# NEOGENE PALEOCLIMATE OF THE GULF OF ALASKA AND REGIONAL CORRELATIONS TO THE BERING SEA REGION

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## ABSTRACT

The Yakataga Formation in the eastern Gulf of Alaska contains an important Neogene glaciomarine record that forms the basis for a paleoclimatic synthesis for the far North Pacific Ocean. This record is based on the physical evidence of tidewater glaciation, foraminiferal biofacies, and regional correlations to deep-sea sections in the Gulf of Alaska and the northwestern Pacific. Regional trends are chronostratigraphically calibrated by planktic foraminiferal and diatom biozonations. Neogene paleoclimatic trends include warm conditions in the early to early middle Miocene; cooling and increased upwelling in the late middle to early late Miocene; localized tidewater glaciation in the latest Miocene to earliest Pliocene; a brief mid-Pliocene warming; and major regional cooling and extensive glaciation beginning in the late Pliocene, extending into the Pleistocene. This paleoclimatic framework is correlated to the Bering Sea on the basis of information in Continental Offshore Stratigraphic Test (COST) wells (Norton 1, Norton 2, St. George 1, St. George 2, North Aleutian Shelf 1, and Navarin 1 wells), as well as outcrop sections in Kamchatka. A consistent, regional paleoclimatic record is apparent in these sections. Major middle Miocene unconformities are important in several of these sections. Regional cold episodes in the latest Miocene to earliest Pliocene and late Pliocene to Pleistocene are consistent with global oxygen isotopic records.

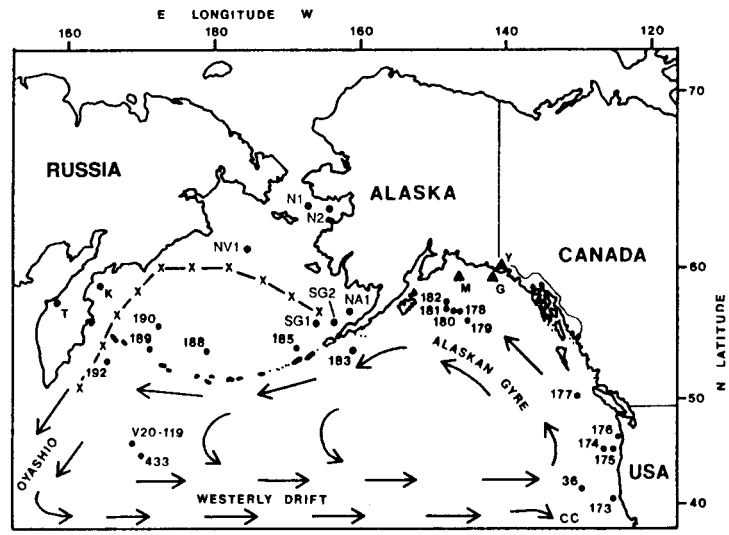


**Fig.1. Index map of the north Pacific Ocean showing the location of DSDP sites (2- and 3-digit numbers) and other key sections or regions for studying the Neogene in this area: Y--Yakataga district; G--Yakataga offshore area; M--Middleton Island; K--Karagin Island; T--Tochilin area. COST wells: NA1--North Aleutian Shelf #1; SG1--St. George #1; SG2--St. George #2; NV1--Navarin #1; N1--Norton Sound #1; N2--Norton Sound #2. V20-119 is a piston core. CC--California Current. Line of "X's" in Bering Sea shows limit of winter sea ice in that area.**

## INTRODUCTION

Recent analysis of Neogene rocks in the eastern Gulf of Alaska and North Pacific Ocean (Lagoe et al., 1993; Zellers and Lagoe, this volume; Eyles et al., 1991; Eyles and Lagoe, 1990) provides a paleoclimatic framework for comparison of other Neogene sections in this area. The drilling of six Continental Offshore Stratigraphic Test (COST) wells during the past decade (Fig.1) penetrated an important record of Neogene depositional and paleoclimate history. This record is particularly significant because the Bering Sea area plays an important role in shaping the climate of the North Pacific Ocean.

