DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

# SUMMARY OF MARINE PLIOCENE SITES IN SOUTHERN AND WESTERN ALASKA

by

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# SUMMARY OF MARINE PLIOCENE SITES IN SOUTHERN AND WESTERN ALASKA

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## INTRODUCTION

This summary of sites in southern and western Alaska that contain marine Pliocene strata was undertaken as part of the U.S. Geological Survey's Pliocene climate project. This report is intended to be an inventory of fossiliferous localities that have the potential for increasing our understanding of high-latitude North Pacific climates during the Pliocene.

The most abundant and extensively exposed marine Pliocene sediments in Alaska are those in the upper part of the Yakataga Formation, along the northeastern margin of the Gulf of Alaska, southern Alaska (Figures 1 and 2). Other well exposed and abundantly fossiliferous Pliocene sediments make up the lower part of the Tugidak Formation, which crops out on Tugidak and Chirikof Islands in the western Gulf of Alaska (Figures 1 and 3). Pliocene sediments also make up the oldest of the series of late Cenozoic marine transgressions on the Seward Peninsula in the vicinity of Nome, western Alaska (Figure 1). The main bases for dating and correlating these various stratigraphic sequences have been mollusks, microfossils, amino acid racemization, and lithostratigraphy. The reliability of dating and correlation for these various Pliocene sequences varies significantly, and there has been no consistent application of any one dating technique to these southern and western Alaskan deposits.

A narrative summary of marine Pliocene deposits in these Alaskan regions is given below, supplemented by an Appendix beginning on page 15.

## THE YAKATAGA FORMATION

Before delving into the details of the Yakataga Formation, it is important to recognize that southern Alaska, compared to adjacent North Pacific regions, has had a relatively cold climate since the early middle Miocene. Marine glaciation in the northeastern Gulf of Alaska began in the early middle Miocene (15-16 Ma), in response to the tectonically-induced rise of coastal mountains that are now up to 6,000 meters high (Plafker, 1987; Marincovich, in press). Marine glaciation resulted in cooling of surface waters and development of a frigophilic marine biota throughout the Gulf of Alaska. As a result, marine mega- and microfaunas of this region reflected a climate that was colder than those to the south <u>or</u> north. This relationship must be kept in mind when reconstructing Pliocene climatic patterns that varied with latitude.

### Megafossils

The Yakataga Formation, of early early Miocene to Holocene age based on its molluscan fauna, may locally exceed 5,000 meters in thickness (Plafker, 1987). Summaries of Yakataga Formation stratigraphy and mega- and microfossil biostratigraphy are given by Addicott and others (1978), Rau and others (1977, 1983) and Plafker (1987). Based on the megafossil (principally molluscan) study of Addicott and others (1978), Yakataga strata assigned a Pliocene age are up to 2,050 meters thick and crop out in coastal mountains of the Chugach and St. Elias ranges for about 330 kilometers along the northeastern Gulf of Alaska margin (Figures 1 and 2). Dating of the Pliocene strata is based on the presence of mollusk species that co-occur in well-dated formations in the U.S. Pacific Northwest (Oregon and Washington), where a sequence of Tertiary molluscan stages (including the Pliocene Moclipsian Stage) has been established by Addicott (1976). However, the particular taxa used to identify the Moclipsian Stage in the Yakataga Formation were not cited by Addicott and others (1978), so that their basis for a Pliocene age call is not clear. Addicott and others (1978) cite four Yakataga Formation stratigraphic sequences (Figure 2) that contain Pliocene strata (and their thicknesses), as follows: Chaix Hills (2,050 meters), Kulthieth Mountain (1,750 meters), Samovar Hills (1,500 meters) and La Perouse Glacier (650 meters). The following points are noteworthy in the data presented by Addicott and others (1978): (1) age assignments in each case are given only as "Pliocene," without "early" or "late" qualifiers; (2) the tops of the Pliocene sequences are drawn as modern erosional surfaces, so that no Pliocene-Pleistocene boundary is present in any section; (3) the upper Miocene-Pliocene boundary in each case is shown as tentative and questioned (*i.e.*, "--?--?--"); (4) the upper Miocene-Pliocene boundary is placed in a major covered interval for two of the four stratigraphic sections (La Perouse Glacier and Samovar Hills) and in sparsely fossiliferous parts of the other two sections.

