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PHANEROZOIC TECTONIC EVOLUTION OF THE CIRCUM-NORTH PACIFIC

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ABSTRACT

The Phanerozoic tectonic evolution of the Circum-North Pacific is recorded mainly in the orogenic collages of the Circum-North Pacific mountain belts that separate the North Pacific from the eastern North Asian and western North American Cratons. The collages consist of tectonostratigraphic terranes, composed of fragments of igneous arcs, accretionary-wedge and subduction-zone complexes, passive continental margins, and cratons, that are overlapped by continental margin arc and sedimentary basin assemblages. The geologic history of terranes and overlap assemblages is highly complicated because of post-accretion dismemberment and translation during strike-slip faulting that occurred subparallel to continental margins.

The complex tectonics of this region is analyzed by the following steps. (1) Tectonic environments for the orogenic collage are assigned from regional compilation and synthesis of stratigraphic and faunal data. The tectonic environments include cratonal, passive continental margin, metamorphosed continental margin, continental-margin arc, island arc; oceanic crust, seamount, and ophiolite, accretionary wedge and subduction zone, turbidite basin, and metamorphic. (2) Correlations are made between terranes. (3) Coeval terranes are grouped into a single tectonic origin, i.e., a single island arc or subduction zone. (4) Igneous arc and subduction zone terranes, that are interpreted as being tectonically linked, are grouped into coeval, curvilinear arc-subduction zone complexes. (5) By use of geologic, faunal, and paleomagnetic data, the original positions of terranes are interpreted. And (6) the paths of tectonic migration are constructed.

Six processes overlapping in time were responsible for most of the complexities of the collage of terranes and overlap assemblages around the Circum-North Pacific. First, in the Late Proterozoic, and the Late Devonian and Early Carboniferous, major periods of rifting occurred along the margins of Northeast Asia and northwestern part of the North American Cordillera. The rifting resulted in fragmentation and formation of cratonal and passive continental margin terranes from each continent that eventually migrated and accreted to other sites along the evolving margins of the original or adjacent continents. Second, from about the Late Triassic through the mid-Cretaceous, a succession of island arcs and tectonically paired subduction zones formed near continental margins. Third, from about mainly the mid-Cretaceous through the Present, a succession of igneous arcs and tectonically paired subduction zones formed along the continental margins. Fourth, from about the Jurassic to the Present, oblique convergence and rotations caused orogen-parallel sinistral and then dextral displacements within the upper plate margins of Northeast Asia and the North American Cordillera. The oblique convergences and rotations resulted in the fragmentation, displacement, and formerly duplication of more-continuous subduction zones, and passive continental margins. These fragments were subsequently accreted along the margins of the expanding continental margins. Fifth, from the Early Jurassic through Tertiary, movement of the upper continental plates towards subduction zones resulted in strong plate coupling and accretion of the former island arcs and subduction zones to continental margins. Accretions were accompanied and followed by crustal thickening, anatexis, metamorphism, and uplift.

The accretions resulted in the substantial growth of the North Asian and North American continents. And sixth, in the middle and late Cenozoic, oblique to orthogonal convergence between the Pacific Plate, with respect to Alaska and Northeast Asia, resulted in formation of the modern-day ring of volcanoes around the Circum-North Pacific. Oblique convergence between the Pacific Plate and Alaska also resulted in major dextral-slip faulting in Interior and Southern Alaska, and along the western part of the Aleutian-Wrangell arc. Associated with dextral-slip faulting was crustal extrusion of terranes from Western Alaska into the Bering Sea.

INTRODUCTION

A Phanerozoic tectonic model for the Circum-North Pacific region is interpreted for the orogenic collage that occurs along the margins of the eastern North Asian and western North American Cratons. The orogenic collage is composed of tectonostratigraphic terranes and overlap assemblages. tectonostratigraphic terranes consist mainly of accreted fragments of igneous arcs, accretionary-wedge and passive ' subduction-zone complexes, margins, and cratons. The overlap assemblages are sequences of mainly late Mesozoic and Cenozoic continental margin arc and sedimentary deposited on subjacent assemblages that were tectonostratigraphic terranes, or on terranes and subjacent craton margin assemblages.

The basic data for the tectonic model are from a regional compilation and synthesis of a new tectono-stratigraphic terrane map for Circum-North Pacific including the Russian Far East, northern Japan, Alaska, Canadian Cordillera, and U.S.A. Pacific Northwest, the North Pacific Ocean, and the Arctic Ocean (Nokleberg and others, 1994a, 1997a, b). This synthesis, including stratigraphic, faunal, and structural data, enables correlation of terranes that were tectonically displaced from one another, grouping of coeval terranes into a single tectonic origin (e.g., a single island arc or subduction zone), tectonic reconstruction of original positions, reconstruction of paths of tectonic migration, and the tectonic setting of overlap assemblages, mainly continental-margin igneous arcs in the Phanerozoic.

This paper reviews what is known and what reasonably can be inferred about the geology and tectonic evolution of the onshore areas of the Circum-North Pacific. This paper consists of three parts: (1) an introduction and discussion of terms and concepts applied to the components of the Circum-North Pacific orogenic collage; (2) descriptions and interpretations of the origins of terranes and overlap assemblages within the collage; and (3) a model for the Phanerozoic tectonic evolution of the Circum-North Pacific. This paper concentrates on the onshore geology and tectonics of major terranes and overlap assemblages that can be related to igneous arcs and to subduction zones. Because of a lack of comparable geologic data, the details of the geology and tectonics of offshore areas, principally the Arctic Ocean including the Canada Basin, the Bering Sea, and the Sea of Okhotsk, are only briefly summarized herein. For craton and craton margins, this paper only summarizes the important tectonic features of those units and terranes derived from those units. No attempt is made herein to provide complete references because the literature is enormous, and abundant data and interpretations are incorporated in numerous,

excellent recent syntheses (e.g., Plafker and others, 1989, Oldow and others, 1989; Gabrielse and Yorath, 1991; Burchfiel and others, 1993; Monger, 1993; Moore and others, 1994; Monger and others, 1994, and Plafker and Berg, 1994; Monger and Nokleberg, 1996). This paper draws on these syntheses, and also includes previously unpublished data that were jointly compiled and interpreted by the Russian and North American coauthors. Companion papers that present parts of this tectonic model are by Parfenov and others (1993a, b), Natal'in (1993), Parfenov and others (1993a, b), Monger and Nokleberg (1996), and Parfenov (1997). Previous oral versions of the paper were presented by Monger and Nokleberg (1995), Nokleberg and others (1995a, b, c), Parfenov (1995a, b), and Monger and others (1996).

This paper is the result of interpretation of extensive geologic mapping and associated tectonic studies in the Russian Far East, northern Japan, Alaska, the Canadian Cordillera, and the U.S.A. Pacific Northwest in the last few decades. These studies suggest that most of the region consists of a series of fault-bounded tectonostratigraphic terranes, which were accreted onto the margins of the northeastern North Asian and northwestern North American Craton Margins around the Circum-North Pacific, mainly during the Mesozoic and Cenozoic (Saleeby, 1983; Parfenov, 1984, 1991, 1997; Howell and others, 1985; Watson and Fujita, 1985; Parfenov and Natal'in, 1985; Natal'in and others, 1986; Jones and others, 1987; Monger and Berg, 1987; Fujita and Cook, 1990; Khanchuk and others, 1988, 1990, 1992, 1996; Zonenshain and others, 1990; Natal'in, 1991, 1993; Parfenov and others, 1991, 1993a, b, 1995; Sokolov, 1992; Silberling and others, 1992; Zinkevich and Tsukanov, 1992, 1993; Monger, 1993; Moore and others, 1994a, b; Nokleberg and others, 1994a, 1997a, b; Plafker and Berg, 1994; Tabor, 1994; Monger and Nokleberg, 1996; Sokolov and Byalobzheskiy, 1996; Khudoley and Sokolov, 1998).

Compared to previous tectonic analyses of parts of the region (Box, 1985a; Howell and others; 1985; Parfenov and Natal'in, 1985; Plafker and Berg, 1994), this tectonic analysis employs following steps that have accomplished by a large international collaborative team for the entire region of the Circum-North Pacific (Nokleberg and others, 1994a, 1997a; 1998): (1) define and utilize a systematic set of tectonic definitions; (2) compile, synthesize, and interpret of a large amount of stratigraphic, age, and structural data in order to construct regional terrane and overlap assemblage maps with detailed explanations, references, and stratigraphic columns; (3) perform systematic correlations of terranes and overlaps assemblages, once parts of continuous geologic units, that were tectonically separated by rifting and (or) strike-slip faulting; (4) perform systematic evaluation of correlations and tectonic linkages, as defined below; (5) systematically evaluate and employ higher quality paleomagnetic data (where not conflicting with stratigraphic and faunal data); and (6) construct a tectonic model that is based on the previous steps and in which the geologic units are scaled proportionally to those on the regional terrane and overlap assemblage maps of the region (Nokleberg and others, 1994a, 1997a). This project also represents the first attempt of a large group of geologists from Russia, Alaska, and the Canada to interpret together the tectonic origin of this vast and geologically complicated region of the earth. The project consists of a number of geologists who have each gathered field data and observations in their respective parts of the Russian Far East, Alaska, and the Canadian Cordillera over many years, and who have been able to work together in a large international team to compile, synthesize, and publish basic data, geologic and mineral resource maps, and interpretative articles.

Three groups of figures provide important illustrations for this paper. (1) The first group consists of four generalized geologic/tectonic maps for the region that are page-size simplifications of more detailed maps of major terranes, overlap assemblages, oceanic plates, rifts, and major faults, and other major geologic features of the Circum-North Pacific (Figures 1-4). These figures are adapted from Nokleberg and others, 1994a, 1997a, b, and Monger and Nokleberg, 1996). One pair of figures shows major terranes (Figures 1, 2). The other pair shows major igneous-arcrelated overlap assemblages and subduction zone terranes, mainly of Mesozoic and Cenozoic age (Figures 3, 4). (2) A second group are plots of paleolatitude versus time for terranes and overlap assemblages in Russian Far East, Alaska, and the Canadian Cordillera, and for North Asian and North American Cratons (Figures 5, 6). These two figures and companion data in Table 3 summarize vital paleomagnetic data that can be used to interpret paleolatitudes through geologic time, when not conflicting with stratigraphic and structural data, in order to define paths of tectonic migrations through geologic time. And (3) a third group consists of eleven time-stage diagrams that portray, in schematic plan view, the tectonic evolution of the Circum-North Pacific from the Devonian through the Present (Figures 7-17, with explanation in Figure 18). Another set of figures, published by Nokleberg and others (1994a), consist of 167 stratigraphic columns for major terranes in the study area. These stratigraphic columns, along with detailed descriptions of map units, provide base data for terranes and sedimentary and igneous assemblages, and permit correlations among or between terranes that have common tectonic environments.

Associated Studies

This study is part of a project on the major mineral deposits, metallogenesis, and tectonics of the Russian Far East, Alaska, and the Canadian Cordillera. The project provides critical information for collaborators and customers on bedrock geology and geophysics, tectonics, major metalliferous mineral resources, metallogenic patterns, and crustal origin and evolution of mineralizing systems for the Russian Far East, Alaska, and the Canadian Cordillera. The major scientific goals and benefits of the project are to: (1) provide a comprehensive international data base on the mineral resources of the region that is the first, extensive knowledge available in English; (2) provide major new interpretations of the origin and crustal evolution of mineralizing systems and their host rocks, thereby enabling enhanced, broad-scale tectonic reconstructions and interpretations; and (3) promote trade and scientific and technical exchanges between the North America and Eastern Asia. Data from the project are providing sound scientific data and interpretations for commercial firms, governmental agencies, universities, and individuals that are developing new ventures and studies in the project area, and for land-use planning studies that deal with both mineral potential issues. The Russian Far East part of the project (as well as Alaska and the Canadian Cordillera) has vast potential for known and undiscovered mineral deposits; however, little information existed in English in the West until publication of products from this project.

Published major companion studies for the project are: (1) a report on the metallogenesis of mainland Alaska and the Russian Northeast (Nokleberg and others, 1993); (2) a tectonostratigraphic terrane map of the Circum-North Pacific at 5.0 million scale with a detailed explanation of map units and stratigraphic columns (Nokleberg and others, 1994a); (3) a summary terrane map of the Circum-North Pacific at 10 million scale (Nokleberg and others, 1997a); (4) detailed tables of mineral deposits and placer districts for the Russian Far East, Alaska, and the Canadian Cordillera in paper format (Nokleberg and others, 1996) and in CD-ROM format (Nokleberg and others, 1997b); and a GIS presentation of summary terrane map, mineral deposit maps, and metallogenic belt maps of the Russian Far East, Alaska, and the Canadian Cordillera (Nokleberg and others, 1998).

A complete listing of the project goals, and methods are available on the Internet/Web at http://minerals.er.usgs.gov/wr/projects/majdeps.html. Major recent articles for the project (Nokleberg and others, 1993, 1994a, 1996, 1997a, b, c, 1998) are available Internet/Web the on http://wrgis.wr.usgs.gov/. This project was started at the invitation of the Soviet Academy of Sciences to the U.S. Geological Survey in 1988. Subsequently, several organizations and many individuals volunteered to work on various aspects of the project that has produced a large variety of articles and maps. Other organizations participating in the project include the Russian Academy of Sciences, ROSKOMNEDRA (now the Russian Ministry of Natural Resources), Alaska Division of Geological and Geophysical Surveys, Geological Survey of Canada, Geological Survey of Japan, Exxon Exxon Exploration Company, University of Alaska, and Michigan State University.

Key Terms for Tectonic Analysis of the Circum- North Pacific

Three key terms for this analysis, defined in Table l along with other important tectonic terms, are tectonostratigraphic terrane, accretion, and overlap assemblage. A tectonostratigraphic terrane (hereafter referred to as terrane) is fault-bounded geologic entity or fragment that is characterized by a distinctive geologic history that differs markedly from that of adjacent terranes. A terrane can also consist of an intensely deformed structural complex bounded by faults. Some terranes may be displaced facies of other terranes. Stratigraphic, faunal, and paleomagnetic evidence suggests that some terranes were originally widely separated from one another, or from the cratons of either North America or North Asia by distances of as much as thousands of kilometers (Plafker and Berg, 1994). Other terranes, however, are interpreted to be displaced from one another or from another site on the same continent by distances of only hundreds of kilometers or less.

Accretion is the tectonic juxtaposition of two or more terranes, or tectonic juxtaposition of terranes to a craton margin, and defines a major change in the tectonic evolution of terranes and craton margins. Geologic units formed before accretion, *i.e.*, preaccretionary units, are inherent to the stratigraphy of the terrane. Geologic units formed after accretion, *i.e.*, post-accretionary units, constitute mainly overlap assemblages that formed in a new stage in the tectonic evolution of the region.

An overlap assemblage is a postaccretion unit of sedimentary or igneous rocks deposited on, or intruded into, two or more adjacent terranes or craton margin. It depositionally overlies, or is interpreted to have originally depositionally overlain, two or more adjacent terranes, or terranes and the craton margin. Overlapping plutonic rocks, which may be coeval and genetically related to overlap volcanic rocks, link or stitch together adjacent terranes, or a terrane and a craton margin. The formation of an overlap assemblage defines a major change in the tectonic evolution of terranes and craton margins, and also provides a minimum age for terrane accretion.

For this tectonic model, terranes are interpreted according to the following interpreted dominant tectonic environments (Table 1): (1) cratonal; (2) passive continental margin; (3) metamorphosed continental margin; (4) continental-margin arc; (5) island arc; (6) oceanic crust, seamount, and ophiolite; (7) accretionary wedge and subduction zone; (8) turbidite basin; and (9) metamorphic, for terranes that are so highly deformed and (or) metamorphosed that determination of the original tectonic environment is difficult to determine. For terranes with complex geologic histories, the chosen tectonic environment is the one most prevalent during the history of the terrane.

Method of Tectonic Analysis

In order to model such a large, widespread, and diverse set of tectonic assemblages, this study undertakes an empirical approach to terrane analysis. First, terranes are classified according to major tectonic environments. Second, correlations are attempted between terranes of the same tectonic environment, similar age, and similar paleomagnetic latitudes (for terranes with paleomagnetic data that do not conflict with stratigraphic and faunal data). And third, igneous arc terranes (both island arc and continental-margin arc terranes) are grouped or tectonically linked with coeval accretionary wedge or subduction zone terranes in a manner that is common around the present-day Pacific Ocean margin. In addition, the ancient Pacific margin is interpreted as broadly similar to the modern margin, i.e., a series of continuous igneous arcs that separate continents and subducting oceanic plates.

This approach is supported by three lines of reasoning. First, the bulk of stratigraphic, faunal, and some paleomagnetic data do not require large separations of most igneous arc terranes from either North America or Northeast Asia. Certain exceptions are the truly exotic Tethyan fauna that occurs in the late Permian Cache Creek subduction zone terrane in the North American Cordillera. Second is the concept that the ancient Pacific Ocean resembled the modern

one, in that it was bordered discontinuously by paired igneous arcs and subduction zones. And third is the concept, that for the most part, igneous arcs and companion subduction zone complexes did not migrate across the ancestral Pacific Ocean. A notable exception to the last item is the origin of the Wrangellia superterrane near the Late Triassic paleoequator and final accretion to the North America continent at a higher paleolatitude in the Cretaceous and early Cenozoic.

Although the incomplete nature of geologic data leaves considerable paleogeographic uncertainty that increases markedly with the age of units, the chief result of this interpretative tectonic model is a series of time-stage diagrams for the tectonic model that successively depict the arrangements of continents, active continental margins, subduction zones, spreading ridges, and oceanic plates for the Phanerozoic. Our time-stage diagrams are based are carefully evaluated data that are compiled from a variety of sources published by a large group earth scientists. We look forward to the accumulation of more data and refinement of the tectonic model herein presented.

COMPLEMENTARY TERMS: TERRANES AND TECTONIC COMPONENTS

Two types of tectonic analysis have been employed to decipher the disorder inherent along the accretionary margins of continents such as the North American Cordillera. One type of emphasises the origins of parts of the tectonic collage as distinct tectonostratigraphic terranes whereas the other type of tectonic analysis emphasises the components of the tectonic collage. These types of tectonic analysis are complimentary. Terrane analysis defines the basic units whereas collage analysis adds an interpretation to the origin of units.

Terrane Analysis

Rock associations that are characterised by the actualistic tectonic settings in which they formed, such as craton margins, arcs, and ocean basins, have been used since plate tectonic concepts first were applied to Cordilleran geology (e.g. Hamilton, 1969). Called tectonic assemblages (Wheeler and McFeely, 1991; Wheeler and others, 1991), tectonostratigraphic elements (Burchfiel, 1993), or tectonostratigraphic terranes (Jones and others, 1981, 1983, 1984), they comprise major units of new geological and tectonic maps of the Canadian and conterminous U.S.A. segments of the North American Cordillera.

Regions whose geology, and in some cases, stratigraphic, faunal, paleomagnetic data are different from those of adjoining regions and from rocks of the craton margin, and which are separated from neighbouring regions by major faults, are called *suspect* or *lithotectonic terranes* (Coney and others, 1980; Silberling and others, 1992). Delineation of terranes focuses attention on the natures and times of linkages between them, and shows how the tectonic collage was constructed. The concept long pre-dates the plate tectonic hypothesis; terranes are analogous to the Alpine nappes or to the massifs and intervening regions in central Asia as described by Argand (1924). Well before terranes were widely promoted, parts of the Cordilleran eugeosyncline had been identified as *fragments of Asia*

(Wilson, 1968, his Fig. 6; later the Stikinia, Alexander, and Sonomia terranes), Alexander terrane (Berg and others, 1972), and Atlin terrane (Wheeler and Gabrielse, 1972), now part of the Cache Creek terrane.

Genetic terminology is readily married to terranes (e.g. Silberling and others, 1992). The North American Cordilleran tectonic collage comprises accreted terranes composed of juvenile arc rocks, ocean floor deposits and their underlying lithosphere, and continental margin terranes containing abundant detritus derived from a craton (Figure 1). For example, the Cache Creek Complex is a terrane composed of oceanic offscrapings that were accreted into an early Mesozoic accretionary complex. Another example exists in northwestern British Columbia that contains four mid-Paleozoic through lower Mesozoic arc assemblages separated from one another by unconformities. The paleoposition of each arc assemblage is uncertain, but together they compose the Stikinia terrane, which in the Middle Jurassic was accreted to form a major component of the North American Cordilleran tectonic collage. Still other terranes contain rocks representing more than one tectonic setting, although one is generally dominant; for example Devonian arc rocks form overlap assemblages on parts of several passive continental margin terranes in the North American Cordillera.

Analysis of Components of Tectonic Collages

The widely used terrane concept has been strongly criticized by Sengör (1990), among others. He proposed use of the terms primary orogenic collage components for fragments accreted by closing intervening ocean basins, and secondary orogenic collage components for fragments displaced within the already accreted collage by strike-slip or other large faults. At first sight, location of major arc terranes (e.g., Kony-Murgal, Stikinia and Quesnellia terranes, Wrangellia superterrane) (Figures 2, 4), oceanward of an early Mesozoic accretionary complex, suggests they are primary components. However, their locations are known with some degree of certainty only after they became part of the Cordilleran collage and interacted with other terranes and craton margin deposits as they do in the Mesozoic. We argue herein that at least the Mesozoic parts of the oceanward arc terranes are more likely segments of the same Ancestral Pacific Ocean arc system that were displaced along the North American plate margin, rather than being separate arcs which migrated across oceans. Because the distinction between primary and secondary components may be impossible in practice to make without paleogeographic control, the term terrane is needed in this type of tectonic analysis. In spite of any terminology differences, our analysis of the tectonic collage around the Circum-North Pacific is similar in principle to that put forward by Sengör and others (1993) for the Paleozoic tectonics of central Asia, although we admit more paleogeographic uncertainty. His first-order units of the Altaid collage are comparable to Cordilleran terranes.

CORRELATION, LINKAGE, AND ALIGNMENT OF MAJOR TERRANES AND OVERLAP ASSEMBLAGES

The interpretation of the geology and tectonics of the Circum-North Pacific presents a major challenge because of the complex variety and number of geologic

units in the region, and because of the complicated tectonic history of the region. The detailed and summary terrane and overlaps assemblage maps of this region, that support our tectonic analysis, define 167 onshore terranes, two cratons, two craton margins, 71 overlap assemblages, and three oceanic plates (summarized in Figures 1-4) (Nokleberg and others, 1994a, 1997). To understand this complex array of geology and thereby construct a relatively detailed tectonic interpretation, three major steps are employed: (1) correlation; (2) tectonic pairing (linking), and, (3) alignment of coeval arc and tectonically linked subduction zones into curvilinear complexes. Prior correlations of bedrock geology and tectonics between the Russian Far East and Alaska have been published by Box (1985a), Howell and others (1985), Parfenov and Natal'in (1985), and Parfenov (1997).

Correlation of Terranes and Overlap Assemblages

The first major step for this tectonic analysis is the correlation of similar coeval terranes and overlap assemblages (Table 2). Correlation can be achieved because terranes and overlap assemblages are workinglevel geologic entities that are defined by geologic mapping and stratigraphic analysis. In this tectonic analysis, correlation is attempted for terranes and overlap assemblages that are interpreted as having been originally contiguous, but have been subsequently tectonically displaced during rifting, major thrusting, or displaced along Late Mesozoic and Cenozoic strikeslip and thrust faults. Correlations are attempted for all units (both terranes and overlap assemblages that are interpreted to have the same tectonic origin, i.e., as parts of a single elongate passive continental margin, island arc, or subduction zone, at the same time and adjacent to each other. In some instances, correlated terranes and overlap assemblages do not always exhibit identical stratigraphy but do share a common age, geographic position (reconstructed in some cases), and tectonic environment that indicate a tectonic origin as part of the same continental margin, island arc, or subduction zone.

