Tectonic Evolution of the Bering Shelf—Chukchi Sea—Arctic Margin and Adjacent Landmasses

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Preface

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The slightly submerged Bering Shelf–Chukchi Sea–Arctic margin region comprises more than 50% of the total United States continental shelf and forms a broad isthmus of continental crust connecting the North American and Asian continents (Fig. 1). The crustal structure of the region has been shaped by Paleozoic, Mesozoic, and Cenozoic accretion related to Pacific plate margin tectonics and by Cretaceous plate motions in the Arctic that displaced crustal fragments of northwestern North America southward to form what is now the northern part of this shelf system. The many sedimentary basins across this shelf region evolved at disparate times and in various tectonic settings with respect to Pacific and Arctic plate margin tectonics. The region is currently undergoing slow localized deformation due to its position within the broad junction of the Asian and North American plates. A harsh climate and remote setting make this region and its adjacent landmasses difficult to work in; thus the overall geologic and tectonic evolution of the crust beneath this region, the continuity of geologic structures between North America and Russia, the tectonic setting of the region's basins, the plate tectonic origin of the Arctic Ocean, and the region's neotectonic history remain poorly known. This volume brings together a number of data-intensive papers that take our knowledge of this remote region a giant leap forward. This preface describes the general geologic setting of the Bering Shelf–Chukchi Sea–Arctic margin, and provides a short summary of the contributions to this volume and their relevance to the geotectonic history of this broad shelf region and surrounding landmasses.

The geologic structure of the upper crust beneath the Bering and Chukchi shelves, and the Aleutian basin of the Bering Sea, is portrayed in Plate 1. This compilation is based on seismic reflection data, exploratory drilling and stratigraphic test wells from the Bering and Chukchi shelves, and on dredge samples from the continental slope (the Beringian margin) of the Bering Shelf. Plate 1 provides the context for the chapters in this volume that discuss data acquired along the Bering-Chukchi Deep Seismic Transect and the ties of the seismic data to geologic features in adjacent parts of Alaska and northeastern Russia (Klemperer et al., this volume, Chapter 1). The tectonic setting of the Bering-Chukchi Shelf and its sedimentary basins is shown by displaying these data in the context of the tectonostratigraphic terranes and major structural features in the adjacent landmasses (Plate 1 and Klemperer et al., this volume, Chapter 19). The Bering and Chukchi shelves may be economically significant because they constitute by far the largest area of outer continental shelf in the United States, and they represent a significant portion of the Russian outer continental shelf as well. Although several exploratory wells drilled into the Alaska sectors of the Bering and Chukchi shelves have failed to encounter economic quantities of oil or gas, the petroleum potential of extensive parts of these shelves, underlain by significant thicknesses of sedimentary rocks, has not yet been fully evaluated (Grantz et al., 1987; Thurston and Theiss, 1987; Marlow et al., 1987; Craig et al., 1985; Sherwood et al., this volume).

In most areas, the offshore structural data shown for the sedimentary basins (Plate 1) were adapted from published sources cited in the plate explanation, but those from the Chukchi Shelf were interpreted by the authors from sources identified in Grantz et al. (1987, 1990). The tectonostratigraphic terranes of adjacent portions of Alaska and northeastern Russia were generalized from Silberling et al. (1994), Nokleberg et al. (1998), and other sources cited in Plate 1, including the geographic information system (GIS) database that is part of this volume (Klemperer et al., Chapter 19). Data for the stratigraphy of the offshore basins and exploratory and stratigraphic test wells of the Bering and Chukchi shelves, and of the dredge samples collected from the Beringian margin, are also summarized from sources cited in Plate 1.

The display of geologic features across an area as large and geologically diverse as the Bering and Chukchi shelves, in a manner that accurately conveys its rock units and upper-crustal structure, requires selectivity in the features displayed. Only faults and folds of significance are shown, and structural contours to basement are generalized. In particular, the disparity in age between the various sedimentary basins of the Bering and Chukchi shelves prevented a choice of a single chronostratigraphic or lithostratigraphic horizon as the structural contour

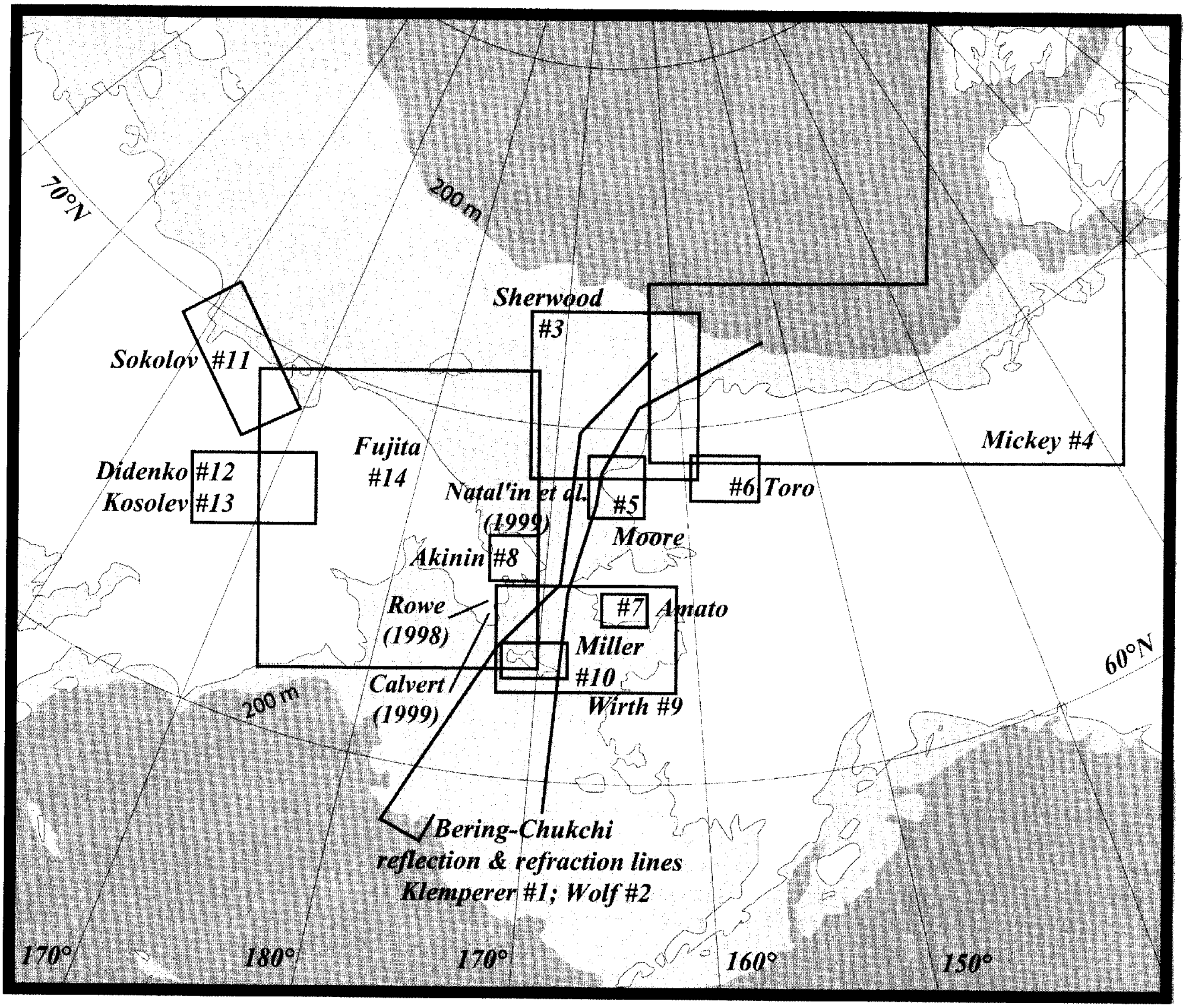

Figure 1. Index diagram for Alaska; northeastern Russia; and Bering, Chukchi, and Beaufort shelves showing approximate location of studies discussed in various chapters of this volume. Names are first authors and numbers are individual chapters. Regional studies by Blodgett et al. (Chapter 15), Dumoulin et al. (Chapter 16), Miller et al. (Chapter 17), Lawver et al. (Chapter 18), and Klemperer et al. (Chapter 19) are not shown because they cover entire region of map. The location of three additional field-based studies carried out as part of the larger seismic transect project include Rowe (1998), Calvert (1999), and Natal'in et al. (1999).

datum for the entire map area. The location and a synopsis of the stratigraphy of these basins are shown in Plate 1.