This paper makes a preliminary comparison of the Bering Sea sections to the previously developed Neogene paleoclimatic framework as developed from data in the eastern Gulf of Alaska and North Pacific Ocean (Lagoe et al., 1993). Basic data for the comparison comes from Minerals Management Service (MMS) reports on the Bering Sea COST wells (Turner et al., 1983a, 1983b, 1984a, 1984b, 1984c, and 1988) and consultants' paleontological reports to the MMS. The specific objectives of this paper are (1) to briefly summarize the paleoclimatic framework based on the Gulf of Alaska and North Pacific Ocean sections; (2) to examine the paleontological record of the Bering Sea COST wells in order to determine whether this paleoclimatic framework can be recognized in the Bering Sea region; and (3) to briefly comment on the regional signficance of these relationships.

## THE YAKATAGA FORMATION

The Yakataga Formation is composed of up to 7 km of glaciomarine and normal marine rocks in the eastern Gulf of Alaska. This represents one of the most extensive records of Neogene glaciation in the northern hemisphere (Plafker and Addicott, 1976; Eyles et al.,

1991). Recently, Lagoe et al. (1993) provided a synthesis of this record and its paleoclimatic significance. Paleoclimatic inferences were derived from the physical evidence of tidewater glaciation (dropstones, faceted/striated clasts, glaciomarine diamictites) and foraminiferal biofacies analysis. In the eastern Gulf of Alaska, this record is chronostratigraphically calibrated by planktic foraminiferal biostratigraphy and limited paleomagnetic stratigraphy.

A composite of the onshore Yakataga Formation record (Fig.2) illustrates some of the key relationships. Initial tidewater glaciation is reflected by dropstones in the basal Yakataga Formation. These are accompanied by subarctic planktic foraminiferal assemblages dominated by left-coiling *Neogloboquadrina pachyderma*. Within this lowermost Yakataga interval are a few glaciomarine diamictites. This lower glaciomarine-influenced interval is overlain by normal marine sediments with little physical evidence of tidewater glaciation. Planktic foraminiferal assemblages in these rocks contain right-coiling *Neogloboquadrina pachyderma* and more abundant globorotalids (*Globorotalia* cf. *G. suterae; Globorotalia scitula*), reflecting cool-temperate surface water temperatures. This warmer climatic interval is overlain by serveral km of diamictite-dominated rocks that are evidence of extensive tidewater glaciation.

## PALEOCLIMATIC FRAMEWORK

The Yakataga Formation was correlated by Lagoe et al. (1993) to three key sections in the Gulf of Alaska and the northwestern Pacific Ocean: Deep Sea Drilling Project (DSDP) sites 178, 183, and 192 (see Fig.1 for locations). These sections corroborate the Yakataga paleoclimatic relationships and provide important chronostratigraphic and paleoclimatic information from diatom biofacies. The Neogene paleoclimatic framework (Fig.3) that results from combining these DSDP sections with the Yakataga data can be summarized as follows (after Lagoe et al., 1993):

- Early and early middle Miocene is a period of warm climate throughout the Gulf of Alaska and the northwestern Pacific Ocean.
- Significant cooling occurred during the late middle and early late Miocene, leading to increased upwelling and the deposition of extensive diatom-rich sediments (Barron and Baldauf, 1990).