An important step for this study is the correlation, where possible, of cratonal, passive continental margin, and continental margin terranes to either the North Asian Craton or Craton Margin, or to the North American Craton or Craton Margin. This type of correlation helps establish the Late Proterozoic, and Paleozoic geology of the Circum-North Pacific before various episodes of rifting and accretion. Correlations are summarized in Table 2 and explained in Appendix 1. Correlations were achieved by Nokleberg and others (1) 1997a) by: interpreting environments for all major units (Figures 1-4); (2) for units with the same tectonic environment, comparing their geologic characteristics, including stratigraphic, magmatic, structural, metamorphic, paleontologic, isotopic data, and paleomagnetic data (where not conflicting with other geologic data); and (3) comparing the stratigraphy of units as illustrated in the 167 stratigraphic columns for major terranes and overlap assemblages around the Circum-North Pacific (Nokleberg and others, 1994a). This correlation of terranes and overlap assemblages: (1) illustrates original continuity of rock units around the Circum-North Pacific; (2) provides important constraints on the past tectonics of the region; and (3) constitutes a series of interpretations to be further evaluated by additional stratigraphic, geochemical, isotopic, paleomagnetic, and geophysical studies.

Tectonic Pairing (Linkage)

The second major step for this tectonic analysis is tectonic pairing (linkage) (Table 2). Two types of tectonic pairing are utilized in this study: (1) tectonic pairing of subduction-related igneous arcs, now preserved as various igneous arc terranes or overlap assemblages, to former subduction zones, now preserved as accretionary wedge or subduction zone terranes; and (2) tectonic pairing of belts of anatectic-related igneous rocks and major faults (sutures) that bound terranes. Tectonic pairings are summarized in Table 2 and Appendix 1.

The first type of tectonic pairing is based on: (1) analyzing the stratigraphy and structure of terranes in order to determine the tectonic environment, i.e., defining an igneous arc or subduction zone, or related tectonic environment; (2) interpreting a physical proximity, i.e., that specific igneous arc terranes were originally adjacent to specific subduction zones; (3) interpreting linkages between collisional foreland basins and collisional orogens; (4) determining the similarity in age of formation of igneous arc and subduction zone terranes; (5) for subduction and accretionary wedge terranes, where not disrupted by later deformation, determining subduction polarity from tectonic transport direction in the melange; and (or) (6) where possible, recognizing the occurrence of disrupted layers of arc-derived volcanic volcaniclastic units from a specific igneous arc, in the melange of the (companion) accretionary wedge or subduction terrane.

The second type of tectonic pairing occurs between belts of anatectic-related igneous rocks and major fault (sutures) that bound terranes. This type of linkage is based on the spatial and temporal association of collisional (S-type) granitic plutons and associated volcanic rocks with: (1) major fault zones (sutures) between terranes, or between a terrane and a craton margin; and (or) (2) belts of highly deformed, regional-grade metamorphic rocks that occur along the fault zones. Anatectic-related igneous belts are interpreted as forming either during accretion of one terrane to another, or during the accretion of one or more terranes to a craton margin.

Alignment of Coeval Arcs and Subduction Zones

The third major step for this tectonic analysis is the grouping of terranes and overlap assemblages into larger entities that were probably once continuous igneous arcs and companion subduction zone (or accretionary wedge) complexes. Those grouping of coeval units is based, to varying degrees, on: (1) similar stratigraphy, fauna, rock unit age, structure; (2) paleomagnetic data, to a lesser degree; and (3) an assumption of simplicity. The result of these groupings is the alignment of coeval igneous arc overlap assemblages and igneous arc terranes, and tectonically (companion) accretionary wedge subduction zone terranes into coeval, curvilinear arcsubduction zone complexes. This philosophy results in the interpretation of single rather than multiple continental margin or island arc-subduction zone

complexes. Alignment of coeval arcs and subduction zones are illustrated below in various parts of the tectonic model (Figures 7-18).

Advantages of Correlations, Tectonic Linkages, and Alignments

Our correlations, tectonic linkages, alignments of terranes and overlap assemblages, and the derivative tectonic model will probably change as additional data are acquired and new ideas are created. Our tectonic model is more highly developed for the later Mesozoic and Cenozoic stages when correlations and linkages can be made between the units accreted to the North Asian and North American Cratons. Some problems are inherent to the correlation, linkage, and alignment of terranes and overlap assemblages. In the case of terranes having originated during rifting of cratonal margins, and then having undergone sub-orthogonal convergence, terrane correlation is relatively simple. More complex problems may arise when large-scale strike-slip faults interfere with terrane origin, dispersion, accretion, and post accretion history.

APPENDIX CONTAINING DESCRIPTIONS OF GEOLOGY, CORRELATIONS, AND LINKAGES OF MAJOR TERRANES AND OVERLAP ASSEMBLAGES AROUND THE CIRCUM-NORTH PACIFIC

Appendix 1 provides a detailed descriptive and interpretative section on the geology, correlations, and tectonic linkages of terranes and overlap assemblages for the Circum-North Pacific. In order to present the tectonic model as the major part of the article. In Appendix 1, at the end of the article, units are described and interpreted in the following order: (1) continental margin and cratonal terranes; (2) Late Paleozoic through mid-Cretaceous island arc terranes of the Wrangellia superterrane; (3) Triassic through mid-Cretaceous continental margin arcs, island arcs, and tectonically paired subduction zones; (4) Late Cretaceous and Early Cenozoic continental margin arcs, island arcs, and tectonically paired subduction zones; (5) Middle and Late Cenozoic continental margin arcs and tectonically paired subduction zones; and (6) linkages between belts of anatectic-related igneous rocks and accretions of terranes. For each of these six groups, the descriptions of correlations, linkages, and alignments of terranes and overlap assemblages are presented in a counter-clockwise order, starting with Russian Southeast and ending with Southeastern Alaska and the southern Canadian Cordillera. Summary tables of correlations and linkages of terranes and overlap assemblages for the Circum-North Pacific are also provided in Table 2.

PALEOMAGNETIC CONSTRAINTS

Paleomagnetic Constraints for Plate Reconstructions of Northeast Asia and North America

In the reconstructions of major tectonic plates presented in this study, principally the North American Craton and the North Asian Craton, a hierarchical, two-level approach was utilized. The first level was to reconstruct the relative positions of North America and

North Asia for each time interval (stage). The second level was to position the relatively smaller terranes with respect to the major plates. The positions of terranes were determined primarily on the basis of stratigraphic and faunal data, and to a lesser degree on the basis of paleomagnetic data. In cases of data conflict, as discussed below for specific terranes for specific time-stage diagrams, terranes are positioned according to stratigraphic and faunal data rather than by paleomagnetic data.

For the Devonian to the Present, the time span that is modeled in this study, the relative motion between the North America and North Asia Cratons consisted of two phases. (1) Before amalgamation of Pangea in the Permian, Asia consisted of several different plates. The North Asian Craton, one of the principal plates for this study, was sutured to Baltica (the Russian Platform) in the Late Carboniferous to Permian, during the final stage of formation of Pangea. Baltica and North America were already sutured in the Silurian-Early Devonian Caledonian orogeny. And (2) after amalgamation of Pangea in the Permian, the second major phase of relative motion between North America and Asia was controlled by a protracted series of rifts that culminated in Jurassic and subsequent sea floor spreading that formed the North Atlantic Ocean. These two phases of plate motion (first suturing and subsequent rifting), control our methodology for defining plate position in the tectonic model. Subsequent to the Permian, the relative positions of Asia and North America are constrained by plate reconstructions of the North Atlantic, for older times, paleomagnetic data are used as the principal constraint.

Plate reconstructions of the North Atlantic (i.e., North America relative to North Asia) utilized in this study are from two principal sources. Reconstructions constrained by oceanic sea floor spreading data are based the study of Srivastava and Tapscott (1986) that encompasses the Early Cretaceous to Present. From Permian to Late Jurassic, motion between North America and Asia was accommodated by rifting primarily in the Rockall and North Sea areas around the British Isles. This rifting must have been accompanied by some horizontal motion between the plates, but published estimates of this motion indicate only a few tens of kilometers of motion (e.g. Barton and Wood, 1984; Latin and White, 1990).

For pre-Permian reconstruction, before North Asia was amalgamated to Pangea, the relative positions of North Asia and North America are based on paleomagnetic data using the compilation by Van der Voo (1990) for North America and Baltica. For Siberia, data are from Khramov (1971, 1979, 1986a, b), Khramov and others (1985), and Didenko and Pechersky (1993). An additional constraint in the Paleozoic plate reconstructions is provided by geologic data. As is well known, paleomagnetic data alone cannot provide a unique plate reconstruction, because of inherent longitudinal uncertainty.

Paleomagnetic Constraints for Terranes and Overlap Assemblages

For utilization of paleomagnetic data to construct the tectonic model, all paleomagnetic data available in the literature were compiled (Table 3) and graded according to the selection criteria listed below. Each data set have been evaluated and ranked, and

accordingly assigned a grade between A (very good) and D (marginal). All other data in the literature were rejected until such time as positive magnetic stability tests of some type are available for them. The ranked paleomagnetic data are provided in Table 3. The complete compilation of the paleomagnetic data is available from D.B. Stone (or his World-Wide Web (WWW) site http://www.gi.alaska.edu/TSRG/People/Stone/. For the tectonic model, paleolatitudes mainly from data graded A, B, or C were utilized to constrain the latitudes of terranes for each time interval (stage) of the tectonic model. In some cases, the interpreted positions of specific terranes, according to stratigraphic and faunal data, conflict with positions interpreted from paleomagnetic data. In cases of conflict, terranes are positioned primarily according to stratigraphic and faunal data and secondarily according to supporting paleomagnetic (paleolatitude) data. For each timeinterval (stage) of the tectonic model, both supporting and conflicting paleomagnetic (paleolatitude) data are discussed. These discussions, of apparent conflicts for terrane position according to stratigraphic and faunal data on the one hand, versus paleomagnetic data, on the other hand, will outline important new areas for future studies. Supporting paleomagnetic data are defined as those higher quality paleolatitude values, as graded by criteria given below, that agree within about five to eight degrees of positions determined by other geologic and faunal data. Conflicting paleomagnetic data consist of paleolatitude values that differ more than about eight to ten degrees.

The criteria for ranking of paleomagnetic data are as follows. Grade A: Multiple demagnetization steps must have been applied to most or all of the samples, and statistically good fold or reversal tests were quoted, though in some cases other evidence of a positive stability test were accepted (e.g. conglomerate test or a baked contact test). Grade B: Multiple demagnetization steps have been applied to a significant number of the samples, and the author claims to have established positive stability for the magnetization. Grade C: Single level, blanket demagnetization techniques have been applied, and the author claims positive stability tests but has no supporting data, or, normal and reversely magnetized samples are combined (without any quantitative evidence that the magnetizations are antipodal). Grade C was also assigned to cases where ancient horizontal was poorly constrained, as for instance in data from intrusive rocks. Grade D: The author claims to have data that represent the paleomagnetic field, but gives no supporting evidence. Grade D is also used for cases where the data are apparently "clean", but where normal stability tests are not possible. All other data in the literature were rejected.

Paleolatitudes are calculated from the latitudinal displacements between the paleomagnetic poles for the sampled localities with respect to the Siberian Craton for the Russian Northeast, or with respect to the North American Craton for Alaska and Canada. For the Russian Northeast, much of the data is derived from the compilations of Khramov (1971, 1979, 1986) as reported in the global paleomagnetic data base by Lock and McElhinny (1991). The composite apparent polar wander path (APWP) for the Siberian Craton for the pre-Triassic is taken from Khramov (1991) who utilized data directly related to the craton. For the

Triassic to the present, the APWP of Besse and Courtillot (1991) is utilized. This latter APWP is based on paleomagnetic pole position data from many places rotated into the reference frame of the Siberian Craton using paleogeographic reconstruction poles. The North American APWP is taken from Van der Voo (1993) for Paleozoic and older time, and from Besse and Coutillot (1991) for the Triassic to the present. The majority of displacements are southerly with respect to either the Siberian Craton or North American Craton; northerly displacements are listed as negative.

Paleomagnetic Variation Diagrams

For this paleomagnetic analysis, five diagrams illustrating paleomagnetic versus time values for terranes and overlap assemblages in the Circum-North Pacific are presented (Figures 5A-E). These figures the paleolatitudes illustrate calculated paleomagnetic inclination data from various combinations of terranes from the Russian Far East, Alaska, and the Canadian Cordillera. Two other paleomagnetic diagrams illustrate paleolatitude versus time values for the North Asian (Siberian) or North American Cratons respectively (Figures 6A, B). These paleomagnetic latitudes are all interpreted as ancient geographic latitudes using the common assumption that the time-averaged magnetic pole coincides with the geographic pole. The geologic age assigned to each of the paleomagnetic data points is based on information given by the cited authors, but when several points have the same nominal age, then separations of about 2 Ma are arbitrarily inserted to improve the clarity of the figures.

Two diagrams are presented that illustrate plots of paleolatitude versus time for the North Asian (Siberian) and North American Cratons, respectively (Figures 6A, B). These values on these diagrams are calculated from the separation of the Siberian and North American sampling localities, and paleomagnetic reference poles for the appropriate continental block. The two sets of reference poles were derived from Besse and Courtillot (1991) for poles of Mesozoic age, and from Van der Voo (1991, 1990, 1993) and Didenko and Pechersky (1993) for poles of Paleozoic age for North America and North Asia respectively. Quite large variations exist in the published apparent polar wander paths for North Asia and to a lesser extent for North America, thus these reference latitudes should only be used as a guide.

Kolyma-Omolon Superterrane

The plot of paleomagnetic poles versus time values for the Kolyma-Omolon superterrane (Figure 5A) includes the Omulevka and Omolon terranes plus smaller terranes that accreted to the Kolyma-Omolon superterrane before collision with the North Asia Craton and adjacent passive continental margin (Verkhoyansk fold and thrust belt) at about the Middle to Late Jurassic. The paleolatitudes of the Kolyma-Omolon superterrane, from about the Middle Jurassic, closely match the latitudes expected for their present geographic positions. Farther back in time, a strong indication exists that the terranes are displaced to the south by about 20 degrees of latitude. However, by the Devonian, two grade A data points indicate that the North Asian Craton and the Kolyma-Omolon

superterrane were in close proximity. The exception is the single locality from the Rassokha terrane (KRS) which yields a considerably lower paleolatitude. This could represent with a very rapid southerly excursion in the latest Devonian and Early Carboniferous, a problem with the interpretation of the geologic relationships between these terranes, or perhaps an unresolved magnetic overprint.

Outboard Terranes in Russian Northeast

The plot of paleomagnetic poles versus time values for outboard terranes (Figure 5B) is for terranes occur outboard of the Kolyma-Omolon superterrane towards the Pacific Ocean. These terranes formed in a variety of tectonic settings and yield paleomagnetic data of variable quality. If the grade A data are given more weight than the other data sets, then a clear northward trend occurs for paleolatitude values that accelerates in the mid- and Late Cretaceous, such that these outboard terranes arrived at present-day latitudes by the Eocene. Together, all the data yield a very noisy picture, suggesting that some of the data sets, although they passed the selection criteria, may still contain a large component of remagnetization. Some of the grade B and C data were given relatively high grades on the basis of passing a fold test. It is possible that the discrepancies seen may be due to post-remagnetization folding, thereby giving a false impression of an original paleomagnetic record. As defined above, grade A data pass more than one stability test.

Interior and Arctic Alaska

The plot of paleomagnetic poles versus time values for Interior and Arctic Alaska (Figure 5C) is for all the terranes that occur north of the Denali fault system. Only one data point exists north of the Brooks Range in the Arctic Alaska superterrane (AA). This data point, for passive continental margin terrane, is interpreted as having formed originally adjacent to the North American Craton in the Canadian Arctic. The other data points are for terranes south of the Brooks range and from the Bering Sea region. For this region, the data hints at greater than 10° of northward motion between the mid- and latest Cretaceous.

South-Central Alaska

The plot of paleomagnetic poles versus time values for South-Central Alaska (Figure 5D) is for all terranes south of the Denali fault and between from the eastern Gulf of Alaska to the Bering sea. With the exception of the data point for the Togiak terrane, paleolatitudes clearly increase onward from the Late Carboniferous. This trend accelerates markedly in the mid-Cretaceous.

Southeastern Alaska and Canadian Cordillera

The plot of paleomagnetic poles versus time values for Southeastern Alaska and Canadian Cordillera (Figure 5E) contains data for all terranes in this region. This plot shows a very marked northward increase of paleolatitude from the Late Carboniferous to the late Tertiary. Care should be taken when analyzing this figure not only because of the wide

range of present-day latitudes of the sampled sites, but also because the overall motion of the North American continent is very similar to that for these terranes. Relative to North America (Figure 6B), the motions are dominantly northward, but at a lower rate than the absolute paleolatitude motions shown in Figure 5E.

Paleomagnetic Dilemma: Loci of Accretion of Wrangellia Superterrane

A major paleomagnetic dilemma exists for the loci of accretion of superterranes to the margin of the North American Cordillera in the mid-Cretaceous to early Tertiary. The dilemma consists of two conflicting hypotheses for the loci of accretion of the Wrangellia superterrane that constitutes most of the Insular superterrane, and the Intermontane superterrane that consists of the Stikinia, Quesnellia, and Cache Creek terranes (Cowan, 1994; Cowan and others, 1997). One hypothesis, based on geologic evidence, including magmatic and stratigraphic ties, interprets the Wrangellia superterrane as accreting at a northerly paleolatitude, approximately at it's present latitude. The other hypothesis, based on paleomagnetic data for both stratified and plutonic rocks, interprets the Wrangellia superterrane and the western part of the Intermontane terrane as accreting at a paleolatitude approximately farther 3,000 km south. This hypothesis is informally named the Baja British Columbia controversy, in reference to accretion of the Wrangellia superterrane at the approximate latitude of Baja California (Umhoefer, 1987; Cowan and others, 1997; Dickinson and Butler, 1998). In our tectonic model, these two hypothesis are named the northern-accretion interpretation and southern-accretion interpretation.

Our tectonic analysis cannot currently discriminate between the two interpretations. Instead, the applicable parts of the tectonic model describe both the geologic and paleomagnetic data that support the northernaccretion interpretation, and the moderately abundant paleomagnetic data that support the southern-accretion interpretation. Accepting the northern-accretion interpretation requires radical reinterpretation of the paleomagnetic studies. Accepting the southernaccretion interpretation requires: (1) reinterpretation of the geologic data supporting the northern-accretion interpretation (Monger and Price, 1997); (2) construction of a southerly route of tectonic migration starting in the Late Triassic when the Wrangellia superterrane is interpreted to have formed at about 10° paleolatitude (as discussed by Irving and others (1996) and Cowan and others (1997); (3) accretion of the Wrangellia superterrane and possible western part of the Wrangellia (Insular) superterrane at the latitude of present-day Baja California at about 90 to 95 Ma (Irving and others, 1996; Cowan and others, 1997); and (4) a complicated tectonic and rapid migration of the Wrangellia (Insular) superterrane and western part of the Intermontane superterrane along the western margin of the North American Cordillera for a distance of about 3,000 km from about 83 to 34 Ma (Cowan and others, 1997) along a series of faults (such as the Fraser Creek-Straight Creek and Yalakom-Ross Lake fault systems and the Pasayten Fault in the southern Canadian Cordillera) that do not display this amount of displacement (Monger and Price, 1996). The various facets of this dilemma are discussed by Cowan (1994),

Irving and others (1996), Monger and Price (1996), Cowan and others (1997), Monger (1997), and Dickinson and Butler (1998). Proposed tests of the two hypotheses are discussed by Cowan and others (1997).

PHANEROZOIC TECTONIC MODEL FOR THE CIRCUM-NORTH PACIFIC

Introduction

This section presents a model for the Phanerozoic tectonic evolution for the major geologic units of the Circum-North Pacific based on the geologic and paleomagnetic constraints outlined above. The model attempts to: (1) integrate stratigraphic, age, structural, and paleomagnetic data, and field relations for the Circum-North Pacific as summarized in Tables 2 and and Appendix 1, and in supporting studies (Nokleberg and others, 1994a; 1997a); and (2) portray the regional tectonic interactions between the North Asian and North American continents for the Phanerozoic (Devonian through the Present) (Figures 7 through 17 with explanation in Figure 18). The tectonic model illustrates: (1) proportionally sized units with reference to the summary terrane and overlap assemblages maps in Figures 1 through 4 (Nokleberg and others, 1994a, 1997a); and (2) known or interpreted displacements along major strike-slip and thrust faults. The tectonic model, however does not incorporate internal deformation of terranes.

The tectonic model provides a guide for future research by: (1) integrating geologic, paleontologic, isotopic, and paleomagnetic data from both the Russian Far East, Alaska, the Canadian Cordillera, the Pacific Ocean, and the Arctic Ocean; (2) proposing a new, unified interpretation that spans the area from northeastern part of the North Asian Craton to the northwestern part of the North American Craton; and (3) identifying problems with data and interpretations. Because of a lack of abundant Proterozoic and older rock units, exterior to the craton margins, the model starts with the Devonian (Figure 7). For various published tectonic reconstructions for the Proterozoic, that illustrate highly different global interpretations, the studies of Daziel (1991), Hoffman (1989, 1991), Moores (1991), Ross and others (1992), Scotese (1997), and Unrug (1997) are recommended.

An important consequence of terrane recognition and analysis is that the margins of terranes have been tectonically removed, either by dislocation of terranes from a distant locations, or by tectonic erosion of the margins of terranes. In the case of dislocation, detailed analysis of each terrane with respect to in-place overlap assemblages, passive continental margin assemblages, and cratonal assemblages should provide the original site of origin. In the case of tectonic erosion, as in the case of subduction zone terranes, large parts of the original unit (e.g., an oceanic plate) may have been thrusted to great depths and thereby may essentially have disappeared.

In some previous tectonic analyses, terranes have been portrayed as discrete, fault-bounded entities. This type of portrayal, sometimes termed either *iceberg or motorboat tectonics*, is partly the result of terranes being defined as fault-bounded units with distinctive stratigraphies. However, our tectonic analysis attempts to: (1) recognize that each terrane was once part of a larger, more-continuous stratigraphic succession of

regional extent that originally was rarely bounded by faults; (2) correlate and group coeval terranes; and (3) where geologic data permit, group coeval igneous arc terranes and tectonically-linked subduction zone terranes into collinear, regional-extent arc-subduction zone complexes. This type of tectonic synthesis might be termed *spaghetti tectonics*.

An important interpretation in the tectonic model that a succession of coeval single arcs and companion subduction zones formed on, or near the margins of the North Asian and North American continents, rather than arcs having migrated across ocean basins to accrete eventually to the margins of the continents. The consequences of this interpretation is that many of the complexities of the collage of accreted terranes in the region (Figures 1-4) are the result of oblique subduction and resultant strike-slip displacements within active continental margins. Substantiation of this interpretation will require: (1) determination of the facing directions of the arcs with respect to cratons; (2) correlation of coeval arc and tectonically linked (companion) subduction zones to establish them as different parts of a former, single, curvilinear single arc/subduction zone systems; and (3) determination of the linkage of arcs to cratons. These two interpretation are reasonably well established for most of the Mesozoic and Cenozoic, but less so for the

For each time interval (stage) in the below model, specific (numbered) tectonic events are described in a clockwise order, starting with the Russian Southeast and ending with the southern Canadian Cordillera. Following descriptions of some specific tectonic events are summaries of supporting data, and summaries of paleolatitude data that either support or conflict the of terranes and interpreted positions assemblages for each time interval. The face values of paleolatitude from Table 3 are employed; however, in some cases, the usage of data with 95% confidence limits implies a higher level of agreement than may be warranted. The time scale for the tectonic model is from Palmer (1983).