Structural contours in the Canada and Aleutian basins are drawn on the top of oceanic layer 2, which is overlain by Lower Cretaceous marine sedimentary strata in the Canada basin and by strata of unspecified Mesozoic age in the Aleutian basin. In the Hope and Norton basins of the Inner Chukchi and Bering shelves, and in the Navarin, Saint George, and Bristol Bay basins of the Outer Bering Shelf, the structural contours are also drawn on acoustic basement, but acoustic basement there is continental crust composed of several tectonostratigraphic terranes, which are overlain by marine and nonmarine sedimentary strata that are Paleocene to middle Eocene age at their base (Plate 1). In the Arctic Alaska basin of the North Slope and eastern Chukchi Shelf, acoustic basement is not a useful structural contour horizon because it is variable in its structural and stratigraphic position, and is commonly structurally complex. For this basin we chose to highlight the depth to the lowest stratigraphic horizon that displays only moderate structural complexity and that can be followed across the entire basin using public-domain seismic reflection data (cited in Grantz et al., 1987, 1990).

On the Chukchi Shelf, this horizon is the base of the Lisburne Group (Upper Mississippian) in the lower part of the Lower Mississippian to Lower Cretaceous Ellesmerian sequence of the Arctic Alaska basin (Grantz et al., 1987, 1990; Sherwood et al., Chapter 3).

The first chapter of this volume presents the main results of the Bering-Chukchi Deep Seismic Transect, the result of a multidisciplinary, multi-institutional, international collaborative effort with Russian scientists carried out with the goal of better understanding the evolution of the continental crust beneath the Bering-Chukchi-Arctic region. The project, funded by the Continental Dynamics Program of the National Science Foundation, involved the collection of two seismic reflection profiles (Fig. 1). The transect imaged the full thickness of the crust across the entire width of the continental shelf that connects North America and Asia (Klemperer et al., Chapter 1) (Plates 1 and 2). These deep seismic data provide a unique new perspective on the structure, thickness, age, and history of the entire crust beneath this broad continental shelf. The northern part of the line images intact, almost flat-lying sequences possibly as old as Precambrian and their underlying Precambrian continental crust beneath the northern Chukchi Sea. This continental crust and its sedimentary cover are part of the Arctic Alaska microplate, a fragment of rifted crust that was displaced southward from northwestern Canada during formation of the Canada Basin (Plates 1 and 2). The central part of the seismic line, from the vicinity of the Kotzebue Arch north of the Bering Strait to the Matthew Arch (Plate 1), images continental crust that exhibits prominent subhorizontal reflectivity throughout the lower crust and a sharp, well-defined Moho. This crust is believed to have been thickened during the Jurassic and Early Cretaceous Brookian orogeny and subsequently extended during Cretaceous to early Tertiary magmatic activity. The southern end of the transect images only sporadically reflective crust that thins beneath the large Cenozoic basins that developed beneath the Outer Bering Shelf. There is little or no evidence for the offshore continuation of the prominent right-lateral strike-slip faults of Alaska. The displacement on two of these faults, the Kaltag and Kobuk, appears to have dissipated in transtensional offshore fault systems that created the Norton and Hope basins (e.g., Worral, 1991).

Collection of the seismic reflection data along the transect represented an opportunity for additional geophysical experiments, including simultaneous collection of refraction data from shore-based stations to determine the crustal structure and velocity distribution beneath the Bering Shelf and Chukchi Sea (Wolf et al., Chapter 2). An important conclusion of this work, in conjunction with reflection data along the transect and gravity modeling, is that the crustal root that underlies the Brooks Range in eastern Alaska is absent along the projection of the range into the southern Chukchi Sea.

Sherwood et al. (Chapter 3) comprehensively synthesize data for the thick sedimentary cover that underlies the northern part of the transect in the Hanna Trough beneath the northern Chukchi Sea (Fig. 1; Plates 1 and 3–5). Mickey et al. (Chapter 4) summarize biostratigraphic data that support a rotational opening model for the Canada Basin, an event that created the Arctic continental margin of Alaska. This margin was imaged at the very northern end of the seismic transect (Plates 1 and 2).

The seismic reflection and refraction studies were augmented by geologic field work involving 10 separate field parties to points in northeastern Russia and westernmost Alaska (Fig. 1); these results are partially described in this volume. Moore et al. (Chapter 5) investigated the structural and thermal history of the Lisburne Hills thrust belt, which continues into the Chukchi Sea as the Herald Arch. Although post-Cenomanian thrust displacement is manifest in the Herald Arch and its foreland folds to the northeast based on offshore seismic reflection data, apatite fission-track data from onland exposures indicate that late Early Cretaceous uplift of thrust-faulted rocks on the Lisburne Peninsula is coeval with Brookian structures in the main Brooks Range to the east. This correlation is of interest because the Brooks Range is almost orthogonal in trend to the Lisburne Hills. Toro et al. (Chapter 6) detail the tectonic history of the west-central Brooks Range based on three seasons of geologic mapping and sampling. Here, the core of the Brooks Range is an elongate dome with significant structural relief that plunges westward, toward the Chukchi Sea. Early shortening (pre-112 Ma) is overprinted by tectonic exhumation ca. 90 Ma, related to the gravitational collapse of previously thickened continental crust. Late-stage north- to northwest-trending normal faults cut the Brooks Range structures and are similar in age and orientation to the Paleogene transtensional faults that created the Hope Basin, which underlies the southern Chukchi Sea. Chapters 7 and 8 describe structural and metamorphic aspects of the evolution of gneiss domes that occur on both sides of the Bering Strait. The Kigluaik dome of the Seward Peninsula, described by Amato et al. in Chapter 7, is a well-documented case of coeval but orthogonal structures formed by high-temperature flow in the crust. Data from the Kigluaik Mountains clearly indicate that the crust beneath this region was at elevated temperatures (granulite conditions in the mid-crust) and capable of flow during the Cretaceous. Geobarometry and geothermometry together with thermochronology for the Koolen dome in northeastern Russia document temperatures and pressures as high as >700°C and 4–5 kbar; uplift to shallow levels of the crust is bracketed between 104 and 94–88 Ma. These metamorphic culminations were created by the rise of mid-crustal rocks during Cretaceous magmatism and regional, mostly north-south oriented extension. Wirth et al. (Chapter 9) describe new data on Neogene basalt fields that straddle the seismic transect across a broad region of the Bering Shelf. These lavas carried mantle and crustal xenoliths from depth to the surface, thus providing hand samples of the crust and mantle imaged by the seismic profile. The abundance of gabbroic xenoliths attests that mafic intrusions are common in the middle to lower crust in the region of the transect. Miller et al. (Chapter 10) present preliminary U-Pb SHRIMP ages on individual zircons from gneissic plagioclase-pyroxene xenoliths collected by Wirth et al. (Chapter 9). These data suggest that the crust beneath the transect near Saint Lawrence Island was metamorphosed and mobilized under granulite facies conditions in the Late Cretaceous–Paleocene and that Cretaceous igneous rocks (ca. 90 Ma) are involved in this deformation and metamorphism.