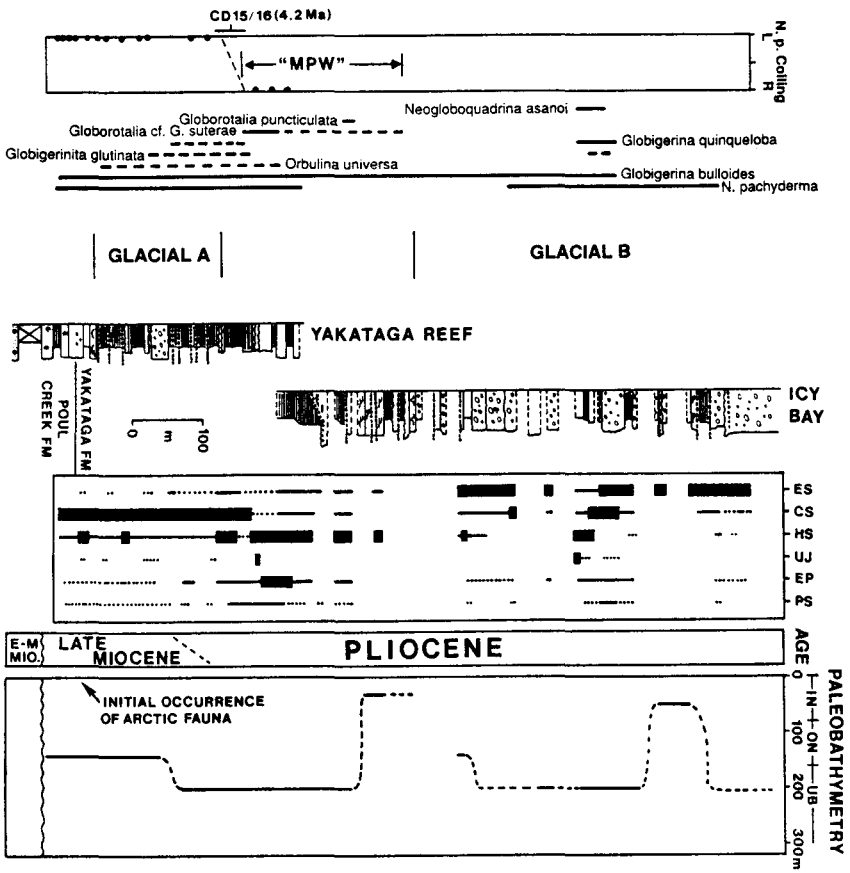


**Fig.2. Summary of stratigraphic relationships in the onshore Yakataga Formation, Yakataga District, eastern Gulf of Alaska (see Fig.1). Coiling of *Neogloboquadrina pachyderma* ("Np coiling") indicates shift from subarctic surface water temperatures in basal Yakataga to cool-temperate during mid-Pliocene (MPW). Distribution of other planktic foraminifera also shown. Two glacial episodes (A and B) are based on presence of dropstones and glaciomarine diamictite. Distribution of benthic foraminifera defines paleobathymetric relationships: ES--*Elphidium* spp.; CS--*Cassidulina* spp.; HS--*Haplophragmoides* spp.; UJ--*Uvigerina juncea*; EP--*Epistominella pacifica*; and PS--planktic spp. Initial appearance of subarctic/arctic benthic foraminifera occurs in basal Yakataga Formation, along with first dropstones. Age of earliest Yakataga glaciation is 5.0-6.7 Ma (from Lagoe et al., 1993).**