Mesozoic and Cenozoic Changes in Plate Motions

Two major changes in Mesozoic and Cenozoic plate motions are interpreted for the Circum-North Pacific, and were probably responsible for much of the tectonic evolution of the region (Plafker and others 1989, 1994; Monger and Nokleberg, 1996). Each change was superposed on long-lived convergent plate margins. One major change occurred in about the mid-Cretaceous and consisted of a reversal of relative offset between continental and oceanic plates. The other change occurred in the early Tertiary and consisted of overriding of the Kula-Farallon ocean ridge and capture of part of the Kula Ocean plate.

Prior to about the mid-Cretaceous, for both the Russian Far East, Alaska, and the Canadian Cordillera, the oceanic plates in the Circum-North Pacific were generally rotating clockwise with respect to the North Asian and North American continents, thereby producing a component of sinistral slip to major fault systems (Engebretson and others, 1985). From about the Late Cretaceous through the Present, the Pacific Plate has been rotating counter-clockwise with respect to the North American continent, thereby producing a component of dextral slip to major fault systems

(Engebretson and others, 1985). An intense period of orthogonal convergence between the Ancestral Pacific Ocean plate and the North American continent is interpreted for the mid-Cretaceous.

This change in absolute plate motions, that was superposed on a long-lived convergent plate margin, is probably responsible for the Canadian Cordillera mountain belt (Monger and Nokleberg, 1996). In Alaska and the Canadian Cordillera, beginning with the Middle Jurassic and ending in the early Tertiary, most igneous arc/subduction zone complexes were accreted to the North American Craton Margin and new continental margin arcs were built on the mobile collage of accreted terranes. Subsequently these arcs were fragmented by mainly dextral-slip faults and overprinted by still younger arcs. This change probably resulted from long-continued northwestward, then westward movement of the North American plate towards the subduction zone (Engebretson and others, 1985). The combination of strong plate coupling with oblique convergence created optimum conditions for orogen-parallel movements within the margin of the upper plate (Jarrard, 1986). Such movements probably occurred throughout much of the middle and late Mesozoic, but are recorded in the substantial displacement along Late Cretaceous and early Tertiary dextral-slip faults in Alaska and the Canadian Cordillera.

The other change in absolute plate motion was the subduction or overriding of the Kula-Farallon Ocean ridge along the margin of southern Alaska in the early Tertiary (Bradley and others, 1993), and the accretion of a fragment of the Kula Ocean plate that underlies the modern Aleutian-Bowers sedimentary basin in the southern part of the Bering Sea (Scholl and others, 1992, 1994). The subduction of the oceanic ridge in the early Tertiary is interpreted as causing: (1) a regional metamorphic welt and formation of anatectic granites (Plafker and others, 1989; 1994); (2) rapid changes in components strike-slip movements along subduction zone bordering early Tertiary margin of Southern Alaska (Bradley and others, 1993); and (3) formation of two extensive belts of early Tertiary granitic rocks that formed in a near-trench environment (Bradley and others, 1993).

Middle through Late Devonian (387 to 360 Ma) (Figure 7)

During the Middle to Late Devonian (387 to 360) Ma) the major tectonic events were: (1) continuation of sea-floor spreading in the North Pacific; (2) formation of an arc and associated subduction zone extending out from the North Asian Craton Margin; (3) formation of an arc and associated subduction zone along the North American Craton Margin; and (4) inception of Sicker arc and associated subduction in the Wrangellia superterrane. Sedimentation continued along the passive continental margins of North Asia and North America.

Specific Tectonic Events for Middle through Late Devonian

(1) Previously in the Late Proterozoic, rifting occurred along both the eastern margin of the North Asian Craton Margin (NSV, KN). In the Russian Northeast, this event formed: the Kotelnyi (KT),

Omulevka (OV), Prikolyma (PR), Nixon Fork-Dillinger-Mystic (NX, DL, MY), and Viliga (VL) passive continental margin terranes; and the Avekova (AK), Kilbuck-Idono (KI), Okhotsk (OK), and Omolon (OM) cratonal terranes. Before the rifting, these terranes were parts of either the North Asian Craton (NSC) or North Asian Craton Margin (NSV).

(2) Between the Russian Northeast and Alaska, the continuation of sea-floor spreading continued, resulting in the formation of the Angayucham and ancestral Pacific Oceans. This long-lived period of sea floor spreading is interpreted as having started with the breakup of the Rodinia supercontinent at about 750 Ma (Moores (1991). The Angavucham Ocean is interpreted to have formed during either very slow, or sporadic seafloor spreading that occurred discontinuously from the Late Devonian to Early Jurassic.

- (3) A short-lived continental-margin arc and associated subduction zone extended out from the North Asian Craton Margin (NSV). The arc is preserved in: sporadic occurrences of marine and continental volcanic and associated rocks and subduction-related granitic rocks in the southern part of the craton margin (NSV); units that overlie parts of the Okhotsk (OK), Akekova (AK), Omolon (OM) cratonal terranes, in the Oloy (OL) and Yarakvaam (YA) island arc terranes; and in the Beryozovkha (BE) turbidite basin terrane. Associated with this arc was the older part of the Galam (GL) accretionary wedge terrane.
- (4) An extensive continental-margin arc and associated subduction zone formed along the margin of North America Craton Margin (NAM). The arc is preserved in sporadic occurrences of marine volcanic and associated rocks and shallow- to deep-level, subduction-related granitic rocks in various parts of the Arctic Alaska (AA), Coldfoot (CO), Ruby (RB), Seward (SD), Yukon-Tanana (YT), and Kootenay (KO) terranes. The Devonian arc is interpreted as extending discontinuously from Arctic Alaska to northern California (Rubin and others, 1991; Mortensen, 1992; Smith and Gehrels, 1992; Nokleberg and others, 1994a; Plafker and Berg, 1994).
- (5) The Sicker island arc was active along most of the length of the Wrangellia superterrane (WR), at this time composed only of the Alexander terrane (AX). Associated with the Sicker arc was an unknown subduction zone (UNK). In the southern Canadian Cordillera, the Sicker arc is defined by the Sicker Group that consists of Upper Devonian arc-related volcanic and sedimentary strata with a U-Pb zircon age of 367 Ma, and coeval intrusions (Muller, 1980; Parish and McNicoll, 1991). Insufficient data exist to ascertain the relative positions of the Wrangellia superterrane (WR) and associated subduction zone. On the basis of paleomagnetic, geologic, geochronologic, faunal data, Wrangellia superterrane the (Alexander terrane, AX) may be derived from the Scandinavian margin of Baltica (Barents Sea region) (Bazard and others, 1993, 1994; Butler and others, 1997) or possibly from Australia (Gehrels and Saleeby, 1987; Butler and others, 1997).
- (6) Along the western margin of North America, subsequent to the time span of this figure, latest Devonian and Early Mississippian rifting is interpreted as forming the Yukon-Tanana (YT) and Kootenay continental margin terranes, and Zolotogorskiy (ZL) passive continental margin terrane.

Summary of Paleolatitude Data for Middle through Late Devonian

For the Russian Far East, supporting paleolatitude data (Table 3) are: (1) a value of 36° (grade A) for the Omolon terrane. Conflicting paleolatitude data (Table 3) are a value of 12° (grade A) for the Rassokha terrane.

For Alaska, supporting paleolatitude data (Table 3) are: (1) a value of 14° (grade B) for the Karheen Formation in the Alexander sequence of the Wrangellia superterrane; (2) a value of 36° (grade A) for the Ordovician Novi Mt. Formation in the Nixon Fork terrane. Conflicting paleolatitude data are a value of 23° (grade A) for the Ordovician Telsitna Formation in the Nixon Fork terrane.

Pennsylvanian (320 to 286 Ma) (Figure 8)

During the Pennsylvanian (320 to 286 Ma) the major tectonic events were: (1) continued sea-floor spreading in the North Pacific; (2) inception of the older parts of Stikinia-Quesnellia arc (Stikinia and Quesnellia terranes) (Table 2) and associated subduction zone offshore of the North American Craton Margin; and (3) formation of the Skolai island arc associated subduction in the Wrangellia superterrane. Sedimentation continued along the passive continental margins of North Asia and North

Specific Tectonic Events for Pennsylvanian

- (1) In the central Russian Far East, dextral-slip occurred along the Mongol-Okhotsk suture (MO), resulting in displacement of the southern margin of the North Asian Craton (NSC) relative to the Mongol-Okhotsk Ocean.
- (2) Between the Russian Northeast and Alaska, sea-floor spreading formed the Oimyakon, Ancestral Pacific, Angayucham, and Goodnews Oceans. The Angayucham Ocean is interpreted to have formed during either very slow, or sporadic sea-floor spreading that occurred discontinuously from the Late Devonian to Early Jurassic. Within the Angayucham Ocean were the Kilbuck-Idono cratonal (KI), derived from the North Asian Craton (NSC) and Nixon Fork-Dillinger-Mystic passive continental margin terranes (NX, DL, MY), derived from the North Asian Craton Margin. During this time span, before accretion to the North American continent, the Nixon Fork-Dillinger-Mystic terrane may have experienced several post-rifting events that formed additional units, such as the siliciclastic rocks of the Sheep Creek Formation, and the Mt. Dall Conglomerate.
- (3) The intraoceanic Omulevka Ridge, that separated the Oimyakon and Angayucham Oceans, consisted of the Omulevka (OV), Prikolyma (PR), and Omolon (OM) terranes. These terranes were previously rifted from North Asian Craton and Craton Margin in the Late Proterozoic. The Paleozoic Yarakvaam (YA), Oloy (OL), and the Alazeya (AL) island arc terranes, together with the Beryozovka turbidite basin terrane (BE), are interpreted as parts of an active island arc that were located on an extension of the Omulevka Ridge.
- (4) Within the Angayucham Ocean, between the North Asian and North American Cratons were the

large Taimir Peninsula collage (TA) (Vernovskiy and others (1998) and the Chukotka (CH) passive continental margin terrane (Nokleberg and others, 1994a). The Taimir Peninsula collage (TA) is interpreted as a series of Late Proterozoic ophiolite, island arc, and passive continental margin terranes (Zonenshain and others, 1990; Vernikovskiy and others, 1998). The Chukotka terrane is interpreted as a rifted fragment of the North Asian Craton margin (Zonenshain and others, 1990; Nokleberg and others, 1994a).

(5) Offshore of the southern Canadian Cordillera were the Yukon-Tanana (YT) and Kootenay (KO) terranes, fragments of the North American Craton Margin (NAM), that formed during latest Devonian and Early Mississippian rifting. This rifting also formed the Slide Mountain and Seventymile Oceans. An extensive but thin submarine fan was deposited in the Slide Mountain Ocean (Anvil Ocean of Templeman-Kluit, 1979) between the Yukon-Tanana (YT) and Kootenay (KO) metamorphosed continental margin terranes and the North American Craton

Margin (NAM) (Appendix 1).

(6) At an unknown location, the Skolai island arc was active along the length of the Wrangellia superterrane (WR). Associated with the arc was a presumed (unknown) subduction zone (UNK). The Skolai arc consists mainly of Early to Middle Pennsylvanian plutons, and Pennsylvanian and Permian marine volcanic and volcaniclastic rocks, including andesite, dacite, basalt, volcanic breccia, graywacke, and shale (Nokleberg and others, 1994b). The basement for the Skolai arc may in part be the Alexander sequence that contains a fragment of an early and middle Paleozoic continental-margin arc (Nokleberg and others, 1994b). Insufficient data exist to ascertain the relative positions of the Wrangellia (WR) terrane (Skolai arc), and associated subduction zone, with respect to the Stikinia and Quesnellia island arcs and their associated subduction zones. Faunas in the Slana Spur and Eagle Creek (former Mankommen) Formations of the eastern Alaska Range indicate a high-latitude environment (Petocz, 1970).

(7) Subsequently in the Permian, the major part of the Stikinia arc formed on, and overlapped the Yukon-Tanana terrane and, to a lesser degree, the Stikinia (ST) terrane, after weak initiation of the arc in the Mississippian. This arc, defined by Permian granitic plutons in the Yukon-Tanana terrane, and by the Stikine Assemblage in the Stikinia terrane, may have been tectonically linked to subduction of part of the Seventymile Ocean. Evidence in the Yukon Territory favors the Stikine part of the arc facing towards the North American continent (Monger and Nokleberg, 1996). Along strike, the extension of the arc occurs in the Harper Ranch Group of the Quesnellia (QN) island arc terrane. This part of the arc was tectonically linked to subduction of part of the Cache Creek ocean (Monger and Nokleberg, 1996).

(Monger and Nokleberg, 1996).

(8) The faunas of the Quesnellia and Stikinia terranes are closest to those of the southwestern United States and northern Andean regions, and the probably formed at lower latitudes than their present positions along the continental margin. Quantitative estimates suggest that Stikinian faunas were located anywhere from near 0 to 8000 km away from the craton (Belasky and Runnegar, 1994). The paleolocation of Early Permian faunas is equivocal for the Wrangellia

superterrane. Petocz (1968) and Yole (1969) suggested a high latitude, Uralian or Canadian Arctic affinity, whereas Belasky and Runnegar (1994) suggested low-latitude positions southeast of the present position of the Stikinia terrane. Paleomagnetic constraints on faunal locations are provided by Late Pennsylvanian-Permian data from the Slide Mountain terrane, which suggest a post-Permian latitudinal shift of about 20° northward with respect to the craton (Richards and others, 1994; Table 3), whereas those from the Stikinia terrane exhibit little or no shift (Irving and Monger, 1987; Table 3).

Summary of Paleolatitude Data for Mississippian, Pennsylvanian, and Permian

For the Russian Far East, conflicting paleolatitude data (Table 3) are a value of 54° (grade A) for unnamed sedimentary and volcanic rocks overlying the Omolon terrane.

Alaska and the Canadian Cordillera, supporting paleomagnetic data (Table 3) are: (1) a value of 8° (grade A) for the Pennsylvanian Landrones and Klawak units in the Alexander sequence of the Wrangellia superterrane; (2) a value of 14° (grade A) for the Mississippian Peratrovich unit in the Alexander sequence of the Wrangellia superterrane; and (3) values of 6 and 7° (grades B, C) for the two localities in the Pennsylvanian and Permian Hasen Creek and Station Creek Formations in the Wrangellia sequence Wrangellia superterrane. Conflicting paleomagnetic data (Table 3) are: (1) values of 2 and 9° (grade A) for two localities (Sylvester allochthon and Sliding Mountain) in the Slide Mountain terrane; and (2) a value of 23° (grade A) for the Asitka Group in the Slide Mountain terrane in the central Canadian Cordillera.

Carnian through Norian (230 to 208 Ma) (Figure 9)

During the Carnian to Norian (230 to 208 Ma) the major tectonic events were: (1) inception of continental-margin arcs and associated subduction in the Russian Far East; (2) continued formation of the Stikinia island arc and inception of Talkeetna-Bonanza island arc and associated subduction zones offshore of North America (Table 2); and (3) beginning of oroclinal warping of the Stikinia and Quesnellia island arcs and associated subduction zones during oblique-sinistral convergence between the Ancestral Pacific Ocean plate and North America. Sedimentation continued along the passive continental margins of North Asia and North America.

Specific Tectonic Events for Carnian through Norian

(1) In the central Russian Far East, the continental margin Uda arc, defined by the Uda volcanic-plutonic belt (ud) and associated units, commenced activity and was associated with subduction and sinistral transpression of the Mongol-Okhotsk Ocean Plate to form the Turkuringra-Dzhagdi (TD), Ulban (UL), and older part of Galam (GL) terranes (Table 2). Subduction and sinistral transpression occurred along the Mongol-Okhotsk suture (MO).

(2) In the central Russian Far East, the extensive Kony-Murgal continental margin and island arc commenced activity as an offshore extension of the Uda arc. Associated with the arc was subduction of

part of the Ancestral Pacific Ocean plate to form the Talovskiy (TL) and Penzhina-Anadyr (PA) terranes (Table 2). Inboard of the Kony-Murgal arc (KM), the Okhotsk (OK) cratonal terrane was accreted to the North Asian Craton (NSC), together with the Viliga (VL) passive continental margin terrane, and the Omolon (OM) and Avekova (AK) cratonal terranes. The Kony-Murgal terrane contains Triassic, Jurassic, and Neocomian Boreal faunas (Dagis and others, 1979; Dagis and Dagis, 1984; Zakharov and others, 1984). The Viliga terrane contains Carboniferous, Permian, Triassic, and Jurassic Boreal faunas.

- (3) The Alazeya arc, consisting of the Alazeya (AL) and Khetachan (KH) island arc terranes, continued activity and moved towards the Omulevka Ridge. Associated with the Alazeya arc was subduction of part of the ancestral Pacific Ocean to form the Aluchin (AC) and Argatas (AG) accretionary wedge terranes. These terranes can be traced by magnetic anomalies under extensive Cenozoic deposits of the Russian Northeast (Parfenov, 1991). Behind the arc, were fragments of prior Devonian Pennsylvanian island arcs, including the Beryozovka turbidite basin (BE), and Oloy (OL), and Yarakvaam (YA) island arc terranes.
- (4) In the Russian Northeast, the Kotelnyi passive continental margin terrane was accreted and became part of the Taimyr Peninsular collage (TA, KT). Between the Russian Northeast and Alaska, slow or episodic sea-floor spreading continued to form the Angayucham, Goodnews, and Seventymile Oceans. Within these oceans were previously rifted terranes, including the Kilbuck-Idono cratonal (KI), Nixon Fork-Dillinger-Mystic passive continental margin terrane (NX, DL, MY). During this time span, before accretion to the North American continent, the Nixon Fork-Dillinger-Mystic terrane may have experienced several post-rifting events that formed additional units, such as the Triassic basaltic rocks in the Tatina River area.
- (5) Offshore of the southern Canadian Cordillera, the complex Stikinia-Quesnellia island arc and associated subduction zones were active (Table 2). The Stuhini-Takla part of the Stikinia-Quesnellia arc is preserved in the Stikinia (ST) terrane, whereas the Takla-Nicola of the Stikinia-Quesnellia arc is preserved in the Quesnellia (QN) terrane. The Stikinia-Quesnellia arc is interpreted as having formed stratigraphically on the Yukon-Tanana (YT) and Kootenay (KO) terranes, previously rifted fragments of North American Craton Margin (Mihalynuk and others, 1994). On the outboard side of the arcs was subduction of part of the Cache Creek Ocean plate to form the Cache Creek terrane. The Cache Creek terrane and similar subduction zone assemblages, that were also tectonically linked to the Talkeetna-Bonanza arc, along with the Chugach, possibly Bridge River, and Baker terranes, all contain exotic Permian Tethyan faunas in carbonate blocks in matrices of mainly early Mesozoic age. The Cache Creek terrane contains detritus probably derived from the Stikine or Quesnel part of the Stikinia arc (Monger and Nokleberg, 1996).
- (6) Also occurring was obduction of parts of the Seventymile and Slide Mountain Ocean (Anvil Ocean of Templeman-Kluit, 1979) plates onto the Yukon-Tanana (YT) and Kootenay (KO) terranes, and of the Slide Mountain Ocean plate onto the North American

Craton Margin (NAM). Part of the obduction occurred by the Late Triassic and (or) Early Jurassic when granitic plutons of the Stikinia-Quesnellia arc intruded across the intervening fault in the Canadian Cordillera.

(7) Oroclinal warping of the Stikinia arc (Stikinia (ST) and Quesnellia (QN) terranes) and associated subduction zones commenced in response to a combination of oblique convergence and arc migration towards the companion subduction zone of the Cached Creek terrane (Mihalynuk and others, 1994). Migration of the Stikinia-Quesnellia arc and associated terranes towards North America was accomplished by subduction of the Seventymile Ocean along the continental margin and by obduction.

(8) The Talkeetna-Bonanza arc formed along the length of the Wrangellia superterrane. The Talkeetna part of the arc is preserved in the Talkeetna Formation and coeval granitic plutonic rocks of the Peninsular sequence. At this time, the Bonzana part of the arc is preserved in the Cadwallader island arc terrane. Associated with the island arc was subduction of part the Cache Creek Ocean plate to form the Chugach (CG), possibly Bridge River (BR), and Baker (BA) terranes (Table 2). These terranes locally contain early Mesozoic blueschist (Plafker and others, 1994).

(9) During subduction of the Cache Creek Ocean plate to form the Talkeetna-Bonanza and Stikinia arcs, limestone blocks containing mainly Permian Tethyan faunas were accreted, locally in thick and extensive blocks in the subduction zone complexes of the Chugach and Cache Creek terranes (Monger and Berg, 1987; Monger and Nokleberg, 1996). Tethyan faunas are generally interpreted as being derived from the late Paleozoic and early Mesozoic Tethys Ocean of the Mediterranean region, Middle East, Himalayas, Southeast Asia, eastern China, Russian Southeast, and Japan (Monger and Ross, 1971; Monger and others, 1972; Stevens and others, 1997).

(10) In the Wrangellia superterrane (WR), backarc rifting or hot-spot activity formed the widespread basalt fields of the Nikolai Greenstone and Karmutsen Formation (Barker and others, 1989; Richards and others, 1991; Lassiter and others, 1995). The mafic magmatism resulting in the Nikolai Greenstone and Karmutsen Formation was first interpreted as forming in a rift setting (Barker and others, 1989). Alternatively, the mafic magmatism may have formed in a short-lived mantle plume setting similar to that in Java (Richards and others, 1991; Lassiter and others, 1994).

Summary of Paleolatitude Data for Carnian through Norian

For the Russian Far East, supporting paleolatitude data (Table 3) are a value of 78° (grade C) for the North Asian Craton Margin (Verkhoyansk fold belt). Conflicting paleolatitude data (Table 3) are: (1) a value of 57° (grade C) for the North Asian Craton Margin (Verkhoyansk fold belt); (2) a value of 27° for the Okhotsk terrane: (3) values of 42 to 54° (grade C) for three localities in the Omolon terrane; and (4) a value of 19° (grade B) for a locality at Penzhino Gulf in the Talovskiy terrane.

For Alaska and the Canadian Cordillera, supporting paleolatitude data (Table 3) are: (1) values ranging from 4 to 18° (grades A, C) for the seven localities (McCarthy, Healy, Mount Hayes

quadrangles; Clearwater Mountains (two localities); Amphitheater Mountains, Rainy Mountain, Slana River (two localities)) in the Nikolai Greenstone in the Wrangellia sequence of the Wrangellia superterrane in southern Alaska; (2) a value of 18 (grade A) for the Karmutsen Formation in the Wrangellia sequence of the Wrangellia superterrane in the southern Canadian Cordillera; (3) a value of 17° (grade A) for the Hound Island unit in the Alexander terrane in Southeastern Alaska; (4) a value of 28° for the Nicola Volcanics in the Quesnellia terrane in the southern Canadian Cordillera; and (5) a value of 20° for the Guichon batholith in the Quesnellia terrane in the southern Canadian Cordillera.

