UNITED STATES
DEPARTMENT OF THE INTERIOR
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UPPER TERTIARY HIGH-LEVEL PLUTONS OF THE SMEATON BAY AREA, SOUTHEASTERN ALASKA

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By

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This report is preliminary
and has not been edited or
reviewed for conformity with
Geological Survey standards

Contents

Introduction

In 1973-5, the U.S. Geological Survey and mining interests discovered three small, upper Tertiary (Miocene or younger) high-level plutons about 65 km east of Ketchikan in southern southeastern Alaska (fig. 1). These plutons, which include two composite felsic stocks and a gabbro stock, were each briefly studied during reconnaissance geologic mapping by the Geological Survey of the eastern half of the Ketchikan 1:250,000 quadrangle. However, particular interest now centers on the felsic stocks following recent public disclosure by the U.S. Borax and Chemical Corporation of the discovery of a major molybdenum deposit in one of them.[1/] This preliminary report briefly outlines the geologic setting and summarizes the limited geologic and geochemical information on these newly recognized late Tertiary plutons and associated mineralization. It is based on reconnaissance investigations by the U.S. Geological Survey; results of company exploration and diamond drilling have not been made public.

Previous Investigations

Published reports on the geologic setting of the region include U.S. Geological Survey reports by Buddington (1929) and Buddington and Chapin (1929). The only published geologic map of the Smeaton Bay area is a reconnaissance map of shoreline geology in Buddington and Chapin (1929).

[1/] Newspaper accounts, based on public statements by U.S. Borax and Chemical Corp., report a potential ore body in excess of 100 million tons grading from 0.20% to 0.35% MoS_2.

Recent Investigations

In 1972-73 a U.S. Geological Survey and U.S. Bureau of Mines party examined the Granite Fiords Wilderness Study Area, a proposed Wilderness Area of 2,600 km^2, in the northeastern Ketchikan and southeastern Bradfield Canal 1:250,000 quadrangles. The southern boundary of this area lies approximately 10 km north of the Smeaton Bay area. A bulletin report on the mineral resources of the Granite Fiords area has been prepared (Berg and others, in press). The Granite Fiords report includes geologic and aeromagnetic maps of that area. Recent studies on the geology of Bradfield Canal A-1 and Ketchikan D-1 quadrangles, on the northeastern boundary of the Granite Fiords area, have also been reported by J. G. Smith (in press).

In 1975, a U.S. Geological Survey party completed reconnaissance geologic mapping of that portion of the Ketchikan 1:250,000 quadrangle east of east Behm Canal and south of the Granite Fiords area. This preliminary report is based largely on information obtained during the 1975 geologic reconnaissance.

Geologic Setting

The Smeaton Bay area lies within the Coast Range metamorphic-plutonic complex, a linear terrane of plutonic and metamorphic rocks which extends 1,700 km through the length of coastal British Columbia and southeastern Alaska. A recent summary discussion of the setting of the Coast Range complex has been presented by Roddick and Hutchison (1974), and Hutchison (1970) has reported on the geology of the complex in the nearby Prince Rupert region. For this report, however, the discussion of geologic setting is drawn mainly from the 8,200 km^2 peninsula between east Behm and Portland Canals, herein termed the Portland Peninsula. There the complex forms three irregular belts that trend northwest. An eastern belt near Portland Canal consists mainly of discrete plutons of granodiorite and quartz monzonite. A central belt in the western and central parts of the peninsula consists of high-grade paragneiss and foliated plutonic rocks. A western belt near Behm Canal consists of schist and amphibolite, and, in the southwestern sector, subordinate plutonic rocks.

Lithology

Plutonic rocks, which underlie three-quarters of the peninsula are, in a general way, progressively more silicic and massive eastward across the complex. Near Behm Canal the plutonic rocks are predominantly foliated to gneissic (locally migmatitic) diorite, quartz diorite and granodiorite. Contacts are gradational and not well defined. Foliation, gneiss screens, elongate plutons and other structural elements all trend north to north-northwest, and dip steeply either east or west, although eastward dips predominate. Remarkable sections through this terrane are well exposed in the several deep fiords that cross these structural trends. Smeaton Bay itself affords an accessible and representative section through these foliated to gneissic plutonic rocks.