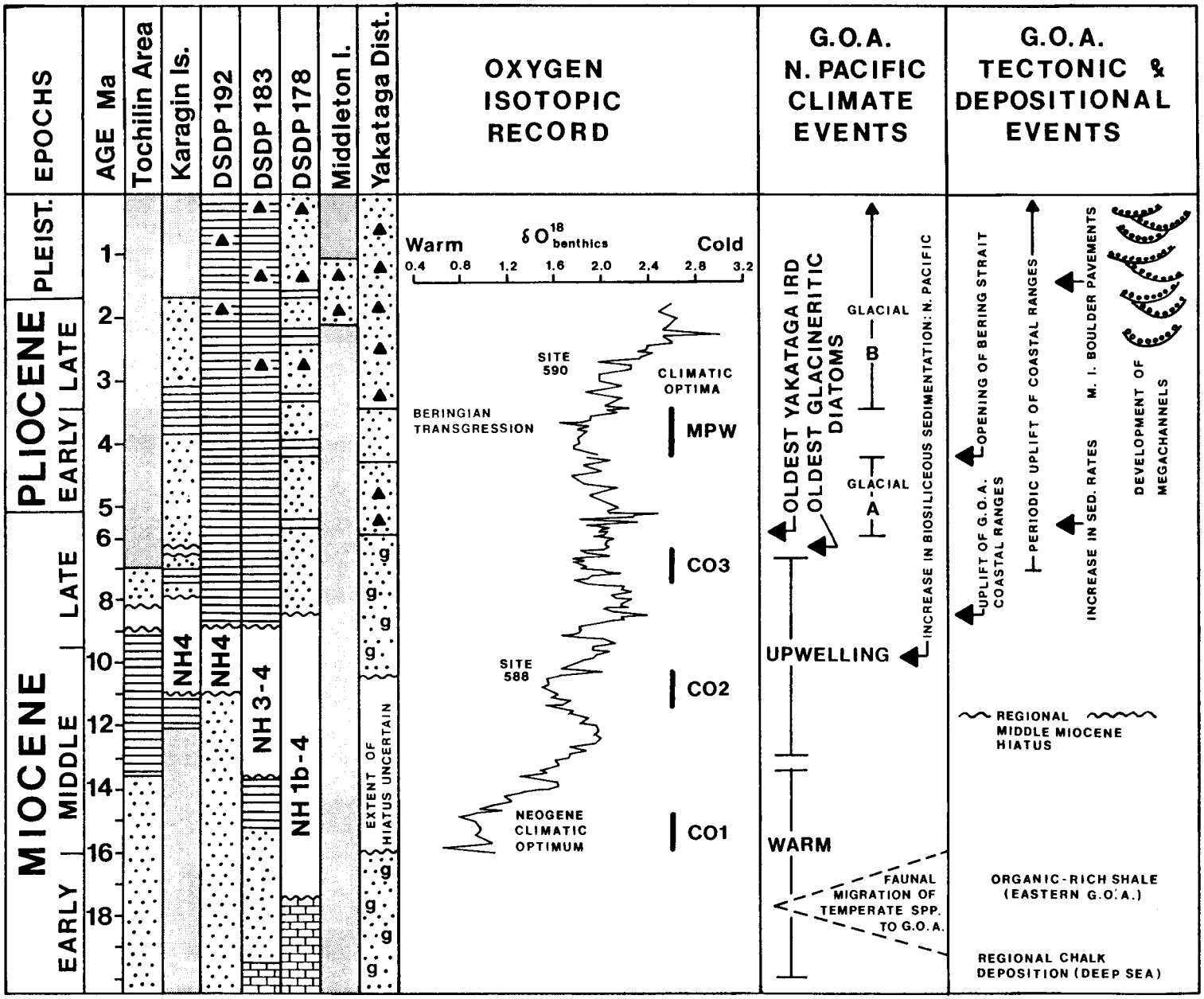


**Fig.3. Neogene paleoclimatic framework for the far North Pacific area (from Lagoe et al., 1993). Lithologic symbols for stratigraphic columns: stipple: fine- and coarse-grained clastics; horizontal lines: diatomaceous sediments; brick pattern: chalk; solid triangles: ice-rafted debris (IRD); G: glauconite; blank: missing section due to unconformities; shaded: intervals not represented by specific column. See Lagoe et al. (1993) for sources of other information. CO1 to CO3 and MPW are climatic optima. M.I. is an abbreviation for Middleton Island.**