Hettangian through Callovian (208 to 163 Ma) (Figure 10)

During the Hettangian to Callovian (208 to 163) Ma), the major tectonic events were: (1) continuation of continental-margin arcs and associated subduction in the Russian Far East; (2) beginning of assembly of previously rifted cratonal, passive continental margin, and island arc terranes in the Russian Southeast to form the Kolyma-Omolon superterrane; (3) continuation of the Talkeetna-Bonanza and Stikinia-Quesnellia arcs, and formation of companion subduction zones (Table 2); (4) continued oroclinal warping of the Stikinia-Quesnellia arc and associated subduction zones during oblique-sinistral convergence between the Ancestral plate Pacific Ocean and North American. Sedimentation continued along the passive continental margins of North Asia and North America; and (5) with the beginning of accretion of the Stikinia-Quesnellia arc at about 185 Ma, the start of mountain building in the North American Cordillera.

Specific Tectonic Events for Hettangian through Callovian

(1) In the Russian Southeast, the Monakin continental margin arc (consisting of the Monakin volcanic-plutonic belt (mo) and the Umlekan continental margin arc (consisting of the Umlekan-Ogodzhin volcanic-plutonic belt (uo) and associated units) commenced activity. Associated with this arc was oblique (sinstral) subduction of part of the Ancestral Pacific Ocean plate to form the Samarka (SMA), Khabarovsk (KB), and Badzhal (BD) terranes (Table 2).

(2) In the central Russian Far East, the continental margin arc Uda arc (consisting of the Uda volcanic-plutonic belt (ud) and Uda-Zeya sedimentary basin (uz)) continued to form. Associated with the arc was subduction and sinistral transpression of part of the Mongol-Okhotsk Ocean plate to form the Turkuringra-Dzhagdi (TD), Ulban (UL), Galam (GL), and terranes (Table 2). Subduction and sinistral transpression occurred along the Mongol-Okhotsk suture (MO).

(3) In the central Russian Far East, the extensive Kony-Murgal island arc (Kony-Murgal terrane (KM)) continued to form as an offshore extension of the Uda arc. Associated with the arc was subduction of part of the Ancestral Pacific Ocean plate to form the Talovskiy (TL) and Penzhina-Anadyr (PA) terranes (Table 2). Inboard of the Kony-Murgal island arc (KM) were the Okhotsk (OK), Avekova (AK), and Omolon (OM) cratonal terranes that were previously rifted from the

North Asian Craton (NSC), and the Viliga (VL), and passive continental margin terranes that were previously rifted from the North Asian Craton Margin (NSV). Behind the arc, were fragments of prior Devonian Pennsylvanian island arcs, including the Beryozovka turbidite basin (BE), and Oloy (OL), and Yarakvaam (YA) island arc terranes.

(4) In the Russian Northeast, during the Bathonian, the Alazeya island arc, consisting of the Alazeya (AL) and Khetachan (KH) island arc terranes, collided with the various terranes of the Omulkevka Ridge (Omulevka (OV), Prikolyma (PR), Rassokha (RO) passive continental margin terranes) to form the Kolyma-Omolon superterrane. During this collision, fragments of the older part of the Angayucham Ocean plate were obducted onto the Omulevka terrane to form the Munilkan (MU), Uyandina (UY), Kybytygas (KY), and Indigirka (IN) ophiolite terranes (Oxman and others, 1995). The southern part of the Kolyma structural loop was formed during the convergence of the Alazeya arc towards the Omulevka Ridge.

(5) Near Northern Alaska, the Angayucham Ocean (Kobuck Sea of Plafker and Berg, 1994) continued to form along with the South Anyui Ocean. Scarcity of continental-derived detritus in the Angayucham terrane, and the considerable age span of the terrane (Devonian to Early Jurassic) suggests that the ocean may have been up to several thousand kilometers wide (Plafker and Berg, 1994) or that sea floor spreading was slow and (or) sporadic (this study). Previously rifted terranes, including the Kilbuck-Idono cratonal (KI), and the Nixon Fork-Dillinger-Mystic passive continental margin terranes (NX, DL, MY), continued to migrate towards North America.

(6) Outboard of the southern Canadian Cordillera, a complex array of island arcs and subduction zone assemblages continued to be deformed into an oroclinal warp (Mihalynuk and others, 1994). Oroclinal warping is interpreted as forming in response to: (1) oblique-sinstral convergence between the Ancestral Pacific Ocean plate and the Stikinia-Quesnellia arc; and (2) arc migration towards the companion subduction zone (trench rollback), similar to tectonics of the present-day Banda arc in Southeast Asia (McCaffrey and Abers, 1991; Mihalynuk and others. 1994). After oroclinal warping, the arcs and associated Cache Creek subduction zone terrane, previously part of a linear arc-subduction zone system, occurred on opposite sides of the oroclinal warp with the Cache Creek subduction terrane on the inside of the oroclinal warp.

(7) Also occurring was obduction of parts of the Seventymile and Slide Mountain Ocean plates onto the Yukon-Tanana (YT) and Kootenay (KO) terranes, and of the Slide Mountain Ocean plate onto the North American Craton Margin (NAM) (Mihalynuk and others, 1994). (Part of the obduction occurred by the Late Triassic and (or) Early Jurassic when granitic plutons of the Stikinia-Ouesnellia arc intruded across the intervening fault in the Canadian Cordillera.) During the final stage of obduction of the Slide Mountain terrane (SM) over the Kootenay metamorphosed continental margin terrane (KO), these terranes started to obduct onto the North American Craton Margin (NAM). Migration of the Stikinia-Quesnellia arc and associated terranes towards North America was accomplished by subduction of the Seventymile Ocean along the continental margin and by obduction.

(8) On the inner limb of the oroclinal warp, the subduction-related volcanic and plutonic arc rocks of the Quesnellia part of the arc, consisting of the Takla, Rossland, and coeval igneous belts, formed in response to continued subduction of part of the Cache Creek Ocean plate (CC) (Mihalynuk and others, 1994). On the outer limb of the oroclinal warp, away from North America, the Stikinia part of the arc consisted of the extensive suite of the subduction-related volcanic and plutonic arc rocks of the Hazelton group that formed in response to opposed subduction of both the Cache Creek Ocean plate (CC) and ancestral Pacific Ocean plates (Mihalynuk and others, 1994).

(9) In the hinge of the oroclinal warp, coeval, subduction-related granitic plutonic rocks also intruded the passive continental margin Yukon-Tanana terrane (YT) that may have been the stratigraphic basement to part of the Stikinia island arc (Mihalynuk and others, 1994). The plutonic rocks also intrude the structurally overlying Slide Mountain (SM) and Seventymile (SM) terranes.

(10) Outboard and perhaps at lower paleolatitude (either 25 or 45°), the Talkeetna-Bonanza arc continued activity in the Wrangellia superterrane (WR). The extensive Talkeetna-Bonanza arc formed along most of the length of the Wrangellia superterrane with coeval equivalents in the Cadwallader (CD) island arc and Methow (MT) turbidite basin terranes. Associated with the Talkeetna-Bonanza arc was subduction of part of the Cache Creek Ocean plate to form the Chugach (CG), Bridge River (BR), and possibly Baker (BA) terranes (Table 2).

Summary of Paleolatitude Data for Hettangian through Callovian

For the Russian Far East, supporting paleolatitude data (Table 3) are a value of 72° (grade C) for the Omolon terrane. For the Canadian Cordillera, paleolatitude data (Table 3) supporting the southern-accretion interpretation for the Wrangellia superterrane are: (1) a value of 24° (grade A) for the Bonanza group overlying the Wrangellia sequence of the Wrangellia superterrane in the central Canadian Cordillera; (2) two values of 19 and 24° (grade C) for the Copper Mountain and Tulameen units in the Quesnellia terrane in the southern Canadian Cordillera; and (3) seven values ranging from 28 to 37° (grades A, B, C) for the Topley intrusives, and the Telkwa Formation (six localities) in the Stikinia terrane in the southern Canadian Cordillera.

Oxfordian through Kimmeridgian (163 to 144 Ma) (Figure 11)

During the Oxfordian to Kimmeridgian (163 to 144 Ma), the major tectonic events were: (1) establishment of a series of continental margin arcs and companion subduction zone assemblages around the Circum-North Pacific (Table 2); (2) initiation of rift grabens that subsequently formed the Amerasia and Canada Basins; and (3) ending of the previous long-lived period (Late Proterozoic through Early Jurassic) of passive sedimentation along the margins of North Asia and North America.

Specific Tectonic Events for Oxfordian through Kimmeridgian

(1) In the Russian Southeast, the Monakin arc (Monakin volcanic-plutonic belt) (mo) and the Umlekan arc (Umlekan-Ogodzhin volcanic-plutonic belt and associated units) (uo) continued activity. Associated with the arcs was oblique (sinstral) subduction of part of the Ancestral Pacific Ocean plate to form the Samarka (SMA), Khabarovsk (KB), and Badzhal (BD) terranes (Table 2). In the same region, the Bureya (BU) superterrane accreted against the Ulban accretionary wedge terrane (UL) along the Mongol-Okhotsk fault (MO) thereby closing the Mongol-Okhotsk Ocean.

(2) In the central Russian Far East, the continental margin Uda arc (Uda volcanic-plutonic belt (ud) and Uda-Zeya sedimentary basin (uz)) continued to form. Associated with the arc was subduction and sinistral transpression of part of the Mongol-Okhotsk Ocean plate to form the Turkuringra-Dzhagdi (TD), and Ulban (UL) terranes (Table 2). Subduction was associated with sinistral transpression along the

Mongol-Okhotsk suture (MO).

(3) In the central Russian Far East, the extensive Kony-Murgal continental margin and island arc (KM) continued to form as an extension of the Uda continental margin arc (ud). Associated with the arc was subduction of part of the Ancestral Pacific Ocean plate to form the Talovskiy (TL) and Penzhina-Anadyr (PA) terranes (Table 2). The Kony-Murgal island arc overlapped the Okhotsk (OK) and Avekova (AK) cratonal terranes that were previously rifted from the North Asian Craton (NSC), and the Viliga (VL) passive continental margin terranes that were previously rifted from the North Asian Craton Margin (NSV). (4) As a transform extension of the Kony-Murgal terrane, the West Pekulney island arc terrane (WP) was initiated. Associated with the arc was subduction of part of the Ancestral Pacific Ocean plate to form the Pekulnev terrane (PK).

(4) The Kolyma-Omolon superterrane (KO) continued to migrate towards the North Asian Craton Margin (NSV). During migration, the Uyandina arc (consisting of Uyandina-Yasachnaya volcanic belt in western part of the extensive Indigirka-Oloy sedimentary-volcanic-plutonic assemblage (io)) started to form along the leading edge of the superterrane. Associated with the Uyandina arc was subduction of the oceanic crustal rocks preserved in the Garbyn'ya and Debon Chersky Range ophiolite belt (Oxman and others, 1995) that is herein interpreted as a remnant of

the Oimyakon Ocean plate (Table 2).

(5) On the opposite side of the Kolyma-Omolon superterrane, the Oloy island arc (ol) formed in response to subduction of part the South Anyui Ocean plate. Along one part of the North Asian Craton (NSC), the Svyotoy-Nos arc continental margin arc formed along the margin of the Taymyr Peninsula collage in response to subduction of another part of the South Anyui Ocean plate to form the South Anyui subduction zone terrane (SA).

(6) Near Northern Alaska, the Angayucham Ocean continued to form along with the South Anyui Ocean. Scarcity of continental-derived detritus in the Angayucham terrane, and the considerable age span of the terrane (Devonian to Early Jurassic) suggests that the ocean may have been up to several thousand

kilometers wide (Plafker and Berg, 1994) or that sea floor spreading was slow and (or) sporadic (this study).

(7) Adjacent to the North American Craton Margin (NAM), two extensive arcs formed. The Nutesyncontinental-margin arc formed in response to subduction of part of the South Anyui Ocean plate to form the Velmay subduction zone terrane (VE). The Koyukuk (KY), Togiak (TG), and Nyack (NY) island arc terranes formed in response formed in response to subduction of an (inner) Angayucham Ocean plate to form the Angayucham (AG) subduction zone terrane (Table 2). Locally substantial terrigenous detritus in Jurassic turbidite deposits in the lower structural part of the Angavucham terrane (Slate Creek subterrane of Moore and others, 1994b) may have been derived from erosion of the North American Craton Margin (NAM) (Moore and others, 1994b). The polarity of the island arc was continentward, towards the North American Craton Margin (NAM). Outboard of island arc were the outer Angayucham and the Goodnews Oceans that continued to form during sea-floor spreading. In response to sea-floor spreading, the Kilbuck-Idono cratonal and the Nixon Fork-Dillinger-Mystic passive continental margin terranes (NX, DL, MY) accreted onto the North American Craton Margin (NAM) at about the same time as obduction of the Stikinia-Ouesnellia island arc described below.

(8) North of Northern Alaska, rift grabens. depicted as the early stages of rifting associated with sea-floor spreading, were initiated for the opening of the Amerasia and Canada Basins (Grantz and others, 1998). These grabens were the first stage of creation of new oceanic crust in the Early Cretaceous, described

(9) Offshore of Southern Alaska and the northern Canadian Cordillera, a subduction zone, with a component of sinistral-slip is inferred to have formed along, and parallel to the continental margin in order to accomplish migration of the Wrangellia superterrane towards North America. Remnants of the subduction zone may be preserved in the terrane of ultramafic and related rocks that occurs discontinuously along the Denali strike-slip fault for several hundred kilometers (Nokleberg and others, 1994b). The mafic and ultramafic rocks may in part be derived from the Farallon Ocean Plate that separated the Wrangellia superterrane from North America.

(10) In the southern Canadian Cordillera, regional thrusting occurred with obduction of the Stikinia (ST), Quesnellia (QN), Cache Creek (CC), Slide Mountain (SM), Yukon-Tanana (YT), and Kootenay (KO) terranes over the Cassiar (CA) terrane and the North American Craton Margin (NAM). This compressional event marked the beginning of a major orogenic event, including regional metamorphism, deformation, crustal thickening, anatectic magmatism, and uplift in the core of the Canadian Cordillera (Monger and Nokleberg, 1996). The Nelson plutonic suite (ns), that intrudes the Kootenay, Quesnellia, Cache Creek, and Stikinia terranes, formed during this compressional event. The Nelson plutonic suite consists chiefly of granodiorite, quartz monzonite, and local monzonite plutons that yield isotopic ages mainly of 185-155 Ma with local crustal inheritance (Parrish and others, Woodsworth and others, 1992). By the Late Jurassic (about 155 Ma), detritus from the emergent orogenic welt in the eastern Canadian Cordillera was shed eastwards onto the craton margin (Cant, 1989).

(11) The extensive Gravina island arc continued activity along the length of the Wrangellia superterrane. Remnants of the arc are preserved in the Kahiltna (kh) and Gravina-Nutzotin-Gambier (gg) assemblages that occur only on the Wrangellia superterrane. Associated with the arc was subduction of part of the Farallon Ocean plate to form the Chugach (CG), Bridge River (BR), Easton (EA), and Baker (BA) terranes (Table 2).

Summary of Paleolatitude Data for Oxfordian through Kimmeridgian

For the Russian Far East, conflicting paleolatitude data (Table 3) are: (1) a value of 39° (grade A) for the Indigirka-Oloy assemblage overlying the Omolon terrane; (2) values of 62 and 69° (grade A) for the Omulevka terrane; and (3) a value of 65° (grade B) for the Viliga terrane.

For Alaska, paleolatitude data (Table 3) supporting the southern-accretion interpretation for the Wrangellia superterrane are: (1) a value of 32° (grade B) for the Naknek/Chitina units in the Peninsular sequence of the Wrangellia superterrane; and (2) a value of 39° (grade C) for the Westcoast Complex in the Wrangellia sequence of the Wrangellia superterrane. However, the values for (2) and (3) have 95% confidence limits that include 90°.

Neocomian (144 to 120 Ma) (Figure 12)

During the Neocomian (144 to 120 Ma), the major tectonic events were: (1) continuation of the continental margin and island arcs and companion subduction zone assemblages around the Circum-North Pacific (Table 2); (2) final accretion of major Kolyma-Omolon superterrane in the Russian Northeast; (3) inception of opening of the Amerasia, Canada, and Eurasia Basins in response to sea-floor spreading in the Arctic Ocean; (4) the beginning of accretion of the Wrangellia superterrane in the Southern Canadian Cordillera (northern-accretion interpretation); and (5) around the Circum-North Pacific, continued sinstral transpression between oceanic plates and continents.

Specific Tectonic Events for Neocomian

- (1) Far to the south of the southern Russian Far East, at about 30° paleolatitude (Table 3), the Mainitskiy island arc (Mainitskiy terrane, MAI) commenced activity. Associated with this arc was subduction of part of the adjacent oceanic plate to form the Alkatvaam accretionary wedge terrane (AV) (Table 2). This arc and companion subduction zone migrated northwards towards the Okhotsk-Chukotka continental-margin arc.
- (2) In the Russian Southeast, the Umlekan arc (Umlekan-Ogodzhin volcanic-plutonic belt (uo), and associated units) continued activity. Associated with this belt was subduction of part of the Ancestral Pacific Ocean Plate to form the Samarka (SMA), Khabarovsk (KB), and Badzhal (BD) terranes (Table 2).
- (3) In the central Russian Far East, the continental margin arc Uda arc (Uda volcanic-plutonic belt (ud), and Uda-Zeya sedimentary basin (uz) continued to form. Associated with the arc was subduction and sinistral transpression of the final remnant of the Mongol-Okhotsk Ocean plate, thereby forming the

Ulban (UL) terrane (Table 2). Sinistral transpression continued along the Mongol-Okhotsk suture (MO).

- (4) In the central Russian Far East, the extensive Kony-Murgal continental margin and island arc and West Pekulney (WP) island arc continued to form. Associated with these arcs was subduction of part of the Ancestral Pacific Ocean plate to form the Talovskiy (TL), Penzhina-Anadyr (PA), and Pekulney (PK) terranes (Table 2).
- (5) Behind the Kony-Murgal arc, the Kolyma-Omolon superterrane (KO) was accreted between at about 140 to 100 Ma. During the early stage of accretion, the Main collisional granite belt (ma) (144 to 134 Ma) formed (Layer and others, 1995; Fujita and others, 1997). At about the final stage of accretion, the subduction-related Northern granite belt (no) formed at about 127 to 120 Ma (Fujita and others, 1997). In contrast to the Main granite belt, the coeval Northern granite belt is interpreted as forming in response to subduction related to closure of an inlet of the South Anyui Ocean. As a result, the northern bend of the Kolyma structural formed (Sengor and Natal'in, 1996a). As a continuation of the structural loop, the extension-related Transverse granite belt formed (Parfenov, 1992; 1995c).
- (6) The Oloy island arc, and the opposing Nutesyn and Koyukuk island arcs continued to be active on the opposite sides of the South Anyui and Angayucham Oceans. Parts of these arcs are preserved in the Nutesyn (NUT), Koyukuk (KY), Togiak (TG), and Nyac terranes. Associated with these arcs was subduction of parts of the South Anyui and Angayucham Ocean plate thereby forming the South Anyui (SA), Velmay (VE), and (inner) Angayucham (AG) terranes. The polarity of the Koyukuk, Togiak, and Nyac island arcs was oceanward, away from the North American passive continental margin (Arctic Alaska superterrane, AA). After initial of accretion of the Koyukuk arc with Arctic Alaska, beginning in the Late Jurassic at about 160 to 145 Ma (Moore and others, 1994), subduction flipped to outboard of the new continental margin of North America.
- (7) In the Arctic, at about 140 to 135 Ma, sea-floor spreading and associated rifting, that started with the formation of grabens in the Late Jurassic or earlier, formed (Lawver and Scotese, 1990; Grantz and others, 1990, 1991, 1998): (1) new oceanic crust and three large sedimentary basins, the large Amerasia (ab) and Canada (cb) basins; and (2) a collage of passive continental margin terranes derived from the North American Craton Margin (Artis Plateau (AP), Chukchi Cap (CC), Chukchi Spur (CS), and Northwind Ridge (NR) terranes). Sea-floor spreading and opening of the Amersia, Canada, and Eurasia Basins is herein interpreted as causing; (a) closure of the inner Angayucham Ocean; (b) subduction of the North American continental margin (Chukotka terrane (CH) and the Arctic Alaska superterrane (AA)); (c) beginning of closure of the South Anyui Ocean; (d) intense deformation and metamorphism of the southern margin of the eastern Chukotka terrane (CH) and southern Arctic Alaska superterrane (AA) to form the Seward (SD), Coldfoot (CO), and Ruby (RB) terranes; (e) formation of an extensive blueschist facies belt in both the subducted continental margin (Arctic Alaska superterrane (AA), and Seward (SD), Coldfoot (CO), and Ruby (RB) terranes) and in the overthrust Angayucham terrane (AG); and (f) deposition of

synorogenic Early to mid-Cretaceous flysch in the Koyukuk basin in Western Alaska. For additional information on the details of the opening of the Canada Basin, whether by rifting and rotation, or by strike-slip translation, or a combination of the two processes, please refer to the analyses by Grantz and others (1990, 1998) or Lane (1994, 1997).

(8) A subduction zone is portrayed along the North American Craton Margin (NAM). Underthrusting along this subduction zone resulted in consumption of the Farallon Ocean plate. The small tectonic lenses of terranes of alpine ultramafic and related rocks along the ancestral Denali fault (Nokleberg and others, 1985, 1994a) may be remnants of these subduction zone assemblages that may have been mostly thrust under the craton margin.

(9) The Gravina arc continued to form. Associated with the Gravina arc was subduction of part of the Farallon Ocean plate to form the Chugach (CG), Bridge River (BR), Easton (EA), and Baker (BA) terranes. Part of the arc was preserved in the Kahiltna (kh) and Gravina-Nutzotin-Gambier (gg) assemblages that occur only on the Wrangellia superterrane.

(10) The Wrangellia superterrane, started to accrete at about 60° paleolatitude (northern-accretion interpretation) with the continentward part of the Wrangellia superterrane impinging onto the Southern Canadian Cordillera. With accretion, the arc extended into the southern Canadian Cordillera with the formation of two major overlap assemblages, the coeval Tahtsa-Three Sisters magmatic assemblage (tt) and the Spences Bridge volcanic-plutonic belt (sb). Alternatively, the Wrangellia superterrane was far to the south at about 35° paleolatitude (southern-accretion interpretation).

Summary of Paleolatitude Data for Neocomian

For the Russian Far East, supporting paleolatitude data (Table 3) are: (1) a value of 32° (grade A) for the Mainitskiy terrane; (1) a value of 76° (grade C) for the Khetachan terrane; and (2) a value of 88° (grade C) for the Eropol subterrane of the Oloy terrane. Conflicting paleolatitudes for the Russian Far East (Table 3) are: (1) a value of 62° (grade C) for a locality at Penzhino Gulf in the Talovskiy terrane; and (2) a value of 74° (grade C) for the Alkatvaam terrane.

For Alaska and the Canadian Cordillera, supporting paleolatitude data (Table 3) are: (1) values of 69 and 74° (grade B) for the Nanushuk Group and Kaparuk River Formation overlying the North Slope subterrane of the Arctic Alaska terrane; (2) a value of 69° (grade A) for another locality (Melozitna quadrangle) in the Koyukuk terrane; (3) values of 67 and 69° (grade A) for two localities (Melozitna and Nulato quadrangles) in the Koyukuk terrane; and (4) a value of 53° (grade B) for the Axelgold pluton intruding the northern Cache Creek terrane. The latter value supports the northern-accretion interpretation for the Wrangellia superterrane. For Alaska and the Canadian Cordillera, paleolatitude data (Table 3) supporting the southern-accretion interpretation for the Wrangellia superterrane are a value of 36° (grade B) for the Duke Island ultramafic complex that is part of the Gravina-Nutzotin-Gambier overlap assemblage in Southeastern Alaska.