On the eastern side of the peninsula, adjacent to Portland Canal, the plutons are more well defined, and typically are more equant than elongate. Granodiorite and quartz monzonite predominate; quartz diorite and diorite are largely absent. Although some of these plutons have distinctive planar fabric, others are nearly massive except near contacts. Foliation and schlieren, where present, commonly form a distinctive pattern within each pluton that we interpret as primary intrusive structure. This is in marked contrast to the pervasive and throughgoing foliation in the plutonic rocks in the western portion of the peninsula.

Regionally metamorphosed amphibolite facies gneiss and schist are subdivided into two principal lithologic assemblages: 1) predominantly pelitic and quartzo-feldspathic paragneiss containing minor amphibolite and marble; and 2) amphibolite, including amphibolitic gneiss and schist, with minor pelitic gneiss and migmatite.

The paragneiss crops out in many discontinuous areas throughout the western and central parts of the peninsula. The most distinctive and characteristic rock type is layered (few mm to 2 cm) sillimanite-garnet-biotite-quartz-plagioclase metapelitic gneiss. Sillimanite is particularly conspicuous locally where it forms mats of oriented needles on surfaces of biotite-rich layers. Kyanite occurs instead of sillimanite in the westernmost portions of the paragneiss terrane, near east Behm Canal, indicating a lower metamorphic grade.

Gray biotite-quartz-plagioclase quartzofeldspathic gneiss is about as abundant as metapelitic gneiss within the paragneiss unit, but is less diagnostic of metamorphic conditions than the sillimanite- or kyanite-bearing gneisses. In some areas the biotite-quartz-plagioclase gneiss grades imperceptably into foliated or gneissic granodiorite, and contacts between the units are indistinct. Minor layers of marble and amphibolite are locally interlayered with the paragneiss.

The amphibolite unit crops out in a well defined belt 4 to 8 km wide that trends north. The belt crops out west of the paragneiss and plutonic terranes and extends from Work Channel in British Columbia, through Nakat Bay at the southern tip of the peninsula, across Boca de Quadra to the mouth of Smeaton Bay. North of Smeaton Bay a much narrower band of amphibolite continues for many kilometres along the eastern shore of east Behm Canal. Several large physiographic features (e.g., Nakat, Vixen, and

Badger Bays and associated stream valleys) parallel the foliation in the amphibolite belt.

The typical rock type in the unit is biotite-hornblende amphibolite with a trace to moderate amounts of quartz. Almandine garnet is locally present, but is seldom abundant; garnet porphyroblasts may be as large as 3 cm. Amphibolitic gneiss and biotite-hornblende-quartz-plagioclase schist are also common. Layers of metapelitic rocks constitute a minor portion of the unit, and marble is a rare constituent. Elongate bodies of trondhjemite are also associated with the amphibolite unit.

West of the amphibolite belt is an assemblage of relatively low-grade schists. This terrane faces Revillagigedo Channel north and south of Boca de Quadra, but does not extend as far north as Smeaton Bay. Rocks of this terrane are metasedimentary and metavolcanic schists of greenschist and lower amphibolite facies. They include quartz-muscovite schist, albite-actinolite-chlorite±quartz schist, quartz-muscovite-biotite-garnet schist, and minor marble.

Not shown on figure 1 are Quaternary basalt flows and associated fragmental rocks that crop out in several small isolated patches north of Smeaton Bay.

Geochronology

Potassium-argon age determinations on minerals from metamorphic and plutonic rocks in the area of figure 1 delineate three northwest-trending belts, each with a distinctive pattern of ages. These belts coincide roughly with the three northwest-trending belts described on page 3. The age data identify two regional tectonic events and indicate that regional metamorphism and associated plutonic activity ceased by about 40 million years ago, or about the middle of the Eocene Epoch.

Concordant 50 m.y. biotite and hornblende ages characterize the eastern belt of equant granodiorite and quartz monzonite plutons that stretch northwest along the northeast side of the Coast Range plutonic-metamorphic complex. The ages in this belt represent intrusive ages of Eocene plutons.

Ages from the central belt are mildly discordant; hornblende averages about 52 m.y. and biotite about 44 m.y. These ages characterize the high-grade schist and gneiss, and the strongly foliated granodiorite and quartz diorite of the western and central portions of Portland Peninsula. Mineral ages show no correlation with rock type or position within the belt. This pattern of apparent ages in a high-grade metamorphic terrane suggests that the ages were set by a mid-Tertiary thermal event.