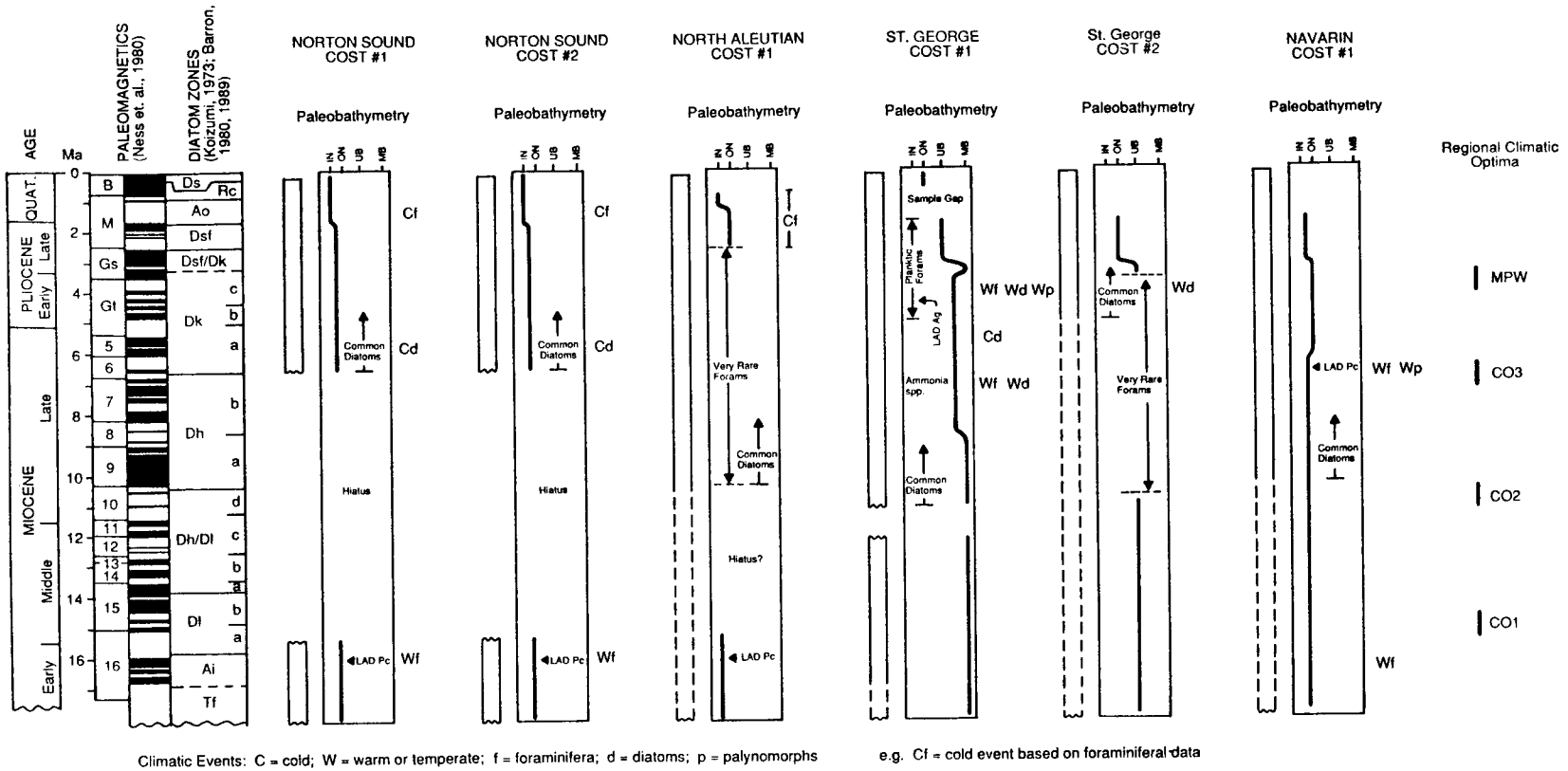


**Fig.4. Summary of stratigraphic relationships in Bering Sea COST wells. Paleobathymetric curves are interpreted from information in MMS reports and consultants reports. IN--inner neritic (0-50 m); ON--outer neritic (50-150 m); UB--upper bathyal (150-500 m); MB--middle bathyal (500-2000 m). Abbreviations for climatic events shown at bottom of figure. Note the good agreement of climatic events in the Bering Sea wells with the Neogene paleoclimatic framework (Fig.3). LAD Ag is the last appearance datum of *Anomalina glabrata*; LAD Pc is the last appearance datum of *Porosorotalia clarki*.**

- The first evidence of tidewater glaciation in the eastern Gulf of Alaska (Yakataga Fm) and DSDP sites 183 and 192 occurs in the latest Miocene and continues into the earliest Pliocene. This is significantly earlier than the late Pliocene age (ca. 2.4 Ma) usually given for initiation of northern hemisphere glaciation.