Albian through Santonian (100 to 85 Ma) (Figure 13)

During the Albian though Santonian (100 to 85 Ma), the major tectonic events were: (1) establishment of a series of continental margin arcs and companion subduction zone assemblages almost continuously around the Circum-North Pacific (Table 2); (2) continued opening of the Amerasia, Canada, and Eurasia Basins; (3) completion of accretion of the Wrangellia superterrane; and (4) in the eastern part of the Circum-North Pacific, a change to orthogonal compression between the Farallon Ocean plate and the North American continental margin.

Specific Tectonic Events for Albian through Santonian

- (1) Far to the south of the southern Russian Far East, at about 50° paleolatitude, the extensive Olyutorka island arc commenced activity (Table 3). Parts of the arc are preserved in the Nemuro (NE), Kronotskiy (KRO), and Olyutorka-Kamchatka (OK), and Iruneiskiy (IR) terranes. Associated with the arc was subduction of part of adjacent oceanic plate to form the Vetlovskiy (VT) terrane (Table 2). This arc and companion subduction zone migrated northwards towards the Okhotsk-Chukotka continental-margin arc.
- (2) In the northern part of the Russian Southeast, at the end of the Neocomian, subduction was replaced by sinistral-slip faulting parallel to the continental margin. This faulting resulted in structural interleaving of the previously active Taukha (TU), Sergeevkha (SG), and Samarka (SMA) subduction-zone terranes. This structural interleaving is interpreted as similar to the present-day region of Southern California and resulted in formation of the fault-bounded basin of marine turbidites now preserved in the Zhuravlesk-Tumnin turbidite basin terrane (ZT) (Golozubov and Khanchuk, 1996).
- (3) In the northern part of the Russian Southeast, the Khingan-Okhotsk continental margin arc (ko) started to form. Associated with the arc was subduction zone of part of the Ancestral Pacific Ocean plate to form the Khabarovsk (KB), Amur River (AM), Kiselyovka-Manoma (KLM), and Badzhal (BD) terranes (Table 2).
- (4) In the Russian Northeast, the Mainitskiy island arc and associated Alkatvaam (AV) accretionary wedge terranes were accreted to the active continental margin by the beginning of the Albian when deposition of the overlying Kuibiveem sedimentary assemblage (kb) commenced. The Kuibiveem assemblage (included in unit oc, Figure 3) is interpreted as a forearc unit to the Okhotsk-Chukotka continental margin arc (oc).
- (5) In the Russian Northeast, subduction stepped seaward, partly as a result of the accretion of the Mainitskiy arc and associated subduction zone preserved in the Alkatvaam (AV) terrane. Consequently, the Okhotsk-Chukotka continental margin arc (oc) and related Penzhina (forearc) sedimentary basin (pn) started to form on the new continental margin. This major Andean-type arc overlapped the previously accreted Kolyma-Omolon superterrane and adjacent terranes in both the Russian Northeast and Western Alaska. The arc extended for about 3,500 km along the active Russian Northeast and

western Alaska continental margin. Associated with the arc was oblique subduction of part of the Ancestral Pacific Ocean plate to form the West-Kamchatka (WK), Ekonay (EK), and Yanranay (YN) terranes.

(6) In the Arctic Ocean, sea-floor spreading and associated rifting continued (Lawver and Scotese, 1990; Grantz and others, 1990, 1991, 1998) with the formation of new oceanic crust and the combined Lomonsov, Alpha, and Mendeleev Ridges (lo, am) that are interpreted as large piles of hot-spot basalt and associated deposits (Grantz and others, 1990, 1991, 1998). The large Amerasia (ab), Canada (cb) and Eurasia (eb) Basins continued to form. During the opening of the basin, North American continental margin terranes, including the Arctic superterrane (AA) and the Chukotka terrane (CH), and outboard oceanic and island terranes migrated towards the North Asian Craton and previously accreted Kolyma-Omolon superterrane. The opening of the Amerasia (ab), Canada (cb) and Eurasia (eb) Basins in is interpreted as having caused oroclinal warping of Northern Alaska and the northern part of the Russian Far East. Oroclinal warping may have also caused a second phase of deformation in the Verkhoyansk fold and thrust-belt and formation of the West Verkhoyansk collisional granite belt (wk) (90 to 120 Ma) along the Lena fault (LE).

(7) Also during the opening of the Amerasia (ab), Canada (cb) and Eurasia (eb) Basins, the South Anyui and Angayucham Oceans were closed, and the Chukotka (CH) and Arctic Alaska terranes (AA) were accreted to Northeast Asia. During closure, the major Nutesyn and Koyukuk island arcs and companion subduction zones were thrust onto the continental margin Chukotka terrane (CH) and Arctic Alaska superterrane (AA) in thrust sheets that are up to 150 km wide in Northern Alaska. The overthrust subduction zone terranes include the South Anyui (SA), Velmay (VE), Angayucham (AG), Goodnews (GD) terranes. The overthrust island arc terranes include the Nutesyn (NU), Koyukuk (KY), and Togiak (TG) terranes. A final stage of blueschistfacies metamorphism of oceanic and continentalmargin terranes occurred during thrusting. The lack evidence of a huge Himalayan-type mountain range in the Russian Northeast suggests either that: (1) strikeslip translation was more dominant than rifting in formation of the Canada Basin (Lane, 1994, 1997); and (or) (2) a major part of the rift migration of the Russian Northeast away from the Canada Basin was absorbed in the subduction zone associated with formation of the Okhotsk-Chukotka arc.

(8) During accretion, the southern margin of the eastern Chukotka terrane (CH), southern part of the Arctic Alaska superterrane (AA), and the outboard Seward (SD), Coldfoot (CO), and Ruby (RB) terranes continued to be intensely deformed and metamorphosed. At the end of accretion, a period of extensional deformation occurred along the southern margin of the Arctic Alaska superterrane (AA) (Miller and Hudson, 1991).

(9) In Southwestern Alaska, back-arc continentalmargin sedimentation in Kuskokwim basin (kw) occurred in a dextral wrench fault setting (Bundtzen and Miller, 1997).

(10) Along the margin of the Alaska and the western Canadian Cordillera, the accretion of the Wrangellia superterrane (WR) was completed at about

95 Ma (northern-accretionary interpretation). Several major geologic events are interpreted as caused by the accretion of the Wrangellia superterrane. (a) The extensive Gravina island arc, that formed along the leading edge of the superterrane, and the Spences Bridge volcanic-plutonic belt ceased activity after accretion. (b) The Kahiltna (kh) and Gravina-Nutzotin-Gambier (gg) assemblages were thrust under North American continental margin (Stanley and others, 1990; McClelland and others, 1991, 1992a, b; Nokleberg and others, 1994a) and were intensely deformed during a major period of orthogonal convergence that replaced the previous sinistral convergence. (c) The northeastern-most boundary of the accreted Wrangellia superterrane became the locus Late Cretaceous high-grade metamorphism, plutonism. contractional deformation. thickening, uplift, and erosion that characterizes the Coast Mountains of the Canadian Cordillera, Southeastern Alaska, and Southern (McClelland and others 1991, 1992a, b; Pavlis and others, 1993; Plafker and Berg, 1994; Monger and Nokleberg, 1996). (d) In the inboard Yukon-Tanana terrane, a regional core-complex formed, with development of a subhorizontal fabric, imbricate thrusting of large subhorizontal nappes, and subsequent extension with removal of as much as 10 km of crust (Pavlis and others, 1993). (e) The southern part of Gravina arc and companion subduction zone was doubled during the latest stage of sinistral-slip faulting during accretion of the Wrangellia superterrane (McClelland and others 1991, 1992a, b; Monger and others, 1994; Monger and Nokleberg, 1996). The Methow turbidite basin terrane, an Early and mid-Cretaceous forearc part of the Gravina arc, and the companion Bridge River and Easton subduction zone terranes were structurally imbricated behind the southern part of the Gravina-Nutzotin-Gambier (gg) assemblage (Monger and others, 1994). (f) In the eastern Canadian Cordillera, the mainly orthogonal convergence and accretion of the Wrangellia superterrane initiated eastward thrusting of the North American Craton Margin (NAM) over the North American Craton (NAC). And (g) coeval with thrusting and occurring along the axis of thrusting was intrusion of the Omineca-Selwyn belt (om) granitic belt that occurs along the length of the Canadian Cordillera, Alaska, and the northern part of the Russian Northeast. The belt was generated during an intense period of anatectic melting, major regional thrusting, and crustal shortening and thickening, all related to orthogonal convergence. Alternatively, Wrangellia the superterrane accreted far to the south at about 35° paleolatitude along the margin of Baja British Columbia (latitude of present-day Baja California) (southern-accretion interpretation).

Summary of Paleolatitude Data for Albian through Santonian

For the Russian Far East, supporting paleolatitude data (Table 3) are: (1) three values ranging from about 28 to 37° (grades A, B) for the Nemuro terrane; (2) a value of 42° (grade A) for the Vetlovskiy terrane; (2) a value of 76° (grade C) for the Omolon terrane; (3) a value of 76° (grade A) for Cretaceous rocks overlapping the Ekonay terrane; and (4) a value of 88° (grade C) for a locality in the Okhotsk-Chukotka

volcanic-plutonic belt overlying the Viliga terrane. Other paleolatitudes of 22 and 24° (grade A) for Late Triassic through Early Cretaceous rocks of the Ekonay terrane probably represent ages of oceanic lithosphere that comprise this accretionary wedge complex.

For Alaska and the Canadian Cordillera, paleolatitude data (Table 3) supporting the northernaccretion interpretation for the Wrangellia superterrane are values of 60° for the Skelly Creek batholith and Summit stock in the Coast-North Cascade plutonic belt. Paleolatitude data supporting the southernaccretion interpretation for the Wrangellia superterrane are (Table 3): (1) a value of 24° (grade B) for the Chignik/Hoodoo units in the Peninsular sequence of the Wrangellia superterrane; (2) a value of 32° (grade B) for the MacColl Ridge Formation in the Wrangellia sequence of the Wrangellia superterrane in southern Alaska; (3) a value of 37° (grade A) for the Methow terrane in the southern Canadian Cordillera; and (4) a value of 38° (grade C) for the Silverquick/Powell Creek units in the Tyaughton Basin in the central Canadian Cordillera. Paleolatitude data supporting an intermediate loci for the accretion of the Wrangellia superterrane are values of 46 and 53° (grade A) for localities in the Spences Bridge volcanic-plutonic belt in the Southern Canadian Cordillera.

Campanian though Early Eocene (82 to 52 Ma) (Figure 14)

During the Campanian though Early Eocene (82 to 52 Ma), the major tectonic events were: (1) the continuation of a series of continental margin arcs and companion subduction zone assemblages around the Circum-North Pacific (Table 2); (2) completion of opening of the Amerasia, Canada, and Eurasia Basins; (3) completion of accretion of the Wrangellia superterrane; (4) in the eastern part of the Circum-North Pacific, a change to dextral transpression between the Kula Ocean plate and the North American continental margin; and (5) northward migration of previously accreted terranes along the margin of the North American Cordillera.

Specific Tectonic Events for Campanian though Early Eocene

(1) Far to the south of the southern Russian Far East, at about 60° paleolatitude (Table 3), the extensive Olyutorka island arc continued to form. Parts of the are preserved in the Nemuro (NE), Kronotskiy (KRO), and Olyutorka-Kamchatka (OK), and Iruneiskiy (IR) island arc terranes. Associated with the arc was subduction of part of the adjacent oceanic plate to form the Vetlovskiy (VT) terrane. This arc and companion subduction zone migrated northwards towards the Okhotsk-Chukotka continental-margin arc and accreted in the early Eocene accretion at about 50 Ma (Heiphetz and others, 1994; Brandon and others, 1997). Accretion of the Olyutorka island arc occurred against the West Kamchatka accretionary wedge terrane (WK) (Figure 1) along the Vatyn thrust (VT) which is interpreted as a long-angle, seaward-dipping zone of obduction (Brandon and others, 1997; Ramthun and others, 1977). Alternatively, Geist and others (1994) infer that the Olyutorka arc and it's companion subduction zone formed near the margin of Northeast Asia.

- (2) In the southern Russian Far East, the East Sikhote-Alin (es) continental margin arc and related deposits continued to form. This major Andean-type arc overlapped previously accreted adjacent terranes in both the Russian Southeast and to the south. This arc extended for a distance of over 1,600 km along the active Russian Southeast continental margin. Forming as part of the arc was the West Sakhalin (WSA) turbidite basin terrane. Associated with the arc was oblique subduction of part of the Pacific Ocean plate (PAC) to form the Hidaka (HI), Aniva (ANV), and Nabilsky (NAB) terranes (Table 2).
- (3) In the central Russian Far East, the Okhotsk-Chukotka continental-margin arc continued activity. Parts of the arc are preserved in the Okhotsk-Chukotka volcanic-plutonic belt (oc) and related Penzhina (forearc) sedimentary basin (pn). Associated with the arc was subduction of part of the Pacific Ocean plate (PAC) to form the West-Kamchatka (WK) and Ekonay (EK) terranes (Table 2). Local plutons in the Okhotsk-Chukotka volcanic-plutonic belt intruded under extension, probably as the result of rollback of the subduction slab during the Late Cretaceous (Amato and Wright, 1997; Bering Strait Geologic Field Party, 1997). Also in the same region, the Okhotsk-Chukotka and East Sikhote-Alin continental-margin arcs were offset in a sinistral sense along the Mongol-Okhotsk fault system (MO).
- (4) Between the Russian Far East and Alaska, continental margin arcs and companion subduction zones in each region were connected by a major transform fault. From Western Alaska into the Bering Sea region tectonic escape (crustal extrusion) of terranes occurred along major dextral-slip faults, including the Denali (DE), Nixon Fork (NF), Kaltag (KA), and companion faults (Scholl and others, 1992, 1994). In association with movement on these major dextral-slip faults, dextral-wrench sedimentary basins formed, including the Kuskokwim Group (kw) (Plafker and Berg, 1994; (Bundtzen and Miller, 1997). The crustal extension and wrench faulting were associated with a major period of extension in Interior Alaska according to the interpretation of Miller and Hudson (1991). The mid- and Late Cretaceous extension is interpreted as forming warm, thin continental crust that was favorable for crustal extrusion and dextral-wrench faulting (Scholl and others, 1992, 1994).
- (5) In the Arctic Ocean by the early Tertiary, in the region of the Amerasia (ab), Canada (cb) and Eurasia (eb) Basins, sea-floor spreading and associated rifting was completed (Grantz and others, 1990, 1991, 1998). The formation of the Lomonsov (lo), and Alpha and Mendeleev Ridges (am), that are interpreted as large piles of hot-spot basalt and associated deposits, was completed, and the Lomsonsov Ridge (lo) may have been rifted from the combined Alpha and Mendeleev Ridges (am) (Grantz and others, 1990, 1991, 1998). Alternatively, the Lomsonsov Ridge (lo) may be a rifted fragment of the Taymyr Peninsula collage (L.M. Parfenov, this study). Sedimentation continued in the large Amerasia (ab), Canada (cb) and Eurasia (eb) Basins.
- (6) In the Paleocene (about 56 to 60 Ma), in the Bering Sea, major counter-clockwise rotation (oroclinal bending) of the Pacific Ocean plate (PAC) occurred (about 30° to 50°) (Lonsdale, 1988). The rotation resulted from compression between Eurasia and North America (Plafker and Berg, 1994). At the

same time, the extension of dextral-slip faults from Western Alaska into the Bering Sea resulted in capture and accretion of a fragment of the Kula Ocean plate (KULA) (Scholl and others, 1992, 1994). Also as part of the rotation, the Seward Peninsula region was faulted southward relative to Northern Alaska (Plafker and Berg, 1994).

(7) In Southern Alaska and the Canadian Cordillera. in response to oblique subduction of the Kula Ocean plate (KULA), the major Kluane continental-margin arcs formed (Bradley and others, 1993). Parts of the arc are preserved in the Kuskokwim Mountains volcanicplutonic belt (km) and Alaska Range-Talkeetna Mountains igneous belt (at). The coeval Coast arc formed along the margin of the Canadian Cordillera. Parts of this arc are preserved in the Coast-North Cascade plutonic belt and the Kamloops magmatic belt (ka). These continental margin arcs overlapped the previously accreted Wrangellia superterrane adjacent inboard terranes and extended for a distance of over 3,200 km along the active Canadian Cordillera and

Alaska continental margin. Associated with these continental-margin arcs was the subduction of the

laterally extensive Chugach terrane (CG) and the Pacific

Rim terrane (PR) (Table 2).

8) Along the active margin of the Canadian Cordillera, the rapid northward migration of the Kula Ocean plate (KULA), that started to form at about 85 Ma (Englebretson and others, 1985), resulted in formation of major dextral-slip faults in North American Cordillera, including the Denali (DE), Tintina (TI), Ross Lake (RL), and companion faults (Plafker and Berg, 1994). Oblique subduction of the Kula-Farallon oceanic ridge occurred at about 50 to 60 Ma along the southern margin of Alaska (Bradley and others, 1993). The subduction of the oceanic ridge in the early Tertiary is interpreted as causing: (1) a regional metamorphic welt and formation of anatectic granites (Plafker and others, 1989; 1994); (2) rapid changes in components strike-slip movements along subduction zone bordering early Tertiary margin of Southern Alaska (Bradley and others, 1993); and (3) formation of two extensive belts of early Tertiary granitic rocks that formed in a near-trench environment (Bradley and others, 1993).

(9) In the southern Canadian Cordillera and northeastern Washington, regional extension occurred. The extension is interpreted either as: the result of a change from transpression to transtension at about 55 Ma (Parrish and others, 1988); caused by a change of obliquity of convergence of the oceanic plate, or alternatively, but likely, collapse of overthickened thrust units.

(10) In the Canadian Cordillera, the eastward thrusting of the North American Craton Margin (NAM) over the North American Craton (NAC) ended

at about 60 Ma.

(11) With the southern-accretion interpretation for the Wrangellia superterrane, northward, rapid transport of the superterrane (not shown on Figure 14) commenced (Irving and others, 1996; Cowan and others, 1997) along unknown dextral-slip faults (Monger and Price, 1996). As summarized above, the total amount of Late Cretaceous and early Tertiary northward translation in the Canadian Cordillera is under debate (Monger, 1993; Cowan, 1994). Some paleomagnetic studies suggest that for this interval, the inner parts of the Canadian Cordillera, west of the

Tintina (TI) and northern Rocky Mountain Trench (NR) faults (Figures 2, 14), were displaced northwards by 1,200 to 1,400 km, whereas early Late Cretaceous plutons and stratified rocks in the Coast Mountains of Canada were displaced about 3,500 km (Irving and others, 1996). However, displacements based on offsets of geological units across faults are much smaller (see discussion in Monger and Nokleberg, 1996, p. 16). Resolution of this problem is clearly of major importance.

Summary of Paleolatitude Data for Campanian through Early Eocene

For the Russian Far East, supporting paleolatitudes (Table 3) are values of 49 to 60° (grades A, B, C) for four localities in the Olyutorka-Kamchatka terrane (Koryakia Sediments, Machevna Bay, Apuka River, Olytorskii Ridge, Koryak Highlands). Conflicting paleolatitudes (Table 3) are: (1) values of 37 to 43° (grade C) for three localities in the West Sakhalin terrane; (2) values of 32 and 81° (grades B, C) for two localities in the Olyutorka-Kamchatka terrane (Javevyn Bay, Tavlovka River); (3) a value of 25° (grade A) for the Kronotskiy terrane; (4) a value of about 39° (grade A) for the Kamchatskii Mys terrane that occurs at the western edge of the incipient Aleutian-Wrangell arc (Figure 15); and (5) a value of about 43° (grade A) for unnamed sedimentary rocks in the Komandorski Islands (Medny Island).

For Alaska and the Canadian Cordillera, supporting paleolatitude data (Table 3) are: (1) values of 67 to 78° (grade A) for various volcanic rock units in the Interior Alaska volcanic belt (Unalakleet quadrangles, Yukon-Koyukuk basin, Yukon-Tanana Upland); (2) values of about 70 to 80° (grade A) for overlap volcanic rocks in southern Alaska, include two localities in the Talkeetna Mountains volcanic-plutonic belt, and two localities in the Cantwell Formation; and (2) a value of 67° (grade A) for the Masset Formation overlying the southern Wrangellia superterrane; The values for items (2) and (3) support the northern-accretion interpretation for the

Wrangellia superterrane.

For Alaska and the Canadian Cordillera, paleolatitude data (Table 3) supporting the southernaccretion interpretation for the Wrangellia superterrane are: (1) a value of 55° (grade A) for the Chickaloon Formation overlying the Peninsular sequence of the northern Wrangellia superterrane on the Alaska Peninsula; (2) a value of 55° (grade A) for the Arkose Ridge Formation overlying the Peninsular sequence of the northern Wrangellia superterrane in southern Alaska; (3) a value of 43° (grade C) for the Butedale pluton in the Coast-North Cascade plutonic belt; (4) values of about 53 to 57° (grades A, C) for igneous and sedimentary rocks intruding or overlying various parts of the central and southern parts of the Wrangellia terrane (AX and WR sequences) (Point Camden gabbro, Flores Volcanics in the Cascade volcanic-plutonic belt, Carmacks volcanic field, and Coast-North Cascade plutonic belt (Kelowna Volcanics, Butedale pluton); (5) a value of 48° (grade C) for the East Sooke gabbro, part of the Cascade volcanic-plutonic belt overlying the southern Wrangellia superterrane; and (6) a value of 59° (grade A) for the Kamloops volcanic belt in the Southern Canadian Cordillera.

For Alaska, conflicting paleolatitudes are (Table 3): (1) a value of 62° (grade A) for unnamed flows overlying the Kahiltna sedimentary and volcanic assemblage in the Lake Clarke quadrangle, southern Alaska; (2) a value of 0° (grade A) for a locality in the Interior Alaska volcanic belt in the Yukon-Koyukuk basin; and (3) values 63 and 67° (grade A) for the Kuskokwim Mountains belt in the Bering Sea region; and (4) a value of 8° (Grade B) for the Brothers Volcanics overlying the Gravina-Nutzotin-Gambier overlap assemblage in southern Alaska.

Middle Eocene through early Miocene (42 to 23 Ma) (Figure 15)

During the middle Eocene to the early Miocene (42 to 23 Ma), the major tectonic events were: (1) continuation of a series of continental margin arcs and companion subduction zone assemblages around the Circum-North Pacific (Table 2); (2) continuation of sea-floor spreading in the Arctic and eastern Pacific Oceans; (3) in the northern and eastern parts of the Circum-North Pacific, establishment of a new continental margin as the result of the disappearance of the Kula Ocean plate, and inception of subduction of the leading edge of the Pacific Ocean plate: (4) in the eastern part of the Circum-North Pacific, a continuation of dextral transpression between the Pacific Ocean plate (PAC) and the North American continental margin; and (5) and because of counterclockwise rotation of Western Alaska, a change to orthogonal transpression between the Pacific Ocean plate and the Southern Alaska continental margin. The specific tectonic events are interpreted as follows.