Several chapters in the volume consist of regional biostratigraphic and tectonic studies that address broader aspects of the evolution of northeastern Russia and Alaska. Sokolov et al. (Chapter 11) synthesize geologic relationships along the South Anyui suture in northeastern Arctic Russia. This major suture zone is widely believed to represent part of the collision zone between the Arctic Alaska–Chukotka plate and Eurasia. The timing of events within the suture zone thus bears directly on the age of opening of the Canada Basin. Stratigraphic relations in the suture zone indicate that convergence that may be related to opening of the Canada Basin was completed by Early to middle Cretaceous time and may have been followed by post-Albian strike-slip faulting. This timing is compatible with evidence from the Canada Basin that seafloor spreading there ended by the beginning of Aptian time (e.g., Lawver et al., Chapter 18). Didenko et al. (Chapter 12) present paleomagnetic data bearing on the Jurassic-Cretaceous history of the Omolon massif, a large continental fragment involved in the greater Kolyma-Verkhoyansk deformational belt. The data are interpreted to indicate that the Omolon massif underwent translation from 60° ± 10° in the Western Hemisphere via the polar region to 76° ± 8° in the Eastern Hemisphere between Middle Jurassic and Early Cretaceous time, with a 30°–40° counterclockwise rotation relative to Siberia. Since the Early Cretaceous the Omolon massif has been a permanent part of Eurasia. Kolesov and Stone (Chapter 13) describe paleomagnetic data for Devonian strata of the Omolon massif that alternatively indicate that it could have been close to its present position during the Devonian, but rotated 90° with respect to the Siberian craton. Fujita et al. (Chapter 14) provide a summary of seismicity for the Chukotka Peninsula of northeastern Russia and surrounding regions. This seismicity defines modern plate boundaries and zones of deformation through this region and indicates that the Bering Shelf represents a fairly rigid subblock that is rotating clockwise with respect to North America about a pole in western Chukotka.

Blodgett et al. and Dumoulin et al. (Chapters 15 and 16) analyze megafossil and conodont data from Alaska, Russia, and North America. Their analyses show that during the early and middle Paleozoic, Alaska was more closely related biogeographically (and therefore probably paleogeographically) to Eurasia than to North America.

Miller et al. (Chapter 17) summarize the age of northern circum-Pacific magmatism and its tectonic setting through the Mesozoic, contrasting the tectonic history of the continental margins of northeastern Russia, Alaska, and the Cordillera. Although the boundaries and time spans of tectonic and magmatic events in the Cordillera and northeastern Russia appear to be coeval, the nature of magmatism and its tectonic setting often differ. For example, during general tectonic and magmatic quiescence in the U.S. and Canadian Cordillera between 150 Ma and 120 Ma, orogenesis, crustal shortening, and magmatism substantially modified the shelf margin of Siberia. Lawver et al. (Chapter 18) provide a summary of the plate kinematic evolution of all the individual terranes that form the present Arctic region, from the late Paleozoic to the present day. Their global reconstructions provide the framework for all the other regional and subregional studies. The final paper (Chapter 19) by Klemperer et al. is a description of the contents of the CD-ROM accompanying this volume. The CD-ROM contains a GIS-based compilation of geological and geophysical data for the Bering Shelf–Chukchi Sea and adjacent landmasses. Also included on the CD-ROM are an animation of the terrane motions on a globe at 3 m.y. intervals, and supplementary data and digital versions of figures from several other chapters.

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TECTONOSTRATIGRAPHIC TERRANES AND POST-BASEMENT ASSEMBLY ROCKS AND SEQUENCES

(Data from Silberling et al., 1994 and Nokleberg et al., 2001, supplemented by other sources as cited. St. Lawrence Island after Till and Dumoulin, 1994; Brooks Range in part after Moore, et al., 1994)

OCEANIC SEDIMENTARY BASINS

Aleutian and Bowers Basins-Basement of the Aleutian Basin is oceanic crust of either Late Jurassic to Early Cretaceous or Late Cretaceous to earliest Tertiary age. It is overlain by a thick, virtually undeformed sequence of fine-grained terrigenous and pelagic, mainly diatomaceous, sedimentary rocks. Beneath the central basin the sedimentary sequence is 2-3 km thick, but it thickens to as much as 10-12 km at the base of the Bering shelf continental slope and at the base of Bowers Ridge. The section is topped by about 1.0 km of syn-glacial turbidite and fan deposits of mid-Pliocene and younger age. Bowers Basin, south and west of Bowers Ridge, is underlain by oceanic crust of unknown, but presumably pre-middle Eocene age. The overlying sedimentary section is 2-4 km thick and includes diatomaceous units, but is presumed to include abundant terrigenous material derived from nearby Aleutian and Bowers Ridges as well as distal Alaskan and Siberian drainages (Cooper et al., 1987).

Canada Basin-Lower Lower Cretaceous oceanic crust overlain by proximal to distal turbidites and pelagic deposits, sourced mainly in the Mackenzie Delta. Sedimentary successions range from >14 km in thickness beneath the delta to 6 km beneath the abyssal plain in the western part of the basin (Grantz et al., 1990a, 1999b and unpublished).

Far North Pacific Basin-Principally mid-Tertiary to Upper Cretaceous igneous oceanic crust younging from south to north in the map area and overlain by an oceanic sedimentary sequence of turbidite, pelagic and hemipelagic beds. In the Gulf of Alaska, turbidite fans of Eocene to late Cenozoic age as thick as 2500 m are overlain by pelagic diatomaceous units 250-300 m thick. In the northwestern corner of the Pacific Basin igneous oceanic crust is overlain by Late Cretaceous to Holocene pelagic and hemipelagic beds as thick as 1800 m. In the Aleutian Trench these beds are buried beneath a 1 to 3 km-thick wedge of late Quaternary, trench-axis turbidite deposits that thin seaward (Atwater, 1989; Atwater and Severinghaus, 1989; Lonsdale, 1988; Scholl et al., 1977; Stevenson and Embley, 1987).

CONTINENTAL SHELF SEDIMENTARY BASINS

Anadyr Basin-Non-marine to shelfal deposits of late Eocene and younger age deposited in an intra-shelf basin, but similar to the nearby shelf-edge Navarin Basin. Anadyr basin unconformably overlies mildly deformed strata of the Carapace sequence of Worrall (1991) and Upper Cretaceous shallow marine to coal-bearing continental deposits and earliest Tertiary volcaniclastic rocks and lava (Marlow et al., 1983).

Arctic Alaska Basin (including Hanna Trough)-Rift-related Lower Mississippian paralic deposits, Mississippian to lower Lower Cretaceous carbonate and clastic marine stable shelf and slope deposits of northerly provenance (Ellesmerian sequence) and paralic clastic strata of upper Lower Cretaceous and Cenozoic age (Brookian sequence) deposited in a foredeep on the north side of the Brook Range orogen. The Brookian deposits were derived from sourcelands to the south and southwest (Bird, 1988; Grantz et al., 1987; Kirschner and Rycerski, 1988; Sherwood et al., this volume).

Bristol Bay Basin-The North Aleutian Shelf COST No.1 well on the south side of the basin penetrated 5.2 km of late Eocene and younger fluvial, nearshore and deltaic deposits equivalent to the Plio-Pleistocene Milky River, Upper Miocene Bear Lake, and Oligocene-Eocene Stepovak formations of the Alaska Peninsula and older Eocene and Paleocene paralic beds and the coal-bearing Tolstoi formation (Turner, 1988). Seismic reflection data indicate that as much as 4 km of slightly deformed sedimentary strata underlie the base of the well (Marlow et al., 1987). Extrapolation from outcrops on the Alaska Peninsula suggest that the underlying strata are Upper Cretaceous, lowermost Cretaceous and Upper Jurassic marine and paralic sedimentay rocks of the Peninsular terrane.

Hope Basin-Eocene (possibly Paleocene) to Oligocene tuff with middle Eocene olivine basalt overlain by Oligocene (?) to Holocene nonmarine clastic sedimentary rocks with coal beds on the southeast which are interpreted to intertongue with marine and nonmarine strata to the northwest. The section, deposited in west-northwest-trending grabens and half-grabens, is as much as 5.8 km thick (Tolson, 1987).

Navarin Basin-Outer Bering shelf basin containing 13-14 km of generally mildly deformed, principally middle Eocene and younger sedimentary beds (Marlow et al., 1987; Worrall, 1991). In the Navarin COST well No.1 the section is only 3.7 km thick and consists of middle Eocene to Pliocene claystone, siltstone, sandstone, and diatomaceous beds of upper bathyal to inner shelf depositional settings (Turner et al., 1984c). The Navarin Basin unconformably overlies the mildly deformed Upper Cretaceous and Paleogene Carapace sequence of Worrall (1991).