- The mid-Pliocene reflects a warming to at least cool-temperate conditions, with a reduction in glaciomarine influence.

- Major regional glaciation begins in the late Pliocene as evidenced by widespread ice-rafted debris in DSDP sections and thick glaciomarine diamictites in the Yakataga Formation. These conditions continue into the Pleistocene.

## THE BERING SEA RECORD

The paleobathymetry, chronostratigraphy, and paleoclimate of the six Bering Sea COST wells is summarized in Fig.4. Chronostratigraphy is based largely on diatom biostratigraphy in the MMS reports on these wells (Turner et al., 1983a, 1983b, 1984a, 1984b, 1984c, and 1988). The paleobathymetry is based on this author's reinterpretation of consulting reports to MMS on benthic foraminifera and generally agrees with interpretations in the MMS reports listed above. Climatic events for diatoms and palynomorphs are based on interpretations in the MMS reports. The foraminiferal climatic events are based on the author's interpretation of the consultants' reports to MMS on benthic and planktic foraminifera. It is beyond the scope of this paper to go into much detail on this compilation. The COST wells obviously represent a variety of depositional and paleobathymetric settings. However, the paleoclimatic record seems to agree well with the framework of Lagoe et al. (1993) in every case in which a determination can be made. Cold and warm events agree well with the climatic optima recognized for the Neogene in the far north Pacific Ocean (Fig.4). The major paleoclimatic features of the Bering Sea COST wells are as follows:

- Lower Miocene sections reflect relatively warm conditions. In particular, they contain foraminiferal faunas similar to those in coeval rocks of Sakhalin and northern Japan (Voloshinova, 1960a, 1960b; Voloshinova and Budasheva, 1961; and Voloshinova et al., 1970).

- The middle Miocene is commonly represented by an unconformity (Norton 1, Norton 2, probably North Aleutian Shelf 1, possibly St. George 1 and St. George 2).

- A mid-late Miocene climatic optimum (CO3 of Fig.4), recognized by Barron and Baldauf (1990) is identified in the St. George 1 and Navarin 1 on the basis of benthic foraminifera, those faunas again being similar to those on Sakhalin and corroborating evidence from diatoms and palynomorphs.

- Latest Miocene climate is cold, as reflected in diatom biofacies.

- The mid-Pliocene warm interval recognized in the Yakataga Formation and DSDP site 192 is reflected in the St. George wells on the basis of foraminifera, diatoms, and palynomorphs.

- Benthic foraminifera in the late Pliocene and Pleistocene of the Norton Sound wells and North Aleutian Shelf 1 consist of subarctic faunas, dominated by *Elphidium excavatum clavatum* and other cold water species.

This paleoclimatic record also is evident in outcrop sections in Kamchatka. Sections at Tochilin and Kagarin Island (Fig.1) contain paleoclimatic events that generally agree with the patterns found in the Gulf of Alaska, North Pacific, and Bering Sea (Lagoe et al., 1993).

## CONCLUDING REMARKS

The stratigraphic record of the Bering Sea COST wells correlates with the paleoclimatic record of the Yakataga Formation in the eastern Gulf of Alaska. Regional relationships expressed in these sections and DSDP sites provide a paleoclimatic framework in which initial tidewater glaciation began between 5.0 and 6.7 Ma, with major regional glaciation beginning between 2.5 and 3.5 Ma. Further analysis of the Bering Sea COST wells will undoubtedly provide additional details on their depositional history and paleoclimatic significance, but the broad outlines of that history seem well established at this point.

## ACKNOWLEDGMENTS

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