The western belt yields apparent ages that increase from 52 m.y. (hornblende) and 44 m.y. (biotite) near the eastern edge of the amphibolite unit to 80-85 m.y. (hornblende and biotite) on Revillagigedo Island. While biotite and hornblende apparent ages increase smoothly from northeast to southwest they do so at different rates and not in a linear fashion. This pattern suggests that rocks at least as old as 80-85 m.y. on Revillagigedo Island were progressively reset eastward by the mid-Tertiary thermal event.

This distribution of ages and the patterns of discordance indicate two periods of metamorphic-plutonic activity: (1) late Cretaceous (80-85 m.y.) and (2) mid-Tertiary (40-50 m.y.).

Lamprophyre Dikes

The Portland Peninsula lies wholly within an extensive Tertiary lamprophyre dike province described by Smith (1973). Reconnaissance mapping suggests that the areal extent of this dike province is at least 16,000

km^2, and may be significantly larger.

Within the area of this report, most lamprophyre dikes are northeast-trending and nearly vertical; they are parallel to a prominent regional joint set. Erosion along the northeast-trending dikes and joints has produced a strong northeast grain of valleys and ridges oblique to prominent northwest-trending bedrock structures. Closely spaced longitudinal and cross joints facilitate this differential erosion, which strongly emphasizes the dikes in areas of granitic rocks.

The dikes are commonly concentrated in elongate swarms a few kilometres wide. Within a swarm there are hundreds of dikes, and they are nearly ubiquitous. In areas between swarms the dikes are relatively sparse, but never wholly absent. Fewer dikes were noted in areas underlain by metamorphic rocks than in areas of granitic rocks. Perhaps fewer dikes intruded the metamorphic rocks, but equally likely the dark dikes were more easily overlooked in the similarly colored metamorphic rocks.

Dikes range in thickness from a few cm to 20 m; the majority are between 0.5 and 3 m thick. They characteristically maintain uniform thickness and attitude over great distances. In areas of suitable exposure, individual dikes only a metre or so wide may be traced for a kilometre or more vertically and horizontally without notable change in attitude or thickness. Wherever it can be determined, the sense of relative movement of the dike walls is that of simple lateral extension or dilation. There is no evidence of movement parallel to the dikes.

These thousands of aligned northeast-trending lamprophyre dikes are remarkable not only for their uniform attitude, but also for their petrologic and chemical similarity over a large area. They display only small variations in most major oxides; all analyzed samples lie within the alkali basalt field on an alkali:silica diagram. Detailed chemistry and petrology are described by Smith (1973).

Lamprophyre dikes cut Coast Range plutons radiometrically dated at 45-50 m.y. They clearly post-date the major tectonic events and were emplaced during a period of regional extension. Locally, Quaternary volcanics lie on erosional surfaces that truncate lamprophyre dikes. In chemistry and petrography the dikes correlate closely with the undifferentiated Miocene plateau basalts of British Columbia. A Miocene age of intrusion was suggested by Smith (1973).

Upper Tertiary Intrusive Rocks

Three small, equant, non-foliated plutons--a gabbro stock and two composite felsic stocks--crop out within the predominantly gneissic terrane of the Smeaton Bay area. Absence of pervasive foliation or elongation is in marked contrast to all enclosing rock, whether metamorphic or plutonic. A post-tectonic age of emplacement is thus indicated for all three plutons, and is their single most important shared characteristic. Dikes associated with the felsic stocks are localized along the northeast-trending regional joint system that also contains the lamprophyre dikes.

Gabbro

A roughly circular gabbro stock about 10 km^2 in area crops out half way between Rudyerd and Smeaton Bays. It discordantly intrudes the paragneiss and foliated granodiorite units. The stock itself is neither foliated nor metamorphosed, and is surrounded by a narrow contact aureole of hornfels.