It is clear that the ages of the Yakataga Formation Pliocene sequences studied by Addicott and others (1978) are not precisely known. For example, in an earlier work based upon the same data set, Plafker and Addicott (1976, p. 22) stated that the Miocene-Pliocene boundary in the Kulthieth Mountain section could be located only as accurately as "between about 1,800 and 2,100 m above the base of the section." These authors noted that the Pliocene part of this sequence contains "low-diversity molluscan assemblages composed chiefly of modern species," in contrast to Miocene assemblages that "contain many extinct species" (Plafker and Addicott, 1976, p. 22). They did not state the fractions of extinct versus extant species that were used to characterize the Kulthieth Mountain Miocene and Pliocene faunas.

Based on the megafossil literature cited above, the Pliocene interval of the Yakataga Formation is poorly understood: it has not been precisely dated (its age-diagnostic species have not been explicitly noted), it has not been clearly distinguished paleontologically from underlying Miocene strata, and it evidently is not overlain by Pleistocene strata. These factors indicate that a major effort would be required to faunally define and date the Yakataga Pliocene interval, and to relate these Pliocene faunas to those of adjacent North Pacific regions.

## Paleomagnetic Stratigraphy

Fossiliferous strata in the upper part of the Yakataga Formation on Middleton Island (Figure 2) were assigned entirely to the Pleistocene by Addicott and others (1978), but these beds were considered to be of latest Pliocene and early Pleistocene age by Mankinen and Plafker (1987), based on paleomagnetic evidence. These authors stated that their sampled stratigraphic section spans the time interval from just prior to 2.14 Ma to sometime between 0.97 and 1.10 Ma. If true, the oldest part of the Yakataga Formation on Middleton Island would fall within the scope of the Pliocene climate study. For age control, Mankinen and Plafker (1987) refer to poorly constrained "Pliocene and Pleistocene" age inferences based upon mollusks (Plafker and Addicott, 1976) and benthic foraminifers (Rau and others, 1983). Recent studies of the sedimentology of Yakataga sediments on Middleton Island (Eyles and Lagoe, 1989; Lagoe and others, 1989) note that the age range of these strata is not well documented, but could be Pliocene in part. The Middleton Island section is one that merits further study.

## Microfossils

The comprehensive overview of Gulf of Alaska foraminifers (mostly benthic) by Rau and others (1983) differs significantly in its age assignments with the similar summary of megafossil data by Addicott and others (1978). Both studies recognize fossiliferous Pliocene intervals in the Chaix Hills, Kulthieth Mountain, La Perouse Glacier and Samovar Hills stratigraphic sections (Figure 2). However, Rau and others (1983) note the presence of overlying Pleistocene or "undifferentiated Pliocene and Pleistocene" beds in these four sections, whereas Addicott and others (1978) showed these Pliocene beds truncated by modern erosional surfaces. Resolution of these differing age interpretations is necessary for the purposes of the Pliocene climate program, and this could probably be achieved by reexamination of the microfossil and megafossil collections. The relevant megafossils are in U.S. Geological Survey collections in Menlo Park and could be sub-sampled for microfossils. The microfossil samples examined by Rau and others (1983) also are located in U.S. Geological Survey collections in Menlo Park.

Identifying the Miocene-Pliocene boundary in Yakataga sequences is as challenging as determining the Pliocene-Pleistocene boundary. Several Yakataga stratigraphic sequences considered by Addicott and others (1978) to be of middle or late Miocene age are assigned to the Pliocene or "upper Miocene and Pliocene, undifferentiated" by Rau and others (1983). As with the megafossil Pliocene/microfossil Pleistocene controversy noted above, reaching a consensus on the stratigraphic lower limit of Pliocene faunas in the Yakataga Formation must necessarily be part of the Pliocene climate program.

It is noteworthy that microfossil-based dating of Yakataga sequences has relied almost entirely on benthic foraminifers. This has occurred because planktonic foraminifers are relatively uncommon in these largely inner shelf deposits, and because the microfossil workers involved were specialists in benthic foraminifers.

Even when age-diagnostic planktonic foraminifers are present in Yakataga sequences their importance has sometimes not been fully appreciated. For example, the lowermost part of the Yakataga Formation at the Yakataga Reef stratigraphic section is dated as middle Miocene based on mollusks (Allison, 1978; Marincovich, in press) and contains the planktonic species *Globorotalia mayeri* and *G. siakensis* (fide Lagoe, 1983) with last-appearance-datums (LADs) of 10.4 Ma. However, even the most recent study of foraminifers from this sequence (Lagoe, 1983) cites a benthic-based age of "latest Miocene" for this part of the Yakataga Formation. The under-utilization of planktonic microfossils for dating Yakataga strata is a situation that clearly should be addressed by the Pliocene climate program.