Norton Basin-Eocene or older fluvial or deltaic sandstone, shale, coal, and conglomerate overlain by Oligocene to Holocene neritic to upper bathyal, commonly diatomaceous mudstone, shale and sandstone with intervals of paralic beds and marine basalt. Maximum thickness about 4 km (Worrall, 1991; Turner et al., 1983a and b).

Saint George Basin-Outer Bering shelf basin containing 9 to10 km of middle Eocene and younger, little-deformed shallow marine to non-marine conglomerate, sandstone, and mudstone (Marlow et al., 1987; Worrall, 1991). In the St. George COST No. 1 well the section is only 4.2 km thick and rests unconformably on volcanic rock that is most likely of Mesozoic age (Turner et al., 1984a). In the St. George COST No.2 well the section is only about 3.7 km thick and rests on Upper Jurassic shelfal to coal-bearing siltstone, sandstone and conglomerate (Turner et al., 1984b). Similar Jurassic rocks have been dredged in nearby submarine canyons on the continental slope to the west (see tabulation of samples below). Stratiform deposits of the Upper Cretaceous and Paleogene Carapace sequence of Worrall (1991) were not encountered in the St. George COST wells.

TECTONOSTRATIGRAPHIC TERRANES-ALASKA AND BERING SHELF

AA **ARCTIC ALASKA SUPERTERRANE**-Consists of gently dipping to moderately deformed Proterozoic to Lower Devonian carbonates and Ordovician and Silurian marine argillite and graywacke (Franklinian sequence), Middle (Lower?) Devonian to Lower Mississippian nonmarine beds and Upper Mississippian to lower Lower Cretaceous carbonate and clastic marine stable shelf and slope deposits (Ellesmerian sequence) of northerly provenance. The Ellesmerian strata are overlain by nonmarine and marine clastic strata of upper Lower Cretaceous and Cenozoic age (Brookian sequence) derived from sourcelands to the south and southwest.

AG **ANGAYUCHAM TERRANE**-Accretionary complex of predominantly oceanic rocks. Gabbro, diabase, pillow and massive basalt, tuff, chert, graywacke, argillite, and minor conglomerate and limestone. Cherts range from Upper Devonian to Lower Jurassic. Major periods of basaltic volcanism appear to be Late Devonian, mid-Carboniferous, and Late Triassic, but many of the volcanic sequences are not well dated. Thrust sheets of ultramafic rocks (Misheguk Mountain terrane), which occur throughout the AG, represent the roots of an island arc. Includes Tozitna and Innoko terranes southeast of Norton Sound.

CG **CHUGACH TERRANE**-Weakly metamorphosed accretionary wedge of marine graywacke and slatey argillite with rare Upper Cretaceous (Campanian and Maastrichtian) mollusks (Valdez Group) overlain by a subduction melange of Triassic to mid-Cretaceous oceanic sedimentary and volcanic rocks and exotic blocks of ultramafic rocks, limestone, and diorite (McHugh Complex). The melange is overlain by subduction-zone shale, chert, and basaltic tuff in blueschist and greenschist facies. The CG is intruded by mid-Cretaceous trondhjemite and early to middle Tertiary plutonic rocks.

CO **COLDFOOT TERRANE**-Polymetamorphosed Precambrian to Devonian quartz-mica schist, quartzite, calc-schist, marble, metavolcanic rocks (some with glaucophane), locally intruded by upper Precambrian and Upper Devonian orthogneiss and Cretaceous plutons. Occurs in nappes of Jurassic and Cretaceous age that overlie the less metamorphosed nappes of the AA superterrane to the north. Includes Seward terrane of Silberling et al. (1994) and Nokleberg et al. (1998).

KI **KILBUCK-IDONO**-Cratonic fragment of uncertain affinity. Gneiss and schist, including metmorphosed diorite, tonalite and trondhjemite, granite orthogneiss and amphibolite. Minor metasedimentary rocks include garnet amphibolite, quartz-mica schist, marble and banded iron formation. Radiometric ages indicate metamorphism during Precambrian time modified by retrograde greenschist metamorphism during late Mesozoic (?) time.

KY **KOYUKUK TERRANE**-Middle and Upper Jurassic tonalites and trondhjemites of uncertain affinity unconformably overlain by Lower Cretaceous andesitic flows and pyroclastic rocks, tuffaceous graywacke, mudstone and conglomerate, and local intercalations of shelly limestone. Radiometric and fossil ages range from Upper Jurassic to Lower Cretaceous (Aptian).

NY **NYAC TERRANE**-Island arc of andesite, trachyte and basalt flows and breccias, with interbedded shallow-marine volcaniclastic rocks with Middle and Upper Jurassic fossils. Intruded by Lower Cretaceous gabbroic and granitic rocks.

PE **PENINSULAR TERRANE**-Talkeetna volcanic arc of Lower Jurassic andesitic flows, breccias, and volcaniclastic siltstone and sandstone resting on Permian limestone and Upper Triassic (Norian) limestone, argillite, basalt and tuff and overlain by Middle Jurassic to Neocomian fossiliferous shelf and slope lutite, sandstone, conglomerate and calcarenite. The Talkeetna arc is intruded by Jurassic batholithic plutonic rocks of intermediate composition.

RB **RUBY TERRANE**-Fragment of North American craton margin. Proterozoic (?) and Paleozoic phyllite, quartz-mica schist, marble, quartzite, calcschist, amphibolite, greenschist (metabasalt), and locally blueschist. Locally contains metachert and gneissic to non-foliated granitic rocks with both Devonian and Early Cretaceous U-Pb ages. Age of protoliths generally unknown, but Silurian-Devonian fossils occur locally.

TG **TOGIAK TERRANE**-Upper Triassic mid-ocean ridge basalt, diabase, gabbro, and ultramafic rocks overlain by Jurassic and Lower Cretaceous island-arc rocks consisting of marine volcaniclastic rocks, chert, and minor shelly argillaceous limestone and marine and nonmarine andesite and basalt flows, flow breccia and tuff.

TK **TIKCHIK TERRANE**-Volcanic-arc andesite, dacite, rhyolite, pillow basalt and volcaniclastic rocks and radiolarian chert, graywacke, limestone and argillite with marine fossils of Devonian to Triassic age.

YO **YORK TERRANE**-Fragment of North American craton margin. Weakly metamorphosed shallow marine argillaceous and fossiliferous limestone and lutite of Ordovician to Mississippian age. Intruded by small Upper Cretaceous granitic stocks.

TECTONOSTRATIGRAPHIC TERRANES - NORTHEAST RUSSIA

AV **ALKATVAAM TERRANE**-Intensely deformed accretionary wedge and serpentinite melange with fragments of late Paleozoic and Triassic ophiolite and metamorphic rocks overlain by tuffaceous marine turbidites with local intercalations of Upper Triassic, Upper Jurassic, Cretaceous, and Paleocene island-arc volcanic rocks.

CH **CHUKOTKA TERRANE**-Upper Proterozoic metaclastics and metavolcanics overlain by Paleozoic fossiliferous marine shelf sandstones, arkoses, lutites, limestone (locally biohermal) and gypsum, and by Triassic and Lower Jurassic lutite, mafic tuff, graywacke, sandstone, conglomerate and limestone, in places with numerous diabase dikes and sills. May include, or be equivalent to, the Coldfoot terrane of Silberling et al. (1994) and Nokleberg et al. (1998).

EK **EKONAY TERRANE**-Predominantly oceanic accretionary wedge and subduction zone complex consisting of serpentinized ultramafic rocks and layered gabbro; leucogabbro, diabase and plagiogranite; and an assemblage of Upper Paleozoic to Triassic melange of spilitic basalt (rarely andesite and plagiorhyolite), tuff, chert and minor limestone and volcaniclastic rocks. The assemblage contains fragments of Carboniferous to Triassic fossil-bearing rocks.