Our reconnaissance suggests that the stock is zoned. The central part consists of uniform fine-grained subophitic gabbro. Typical samples contain labradorite and "late" oligoclase (65 percent), augite (10 percent), biotite

(10 percent), hypersthene (5 percent), green hornblende (5 percent), magnetite (5 percent) and apatite. In contrast, outcrops near the periphery consist of medium-grained, hypidiomorphic-granular gabbro in poorly defined layers, up to 2 cm thick, that are alternately rich in hornblende and pyroxene. Samples near the periphery have the same minerals as samples from the core, but differ in containing more-calcic labradorite and about 10 percent brown hornblende.

The lack of metamorphism of the gabbro and its intrusion into pelitic schist and gneiss and foliated granodiorite indicate that it is significantly younger than the Cretaceous or lower Tertiary regional metamorphism that so profoundly affected this part of the Coast Range. Biotite from the gabbro gave an age of 23 m.y. by the K/Ar method. For this small high level pluton, this is the age of emplacement.

Felsic Stocks and Dikes

Two composite felsic stocks and a suite of related dikes crop out in the rugged area between the head of Boca de Quadra and Wilson Arm in the Ketchikan B-2 quadrangle (fig. 1). Both stocks have roughly oval outcrops. The larger (4 to 5 km across) appears to be separated from the smaller body (2 km across) by a septum of gneiss about 1 km wide. The country rocks are mostly pelitic gneiss but also include gneissic and foliated granodiorite and quartz diorite. Contacts with the surrounding gneiss and foliated plutonic rocks appear sharp and discordant. A narrow thermal aureole is present locally. The Wilson Arm molybdenum deposit is localized in the southern part of the smaller (northern) stock.

The stocks contain several textural varieties of biotite granite and granite porphyry, all of which lack throughgoing planar fabric. One common rock type is a light gray, fine- to medium-grained, hypidiomorphic granular, biotite granite. This rock contains a few scattered phenocrysts (to 1 cm long) of pinkish-gray perthite and some distinctly subhedral to euhedral light-gray quartz crystals. Plagioclase (An_{20}) is locally sericitized and commonly unzoned, microcline is vein and patch microperthite and perthite, and biotite (2 percent or less) is commonly chloritized. Small subhedral magnetite grains are associated with biotite.

The distinctly porphyritic rocks within the stocks have variable textures, but in general they are very light gray porphyries with scattered fine- to medium-grained biotite, feldspar, and quartz phenocrysts in an aplitic groundmass. They locally contain indistinct clots of fine-grained equigranular biotite granite that fade into very fine-grained aplite. Quartz veinlets and miarolitic cavities are common in some areas. The miaroles are less than 2 mm across and contain clear euhedral quartz prisms, muscovite, and some pyrite. Their walls are discolored by rusty-brown oxide coatings. Phenocrysts in the porphyries are euhedral quartz, normally-zoned plagioclase, film and vein perthite, and brown biotite. Magnetite, apatite, and allanite are accessory minerals commonly associated with the biotite. The groundmass is a very fine grained allotriomorphic mosaic of quartz, simply twinned plagioclase, undulose K-feldspar, and minor biotite. Well-developed graphic intergrowths and extensively clouded feldspar are present in the miarolitic porphyries.

Only one locality in the smaller stock was sampled. This locality is about 1.5 km north of the center of the mineralized area. Several complexly altered and slightly mineralized rock fragments were obtained from highly fractured outcrop. They include chalky white porphyry, silicified(?) porphyry, and bleached fine-grained granite. Networks of thin quartz-molybdenite veins and molybdenite fracture coatings are present in the altered fine-grained granite and silicified(?) porphyry. Pyrite occurs as a few scattered and oxidized euhedra in the porphyries.

Felsic porphyry dikes believed to be associated with the two felsic stocks define a 5 km wide belt that extends from Wilson Arm east-northeast to and beyond the felsic stocks. Our investigations show that this belt is at least 20 km long. The dikes range in thickness from 1 m or less to several tens of metres. They are strongly oriented in an east-northeast direction (about N. 70 E.) parallel to a well-developed regional joint set that also localized lamprophyre dike swarms (Smith, 1973). The felsic dikes are porphyries that contain euhedral quartz, feldspar, and biotite phenocrysts in an aphanitic light-gray groundmass. They commonly contain chloritized grains, small miarolitic cavities, and disseminated pyrite.