Diatoms are present in parts of the Yakataga Formation, but there are no published references about them. However, John Barron (personal communication, 1989) has identified a late Pliocene diatom flora of nine species from the Chaix Hills stratigraphic section (Figure 2). The presence of *Thalassiosira convexa* (LAD = 2.1 Ma) and the absence of *Denticulopsis kamtschatica* (LAD = 2.5 Ma) suggest a latest Pliocene age for a sample located 1,227 meters from the top of the Chaix Hills section. This stratigraphic level, in about the middle of the 2,050-meter Chaix Hills section, was dated as Pliocene by Addicott and others (1978) based on mollusks and as undifferentiated Pliocene and Pleistocene by Rau and others (1983) based on benthic foraminifers. This diatom-based age is the most precise for any Yakataga Formation outcrop, Pliocene or otherwise. It clearly indicates that diatoms should be looked for in other Yakataga samples of suspected Pliocene age.

## Logistics

Most outcrops of the Yakagata Formation occur in the extremely rugged coastal ranges of the Chugach and St. Elias Mountains and are accessible only by helicopter. Summer weather typically consists of nearly steady rain (up to one meter a year in places), fog, and winds that frequently are strong (>100 km/hour). Field geologists working in this region typically lose one-third of their field days to high winds or fog that make helicopter operations hazardous or impossible in the mountainous terrain. Helicopter pilots are entitled to one non-flying day every two weeks, so such days also are lost for field purposes. Tent camps are not desirable in this region due to weather conditions, so operations must be based in a town, the closest of which is Yakutat (Figure 2). Clothing for cold and rainy weather is mandatory, as is training in helicopter and firearms safety (the latter owing to the presence of large brown bears). One should keep in mind that one-third of the field days will be lost to poor weather. The high expenses of doing geologic work in this region means that scientific objectives must be carefully defined and prioritized before arriving in the field. Field work on Middleton Island could probably be carried out from a tent camp, because the nearest town, Cordova, is about 150 kilometers away; for more on tent camps in this region, see the Tugidak Formation write-up, below.

## THE TUGIDAK FORMATION

### Mega- and Microfossils

The Tugidak Formation crops out mostly on Tugidak Island, one of the Trinity Islands that lie immediately south of Kodiak Island, and on adjacent Chirikof Island, in the western Gulf of Alaska. (Figures 1 and 3). The type section of the formation, on Tugidak Island, is said to be about 1,500 meters thick (Moore, 1969), although an unpublished stratigraphic section in U.S. Geological Survey files shows a thickness of 637 meters for the same section. The sediments are richly fossiliferous with well-preserved mollusks. No attempt has been made to search for microfossils, to my knowledge. Mollusks from both Tugidak Island (MacNeil in Moore, 1969) and Chirikof Island (Addicott in Moore, 1969) were considered to be of Pliocene age. A more thorough, but still relatively brief, review of the mollusks by Allison (1978) resulted in a "late Pliocene and Pleistocene" age estimate. The base and top of the formation on Tugidak Island are covered by modern deposits. On Chirikof Island the base of the formation is in fault contact with older rocks, and the top is overlain with apparent conformity by "an unnamed Pleistocene marine formation" (Moore, 1969).

The Tugidak Formation merits further study because of the likelihood that some portion of the Pliocene is represented by its well-preserved mollusks. These outcrops have never been visited by paleontologists. The excellent preservation and diversity of mollusks in U.S. Geological Survey collections indicates that collecting there would be very productive. Preservation of the mollusks is so good that even ligaments and periostraca are preserved on many bivalves. These collections contain many closed bivalves and gastropods filled with fine sediment that could be used for an initial attempt at microfossil analysis.

Outcrops of the main exposures are in low (<30 meters) coastal bluffs that extend for about 16 kilometers along the west coast of Tugidak Island. The low dip of the beds accounts for the length of outcrops, but allows for stratigraphically well-controlled collecting. It would be impractical to work along such a lengthy section by foot. A helicopter would be needed to adequately collect this section and to visit the section on Chirikof Island. Arrangements for setting up a tent camp would probably be made in the nearest town, Kodiak, which is 200 kilometers to the northwest, on Kodiak Island (Figure 3).