At about 50 Ma (Vogt and others, 1979), the Gakkel Ridge (northern extension of the Arctic Mid-Ocean Ridge) was initiated and the modern period of sea-floor spreading was extended into the Arctic ocean, thereby resulting in the North American—Eurasia plate boundary transecting the Russian Northeast. The exact location of the Euler pole changed throughout the Cenozoic, thereby resulting in regional changes in the stress regime (Savostin and others, 1984; Harbert and others, 1987). Analysis of marine magnetic anomalies in the Eurasia Basin, suggests that the Russian Northeast underwent extension from about 56-36 Ma (Savostin and Drachev, 1988; Harbert and others, 1990; Fujita and others, 1997).

Specific Tectonic Events for Middle Eocene through early Miocene

- (1) In the southern Russian Far East, the younger, bimodal volcanic and plutonic rocks of the youngest part of East-Sikhote Alin volcanic-plutonic belt (esa), mainly basalt and rhyolite and associated granitic plutonic rocks, are interpreted as forming in a dextral-transpression tectonic regime.
- (2) In the central and southern Russian Far East, tectonic wedging occurred as the result of the accretion of India plate against Eurasia (Worall and others, 1996). The tectonic wedging resulted in sinistral displacement along the reactivated Mongol-Okhotsk fault (MO) and dextral displacement along the Sakhalin-Hokkaido fault parallel to the margin of the Russian Far East. A complex array of normal faults, en-echelon folds, and thrusts is interpreted as forming within and adjacent to the tectonic wedge (Worall and others, 1996). The relation of sinistral movement along the reactivated Mongol-Okhotsk fault (MO) and

dextral movement along the Denali, Tintina, and related faults in mainland Alaska in unclear.

- (3) In the Russian Northeast, the bimodal volcanic and plutonic rocks of the Kamchatka-Koryak volcanic-plutonic belt are interpreted as forming in a sinistral tectonic regime.
- (4) In the Arctic Ocean, rifting commenced at about 50 Ma along the Gakkel Ridge (GK) (northern extension of mid-Atlantic ridge) and extension into the Russian Northeast (Fujita and others, 1997). Rifting is interpreted as causing eruption of basalts in the Chersky Range at about 37 Ma (Fujita and others, 1997). Sedimentation continued in the large Amerasia (ab), Canada (cb) and Eurasia (eb) Basins.
- (5) In the Bering Sea, a short-lived period of marine arc volcanism formed the Bowers (bw) and Shirshov (sh) ridges. The arc formed on the rear edge of the previously accreted Aleutia terrane, a fragment of the Kula Ocean plate (Scholl and others, 1992, 1994) The Bowers Ridge volcanic belt consists chiefly of intermediate composition volcanic rocks, mainly altered andesite, breccia, volcaniclastic sedimentary rocks, and lesser diatomaceous siltstone (Cooper and others, 1992; Scholl and others, 1992). Sparse dredge samples and DSDP drilling suggest a Miocene age for the volcanic rocks. A trench filled with as much as 12 km of sedimentary rocks is located at the base of the northern and eastern slopes of Bowers Ridge, suggesting that the unit formed in an early Tertiary arctrench system that faced toward the northeast. The Shirshov Ridge volcanic belt consists chiefly of two assemblages. (1) A relatively older oceanic assemblage is composed of amphibolite, gabbro, diabase, basalt, and chert. Chert contains Late Cretaceous (Campanian to Maastrichtian) to early Paleogene microfauna. And (2) a relatively younger volcanic arc assemblage is composed of altered andesite, volcaniclastic sedimentary rocks, and shale of Miocene and younger age (Baranov and others, 1991; Scholl and others, 1992). Alternatively, the Bowers and Shirshov ridges are interpreted as the northward extension of the Olyutorka-Kamchatka island arc by Brandon and others (1997). Also in the Bering Sea, a thick sedimentary prism started to form in the Aleutian-Bowers sedimentary basin (atb) that overlies the Aleutia terrane (Plafker and Berg, 1994; Scholl and others, 1992, 1994).
- (6) From Western Alaska into the Bering Sea, tectonic escape (crustal extrusion) of terranes continued to occur along major dextral-slip faults, including the Denali (DE), Nixon Fork (NF), Kaltag (KA), and companion faults (Scholl and others, 1992, 1994). Dextral-wrench basins continued to form in association with the major dextral-slip faults and were rapidly filled with continental sediments. Coincident with crustal extrusion was counterclockwise oroclinal bending of Alaska that perhaps resulted from compression between Eurasia and North America (Scholl and others, 1992, 1994; Plafker and Berg, 1994). In Southern and Central Alaska, displacement continued along major dextral-slip faults, including the Denali (DE), Nixon Fork (NF), and Kaltag (KA) faults. These and similar dextral-slip faults probably extended into the Bering Sea.
- (7) In the northern Pacific Ocean, the Pacific Ocean plate (PAC) moved northwestward relative to North America. Along the Aleutian megathrust (AL), plate convergence continued to vary from oblique-

orthogonal in the east to oblique in the west. Obliquetranspressive displacement occurred between the Pacific Ocean plate (PAC) and the southern Canadian Cordillera.

(8) In Southern Alaska, as a result of accretion of part of the Kula Ocean plate and step-out of subduction, the western part of Aleutian-Wrangell (al) arc was initiated at about 40 Ma. This part of the arc is preserved in the arc. This major Andean-type arc overlapped the previously accreted Kula Ocean plate and initially extended for a distance of about 3,000 km along the active continental margin of the southern Kula plate in the Bering Straits and terranes previously accreted in Southern Alaska. Associated with the arc was subduction of part of the Pacific Ocean plate (PAC) to form the Prince William (PW) and Yakutat (YA) terranes along Aleutian megathrust (AL).

(9) At about 25 to 30 Ma, a major tectonic change occurred in the Southern Canadian Cordillera with tectonic overriding of the northern segment of the Juan de Fuca ridge and resultant establishment of dextralslip along the Queen Charlotte-Fairweather fault (QC). This tectonic change ended subduction of the Farallon Ocean plate (FAR) and started northward migration and subduction of the Yakutat terrane (YA), resulting in beginning of volcanism in the Wrangellia volcanic field (wr) in the eastern part of the Aleutian-Wrangell arc. Total movement of the Yakutat terrane is estimated at about 600 km (Plafker and Berg, 1994; Plafker and others, 1994). In the interior Canadian Cordillera, movement ceased along major dextral-slip faults, including the Tintina (TI) and Fraser-Straight Creek (FS) faults. Between latitudes 51° and 60° N, the Queen Charlotte-Fairweather transform fault separated the Cascade arc and the Aleutian-Wrangell arc. This fault forms the North American plate margin between Northern Vancouver Island and northern Southeastern Alaska.

(10) Offshore of the southern Canadian Cordillera, sea-floor spreading occurred along the Juan de Fuca oceanic ridge (JF). To the east in the southern Canadian Cordillera, subduction of the Juan de Fuca Plate resulted in initiation of the Cascade continental margin arc (ca). Part of the subducting plate was preserved in the Siletzia (SZ), Olympic Core (OC), and Hoh (HO) terranes along branches of the Cascadia megathrust (CC).

(11) With the southern-accretion interpretation for the Wrangellia superterrane, northward, rapid transport of the superterrane (not shown on Figure 15) was completed (Irving and others, 1996; Cowan and others, 1997) along unknown dextral-slip faults (Monger and Price, 1996).

Summary of Paleolatitude Data for Middle Eocene to early Miocene

For the Russian Far East, supporting paleolatitude data (Table 3) are a value of 65° (grade A) for the Central Kamchatka volcanic belt. Conflicting paleolatitudes (Table 3) are: (1) values of 40 to 47° (grades A, D) for the East Kamchatka volcanic belt; and (2) values of 51 to 65° (grades A) for the Central Kamchatka volcanic belt.

For Alaska and the Canadian Cordillera, supporting paleolatitude data (Table 3) are: (1) a value of 57° (grade A) for sedimentary rocks on Umnak island, near the Aleutian Islands; (2) a value of 74°

(grade D) for a locality in the Interior Alaska volcanic belt in the Yukon-Koyukuk basin; (3) a value of about 51° (grade C) for the Hope pluton in the Cascade volcanic-plutonic belt; and (4) a value of 59° (grade A) for the Resurrection Peninsula ophiolite at the base of the Prince William terrane in Southern Alaska. For Alaska and the Canadian Cordillera, paleolatitude data (Table 3) supporting are a southerly origin for the Prince William terrane (not depicted on Figure 15) are values of 34 to 47° for four localities in the Prince William terrane in southern Alaska (Kiluda Bay, Alitak Bay, Knight Island, Glacier Island). For Alaska and the Canadian Cordillera, conflicting paleolatitudes (Table 3) are: (1) a value of 69° (grade A) for unnamed sedimentary rocks on Amlia Island, part of the Aleutian-Bowers sedimentary basin; and (2) a value of 65° (grade C) for the Quotton pluton in the Coast-North Cascade plutonic belt.

Miocene (20 to 10 Ma) (Figure 16)

During the Miocene (20 to 10 Ma), the major tectonic events were: (1) continuation of a series of continental margin arcs and companion subduction zone assemblages around the Circum-North Pacific (Table 2); (2) back-arc spreading behind the major arcs; (3) opening of major sedimentary basins behind major arcs; (4) in the eastern part of the Circum-North Pacific, a continuation of dextral transpression between the Pacific Ocean plate and the Canadian Cordillera margin, and a continuation of orthogonal transpression between the Pacific plate and the Eastern-Southern Alaska continental margin; and (5) continued sea-floor spreading in the Arctic and eastern Pacific Oceans.

Specific Tectonic Events for Miocene

(1) In the central and southern Russian Far East, after accretion of various terranes in the early Eocene, the Northeast Asia arc commenced activity. Parts of this arc are preserved in the East Japan volcanicplutonic belt (ej), Kuril volcanic arc (ku), and the various parts of the Kamchatka arc consisting of the Central Kamchatka volcanic belt (kc), Central Kamchatka volcanic and sedimentary basin (ck), and West-Kamchatka sedimentary basin (wk). To the northeast, the Okhotsk-Chukotka arc completed activity. The final part of this arc is preserved in the Kamchatka-Koryak volcanic belt (kk). These two major Andean-type arcs overlapped previously accreted adjacent terranes in both the Russian Southeast and to the south. The arcs extended for a distance of about 3,000 km along the Russian Far East active continental margin. Associated with these arcs was subduction of part of the Pacific Ocean plate (PAC) along the Kuril-Kamchatka megathrust $(K\hat{K})$ to form the Kuril-Kamchatka (KUK) subduction zone terrane (Table 2). Intra-arc faulting resulted in tectonic doubling of the Kamchatka-Koryak (kk) arc, starting to become extinct, with respect to the Central Kamchatka arc (kc).

(2) In the southern Russian Far East, regional extension associated with back-arc spreading occurred behind the northern Japan part of the Northeast Asia arc (East Japan volcanic-plutonic belt (ej)), resulting in marine eruption of the Sea of Japan back-arc unit (sj) that consists of mainly tholeiitic basalt and associated rocks.

- (3) In the Sea of Okhotsk, regional extension associated with back-arc spreading occurred behind the Kuril Island and Kamchatka Peninsular parts of the Northeast Asia arc (B.A. Natal'in in Nokleberg and others, 1994a), resulting in marine and continental eruption of tholeitic to alkalic basalt and associated rocks forming Sakhalin-Primorye volcanic belt (sp). This regional extension is also interpreted as the result of seaward rotation of the Kamchatka Peninsula, and in formation major units within the Sea of Okhotsk (as discussed by B.A. Natal'in in Nokleberg and others, 1994a). Back-arc spreading may have occurred simultaneously with trench roll-back and migration of the Northeast Asia arc into the Pacific Ocean.
- (4) A major orthogonal junction occurs between the western end of Aleutian-Wrangell arc (al) and Kamchatka arc (kc). The western terminus of the arc is interpreted as having been obducted onto the Kamchatka Peninsula, thereby forming the Kamchatskiy Mys oceanic terrane (interpreted as the oceanic base of the ancestral Aleutian-Wrangell arc and the Stolbovskoy island arc terrane (interpreted as the older, western part of the arc (Geist and others, 1988 1994)
- (5) In the Arctic Ocean, rifting continued along the Gakkel Ridge (GK). Sedimentation continued in the Amerasia basin (as). Analysis of marine magnetic anomalies in the Eurasia Basin suggests that the Russian Northeast underwent compression from about 36-5 Ma (Savostin and Drachev, 1988; Harbert and others, 1990; Fujita and others, 1997). Geologic mapping reveals that late Miocene thrust faults and companion folds, that were associated with regional compress, occurred along the Myatis and companion faults in the Mona and Chersky Ranges (Gaiduk and others, 1989, 1993). Fault displacements are about 15 to 20 km.
- (6) In the Bering Sea, in the early to middle Miocene, a short episode (approximately 22 to 10 Ma) of sea-floor spreading along the Komandorsky Ridge (KM) formed a small pair of oceanic plates (exhibiting mainly magnetic anomalies 5 and 6). The spreading occurred after the marine arc volcanism that formed Bowers and Shirshov ridge in the middle Eocene and early Miocene (Figure 15).
- (7) From Western Alaska into Bering Sea, tectonic escape (crustal extrusion) of terranes continued to occur along major dextral-slip faults, including the Denali (DE), Nixon Fork (NF), Kaltag (KA), and companion faults (Scholl and others, 1992, 1994). Dextral-wrench basins continued to form in association with the dextral-slip faults and were rapidly filled with continental sediments. A thick sedimentary prism continued to form in the Aleutian-Bowers basin (atb) (Plafker and Berg, 1994).
- (8) In the northern Pacific Ocean, the Pacific Ocean plate (PAC) continued to move northwestward relative to North America. Along the Aleutian megathrust (AL) plate convergence continued to vary from oblique-orthogonal in the east to oblique to transform in the west.
- (9) Intense tectonic disruption occurred in the western part of Aleutian-Wrangell arc, along the western Aleutian megathrust (AL), as a result of the transform coupling between the Pacific and North American plates (Geist and others, 1988). In this area, a complex array of strike-slip, extension, and rotation structures formed (Scholl and others, 1992, 1994;

- Vallier and others, 1994). In the Bering Sea region, a thick sedimentary prism continued to form in the Aleutian-Bowers basin (atb) that overlies a fragment of accreted Kula Ocean plate (Plafker and Berg, 1994; Scholl and others, 1992, 1994).
- (10) In Southern and Central Alaska, displacement continued along major dextral-slip faults, such as the Denali (DF), Nixon Fork (NF), and Kaltag (KA) faults. Estimates of total Cenozoic displacements along the Denali and Tintina faults are between 400 and 500 km each (Nokleberg and others, 1985; Plafker and Berg, 1994; Monger and Nokleberg, 1996). These and companion dextral-slip faults probably extended into the Bering Sea.
- (11) Along the margin of Southern Alaska, the Aleutian-Wrangell continental margin arc continued activity. Associated with these arcs was mainly oblique subduction of the northern edge of Pacific Ocean plate (PAC) along the Aleutian megathrust (AL) to form the Prince William terrane (PW) (Table 2). During northward migration, the Yakutat terrane (YA) started to underthrust the Prince William terrane (PW) along the eastern part of the Aleutian megathrust (AL).
- (12) Offshore of the southern Canadian Cordillera, sea-floor spreading continued along the Juan de Fuca oceanic ridge (JF). Northward movement of the Pacific Ocean plate (PAC) and associated transform displacement on the Queen Charlotte-Fairweather transform fault resulted in continued northward migration and subduction of the Yakutat terrane beneath the margin of Eastern-Southern Alaska.
- (13) In the southern Canadian Cordillera and USA Pacific Northwest, the Cascade continental margin arc continued activity. Associated with this arc was subduction of part of the Juan de Fuca plate (JF) to form the Siletzia (SZ), Olympic Core (OC), and Hoh (HO) terranes (Table 2) along the ancestor of the modern Cascadia megathrust (CC). In the southern Canadian Cordillera and USA Pacific Northwest, regional extension, associated with back-arc spreading, occurred the behind Cascade arc (ca), resulting in continental eruption of the Columbia River basalt (cb) (Wells and Heller, 1988; England and Wells, 1991).

Summary of Paleolatitude Data for Miocene

Supporting paleolatitude data (Table 3) are: (1) a value of 71° (grade D) for unnamed volcanic rocks in overlying the Porcupine terrane in northeastern Alaska; and (2) values of 55-65° (grade C) for three igneous rock localities in the Cascade volcanic-plutonic belt (Mount Barr pluton, Caribou Plug, Caribou Lavas).

Pliocene through Present (4 to 0 Ma) (Figure 17)

During the Pliocene to the present (4 to 0 Ma), the major tectonic events were and are: (1) continuation of a series of continental margin arcs and companion subduction zone assemblages around the Circum-North Pacific (Table 2); (2) continued opening of major sedimentary basins behind major arcs; and (3) in the eastern part of the Circum-North Pacific, a continuation of dextral transpression between the Pacific Ocean plate and the Canadian Cordillera margin, and a continuation of oblique-orthogonal transpression between the Pacific plate and the Eastern-Southern Alaska continental margin; and (4) continued sea-floor spreading in the Arctic and eastern

Pacific Oceans. The modern geodynamic pattern is defined by interaction of the Eurasian, North American, and Pacific plates (Cook and others, 1986; Parfenov and others, 1988; Fujita and others, 1997). The pole of rotation between the Eurasian and North American plates is located on, or near the south coast of the Laptev sea in the Russian Northeast (Cook and others, 1986; Larson and others, 1997). The specific tectonic events are interpreted as follows.

- (1) In the Russian Far East, the Northeast Asia continental margin arc continues activity. Parts of the arc are being preserved in the East Japan volcanic-plutonic belt (ej), the Kuril arc (ku), and the Central Kamchatka volcanic and sedimentary basin (ck), and the East Kamchatka volcanic belt (ek). Associated with the arc is subduction of the western edge of the Pacific Ocean plate (PAC) along the Kuril-Kamchatka megathrust (KK) to form the Kuril-Kamchatka (KUK) terrane (Table 2). A major orthogonal junction occurs between the western end of Aleutian-Wrangell arc (al) and Kamchatka arc (kc).
- (2) In the Arctic Ocean, rifting continues along the Gakkel Ridge (GK) (northern extension of mid-Atlantic ridge) and the extension of the ridge into Russian Northeast. The Gakkel Ridge and extension defines the modern boundary between the North American and Eurasian plates. Analysis of sea-floor spreading anomalies in the Eurasia Basin suggests that the Russian Northeast underwent extension from about 5 to 0.5 Ma (Moma rift episode as discussed by Fujita and others, 1990, 1997) (Savostin and Drachev, 1988; Harbert and others, 1990; Fujita and others, 1997). The youngest change, a northward pole shift, occurred at about 0.5 Ma, as indicated by resurgent or continued thrusting (Imaev, 1991). Focal mechanism studies indicate that the Chersky Seismic Belt (CSB) and adjacent areas are undergoing compression (Cook and others, 1986; Parfenov and others, 1988; Fujita and others, 1990; Riegel and others, 1993). This compression is relieved by extrusion of the Okhotsk block to the southeast (Riegel and others, 1993), and by uplift and thrusting in the CSB area (Koz'min, 1984; Imaev and others, 1990; Koz'min and others, 1996). Sedimentation continues in the Amerasia basin (as).
- (3) In the Russian Far East, Bering Sea, and western Alaska, present-day seismicity defines several new tectonic blocks, including the Amur, Okhotsk, and Bering blocks (Riegel and others, 1993; Fujita and others, 1997; Mackey and others, 1997). Boundaries between blocks defined by epicenters located by teleseismic and regional networks (Fujita and others, 1997)
- (4) In the Russian Northeast, the Bering Sea, and Western Alaska, marine and continental eruption of sparse, generally small, highly dispersed flows of Bering Sea alkaline basalt (ba) occurred in the Quaternary and Recent. This volcanism may possibly be related to dextral-wrench faulting and tectonic escape in this region. Rotation of the Bering block creating extension on the Seward Peninsula and on Chukotka (Mackey and others, 1997), or less possibly, may have formed as the back-arc with respect to the Aleutian-Wrangell arc?
- (5) In Western Alaska and the eastern Bering Sea, tectonic escape (crustal extrusion) of terranes continues along major dextral-slip faults, including the Denali (DE), Nixon Fork (NF), Kaltag (KA), and companion

faults (Scholl and others, 1992, 1994). Dextral-wrench basins continue to form in association with the dextral-slip faults and are still filling with continental sediments. A thick sedimentary prism continues to form in the Aleutian-Bowers basin (atb) (Plafker and Berg, 1994). In Interior and Southern Alaska, displacement continues along major dextral-slip faults, such as the Denali (*DF*) and companion faults. These and similar dextral-slip faults may extend into the Bering Sea.

- (6) In the northern Pacific Ocean, the Pacific Ocean plate (PAC) continues to migrate northwestward relative to North America. Along the Aleutian megathrust (AL), plate convergence continues to vary from orthogonal in the east to oblique to transform in the west.
- (7) Intense tectonic disruption continues in the western part of Aleutian-Wrangell arc along the western Aleutian megathrust (AL), as a result of the transform coupling between the Pacific Ocean plate (PAC) and North American plate (Geist and others, 1988; Scholl and others, 1992, 1994). In the Bering Sea region, a thick sedimentary prism continues to form in the Aleutian-Bowers basin (atb) that overlies a fragment of accreted Kula Ocean plate (Plafker and Berg, 1994).
- (8) Along the margin of Southern Alaska, the Aleutian-Wrangell arc continues activity. Parts of the arc are being preserved in the Aleutian-Wrangell arc (al) and the Wrangell volcanic field arcs. Associated with the arc is mainly oblique subduction of the northern edge of Pacific Ocean plate along the Aleutian Megathrust (AL) to form the Prince William terrane (PW) (Table 2). The Yakutat terrane (YA) continues to migrate northwestward and continues to underthrust the Prince William terrane (PW) along the eastern part of the Aleutian megathrust (AL).
- (9) Offshore of the southern Canadian Cordillera, sea-floor spreading continues along the Juan de Fuca oceanic ridge (JF). Northward movement of the Pacific Ocean plate (PAC) continues with transform displacement on the Queen Charlotte-Fairweather transform fault.
- (10) In the southern Canadian Cordillera, the Cascade continental margin arc continues to form. Associated with the arc is subduction of part of the Juan de Fuca oceanic plate (JF) and formation of a subduction zone complex along the Cascadia megathrust (CC) (Table 2) (Goldfinger and others, 1996, 1997; Fleuh and others, 1997).

CONCLUSIONS

The Mesozoic and Cenozoic, and some of the Paleozoic evolution of the Circum-North Pacific can be explained as a succession of arcs and tectonically paired subduction zones that formed along the margins of the Northeast Asian and North American plates above the subducting oceanic lithosphere of mainly the Mongol-Okhotsk, Cache Creek, Ancestral Pacific, and Pacific Oceans. In both Northeast Asia and in the North American Cordillera, the arcs formed mostly near continental-margins as island arcs or along continental margins. The paleolocations of those arcs, with respect to Northeast Asia and North America, that occur oceanward of coeval accretionary complexes are highly suspect in the Paleozoic, but are successively less so in the Mesozoic. No compelling evidence exists to suppose

that most of these arcs migrated across ocean basins. Geological and faunal data and interpretations suggest formation mostly along the active margin of the Northeast Asian and North American plates. Some arcs formed at sites perhaps far removed from the continent, and were subsequently emplaced by Mesozoic lateral displacements and rotations. Possibly the only truly exotic rocks in the North American Cordillera tectonic collage are: (1) parts of accretionary complexes that are composed mainly of oceanic crustal material with a Tethyan fauna that is exotic with respect to North America; (2) those terranes in western Alaska (Nixon Fork-Dillinger-Mystic) that are interpreted as fragments of the North Asian Craton and Craton Margin; and (3) the Late Proterozoic and early Paleozoic part of the Alexander sequence of the Wrangellia superterrane.

