summary of space-time relations of southern Alaska plutonic belts. The Yakutat-Chichagof belt is not included because of its poorly known age relations. Short dashes indicate where the continuity of a belt is uncertain. The indicated range in age of a belt is not necessarily constant along its length.

Conclusion

The data on plutonic rocks in southern Alaska are incomplete and many problems in the timing, distribution, and origin of plutonism in this region remain to be solved. This report provides an overview that should help to define important regional problems dealing with the spatial continuity and temporal correlation of the many southern Alaska plutonic belts as well as their relation to other regional rock units and structures. It also provides an initial framework for tectonic reconstructions of the Mesozoic and Cenozoic history of the region. Calc-alkaline plutonism has played a major role in the evolution of the tectonically complicated southern Alaska continental margin and most (Hudson, in press), but not all (Hudson, Plafker, and Peterman, 1977; in prep.), of this plutonism may be directly related to episodes of plate convergence and subduction.

Acknowledgments

The report is based on compilations of geologic relations, petrology, and K-Ar data available in the literature. R. B. Campbell shared unpublished K-Ar data from the St. Elias Mountains. Constructive technical reviews of an earlier draft of the report were provided by George Plafker and Marvin A. Lanphere.

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