## Logistics

Tugidak and Chirikof Islands are said to be uninhabited, so a tent camp and helicopter would be necessary to collect these sections. Clothing for cold and rainy weather is mandatory, as is training in helicopter and firearms safety. The islands are said to lack bears, but wild bulls from a long-ago abandoned herd are said to be a problem. It might be possible to work out an arrangement with the U.S. Coast Guard in Kodiak to have them fly people and some supplies to and from Tugidak Island, in order to minimize field expenses. Relatively few field days would be completely lost to poor weather, because walking would always be possible, at least on Tugidak Island, when the helicopter was grounded.

## SEWARD PENINSULA DEPOSITS

The well-known series of late Cenozoic marine transgressions and regressions on the Seward Peninsula of western Alaska (Figure 1) are extensively discussed by several workers in Hopkins (1967). At the time of Hopkins' book it seemed certain that these deposits included seven transgressions that were of late Pliocene through late Pleistocene age. However, ongoing work based on amino acid racemization rates in mollusks, ostracodes and benthic foraminifers has cast doubt on much of the previous dating, especially for the older transgressions. The number of transgressions is now uncertain, but probably is about six.

The "classic" series of marine transgressions at Nome contains relatively abundant mollusks in places. However, it has not been fully realized that many mollusk collections from these "classic" deposits came from mine tailings left by gold miners sifting and tunneling through the gold-bearing beach sands during the 1920s and earlier. A fossiliferous sand bed 10 meters below the ground surface was assumed by geologists to be older than a sand bed only 5 meters below ground, even though the two diggings could be a kilometer, or many kilometers, apart. The stratigraphy pieced together in this fashion was, and is, as much guesswork as science. Attempts to characterize and date these mining deposits by mollusks have been less than fully satisfactory due to the imprecise locality information. Another important factor to keep in mind is that these faunas have never been collected by paleontologists, but by geologists for whom the fossils were a secondary interest. For any future field work it would be necessary for paleontologists to collect at these sites rather than to rely on the efforts of other workers lacking the requisite professional skills.

Most western Alaskan late Cenozoic transgressive deposits are thought to be of Pleistocene age (Hopkins, 1967), largely because all but a few of their mollusk and microfossil taxa are still living. The only molluscan evidence of a Pliocene age for western Alaskan deposits is the presence of *Fortipecten hallae* (Dall) in deposits assumed to belong to the Anvilian transgression. This bivalve occurs in deposits at California River and Solomon, near Nome (just south of Bering Strait) and at Kivalina (300 kilometers north of Bering Strait) (Figure 1). *Fortipecten* is known commonly from several species in Miocene through Pliocene deposits of northernmost Japan and the Far-eastern U.S.S.R., and *F. hallae* is said to be (MacNeil, 1967) morphologically most similar to a "middle Pliocene" species in Japan. The localities near Nome and at Kivalina are thought to belong to the Anvilian transgression and to be about 2.2 Ma old (D.M. Hopkins, personal communication, 1987). This dating is based on K/Ar ages of basalts that overlie supposed Anvilian deposits in the Pribilof Islands (Figurel) (Hopkins, 1967; D.M. Hopkins, personal communication, 1987). Molluscan faunal ties from these radiometrically dated

Pribilof Islands "Anvilian" deposits to the type Anvilian deposits at Nome are weak, due to there being only small faunas at both places.

At this point in time, there is considerable confusion about the number of marine transgressions present in western Alaska, about the assignment of a given faunule to a particular transgression, about the ages of the transgressive events, and about correlations of western Alaskan transgressive deposits with those in northern Alaska (*i.e.*, the Gubik Formation). Fortunately, western Alaskan Pliocene and Pleistocene marine deposits are being systematically reassessed using amino acid racemization techniques. David M. Hopkins (University of Alaska) and Julie Brigham-Grette (University of Massachusetts at Amherst) are the principal investigators pursuing these studies. Cooperation between these workers and U.S. Geological Survey personnel should be mutually beneficial.