MAI **MAINITSKIY TERRANE**-Island-arc and ophiolitic sequences in an accretionary prism and subduction zone. Consists of a lower sequence of serpentinite melange with fragments of late Paleozoic and Mesozoic ophiolite overlain by graywacke, siltstone, tuff, chert with Lower Cretaceous fossils and Permian and Triassic ostoliths, and an upper sequence of Upper Jurassic and Lower Cretaceous island arc volcanic and sedimentary rocks with tholeiitic and andesitic basalt, rhyolite, tuff, radiolarian chert, siltstone, and sandstone. Nappes with disrupted ophiolites, island-arc successions, and ultramafic rocks also occur.

CO **COLDFOOT TERRANE**-Polymetamorphosed Precambrian to Devonian quartz-mica schist, quartzite, calc-schist, marble, metavolcanic rocks (some with glaucophane), locally intruded by upper Precambrian and Upper Devonian orthogneiss and Cretaceous plutons. Occurs in nappes of Jurassic and Cretaceous age that overlie the less metamorphosed nappes of the AA superterrane to the north. Includes Seward terrane of Silberling et al. (1994) and Nokleberg et al. (1998).

VE **VEL'MAY TERRANE**-Subduction zone complex with predominantly oceanic rocks. Mesozoic metabasalt, tuff, chert, siliceous slate and graywacke with tectonic blocks of serpentinized ultramafic rocks, gabbro and plagiogranite.

WKU **UKELAYAT SUBTERRANE of WEST KAMCHATKA TERRANE**-Accretionary prism of fossiliferous Upper Cretaceous (Santonian) to lower Paleocene turbidites, locally with olistostromes, Campanian chert and alkali basalt.

YN **YANRANAY TERRANE**-Accretionary prism comprised of uppermost Jurassic (Tithonian) to Upper Cretaceous (Campanian) oceanic basalt (MORB), hemipelagic deposits, chert and minor limestone and Cretaceous lutite and sandstone with volcaniclastic graywacke, oceanic basalt, chert, bioclastic limestone layers and olistostromes. Exposed in fensters in the Ekonay terrane.

ZL **ZOLOTOGORSKIY TERRANE**-Metamorphosed continental-margin fragment of uncertain affinity. Devonian (?) metaclastics, marble, and metavolcanic rocks overlain by Carboniferous and Permian fossiliferous shelfal sandstone, siltstone and limestone and Upper Jurassic and Lower Cretaceous conglomerate. Intruded by Lower Cretaceous granite.

ONSHORE POST TERRANE-ASSEMBLY SEDIMENTARY "OVERLAP" SEQUENCES

Qs **Qs** - Quaternary sedimentary cover, predominantly nonmarine.

Czs Czs-cb **Czs** - Cenozoic marine and nonmarine sedimentary rocks.
Czs-cb - Nonmarine and marine sedimentary rocks of Colville Basin

CS **CARAPACE SEQUENCE (subsurface unit)**-Broadly deformed stack of Upper Cretaceous, Paleocene, and at least lower Eocene stratiform deposits 3 to 4 km or more thick recorded by seismic reflection data beneath the Bering shelf, and in particular its subshelf basins (the Carapace sequence of Worrall, 1991). Overlain unconformably by middle Eocene (~42 Ma) or younger clastic deposits that constitute the bulk of the fill in the Anadyr, Navarin, St. George, Norton, and Bristol Basins. Underlain unconformably by strongly to slightly deformed early Santonian and earlier Cretaceous, Jurassic, or older sedimentary and igneous rocks of the Ekonay, Mainitskiy, and Alkatvaam terranes of eastern Siberia and the Chugach terrane and sedimentary and perhaps plutonic rocks of the Peninsular terrane of the Alaska Peninsula. The unconformity at the base of the Carapace sequence may be the regional mid-Cretaceous unconformity of the Alaska Peninsula.

Ks Ks-cb Ks-kb Ks-kg Ks-p Ks-yk **Ks** - Cretaceous marine and nonmarine sedimentary rocks.
- **Ks-cb** - Mid- and Upper Cretaceous nonmarine and marine sedimentary rocks of the Colville Basin.
- **Ks-kb** - Cretaceous deposits of the Kuibiveem sedimentary assemblage. Albian to Coniacian marine sandstone, turbidite, siltstone and conglomerate and Santonian and Campanian sandstone, siltstone argillite, conglomerate and rare chert and andesite tuff.
- **Ks-kg** - Cretaceous deposits of Kuskokwim Group. Albian to Coniacian marine turbidites and subordinate shallow-marine and fluvial conglomerate, sandstone and siltstone.
- **Ks-p** - Post-Neocomian Cretaceous deposits overlying the Peninsular terrane. Aptian(?) to Maastrichtian marine and paralic shale, siltstone, sandstone, conglomerate, and locally coal.
- **Ks-yk** - Cretaceous deposits of the Yukon-Koyukuk Basin. Barremian (?) to Albian flyschoid marine graywacke, lutite and conglomerate and mid-Albian to Santonian molassoid fluvial and deltaic sandstone, shale, conglomerate and coal.

POST-TERRANE ASSEMBLY VOLCANIC SEQUENCES AND PLUTONIC ROCKS

QTvf TKvf Kpf **QUATERNARY TO CRETACEOUS FELSIC AND SILICIC IGNEOUS ROCKS**
- **QTvf** - Quaternary and upper Tertiary volcanic rocks
- **TKvf** - Lower Tertiary and Cretaceous volcanic rocks
- **Kpf** - Cretaceous plutonic rocks

TKpi TKvi TKvi-oc **TERTIARY AND CRETACEOUS INTERMEDIATE IGNEOUS ROCKS**
- **TKpi** - Lower Tertiary and Cretaceous plutonic rocks
- **TKvi** - Mid-Tertiary to Cretaceous volcanic rocks
  - **TKvi-oc** - Okhotsk-Chukotsk volcanic-plutonic belt. Cretaceous (Albian to Campanian) basalt, andesite, dacite, rhyolite tuff and nonmarine clastic sedimentary rocks with silicic volcanic rock (mainly ignimbrites) and associated tonalite, quartz diorite and rare granite plutons overlain by Paleocene tholeiitic plateau basalt.

QTvm QTvm-bs **QUATERNARY AND TERTIARY MAFIC IGNEOUS ROCKS**
- **QTvm** - Quaternary and upper Tertiary volcanic rocks
  - **QTvm-bs - Bering Sea volcanic belt.** Mainly latest Miocene to Holocene alkalic basalt and olivine basalt flows, cinder cones, plugs and maar-rim deposits. In places as old as late Oligocene

SUBSURFACE DATA

SELECTED TEST WELLS ON CHUKCHI SHELF AND WESTERN NORTH SLOPE OF ALASKA

(See Sherwood et al., this volume, for stratigraphy of these wells)

CHUKCHI SHELF

POPCORN NO. 1 WELL
[SHELL WESTERN]
Lat 71.8545°N, Long 165.8066°W
Elev. KB = 12.8 m
Total well depth = 3,109.6 m

CRACKERJACK NO. 1 WELL
[SHELL WESTERN]
Lat 71.4188°N, Long 165.5415°W
Elev. KB = 12.8 m
Total well depth = 2,917.8 m

KLONDIKE NO. 1 WELL
[SHELL WESTERN]
Lat 70.7109°N, Long 165.2498°W
Elev. KB = 12.8 m
Total well depth = 3,660.0 m

BURGER NO. 1 WELL
[SHELL WESTERN]
Lat 71.2514°N, Long 163.1946°W
Elev. KB = 12.8 m
Total well depth = 2,500.0 m

DIAMOND NO. 1 WELL
[CHEVRON USA]
Lat 71.3329°N, Long 161.6799°W
Elev. KB = 12.8 m
Total well depth = 2,055.9 m

WESTERN NORTH SLOPE

TUNALIK NO. 1 WELL
[HUSKY-NPRA]
Lat 70.2058°N, Long 161.7155°W
Elev. KB = 33.5 m
Total well depth = 6,198.1 m

PEARD NO. 1 WELL
[HUSKY-NPRA]
Lat 70.7155°N, Long 159.0008°W
Elev. KB = 31.4 m
Total well depth = 3,116.6 m