Geochemical Reconnaissance

Rock and stream sediment geochemical samples were collected at 34 stations in a 10 km by 10 km area between the Blossom and Keta Rivers northeast of the heads of Wilson Arm and Boca de Quadra (Koch and others, 1976). The felsic stocks are exposed in the center of this area, and no geochemical samples were collected further than 4 km from the plutons. The rock samples were from 16 widely spaced geology stations. All major lithologies were sampled; no sample was obviously mineralized.

The geochemical samples were analyzed for 15 elements by standard semi-quantitative spectrographic and atomic absorption methods. Results are reported in parts per million (ppm). These analytical data can not be used to determine anomalous values because of the limited number and selective nature of the samples. We therefore have inferred anomalies by comparing these results with geochemical data for about 2,000 samples collected nearby in Granite Fiords wilderness study area (Berg and others, in press; Koch and others, 1976).

Anomalous amounts of molybdenum were reported from stream sediment samples at 13 of 20 stations. Eleven of these were in the range of 10 to 30 ppm; one was 200 and another 700 ppm. Two rock geochemical samples contained 100 ppm molybdenum; both were gneissic granodiorite or quartz diorite. No other rock samples carried detectable molybdenum. A single tungsten value was reported from a sediment sample, the same sample that yielded 700 ppm molybdenum.

Beryllium values of 5 or 10 ppm were reported for rock samples from 6 of the 16 stations. Two were from quartz porphyry dikes, two from the felsic stocks and two from country rock less than 1 km from the stocks. Five or 10 ppm beryllium was also reported in samples from 6 of the 20 stream sediment stations; all were from streams draining the felsic stocks. These results are in marked contrast to those of Granite Fiords wilderness study area where only 10 of more than 2,000 rock and stream sediment samples had beryllium values in excess of 2 ppm. Niobium values also appear to be slightly elevated in rock and stream sediment samples from the area around the felsic stocks. Values of 20 ppm (limit of determinability) or more were reported for several samples. In the Granite Fiords area only 16 samples contained 20 ppm or more of niobium.

Except for a single sediment sample containing 10 ppm molybdenum, rock and stream sediment samples from near the gabbro stock had no anomalous metal values.

Conclusions

Three small, roughly equant plutons discordantly intrude Eocene and older amphibolite-facies schist and gneiss and foliated plutonic rock of the

Coast Range metamorphic-plutonic complex and adjacent greenschist- to lower amphibolite-facies schist. None of these plutons has any through-going foliation or other structural elements characteristic of the enclosing metamorphic-plutonic terrane.

Available evidence suggests a post-tectonic high level emplacement for the three plutons. The gabbro and the two composite felsic stocks have sharp contacts, and are at least partly enclosed by narrow contact aureoles. Dikes with compositions equivalent to the felsic stocks intersect country rock foliation in the vicinity of these plutons. In addition, the felsic stocks in particular bear internal textural evidence of high level emplacement--porphyritic and granophyric textures, and small miarolytic cavities. These characteristics are in sharp contrast to the deeper crustal environment indicated by the surrounding amphibolite facies metamorphosed bedded rocks and foliated plutonic rocks. Probable high-level emplacement further supports our conclusion that these plutons are significantly younger than the Eocene and older deep seated regional metamorphic events that formed the Coast Range complex. The plutons are cut by lamprophyre dikes and thus at least partly predate them. However, it is not yet known whether any of the plutons cut any lamprophyre dikes.

Biotite from the gabbro gave an age of 23 m.y. (Miocene) by the K/Ar method. We believe that a comparable late Tertiary age is likely for the felsic pluton. A Miocene age has already been tentatively suggested for the lamprophyre dikes (Smith, 1973).

Because a major molybdenum deposit occurs in one of the felsic stocks, further minerals exploration in this region will certainly focus, at least in part, on the discovery of similar small high-level felsic plutons. We suggest that, within this portion of the Coast Range complex, areas favorable for the occurrence of small high-level plutons include areas of greatest crustal extension. One indication of crustal extension is the density of lamprophyre dikes. Any areas of lamprophyre dike swarms that also contain parallel sets of felsic dikes therefore should be closely examined for associated high-level felsic plutons.

Stream sediment samples define an area of anomalous values for molybdenum, beryllium, and niobium surrounding the felsic stocks and associated molybdenum mineral deposit. This distinctive geochemical signature may occur because the deposit is well exposed. Comparably mineralized, but less well exposed plutons may produce subtler geochemical expression.