All Seward Peninsula and Gubik Formation molluscan taxa currently are being reidentified by me and entered into an electronic database. Previously, mollusks identified by W.H. Dall in the early 1900s, by F.S. MacNeil in the 1940s to 1960s, by W.O. Addicott in the 1960s to 1970s, and by L. Marincovich, Jr. from the 1970s to date, have been dealt with by other geologists as a whole. Differences in applied taxonomy and in taxonomic philosophies among these workers have understandably not been taken into account by non-paleontologists. However, during the past year reidentification of all western and northern Alaskan mollusk collections in Menlo Park has been undertaken. This work, by Louie Marincovich, Jr. assisted by Charles Powell, is about one-third done. Completing this faunal database and combining it with amino acid racemization numbers and other data will ideally result in the faunal characterization of aminozones. In the past few years a large number of dates have been generated by amino acid racemization, strontium isotopes, thermoluminescence, electron spin resonance, and perhaps other techniques applied to mollusks and microfossils of western and northern Alaska. Most of this work has been done by Hopkins and Brigham-Grette for western Alaska and by David Carter (U.S. Geological Survey, Anchorage) for northern Alaska.

## Logistics

Nome is served by commercial airlines, but a helicopter is needed for collecting. Clothing for cold and rainy weather is mandatory, as is training in helicopter and firearms safety.

## APPENDIX. SUMMARY OF SOUTHERN AND WESTERN ALASKAN MARINE PLIOCENE SITES

### SOUTHERN ALASKA

#### YAKATAGA FORMATION SITES

1. Chaix Hills (2,050 meters thick)

    Location: 60°03'N, 141°05'W

    Age: late Pliocene, 2.1 to 2.5 Ma (in part), based on diatoms.

    Macrofossils: mollusks, miscellaneous invertebrates, seal bones.

    Microfossils: diatoms, benthic foraminifers; other types have not been looked for.

    Samples in Menlo Park: one drawer of mollusks, some of which are suitable for subsampling microfossils.

    Reference: Addicott and others (1978) for mollusks; Rau and others (1983) for benthic foraminifers; J.A. Barron (personal communication, 1989) for diatoms.

2. Kulthieth Mountain (1,750 meters thick)

    Location: 60°0'N, 142°40'W

    Age: Pliocene based on mollusks.

    Macrofossils: mollusks, miscellaneous invertebrates

    Microfossils: benthic foraminifers; other types have not been looked for.

    Samples in Menlo Park: one drawer of mollusks, some of which are suitable for subsampling microfossils.

    Reference: Addicott and others (1978) for mollusks; Rau and others (1983) for benthic forams.

3. La Perouse Glacier 650 meters thick)

Location: 58°27'N, 137°17'W

Age: Pliocene based on mollusks.

Macrofossils: mollusks, miscellaneous invertebrates.

Microfossils: benthic foraminifers; other types have not been looked for.

Samples in Menlo Park: 3 drawers of mollusks, some suitable for subsampling microfossils; microfossil and pollen samples were collected by L. Marincovich, Jr. in 1975, and are in Menlo Park and Reston microfossil collections.

Reference: Addicott and others (1978) for mollusks; Rau and others (1983) for benthic foraminifers.

4. Middleton Island (1,250 meters thick)

Location: 59°26'N, 146°20'W

Age: late Pliocene and Pleistocene based on mollusks.

Macrofossils: mollusks and miscellaneous invertebrates, marine mammal bones.

Microfossils: benthic foraminifers; planktonic foraminifers.

Samples in Menlo Park: five drawers of mollusks, some suitable for subsampling microfossils.

References: Addicott and others (1978) for mollusks; Rau and others (1983), Lagoe and others (1989) and Eyles and Lagoe (1989) for foraminifers.

5. Samovar Hills (1,500 meters thick)

Location: 60°10'N, 140°41'W

Age: Pliocene based on mollusks.

Macrofossils: mollusks and miscellaneous invertebrates.

Microfossils: benthic foraminifers; other types have not been looked for.

Samples in Menlo Park: one drawer of mollusks, some suitable for subsampling microfossils.

References: Addicott and others (1978) for mollusks; Rau and others (1983) for benthic foraminifers.

## TUGIDAK FORMATION SITES

6. Tugidak and Chirikof Islands (1,500[?] meters thick)

Location: 56°30'N, 154°40'W

Age: late Pliocene and Pleistocene based on mollusks.

Macrofossils: mollusks and miscellaneous invertebrates.

Microfossils: have never been looked for.

Samples in Menlo Park: 4 drawers of mollusks with abundant matrix for subsampling microfossils.

References: Moore (1969) for stratigraphy, Allison (1978) for mollusks.