(SUBSURFACE DATA COUNTINUED)

WELL STRATIGRAPHY, HOPE BASIN

CAPE ESPENBERG NO. 1 WELL [CHEVRON USA]
Lat. 66.410°N, Long. 163.913°W
Elev. KB = 12.2 m
Total well depth = 2,552 m
Data source: Tolson (1987)

Meters below KB	
18-65	Plio-Pleistocene sediments, mainly marine (?)
65-400	Middle and upper Miocene fine-grained sandstone and shale, marine (?)
400-1,082	Lower Miocene sandstone, siltstone and coal; nonmarine with marine (?) interbeds
1,082-1,524	Oligocene (?) nonmarine sandstone, conglomerate and coal
1,524-2,450	Eocene to Oligocene tuff, sandstone, conglomerate and coal. Contains about 40 m of middle Eocene (40.7 +/- 2.0 Ma) olivine basalt at top of interval and 50 m of volcanic conglomerate at base
2,450-2,552 m	Paleozoic (?) crystalline limestone and siliceous and graphitic phyllite

POINT NIMIUK NO. 1 WELL [CHEVRON USA]
Lat. 66.740°N, Long. 162.114°W
Elev. KB = 44 m
Total well depth = 1,924 m
Data source: Tolson (1987)

Meters below KB	
15-267	Plio-Pleistocene sediments, mainly marine (?)
267-800	Pliocene (?) and upper Miocene nonmarine sandstone, shale and coal
800-1,067	Middle Miocene nonmarine sandstone, shale and coal
1,067- ~1,803	Lower Miocene nonmarine sandstone and conglomerate
~1,803-1,817	Eocene to Oligocene tuff and sandstone with about 10 m of Eocene (42.3 +/- 10.2 Ma) olivine basalt near top of unit
~1,817-1,924	Paleozoic (?) dolostone

WELL STRATIGRAPHY, BERING SHELF

NORTON SOUND COST NO. 1 WELL [ARCO]
Lat. 63.7818°N, Long. 166.0862°W
Sea floor depth = 27 m
Total well depth = 4,445 m below sea level
Data source: Turner et al. (1983a)

Meters below sea level	
0-27	Water column
27-372	Pleistocene mudstone; inner neritic
372-549	Upper and middle Pliocene diatomacous sandy mudstone; inner neritic
549-1,107	Middle Pliocene to lower Miocene muddy diatomite and diatomaceous mudstone; inner to middle neritic
1,107-1,403	Lower Miocene to upper Oligocene mudstone; inner to middle neritic
1403-1,496	Upper Oligocene shale, sandstone, and coal; paralic
1,496-2,922	Oligocene mudstone, shale and sandstone; middle neritic to upper bathyal
2,922-3,109	Oligocene or older sandstone and bioturbated mudstone; probably marine
3,109-3,213	Oligocene or older basalt, mudstone and sandstone; probably marine
3,213-3,730	Oligocene or older turbiditic sandstone and mudstone; probably marine
3,730-3,794	Eocene or older fluvial or deltaic sandstone, siltstone, shale, coal and conglomerate; continental
3,794-4,445	Cataclastically deformed sedimentary rocks similar to Paleozoic or Precambrian York Slate of Seward Peninsula

NORTON SOUND COST NO. 2 WELL [ARCO]
Lat. 63.6970°N, Long. 164.1842°W
Sea floor depth = 15 m
Total well depth = 4,506 m below sea level
Data source: Turner et al. (1983b)

Meters below sea level	
0-15	Water column
15-105	No recovery
105-370	Pleistocene shallow mudstone and siltstone; inner neritic
370-1,045	Pliocene and Miocene diatomaceous mudstone, siltstone and muddy sandstone; inner to middle neritic
1,045-1,361	Upper (?) Oligocene mudstone, siltstone, sandstone and coal; paralic
1,361-1,797	Oligocene mudstone, siltstone, sandstone and minor coal; neritic
1,797-2,536	Oligocene mudstone, siltstone, sandstone and coal; paralic to middle or outer neritic
2,536-2,781	Lower (?) Oligocene siltstone and mudstone with minor sandstone and coal; paralic
2,781-3,613	Oligocene and Eocene siltstone, sandstone, mudstone and shale; paralic and continental
3,613-3,741	Eocene sandstone with minor siltstone, mudstone and conglomerate; continental
3,741-3,839	Eocene siltstone, mudstone, sandstone and minor coal; continental
3,839-4,375	Eocene or older sandstone, siltstone, mudstone and coal; continental
4,375-4,506	Quartzite, phyllite and marble similar to Paleozoic rocks on Seward Peninsula

NAVARIN BASIN COST NO. 1 WELL [ARCO]
Lat. 60.184°N, Long. 176.266°W
Sea floor depth = 132 m
Total well depth = 4973 m below sea level
Data source: Turner et al. (1984c)

Meters below sea level	
0-132	Water column
132-442	No recovery
442-1,061	Pliocene and upper Miocene(?) silty or sandy mudstone and diatomaceous ooze; middle and outer neritic
1,061-1,151	Upper Miocene hard, diagenetically altered sandstone and mudstone; middle neritic
1,151-1,501	Upper and middle Miocene bioturbated sandstone and sandy mudstone; middle neritic
1,501-1,608	Middle to lower Miocene fine-grained sandstone and siltstone; middle neritic
1,608-2,147	Upper Oligocene to lower Miocene muddy sandstone, claystone and mudstone; middle and outer neritic
2,147-3,266	Upper Oligocene sandy mudstone, muddy sandstone and claystone; neritic to middle bathyal
3,266-3,717	Lower Oligocene mudstone, claystone and sandy claystone; middle bathyal
3,717-3,869	Upper middle Eocene calcareous, organic-rich claystone; outer neritic to upper bathyal
3,869-4,637	Upper Upper Cretaceous (Maastrichtian), siltstone, sandstone, mudstone, claystone and coal; deltaic-non-marine. Section contains numerous diabase and basalt sills and dikes (whole rock K/Ar age 18-22 Ma)
4,637-4,973	Upper Cretaceous (Campanian or older?) claystone, siltstone, tuff and mudstone; inner neritic to upper bathyal, but mainly outer neritic

ST. GEORGE BASIN COST NO. 1 WELL [ARCO]
Lat. 55.543°N, Long. 166.955°W
Sea floor depth = 135 m
Total well depth = 4167 m below sea level
Data source: Turner et al. (1984a)

Meters below sea level	
0-135	Water column
135-458	No recovery
458-1,067	Upper and lower Pliocene sandstone, siltstone and mudstone; middle neritic to lower bathyal
1,067-1,607	Upper, middle and lower Miocene mudstone, siltstone, sandstone; upper to lower bathyal
1,607-2,533	Upper and lower Oligocene sandstone, siltstone and mudstone; inner neritic to middle and conglomerate; bathyal
2,533-3,134	Upper Eocene and upper middle Eocene sandstone, siltstone, mudstone, inner neritic to middle bathyal
3,134-4,167	Middle Eocene or older basalt, basaltic breccia and tuff (whole rock K-Ar = 38- 23 Ma)

ST. GEORGE BASIN COST NO. 2 WELL [ARCO]
Lat. 55.630°N, Long. 165.458°W
Sea floor depth = 114 m
Total well depth = 4434 m below sea level
Data source: Turner et al. (1984b)

Meters below sea level	
0-114	Water column
114-422	No recovery
422-1,271	Upper and lower Pliocene diatomaceous mudstone, siltstone, muddy sandstone, and minor conglomerate; outer neritic to upper bathyal
1,271-1,820	Upper (?), middle and lower Miocene mudstone, muddy sandstone and siltstone; outer neritic to upper bathyal
1,797-2,536	Upper and lower Oligocene sandstone, siltstone, and mudstone; outer bathyal transitioning downward to inner neritic
3,355-3,799	Lower Oligocene or Eocene (?) marine shelf and non-marine sandstone and siltstone; paralic
3,799-4,052	Lower Cretaceous to Upper Jurassic sandstone, conglomerate, siltstone and minor shale; fluvial or deltaic, and possibly marine shelf environments; paralic
1,361-1,797	Upper Jurassic marine sandstone, siltstone and conglomerate; inner to middle neritic