The Phanerozoic tectonic evolution is most simply explained by a model that consists of six main themes: (1) rifting of the northeastern North Asian and northwestern North American Craton Margins; (2) formation of successions of single island arcs and tectonically paired subduction-zone complexes along or near the margins of the North Asian and North American craton margins, above subducting oceanic plates of the Ancestral Pacific and Pacific Oceans; (3) formation of a succession of continental margin arcs and tectonically paired subduction zones; (4) oblique accretion of arcs and companion subduction zone complexes onto the northeastern North Asian and northwestern North American craton margins, resulting in substantial continental growth of the North Asian and North American continents; (5) deposition of overlap assemblages, mainly derived from continental margin igneous arcs, onto previously accreted terranes; and (6) strike-slip translation of previously accreted arc-subduction zone complexes, overlap assemblages, and fragments of continental margins along the margins of the cratons.

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TABLE 1. Tectonic definitions. Definitions are modified from Coney and others (1980), Jones and others (1983), Howell and others (1985), Monger and Berg (1987), Wheeler and others (1988), Wheeler and McFeeley (1991), and Nokleberg and others (1994, 1997a, b). Note that tectonostratigraphic terrane, accretion, and overlap assemblage are defined in the above section on Key Concepts for Tectonic Analysis and Tectonic Environments.

Term	Definition
Accretion	Tectonic juxtaposition of two or more terranes, or tectonic juxtaposition of terranes to a craton margin. Accretion of terranes to one another or to a craton margin also defines a major change in the tectonic evolution of terranes and craton margins.
Accretionary wedge and subduction zone terrane	Fragment of a mildly to intensely deformed complex consisting of varying amounts of turbidite deposits, continental margin rocks, oceanic crust and overlying units, and oceanic mantle. Divided into units composed predominantly of turbidite deposits or predominantly of oceanic rocks. Units are interpreted to have formed during tectonically juxtaposition in a zone of major thrusting of one lithosphere plate beneath another, generally in zones of thrusting along the margin of a continental or an island arc. May include large fault-bounded units with a coherent stratigraphy. Many subduction zone terranes contain fragments of oceanic crust and associated rocks that exhibit a complex structural history, occur in a major thrust zone, and possess blueschist facies metamorphism.
Basinal deposits	An assemblage of sedimentary and lesser volcaniclastic and volcanic rocks that were deposited onto a single terrane after accretion, or onto a craton margin or craton after a major orogenic event. Includes some foreland and successor basin deposits, and forearc, intra-arc, and backarc deposits.
Collage of terranes	Groups of tectonostratigraphic terranes, generally in oceanic areas, for which insufficient data exist to separate units.
Craton	Chiefly regionally metamorphosed and deformed shield assemblages of Archean and Early Proterozoic sedimentary, volcanic, and plutonic rocks, and overlying platform successions of Late Proterozoic, Paleozoic, and local Mesozoic and Cenozoic sedimentary and lesser volcanic rocks.
Craton (conti- nental) margin	Chiefly Late Proterozoic through Jurassic sedimentary rocks deposited on a continental shelf or slope. Consists mainly of platform successions. Locally has, or may have had an Archean and Early Proterozoic cratonal basement.
Cratonal terrane	Fragment of a craton.
Continental- margin arc terrane	Fragment of an igneous belt of coeval plutonic and volcanic rocks and associated sedimentary rocks that formed above a subduction zone dipping beneath a continent. Inferred to possess a sialic basement.
Foreland basin	Trough or depression filled with clastic deposits that was deposited adjacent to an orogenic belt.
Island arc terrane	Fragment of an igneous belt of plutonic rocks, coeval volcanic rocks, and associated sedimentary rocks that formed above an oceanic subduction zone. Inferred to possess a simatic basement.
Metamorphic terrane	Fragment of a highly metamorphosed or deformed assemblage of sedimentary, volcanic, or plutonic rocks that cannot be assigned to a single tectonic environment because the original stratigraphy and structure are obscured. Includes intensely deformed structural melanges that contain intensely deformed fragments of two or more terranes.
Metamorphosed continental margin terrane	Fragment of a passive continental margin, in places moderately to highly metamorphosed and deformed, that cannot be linked with certainty to the nearby craton margin. May be derived either from a nearby craton margin or from a distant site.
Oceanic crust , seamount, and ophiolite terrane	Fragment of part or all of a suite of deep-marine sedimentary rocks, pillow basalt, gabbro, and ultramafic rocks (former eugeoclinal suite) that are interpreted as oceanic sedimentary and volcanic rocks and the upper mantle. Includes both inferred offshore oceanic and marginal ocean basin rocks, minor volcaniclastic rocks of magmatic arc derivation, and major marine volcanic accumulations formed at a hotspot, fracture zone, or spreading axis.
Overlap assemblage	A postaccretion unit of sedimentary or igneous rocks deposited on, or intruded into, two or more adjacent terranes.
Passive continental margin terrane	Fragment of a craton margin.
Postaccretion rock unit.	Suite of sedimentary, volcanic, or plutonic rocks that formed in the late history of a terrane, after accretion. May occur also on adjacent terranes or on the craton margin either as an overlap assemblage or as a basinal deposit. A relative-time term denoting rocks formed after tectonic juxtaposition of one terrane to an adjacent terrane.
Preaccretion rock unit.	Suite of sedimentary, volcanic, or plutonic rocks that formed in the early history of a terrane, before accretion. Constitutes the stratigraphy and igneous geology inherent to a terrane. A relative-time term denoting rocks formed before tectonic juxtaposition of one terrane to an adjacent terrane.
Seamount and oceanic plateau	Major marine volcanic accumulations generally formed at a hotspot, fracture zone, or spreading axis.
Subterrane.	Fault-bounded unit within a terrane that exhibits a similar but not identical geologic history relative to another fault bounded unit in the same terrane.

Superterrane	An aggregate of terranes that is interpreted to share either a similar stratigraphic kindred or affinity, or a common geologic history after accretion (Moore, 1992). An approximate synonym is <i>composite terrane</i> (Plafker, 1990).
Tectonostrati- graphic terrane	A fault-bounded geologic entity or fragment that is characterized by a distinctive geologic history that differs markedly from that of adjacent terranes (Jones and others, 1983; Howell and others, 1985).
Turbidite basin terrane.	Fragment of a basin filled with deep-marine clastic deposits in either an orogenic forearc or backarc setting. May include continental-slope and continental-rise turbidite deposits, and submarine-fan turbidite deposits deposited on oceanic crust. May include minor epiclastic and volcaniclastic deposits.

TABLE 2. Summary of correlations and tectonic linkages for the Circum-North Pacific. Refer to Appendix 1 for detailed descriptions and interpretations.

	NTINENTAL MARGIN AND REI EMBLAGES IN THE RUSSIAN :	
Unit(s) and Correlations. Age	Tectonic Environment(s)	Tectonic Linkages. Comments
Kabarga, Sergeevka, Kabarga, and Voznesenka terranes of Khanka superterrane. Late Proterozoic and Paleozoic	Passive continental margin	Derived from Gondwanaland supercontinent during Devonian rifting and formation of bimodal volcanic rocks. Contain Late Paleozoic continental margin arc.
Argun and Gonzha terranes. Archean and Paleozoic	Cratonal	Derived from North Asian Craton during Late Proterozoic rifting Dismembered parts of the Altain orogenic system
Oldoi and Mamyn terranes. Proterozoic to middle Paleozoic	Passive continental margin	Derived from North Asian Crator Margin duirng Late Proterozoic rifting; dismembered part of the Altaid orogenic system
Baladek terrane. Archean, Paleozoic, Early Mesozoic	Cratonal	Derived from North Asian Craton during Late Proterozoic rifting.
Ayansk terrane. Paleozoic	Passive continental margin	Derived from North Asian Craton Margin during Late Devonian rifting
Bureya terrane Early Paleozoic and older	Continental-margin arc	Rifted fragment of North China Craton. Dismembered part of Manchurid orogenic system.
LAOELIN-GRODEKO	OVO ISLAND ARC IN THE RUS	
Laoelin-Grodekovo terrane, various back-arc units within Khanka superterrane, and Chongjin terrane (Japan). Permian	Island arc	Formed adjacent to Khanka superterrane.
Spassk terrane of Khanka superterrane. Early and middle Paleozoic	Accretionary wedge	Linked to Laoelin-Grodekovo terrane.
CRATONAL AND PASSIVE AND IN THE RUSSIAN NORT	METAMORPHOSED CONTIN THEAST, ALASKA, AND CANA	
Chukotka terrane, Arctic Alaska superterrane, Cassiar terrane. Proterozoic, Paleozoic, and early Mesozoic	Passive continental margin	Dismembered parts of North American Craton Margin.
Seward terrane (both sides of Bering Straits) Coldfoot, and Ruby terranes. Early and middle Paleozoic (mainly)	Metamorphosed continental margin	Highly metamorphosed and deformed fragments of North American Craton Margin. Contain Late Devonian and Early Mississippian continental- margin arc rocks.
Yukon-Tanana and Kootenay terranes. Paleozoic	Metamorphosed continental margin	Highly metamorphosed and deformed rifted fragments of North American Craton Margin. Contain Late Devonian and Early Mississippian continental-margin arc rocks.
Dillinger, Kular-Nera, Nixon Fork, Prikolyma, Omulevka, Mystic, and Viliga terranes. Paleozoic and early Mesozoic	Passive continental margin	Dismembered fragments of North Asiar Craton Margin (Verkhoyansk fold and thrust belt). Late Devonian and Early Mississippian rifting.
Kilbuck-Idono, Okhotsk, and Omolon terranes. Late Archean, Proterozoic, and Early Paleozoic	Cratonal	Dismembered fragment of North Asian Craton. Late Devonian and Early Mississippian rifting.

Unit(s) and Correlations. Age	Tectonic Environment(s)	Tectonic Linkages. Comments
TRIASSIC TO MID-CRETACEO AND OVERLAP ASSEMBLAGES, AND LI	INKED SUBDUCTION ZONE TER	
Monakin volcanic-pluotnic belt, granitic plutonic rocks of Korea, and volcanic-plutonic belt of Southeast China. Jurassic	Igneous overlap assemblage	Discontinuous parts of Great Hinggan arc.
Badzhal, Khabarovsk, and Samarka terranes. (Also Taukha, and Oshima terranes) Paleozoic to Cretaceous	Accretionary wedge	Linked to Monakin continental margin arc. Also linked to Umlekan arc (below). Remnants of subduction of Ancestral Pacific Ocean. Taukha, and Oshima terranes linked to coeval granitic plutonic rocks of Korea, and volcanic-plutonic belt of Southeast China.
U	mlekan Continental Margin Arc	
Umlekan-Ogodzhin volcanic-plutonic belt. Jurassic and Early Cretaceous	Igneous overlap assemblage	Northern extension of Monakin arc.
Badzhal, Khabarovsk (older Jurassic part), and Samarka terranes. Paleozoic to Cretaceous	Accretionary wedge	Linked to Umelkan arc and to Monakin arc (above). Remnants of subduction of Ancestral Pacific Ocean plate.
	hingan Continental Margin Arc	
Khingan-Okhotsk volcanic-plutonic belt. Early and mid-Cretaceous	Continental margin arc	Formed after collision of Anui microcontinent with Samarka terrane
Amur River, Khabarovsk, and Kiselevka- Manoma terranes. Jurassic and Early Cretaceous	Accretionary wedge	Linked to Khingan continental margin arc. Remnants of subduction of Ancestral Pacific Ocean plate.
	Kema Continental Margin Arc	
Kema terrane, and Early to mid-Cretaceous volcanic rocks of Hokkaido Island. Mid Cretaceous	Igneous overlap assemblage	Transpressive continental margine arc analogus to Tertiary margin of California.
Aniva and Kamuikotan terranes. Cretaceous	Transpressional subduction zone	Linked to Kema arc. Remnants of subduction of Ancestral Pacific Ocean plate.
	Uda Continental Margin Arc	
Uda volcanic-plutonic belt, Uniya-Bom turbidite basin terrane, Umlekan-Ogodzhin volcanic-plutonic belt, and Upper Amur sedimentary assemblage. Late Jurassic and Early Cretaceous	Igneous overlap assemblage	Deposited on, adjacent to, and intruded into the North Asian Craton and Stanovoy block of the North Asian Craton.
Tukuringra-Dzhagdinsk, Galam, and Ulban terranes. Paleozoic	Subduction zone or accretionary wedge	Linked to Uda arc. Remnants of subduction of Mongol-Okhotsk Ocean plate.
	Kony-Murgal Island Arc	
Kony-Murgal terrane. Late Triassic to Early Cretaceous	Continental margin and island arc	
Talovskiy and Penzhina-Anadyr terranes. Mainly Jurassic and Early Cretaceous	Subduction zone and accretionary wedge	Linked to Kony-Murgal arc. Remnants of subduction of Ancestral Pacific Ocean plate.
	Pekul'ney Island Arc	T
West Pekul'ney terrane. Late Triassic to Early Cretaceous	Island arc	
Pekulney terrane. Mainly Jurassic and Early Cretaceous	Subduction zone	Linked to Pekul'ney arc. Remnants of subduction of Ancestral Pacific Ocean plate.

Unit(s) and Correlations. Age	Tectonic Environment(s)	Tectonic Linkages. Comments
	Mainitskiy island arc	
Mainitskiy terrane. Late Jurassic to mid-Cretaceous	Island arc	
Alkatvaam. Late Triassic to Paleocene	Accretionary wedge	Linked to Mainitskiy arc. Remnants of subduction of Ancestral Pacific Ocean plate.
	Uyandina Island Arc	
Uyandina-Yasachnaya volcanic belt. Late Jurassic	Island arc	
Garbyn'ya and Debin ophiolite. Unknown	Ophiolite	Linked to Uyandina arc. Remnants of subduction of Oimyakon Ocean plate
	Oloy and Svyatoy Nos Arcs	
Oloy and and Svyatoy Nos Arcs volcanic belts. Late Jurassic	Continental margin arc	
South Anyui terrane	Subduction zone	Linked to Oloy and Svyatoy arcs. Remnants of subduction of South Anyui Ocean plate.
	Alazeya Island Arc	
Alazeya, Khetachan, and Oloy terranes. Late Paleozoic to Early Jurassic	Island arc	
Aluchin terrane	Subduction zone	Linked to Alazeya arc. Remnant of subduction of Ancestral Pacific Ocean plate.
N	utesyn Continental Margin Arc	
Nutesyn terranes. Mainly Late Jurassic to Early Cretaceous	Continental margin arc	
Velmay terrane. Upper Triassic	Subduction zone	Linked to Nutesyn arc. Remnant of subduction of Angayucham Ocean plate.
	Koyukuk Island Arc	
Koyukuk, Nyac, and Togiak terranes. Mainly Late Jurassic to Early Cretaceous	Island arc	
Angayucham and Goodnews terranes. Devonian to Early Jurassic	Subduction zone	Linked to Koyukuk arc. Remnant of subduction of Angayucham Ocean plate.
	Gravina Island Arc	
Kahiltna sedimentary and volcanic assemblage; Gravina-Nutzotin-Gambier volcanic-plutonic-sedimentary belt; Cadwaller, Methow, Izee, and Wallowa island arc and turbidite basin terranes; Spences Bridge volcanic-plutonic belt; Tahtsa-Twin Sisters-Francois Lake magmatic assemblage. Juassic to mid-Cretaceous with minor Triassic units	Island arc and turbidite basin	
Chugach (younger part, Valdez Group), Pacific Rim, Bridge River, and Baker terranes. Jurassic to Late Cretaceous	Accretionary wedge and subduction zone	Linked to Gravina arc. Remnants of subduction of Cache Creek Ocean plate.

Unit(s) and Correlations. Age	Tectonic Environment(s)	Tectonic Linkages. Comments
	Talkeetna-Bonanza Island Arc	
Peninsular sequence of Wrangellia supterterrane (Talkeetna Formation) in	Island arc	
Alaska; Bonanza Formation and Cadwallader island are and Methow turbidite basin terranes in Canadian Cordillera.		
Late Triassic and Early Jurassic		
Chugach (older part, blueschist and McHugh Complex), Bridge River, and Baker terranes.	Accretionary wedge and subduction zone	Linked to Talkeetna-Bonanza arc. Remnants of subduction of Cache Creek Ocean plate.
Paleozoic, Triassic, and Early Jurassic.		
	Stikinia-Quesnellia Island Arc	
Stikinia and Quesnellia terranes. Permian to Early Jurassic	Island arc	
Cache Creek, Slide Mountain, and Seventymile terranes. Paleozoic and Mesozoic	Subduction zone and accretionary wedge	Linked to Stikinia-Quesnellia arc. Remnants of subduction of Cache Creek Ocean plate.
LATE CRETACEOUS AND EARLY CENC	DZOIC CONTINENTAL MARGIN SUBDUCTION ZONES	ARCS, ISLAND ARCS, AND LINKED
	lin Continental Margin Arc (Late C	retaceous)
East Sikhote-Alin volcanic-plutonic belt, Sorachi-Yezo, West Sakhalin terrane. Cretaceous and early Tertiary	Igneous overlap assemblage	
Hidaka accretionary wedge, younger part of the Aniva, Nabilsky, and Tokoro terranes. Permian to Cretaceous	Accretionary wedge and subduction zone	Linked to East Sikhote-Alin arc. Remnants of subduction of Ancestral Pacific Ocean plate.
Okhots	sk-Chukotka Continental Margin A	
Okhotsk-Chukotka volcanic-plutonic belt and Penzhina sedimentary basin. Cretaceous and early Tertiary	Igneous overlap assemblage	
West-Kamchatka, Ekonay, and Yanranay terranes. Upper Paleozoic, Jurassic and Early Cretaceous	Accretionary wedge	Linked to Okhotsk-Chukotka arc. Remnants of subduction of Ancestral Pacific Ocean plate.
Cictaccous	Olyutorka Island Arc	
Olyutorka-Kamchatka, Iruneiskiy, Kronotskiy, Shmidt, Terpeniya, and Nemuro terranes. Late Cretaceous and Early Tertiary	Island arc	
Vetlovskiy terrane. Late Cretaceous and early Tertiary	Accretionary wedge	Linked to Olyutorka arc. Remnants of subduction of Ancestral Pacific Ocean plate.
	oast North Cascade Continental Ma	rgin Arcs
Kuskokwim Mountains sedimentary, volcanic, and plutonic belt, Alaska Range-Talkeetna Mountains volcanic-plutonic belt, Coast- North Cascade plutonic belt, and Kamloops magmatic belt. Late Cretaceous and early Tertiary	Igneous overlap assemblage	
Chugach terrane (the Late Cretaceous Valdez Group), older part of the Prince William terrane, and Pacific Rim terrane. Late Cretaceous and early Tertiary	Accretionary-wedge and subduction zone	Linked to Kluane and Coast North Cascade arcs. Remnants of subduction of Pacific Ocean plate.

Unit(s) and Correlations. Age	Tectonic Environment(s)	Tectonic Linkages. Comments
AVANA NA	CENOZOIC CONTINENTAL MARG	IN ADOC AND

	CENOZOIC CONTINENTAL MA	RGIN ARCS AND
	INKED SUBDUCTION ZONES	
	heast Asia Continental Margin Arc	
East Japan volcanic-plutonic belt, Central	Igneous overlap assemblages	
Kamchatka volcanic belt, Central		
Kamchatka volcanic and sedimentary basin,		
East Kamchatka volcanic belt, Eastern		
Sakhalin sedimentary basin, and the West		
Kamchatka sedimentary basin.		
Early Eocene to Miocene to Present		
Kuril-Kamchatka terrane.	Accretionary wedge and	Linked to Northeast Asia arc. Remnan
Miocene to Present	subduction zone	of subduction of Pacific Ocean plate
Sea of Japan unit, Sakhalin-Primorye volcanic	Back-arc units	Linked to Northeast Asia arc.
belt, and Kuril unit.		
Oligocene to Miocene		
Aleutia	n-Wrangell Continental Margin A	re
Aleutian volcanic belt, and Wrangell volcanic	Igneous overlap assemblages	
field.	•	
Early Eocene to Miocene to Present		
Attu Island part of Prince William terrane and	Accretionary wedge	Linked to Aleutian-Wrangell arc.
Yakutat terrane.		Remnants of subduction of Pacific
Early Teriary to Present		Ocean plate.
C	ascade Continental Margin Arc	
Cascade volcanic-plutonic belt.	Igneous overlap assemblage	
Eocene to Present		
Siletzia, Olympic Core, and Hoh terranes, and	Subduction zone and accretionary	Linked to Cascade arc. Remnants of
modern-day subduction zone.	wedge	subduction of Juan de Fuca plate.
Eocene to Present.		
Columbia River Basalt Group.	Back-arc unit	Linked to Cascade arc.
Miocene .		