## WESTERN ALASKA (SEWARD PENINSULA)

7. Nome "classic transgressions," California River, Solomon, etc.

Location: 64°30'N, 165°25'W (Nome); other sites are nearby.

Age: Pliocene and Pleistocene based on mollusks; may be about 2.2 Ma for supposed Anvilian beds at Nome, based on K/Ar dates of basalts in Pribilof Islands (Hopkins, 1967).

Macrofossils: mollusks and miscellaneous invertebrates.

Microfossils: benthic foraminifers and ostracodes.

Samples in Menlo Park: three cases of mollusks, but mostly lacking sediment and unsuitable for microfossil subsampling; microfossil samples collected by David Hopkins over many years are in U.S. Geological Survey collections in Menlo Park and Reston.

References: Several chapters in Hopkins (1967); Brigham (1985) for discussion of related amino acid geochronology of northern Alaska.

8. Other sites: Kivalina and Pribilof Islands.

Location: Kivalina - 67°44'N, 164°32'W; Pribilof Islands - 57°N, 70'W

Age: Pliocene and Pleistocene based on mollusks (Kivalina) and K/Ar basalt dates (Pribilof Islands).

Macrofossils: mollusks and miscellaneous invertebrates.

Microfossils: benthic foraminifers and ostracodes.

Samples in Menlo Park: two cases of mollusks from Pribilof Islands, 1 drawer from Kivalina; some suitable for microfossil subsampling.

References: Miscellaneous citations in Hopkins (1967).

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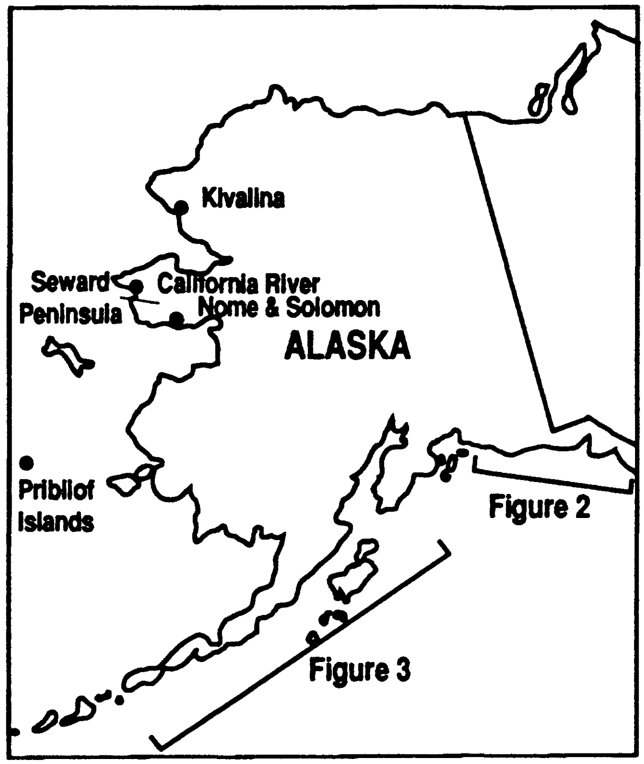