NORTH ALEUTIAN SHELF COST NO. 1 WELL [ARCO]
Lat. 56.274°N, Long. 161.976°W
Sea floor depth = 26 m
Total well depth = 5203 m below sea level
Data source: Turner et al. (1988)

Meters below sea level	
0-26	Water column
26-386	No recovery
386-739	Quaternary and Pliocene mud, sandy to pebbly diatom ooze and clay; middle to outer neritic
739-1,227	Lower Pliocene and Miocene sandstone, diatomaceous mudstone, sandy mudstone and lignite; paralic to middle neritic
1,227-1,458	Lower Miocene sandstone, siltstone and mudstone; inner to middle neritic
1,458-1,704	Upper Oligocene sandstone, siltstone and mudstone; inner to middle neritic
1,797-2,536	Upper Oligocene siltstone, mudstone and sandstone; middle neritic to paralic
1,946-2,382	Lower upper Oligocene sandstone and siltstone; paralic
2,382-2,886	Lower Oligocene sandstone, conglomerate, claystone and coal; paralic
2,886-3,138	Lower Oligocene and upper Eocene sandstone and mudstone; inner to middle neritic
3,138-4,735	Upper and middle Eocene sandstone, conglomerate, siltstone, claystone, mudstone and coal; paralic and nonmarine
4,735-5,203	Lower (?) Eocene mudstone, siltstone, sandstone, and conglomerate; nonmarine

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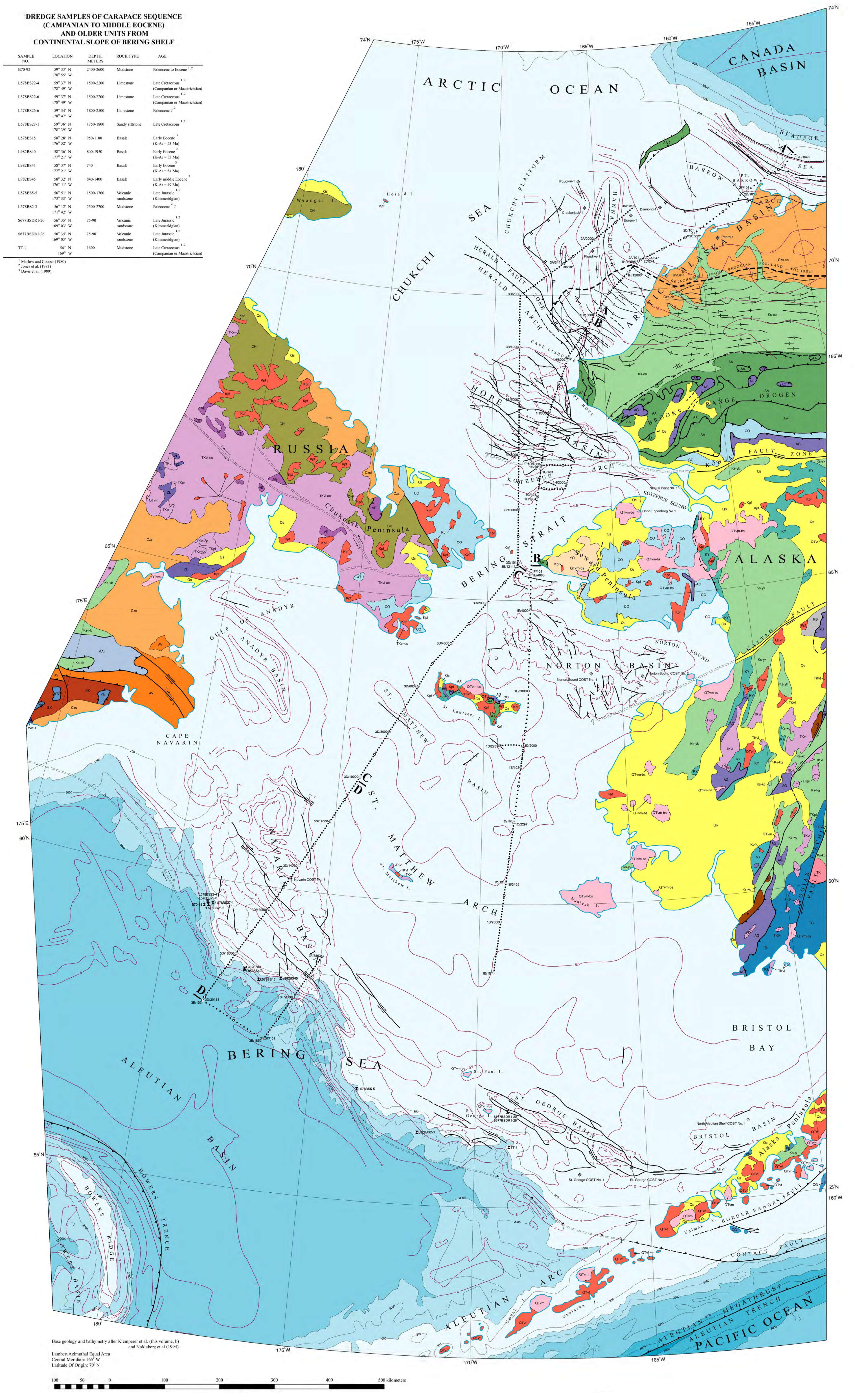
DREDGE SAMPLES OF CARAPACE SEQUENCE (CAMPANIAN TO MIDDLE EOCENE) AND OLDER UNITS FROM CONTINENTAL SLOPE OF BERING SHELF

SAMPLE NO.	LOCATION	DEPTH, METERS	ROCK TYPE	AGE
B70-92	59° 33' N 178° 55' W	2400-2600	Mudstone	Paleocene to Eocene [1,2]
L578BS22-4	59° 37' N 178° 49' W	1500-2200	Limestone	Late Cretaceous [1,2] (Campanian or Maastrichtian)
L578BS22-6	59° 37' N 178° 49' W	1500-2200	Limestone	Late Cretaceous [1,2] (Campanian or Maastrichtian)
L578BS26-6	59° 34' N 178° 47' W	1800-2500	Limestone	Paleocene ? [2]
L578BS27-1	59° 36' N 178° 39' W	1750-1800	Sandy siltstone	Late Cretaceous [1,2]
L578BS15	58° 28' N 176° 52' W	950-1100	Basalt	Early Eocene [3] (K-Ar = 53 Ma)
L982BS40	58° 36' N 177° 21' W	800-1950	Basalt	Early Eocene [3] (K-Ar = 53 Ma)
L982BS41	58° 37' N 177° 21' W	740	Basalt	Early Eocene [3] (K-Ar = 54 Ma)
L982BS45	58° 32' N 176° 11' W	840-1400	Basalt	Early middle Eocene [3] (K-Ar = 49 Ma)
L578BS5-5	56° 51' N 173° 33' W	1500-1700	Volcanic sandstone	Late Jurassic [1,2] (Kimmeridgian)
L578BS2-3	56° 12' N 171° 42' W	2500-2700	Mudstone	Paleocene [2] ?
S677BSDR1-20	56° 35' N 169° 03' W	75-90	Volcanic sandstone	Late Jurassic [1,2] (Kimmeridgian)
S677BSDR1-26	56° 35' N 169° 03' W	75-90	Volcanic sandstone	Late Jurassic [1,2] (Kimmeridgian)
TT-1	56° N 169° W	1600	Mudstone	Late Cretaceous [1,2] (Campanian or Maastrichtian)

[1] Marlow and Cooper (1980)
[2] Jones et al. (1981)
[3] Davis et al. (1989)



Base geology and bathymetry after Klemperer et al. (this volume, b) and Nokleberg et al (1994).