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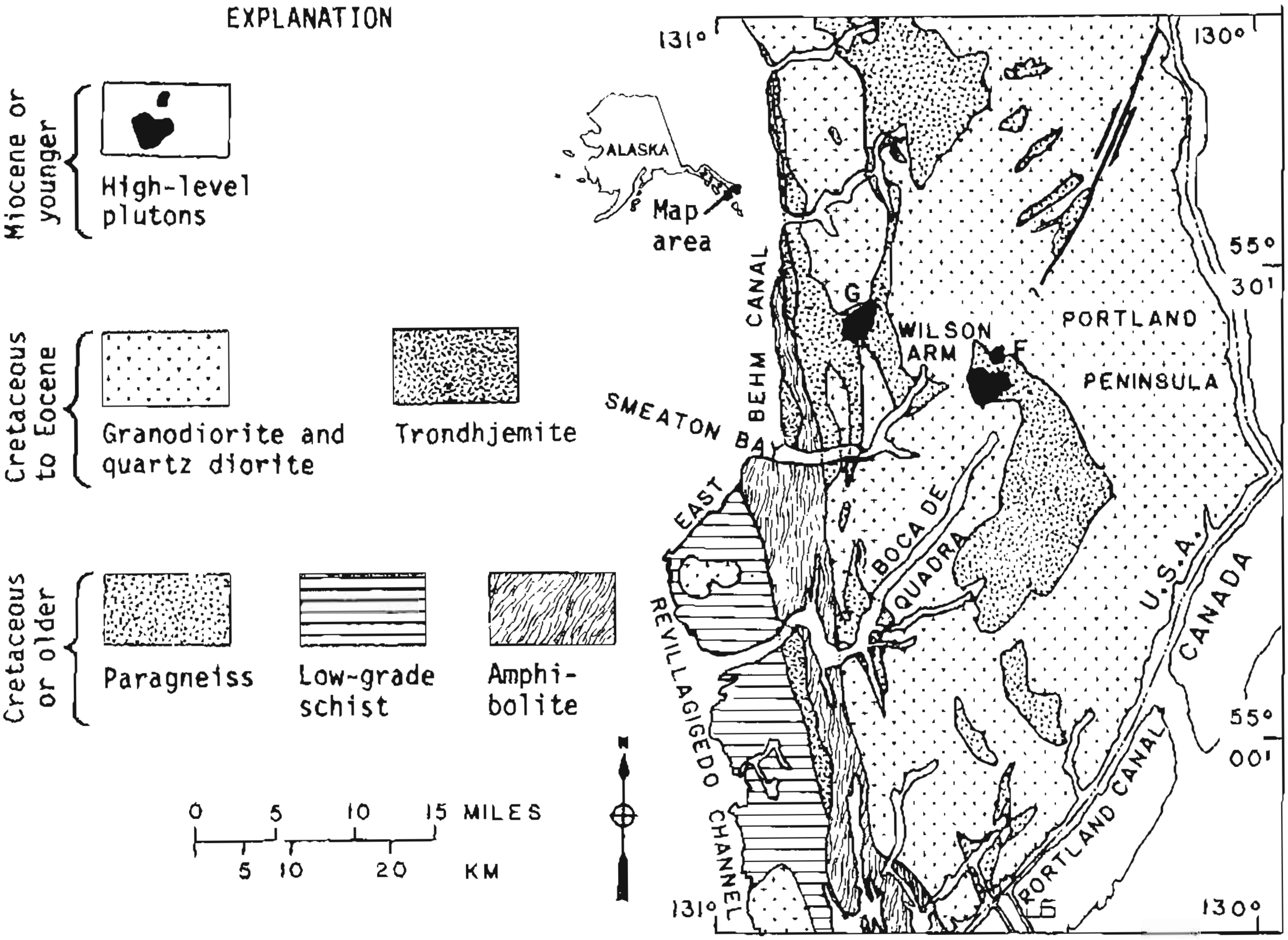

Figure 1.--Generalized geologic map of the Portland Peninsula near Ketchikan, Alaska. High-level plutons: G, biotite-bearing augite-hypersthene gabbro; F, felsic plutons associated with the Wilson Arm molybdenum deposit.