FIGURE 1. Place names used in text

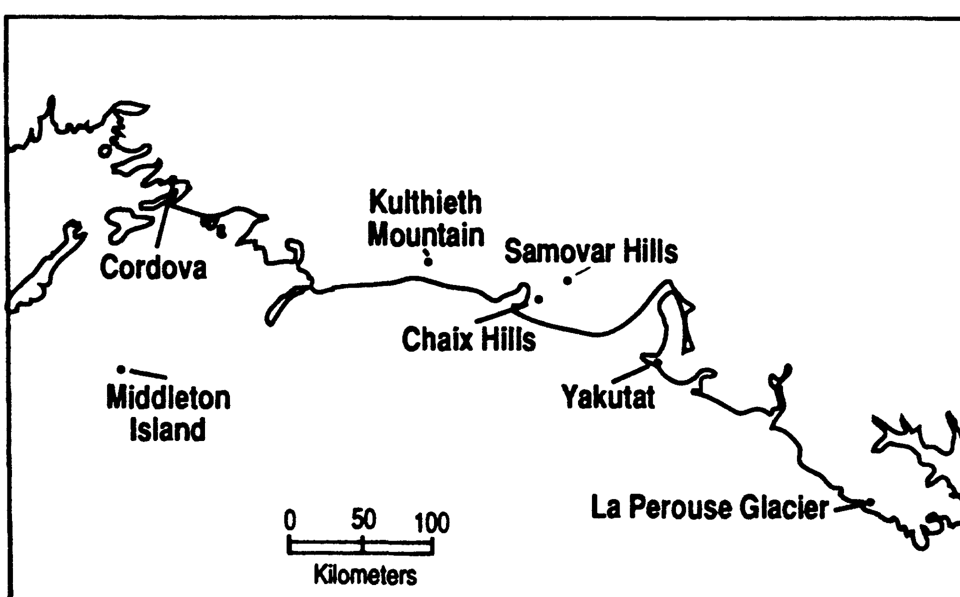


FIGURE 2. Location of Yakataga Formation stratigraphic sections, and associated place names

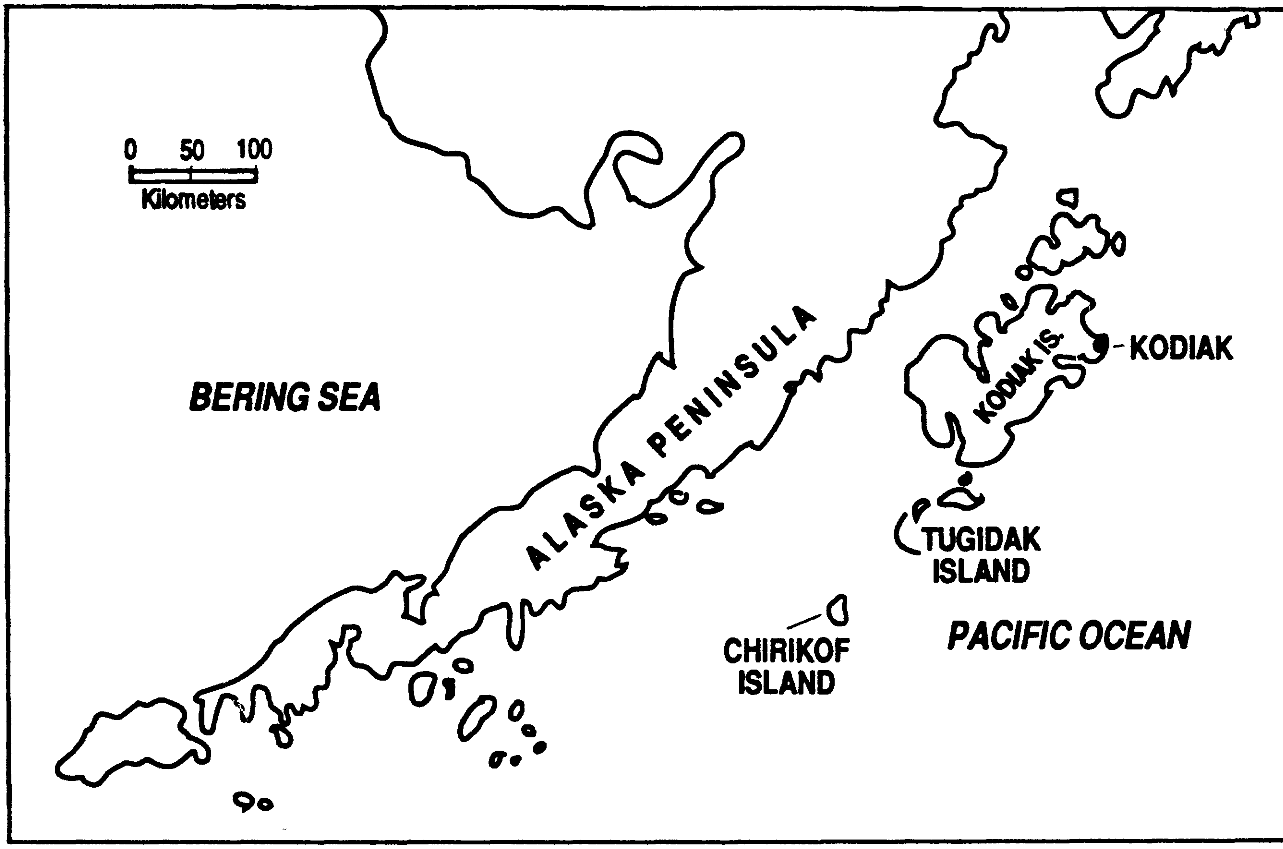


FIGURE 3. Location of Tugidak Formation outcrops and associated place names