Lambert Azimuthal Equal Area
Central Meridian: 165° W
Latitude Of Origin: 70° N

100 50 0 100 200 300 400 500 kilometers

Scale 1 : 3,000,000 at 70°N

MAP SYMBOLS

—2— Structure contour, km, on acoustic basement beneath sedimentary basin or on mildly deformed horizon in lower part of sedimentary basin sequence, as indicated below:-

CANADA BASIN – Oceanic crust of early Early Cretaceous age seaward of COB (Continent-Ocean Boundary); acoustic basement (pre-Mississippian continental crust) of Arctic Alaska superterrane landward of COB. (Grantz et al., 1990a, 1990b, and unpublished)

ARCTIC ALASKA BASIN – Within region with Ellesmerian strata:-base of Ellesmerian Sequence (Lower Mississippian) on North Slope of Alaska, approximate base of Lisburne Group (Upper Mississippian) beneath Chukchi shelf. Outside of region with Ellesmerian strata:-pre-Devonian acoustic basement, including Ordovician and Silurian "argillite and graywacke sequence" of Arctic Alaska terrane. (Bird, 1988; Grantz et al., 1987, 1990a, 1990b and unpublished; Kirschner, 1988; Mayfield et al., 1988; Kirschner and Rycerski, 1988; Sherwood et al., this volume)

HOPE BASIN – Pre-Eocene acoustic basement, probably of Arctic Alaska superterrane and Angayucham terrane. (Tolson, 1987)

NORTON BASIN – Pre-Paleocene acoustic basement consisting of Paleozoic or older metasedimentary rocks that resemble the Seward terrane. (Worrall, 1991)

BERING SHELF – Pre-Middle Eocene acoustic basement consisting of various terranes. (Worrall, 1991)

NAVARIN, ST. GEORGE, AND BRISTOL BAY BASINS – Pre-Middle Eocene acoustic basement consisting of folded bedded rocks of the Carapace sequence and folded sedimentary strata and igneous rocks of the Peninsular terrane. (Worrall, 1991)

ALEUTIAN BASIN – Oceanic crust of Mesozoic age. (Cooper et al., 1987)

—1000— Isobath, m. Depth interval not uniform

Contact of tectonostratigraphic terrane, overlap sequence or igneous intrusive

Fault at surface or underlying relatively thin cover rocks. Dashed where inferred.

Normal fault. Hachure on down thrown side

Strike-slip fault. Arrows show relative horizontal movement

Thrust fault. Saw teeth on upper plate

Inferred fault zone, in places shown beneath cover rocks

North limit of detachment folds on North Slope of Alaska

Anticline or arch

Syncline or trough, dashed where inferred

Hinge line related to rifting of Canada Basin

Continent-Ocean Boundary (COB)

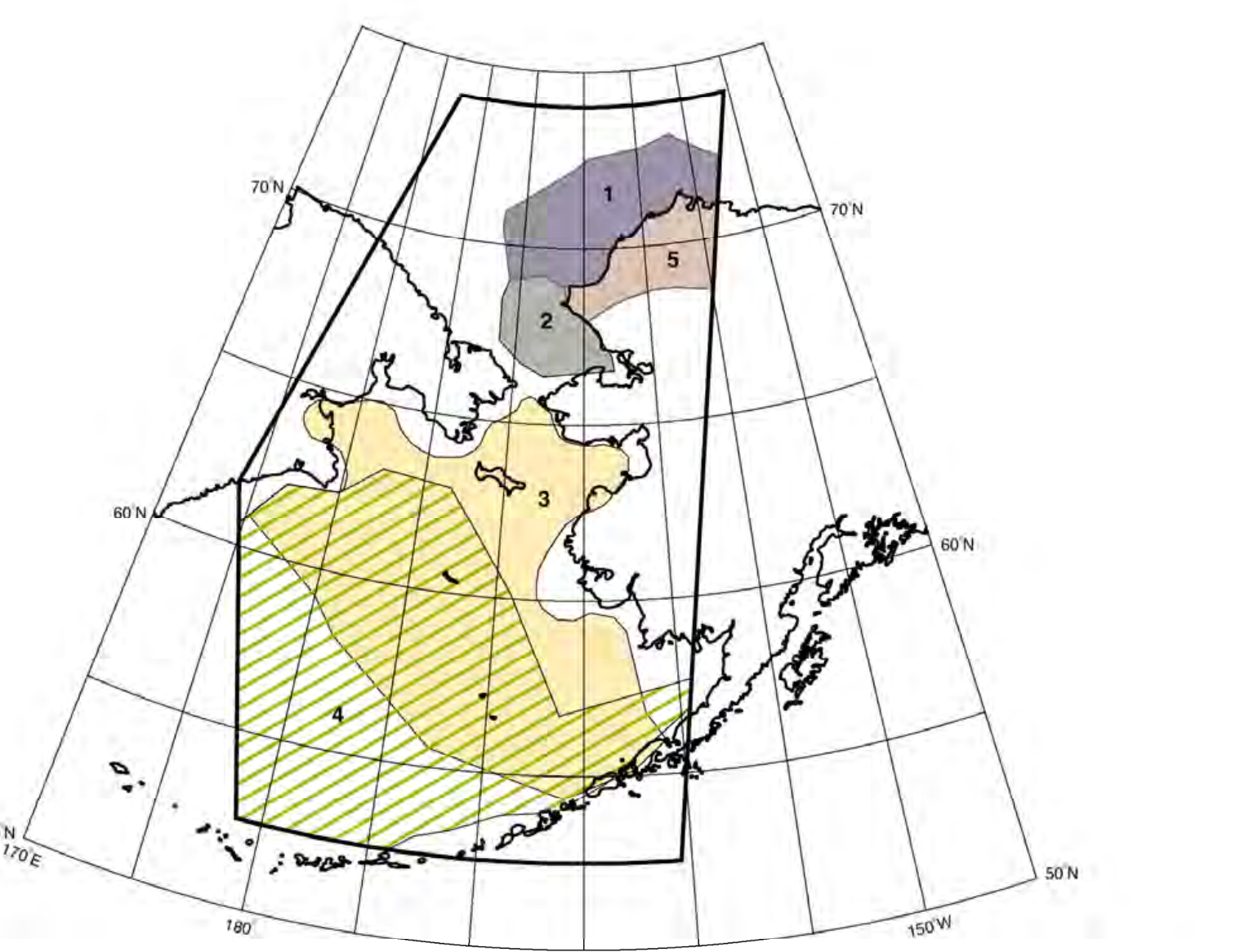
Wedge-out of Ellesmerian sequence on North Slope and Chukchi Shelf. Double hachure faces area with Ellesmerian strata

• ○ ⊙ Seismic reflection profile showing profile number [1B, 3D, etc.] and selected shot points [101, 2000 etc.]

D C Segments of profile displayed in Plate 2 accompanying Klemperer et al. (this volume, a)

⊕ Test wells and stratigraphic (COST) wells

⧗ Dredge sample locality



SOURCES OF STRUCTURAL CONTOURS

1. Grantz et al., 1987, 1990a. 2. Tolson, 1987. 3. Worrall, 1991. 4. Cooper et al., 1987. 5. Bird, 1988; Kirschner and Rycerski, 1988; Mayfield et al., 1988.

GEOLOGIC STRUCTURE OF BERING AND CHUKCHI SHELVES ADJACENT TO BERING-CHUKCHI DEEP SEISMIC TRANSECT AND TECTONOSTRATIGRAPHIC TERRANES OF ADJACENT LANDMASSES

by Arthur Grantz[1], David W. Scholl[1], Jaime Toro[2] and Simon L. Klemperer[1] **Cartographic assembly by Dean L. Miller[1]**

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Geological Society of America Special Paper 360 *Tectonic Evolution of the Bering Shelf, Chukchi Sea, Arctic Margin and adjacent landmasses*
Edited by E. L. Miller, A. Grantz, and S. L. Klemperer

Plate 1, Geologic structure of Bering and Chukchi shelves adjacent to Bering--Chukchi Deep Seismic Transect and tectonostratigraphic terranes of adjacent landmasses, scale 1:3,000,000, by A. Grantz, D. W. Scholl, J. Toro and S. L. Klemperer
Preface, by E. L. Miller, A. Grantz, and S. L. Klemperer