TABLE 3. Paleomagnetic data for the Russian Far East, Alaska, and the Canadian Cordillera. Adapted from global paleomagnetic data base by Lock and McElhinny (1991) combined with an independent literature search. Data for Russian Northeast from compilations of Khramov (1971, 1979, 1986a, b). Longitudes are stated in 360° values, starting at 0° and increasing eastward.

circular distributions, or by the axes of an elliptical distribution, dp, dm. Rank is the evaluation of paleomagnetic data between a grade of A (very good) and D (marginal). Refer to text for additional explanation of evaluation procedure. Explanation of Headings: Number of sites is number of samples, or means of samples that have been combined for a given locality. Paleolatitude is the latitude of the location determined from the inclination of the ancient magnetic field with respect to ancient horizontal, and assumes that the recorded field represents a mean geocentric dipole that would produce the magnetization observed in the rocks. The 95% error bars, indicating scatter of the data points, are represented by a95 for axial dipole. +dl and -dl are the 95% error bars associated with the observed scatter in the data. For paleopoles, latitude and longitude are the location of the axis of a

atb, Aleutian-Bowers sedimentary basin, Amlia Island	Same	Healy Quadrangle	Talkeetna Mountains	Same	at, Alaska Range - Talkeetna Mountains volcanic-plutonic belt, Matanuska Valley	al, Aleutian volcanic belt, Medny Island, Komandorski Islands	Map unit, OVERLAP ASSEMBLAGE, Geographic area	PALEOMAGNETIC DATA FOR MISCELLANEOUS OVERLAP ASSEMBLAGES IN RUSSIAN FAR EAST, ALASKA, AND CANADIAN CORDILLERA
Unnamed sedimentary rocks	Cantwell Formation	Cantwell Formation	Talkeetna Volcanics	Unnamed unit	Talkeetna Volcanics	Unnamed SedimentaryUnit	ROCK UNIT	DATA FOR MISCE
52.1	63.5	63.5	62.5	61.6	61.9	54.8	LAT	LLANE
186.5	211	211	211	211.7	211.5	167.6	LONG	NO SUO
40	Paleocene	Paleocene	54-50	42	Eocene	Paleo- cene?	AGE	ERLAP AS
9	16	18	25	14	28	40	NUMBE R OF SITES	SEMBLA
58.6	61.8	70.6	61.8	52.5	68.8	37	PALEOI -dl	GES IN R
68.8	70.6	80.1	74.3	61.8	78.1	43.2	LATITUDE LAT +dl	USSIAN
80.1	80.1	90.0	88.0	72.4	88.0	50.6	T T	FAR E
64	80	70	70	73	66	41.4	LA	AST, AL
229	172	195	180	281	188	238.1	PALEOPOLE T LONG dp a95, dm	ASKA, A
15	9.6	9.9	12	9	∞	%	OPOLE LONG 95, dm	ND CA
	9.2	9.8				6.9	a95,	NADIA
Stone and others, 1983; Harbert and others, 1984; Harbert, 1987	Panuska and Macicak, 1986	Hillhouse and Gromme, 1982	Hillhouse and others, 1984, 1985	Stamatakos and others, 1987, 1988	Panuska and Stone, 1985; 1990	Bazhenov and Burtman, 1996; Bazhenov and others, 1992	REFERENCE RANK	N CORDILLER
>	В	В	A	C	>		RANK	A

cn, Coast-North Cascade plutonic and related rocks overlying Alexander Terrane (AX), Wrangellia superterrane	Same	Same	cn, Coast-North Cascade plutonic and related rocks overlying Quesnellia terrane (QN), Southern British Columbia	cm, Carmacks volcanic field, Southern Yukon Territory	Same	ca, Cascade volcanic- plutonic belt overlying Quesnellia terrane (QN), Southern British Columbia	Same	ca, Cascade volcanic- plutonic belt overlying Methow (MT) & Bridge River (BR) terranes, Southern British Columbia	Axelgold pluton intruding Cache Creek terrane (CC), North-Central British Columbia	Same, Umnak Island	Map unit, OVERLAP ASSEMBLAGE, Geographic area
Quotton pluton mean (N + S)	Summit stock	Skelly Creek Batholith.	Kelowna Volcanics	Carmacks Group	Caribou Lavas	Caribou Plug	Hope pluton	Mt. Barr pluton	Axelgold intrusion	Unnamed sedimentary rocks	ROCK UNIT
53.3	49.1	49.3	49.9	61	51	51.5	49.1	49.1	56.2	53	LAT
231	242.9	243.5	240.3	225	239	239	238.5	238.5	233.9	191	LONG
44	104	95	52	70	Miocene	Miocene	38	18	125	38	AGE
∞	9	13	28	18	49	17	5	O,	67	29	NUMBER OF SITES
53.9	55.4	51.1	44.5	48.3	52.5	51.1	45.7	42.1	45.7	51.1	PA -dl
65.2	60.2	60.2	52.5	55.4	57.0	55.4	51.1	61.8	52.5	57.0	PALEOLATITUDE 31 LAT +d
78.1	65.2	70.6	61.8	63.5	61.8	60.2	57.0	88.0	60.2	63.5	ITUDE +dl
78	64	78	84	82	84	85	%	72	76	73	LAT
225	194	216	184	109	220	213	208	274	327	234	PALEOPOLE LONG a95, dm
15	5	10	10	∞	Ŋ	տ	6	15	∞	6	1 1
14			9		S	5	Ŋ	13	7		a95, dp
Symons, 1977a	Irving and Archibald, 1990	Irving and Archibald, 1990	Bardous and Irving, 1989	Marquis and Globerman, 1987	Symons, 1969a, b	Symons, 1969b	Symons, 1973b	Symons, 1973b	Monger and Irving, 1980	Stone and others, 1983; Harbert and others, 1984; Harbert, 1987	REFERENCE
C	С	C	A	>	≻	· O	С	C	В	A	RANK

Map unit, OVERLAP ASSEMBLAGE, Geographic area	Same Buted	ek, East Kamchatka volcanic belt overlying Kronotskiy terrane (KRO), Kamchatka Peninsula	ek, East Kamchatka volcanic belt overlying Vetlovskiy terrane (VT), East Kamchatka	gg, Gravina-Nutzotin- Duke Isli Gambier overlap ultramafi assemblage, Duke Island, complex Southeastern Alaska	ia, Interior Alaska volcanic Basalt belt, Yukon Koyukuk basin Melozitna Quadrangle	Same, Unalakleet Basalt Quadrangle	Same Felsic rocks	Same, Yukon-Koyukuk Eocer basin rocks	Same Same	ia, Interior Alaska volcanic Fairl belt, Yukon-Tanana Upland	ka, Kamloops volcanic belt Kam	Unnamed flows overlying Unn
ROCK UNIT	Butedale pluton mean			Duke Island ultramafic complex	i t	ilt	Felsic volcanics rocks	Eocene volcanic rocks	G	Fairbanks Basalt	Kamloops Group	Unnamed flows
LAT	53.3	54.8	55	54.9	65.8	63	63.8	65	65	64.8	51	60.3
LONG	231	162.1	161	228.7	205	200	200.7	203	203	211.5	238.7	205.3
AGE	67	Eocene	Miocene	110	43	51	51-52	55-43	55-43	53	49	44
NUMBER OF SITES	4	42	47	∞	∞	10	33	4	48		24	13
PAL -dl	31.7	31	38.7	27.1	55.4	32.6	58.6	44.5	-3.0	52.5	48.4	51.1
PALEOLATITUDE -dl LAT +d	43.2	39.8	47.0	36.2	74.3	57.0	70.6	78.1	0.0	67.0	58.6	61.8
TUDE +dl	58.6	50.9	57.0	47.9	90	86.0	84.0	90	3.0 ·	84.0	70.4	74.3
LAT	78	53.9	75	68	54	53	69	79	75	60	81	60
PALEOPOLE LONG a95, dm	94.1	68.7	47	33.5	225	263	153	156	186	163	222	149
i i	17	13.3	11.3		22	35	13	38	10	16.9	12.3	12
a95, dp	13	9.9	9.1		21	13	13			15.9	=	
REFERENCE	Symons, 1977a	Bazhenov and others, 1992	Ivanov and others, 1977	Bogue and others, 1995	Harris, 1985	Harris, 1985	Harris, 1985	Harris, 1985; Harris and others, 1986	Harris, 1985; Harris and others, 1986	Roe and Stone, 1993	Symons and Wellings, 1989	Thrupp and Coe, 1986
RANK	С	A	D	В	D	A	A	С	A	A	>	>

Map unit, OVERLAP ASSEMBLAGE, Geographic area	ROCK UNIT	LAT	LONG	AGE	NUMBER OF SITES	PAI	PALEOLATITUDE 31 LAT +d	TUDE +dl	LAT	PALEOPOLE LONG		a95, dp	REFERENCE	RANK
kc, Central Kamchatka volcanic belt overlying Olutorka subterrane (OKO), Olyutorka- Kamchatka terrane, Ilpinskii Peninsula		59.7	165	Eocene	105	48.6	53.9	59.8	81	91	6.5	5.6	Kovalenko, 1992	Α
Same, Malinovskii arca		60.5	167.5	Eocene	113	57.3	65.2	73.9	85	153	8.9	∞ .3	Kovalenko, 1992	Α
Same, Karaginskii Island		59	164	Eocene	37	39.2	51.1	66.1	79	32	15.9	13.4	Kovalenko, 1992	Α
km, Kuskokwim Mountains sedimentary, volcanic, & plutonic belt, Bering Sea region St. Matthew Island	Unnamed volcanic rocks	60.5	187	79	38	58.6	67.0	76.2	80	235	10		Wittbrodt, 1985; Wittbrodt and others, 1989	В
km, Kuskokwim Mountains sedimentary, volcanic, & plutonic belt overlying Togiak terrane (TG), Hagemeister Island	Bristol Bay Volcanics	58.8	199.5	68	74	58.6	63.5	68.8	65	147	Q		Globerman and Coe, 1983, Coe and others, 1985	A
io, Indigirka-Oloy sedimentary-volcanic- plutonic assemblage overlying Omolon terrane (OM), Russian Northeast	Sufoi zone	64.5	155.5	Late Jurassic	∞	27	39	51	21	116	=		Bondenko and Didenko, 1997	>
Unnamed volcanic rocks overlying Porcupine terrane (PC), Porcupine River area	Unnamed volcanic rocks	67.2	218	16	17		71.0		86	201			Plumley and Vance, 1988	D
oc, Okhotsk-Chukotka volcanic-plutonic belt overlying VL, Viliga terrane, Yana-Kolyma Fold Belt		61.8	156	Creta- ceous	24	76.2	88.0	90.0	60	155	12	12	Pechersky 1970	С
sb, Spences Bridge volcanic-plutonic belt, overlying Quesnellia terrane, southern Canadian Cordillera	Spences Bridge Group	49.9	239	100	17	39.3	45.7	53.1	64	321	7.5		Irving and Thorkelson, 1990	>
Same	Spences Bridge Group and Spius Volcanics	50	239	104	47	48.3	52.5	57					Irving and others, 1995	×

area ·	ASSEMBLAGE, Geographic	Map unit, OVERLAP
		ROCK UNIT
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PALEOMAGNETIC DATA FOR MISCELLANEOUS LATE CRETACEOUS AND TERTIARY SEDIMENT WRANGELLIA SUPERTERRANE	DATA FOR MISCE	LLANE	OUS LA	TE CRETACEOUS AND TERTIARY WRANGELLIA SUPERTERRANE	EOUS A	ND TER	TIARYS	EDIME	NTARY	AND VO	LCANI	CROC	TARY AND VOLCANIC ROCKS OVERLYING	(,)
Volcanic and plutonic units overlying or intruding Alexander sequence (AX), Wrangellia superterrane, Keku Strait (too small to depict on Figure 4)	Point Camden gabbro (Kuiu- Etolin belt)	56.9	226.2	23	20	44.5	53.9	65.2	87	142	10		Haeussler and others, 1992	C
Czs, Sedimentary units overlying Peninsular sequence (PE), Wrangellia superterrane, Matanuska Valley	Chickaloon	61.8	211.5	55	60	44.5	53.9	65.2	50	277	12	∞	Stamatakos and others, 1986, 1989	≯
Same	Akrose Ridge	61.8	211.5	55	42	45.7	55.4	67.0	60	139	12	6	Stamatakos and others, 1986, 1989	>
ca, Cascade volcanic- plutonic belt overlying or intruding WR, Wrangellia sequence, Wrangellia superterrane, Vancouver Island	Flores Volcanics	49	234.5	51	12	43.2	52.5	63.5	81	188	10		Irving and Brandon, 1990	>
Same	East Sooke gabbro	48.4	227.5	Paleocene	29	40.9	45.7	51.1	69	151	7	5	Symons, 1973d	C
Same, Queen Charlotte Island	Masset Formation	53.6	227.5	Paleocene	52	57.0	67.0	78.1	72	263	Ξ		Hicken and Irving, 1977;	>
Brothers Volcanics overlying Gravina- Nutzotin-Gambier overlap assemblage (gg) overlying Wrangellia sequence, Wrangellia superterrane, West Brothers Island, Southeastern Alaska (too small to depict on Fig. 4)	Brothers Volcanics	57.3	226.1	76	7	4.5	8.2	12.0	9	314	v		Panuska and others, 1984	В

PALEOMAGNETIC DATA FOR PRE-ACCRETIONARY UNITS IN TERRANES IN RUSSIAN FAR EAS	DAIA FUK PKE-/	ACCKE I	IONAK	L CNITS IN	LEKKA	NES IN K	USSIAN	FAK EA	1,	ASKA, A	ND CAN	ALASKA, AND CANADIAN CURDILLERA	
AA, North Slope Subterrane, Arctic Alaska	Nanushuk Group 68.8	68.8	197	Creta-	98	67.0	67.0 74.3 82.0	82.0	76	149	8.5	Witte, 1982;	В
terrane, Same, Utukok River	7											others, 1987	
Quadrangle					•								

MT, Methow terrane, Mt. Tatlow, Southern Canadian Cordilllera	MY, Mainitskiy terrane	Same, Nulato Quadrangle	Same	KY, Koyukuk terrane, Melozitna Quadrangle	KT, Khetachan terrane, Kolyma-Omolon superterrane, Oloy Depression	KS, Kamchatskiy Mys terrane, Northeast Kamchatka Peninsula (too small to depict on Figure 1; refer to text for discussion)	Same, Ekonay area	Same, Ryelyavaamski area	EK, Ekonay terrane, Khatyrka overlap	AV, Alkatvaam Terrane, Ugol'Naya Gulf	Same, Kuparuk River Field	Map unit, OVERLAP ASSEMBLAGE, Geographic area
Powell Creek Volcanics and Silverquick Formation.		Fluvial-deltaic sedimentary rocks	Cretaceous sedimentary rocks.	Unnamed unit		Kamchatskii Mys		ophiolite		Koryak and Barykovo Group	Kuparuk River Formation	ROCK UNIT
51.3	63.2	64.4	65	66	67	56.2	62.5	62.4	62.5	63	70.4	LAT
123.8	175.3	202	205	206	163.5	163.5	174.5	174.8	174.4	179.5	210.2	LONG
85	Late Jurassic - Early Creta- ceous	Mid- Creta- ceous	Mid- Creta- ceous	Early Creta- ceous	Creta- ceous	Paleocene	Late Triassic	Late Jurassic - Early Creta- ceous	Creta- ceous	Late Cretaceou s	Early Creta- ceous	AGE
	O	116	139	147	69	76	<i>ۍ</i>	O.	5	158	89	NUMBER OF SITES
31.9	21	58.6	55.4	60.2	42	34.5	16	18	63	52	63.5	PA -dl
37.4	31.7	67.0	61.8	68.8	76.2	38.7	24.2	22.0	76.2	74.3	68.8	PALEOLATITUDE di LAT +d
43.7	47.0	76.2	68.8	78.1	90.0	43.2	34.8	26.9	90.0	90.0	74.3	ITUDE +dl
356	6.7	84	77	60	58	62.5	-2.3	38	76	57	49	LAT
26.3	153.5	141	112	159	140	279.6	168.1	236	179	149	214	PALEOPOLE LONG a95, dm
	6.2	9.4	6	9.5	43.1	4.5	6.2	4.1	13.4	25.3	S	1 1
	29	9		9	42.1	0	23	22	76	24.6		a95, dp
Wynne and others, 1995	Didenko and others, 1993	Harris, 1985	Harris, 1985; Harris and others, 1986	Hillhouse and Gromme, 1988	Perchersky, 1973	Pechersky and Shapiro, 1996	Didenko and others, 1993	Didenko and others, 1993	Didenko and others, 1993	Perchersky, 1970	Halgedahl and Jarrad, 1987	REFERENCE
>	>	>	>	A	C	>	≯	>	A	C	×	RANK

Map unit, OVERLAP ASSEMBLAGE, Geographic area	ROCK UNIT	LAT	LONG	AGE	NUMBER OF SITES	-dl	PALEOLATITUDE 31 LAT +d	TUDE +dl	LAT	PALEOPOLE LONG a95, dm		a95, dp	REFERENCE	RANK
NE, Nemuro terrane, Shikotan Island	Kuril Formation	43.8	146.8	Creta- ceous/Pal- eocene	53	33	36.5	40.0	69	46	4.6	ω ü	Bazhenov and Burtman, 1996	>
Same, Shikotan Island	Shikotan Island	43.9	147	Creta- ceous	٠,	13	28.2	53.9	50	48	30	19	Bazhenov and Burtman, 1996	≻
Same	Nemuro Penin.	43	146	Creta- ceous	35	31.1	36.5	42.9	74	37	6	9	Fujiwara, 1974	В
NSV, North Asian Craton Margin, Verkhoyansk fold belt, West Verkhoyansk area	Bedidzhan Group	64	130	Middle & Upper Triassic	64	40	57.0	80.1	35	152	22.9	20.2	Slautsitais, 1971	С
Same	Tagandzhinsk & Up Keltersk Groups	65.5	128	Early Triassic	82	52	78.1	90.0	60	151	29.5	29	Slautsitais, 1971	С
NX, Nixon Fork terrane, Medfra Quadrangle	Telsitna Formation	63.9	205.5	Middle & Late Ordo- vician	14	16.7	22.8	29.9	46	65	10		Plumley, 1984	>
NX, Nixon Fork terrane, Medfra Quadrangle	Novi Mt. Formation	63.9	205.5	Early Ordo- vician	19	31.7	36.5	42.1	60	63	7		Plumley, 1984	>
OK, Okhotsk terrane, Okhotsky massif	Dorbinskaya St.	61.5	142.8	Permian- Triassic	53	24.4	27.1	30.1	7	100	4.4	2.8	Pavlov, 1993	В
OKA, Olyutorka- Kamchatka terrane, Koryak Highlands	Koryakia Sediments	61	170.5	Creta- ceous- Paleocene	15	41	55.4	74.3	69.1	82.7	19.2	16.7	Savostin and Kheyfets, 1989	ಹ
Same, Machevna Bay		60.8	171.6	Latest Creta- ceous-	16	36.7	49.0	65.0	73	47	17	14	Heiphitz and others, 1994	C
Same, Apuka River		61.5	170.5	Late Creta- ceous	15	4	55.1	73.5	69	80	19	16	Heiphitz and others, 1994	A
Same, Javevyn Bay		60.2	170.4	Late Creta- ceous	17	22.5	32.0	44.5	41	75	16	=	Heiphitz and others, 1994	ಹ
Same, Olytorskii Ridge		61	171	Early Creta- ceous		-73.5	55.1	73.5	69.1	82.2	18.8	16.3	Kovalenko, 1992	В
Same, Koryak Highlands	Govena zone	60.9	168.2	Eocene	63	53.9	60.2	67.0	8 4	76	7	7	Kovalenko, 1996	Α

Map unit, OVERLAP ASSEMBLAGE, Geographic	ROCK UNIT	LAT	LONG	AGE	NUMBER	PA	PALEOLATITUDE	HUDE	- 1	PALEOPOLE	1		REFERENCE	RANK
area					OFSITES	ف ا	LAT	<u></u>	LAT	a95, dm	1	a95, dp		
Same, Koryak Highlands	Tavlovka River	61.5	165.4	Late Creta- ceous	G	75.4	81.3	87.2	58	259	16.6	21.7	Alexsyutin and Shipunov, 1997	С
OLE, Eropol subterrane, Oloy terrane, Kolyma- Omolon superterrane, Umkuvevem depression		65	166	Early Creta- ceous	110	80	88.0	90.0	67	168	∞	œ	Perchersky, 1970	С
OM, Omolon terrane, Kolyma-Omolon superterrane, Omolon Massif		63	159.5	Late Creta- ceous	4	54	76.2	90.0	50	171	25.4	24.9	Perchersky, 1970	C
Same, Omolon Massif		64.5	158.5	Middle Jurassic	120	59	72.4	88.0	80	168	15.4	14.9	Perchersky, 1970	С
Same, Omolon Massif		65	159	Late Triassic	42	39	53.9	74.3	76	294	20.6	17.8	Khramov, 1979	С
Same, Omolon Massif		65	159	Late Triassic	153	35	42.1	51.1	61	284	10.7	8.2	Khramov, 1979	С
Same, Omolon Massif		63	159	Triassic	35	35	48.3	67.0	56	248	19.6	16	Perchersky, 1973	С
Same, Omolon Massif	Vodopadnyi Creek.	65	156	Permian	28	44.0	54.0	65.0	73	270	7		Kashik and others, 1990	A
Same, Omolon Massif Perevalniy Creek		65	162	Late Devonian	20	27	35.5	45.7	23	219	12.8	9.1	Kolosev, 1981	A
PW, Prince William terrane, Resurrection Peninsula, Southern Alaska	Ophiolite	60.9	210.7	57	∞	46.6	58.6	73.0	37	167	=		Bol and others, 1992	>
Same, Kiluda Bay, Southern Alaska	Ghost Rocks Formation	57.3	207.7	Paleocene	Ξ	25.8	33.6	43.2	55	93	12	∞	Plumley and others, 1983	≯
Same, Alitak Bay, Southern Alaska	(Same)	56.9	206.1	Paleocene	16	37.6	47.0	58.6	43	269	=		Plumley and others, 1983	>
PW, Prince William terrane, Knight Island, Southern Alaska	Orca Group	60.4	212.4	Paleocene -Eocene	9		47		56	236	21		Hillhouse and Gromme 1977	A
Same, Glacier Island, Southern Alaska	(Same)	60.8	212.8	Paleocene -Eocene	14	25.8	37.6	53.9	72	185	11.0		Bol, 1993	В
QN, Quesnellia terrane, Southern Canadian Cordilllera	Nicola Volcanics	48.9	239.4	Middle Triassic	26	23.5	28.2	33.6	53	349	7	ري.	Symons, 1985b	C

Map unit, OVERLAP ASSEMBLAGE, Geographic area	ROCK UNIT	LAT	LONG	AGE	NUMBER OF SITES	-dl	PALEOLATITUDE dl LAT +d	HD+	LAT	PALEOPOLE LONG a95, dm	1	a95, dp	REFERENCE	RANK
Same	Copper Mountain	49.3	239.5	Jurassic	Ξ	20.6	23.5	26.6	57	12	4-	w	Symons and Litalien, 1984	
Same	Tulameen	49.5	239	Early Jurassic	10	8.7	18.6	31.7	46	119	20	=	Hicken and Irving, 1977	
Same	Guichon batholith	50.5	239	Late Triassic	49	15.5	20.0	25.0	52	12	∞	v	Symons, 1971, 1983b	
OV, Omulevka terrane, Kolyma-Omolon superterrane	Jugo- Suordakhskaya St.	67.5	139.4	Late Jurassic	51	32	68.8	90.0	88	99	53.2	50.5	Neustroev and others, 1993	
Same	Dzhabuldinginska ya St.	67.5	139.4	Middle Jurassic	33	51	61.8	74.3	45	106	12.8	11.7	Neustroev and others, 1993	
RA, Rassokha terrane Kolyma-Omolon superterrane, Omulevka Uplift	Magar and Uvyazkin Group	65	149	Late Devonian & Early Carboni- ferous	78	-15	12.0	14.9	36	310	5.3	2.8	Iosifidi, 1989	
RO, Kronotskiy terrane, Kamchatka Peninsula, Lyakhov Island, Cape Shalistyi		74.5	136.5	Late Creta- ceous	22		25.0		30	184	6	4	Ivanov and others, 1977	
SM, Slide Mountain terrane, British Columbia	Sylvester allochton	59	231.3	Pennsylvanian- Permian	12	5.4	8.5	11.8					Butler and others, 1988; Richards and others, 1993	
SM, Slide Mountain terrane, British Columbia	Sliding Mountain	53.15	238.5	Pennsylvanian - Permian	28	-0.7	1.9	4.5	15.1	36.2	6	ψ	Butler and others, 1988; Richards and others, 1993	
ST, Stikinia terrane, Tyaughton Basin, British Columbia	Silverquick/Powel I Creek	51.3	236.2	Mid- Creta- ceous	21	31.9	37.6	43.2	356	26			Wynne and others, 1993; Maxson and others, 1993	
ST, Stikinia terrane, British Columbia	Topley Intrusives	54	235	Jurassic	∞	20.6	30.8	44.5	56	119	17	=	Monger and Irving, 1980 Symons, 1983a	
Same	Telkwa Formation	54.8	231.9	Early Jurassic	9	26.8	36.5	49.3	27	169	15	=	Vandall and Palmer, 1990	
Same	Telkwa Formation	54.4	231.9	Early Jurassic	10	24.2	30.8	38.7	÷	193	=	7	Vandall and Palmer, 1990	

area	ASSEMBLAGE, Geographic	Map unit, OVERLAP	
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	LAT		
a95, dm	LONG	PALEOPOLI	
	a95, dp	æ	
		REFERENCE	
		RANK	

VT, Vetlovskiy terrane, Kumroch Range, Kamchatka Peninsula	VL, Viliga terrane, Yana- Kolyma Fold Belt	Same, Kuyul subterrane	TL, Talovskiy terrane, Ainynskiy subterrane, Penzhino Gulf	Same	Same	Same	Same	Same	Same	ST, Stikinia terrane, Hazelton Group	Same
Kapitskaya Formation.				Asitka Group	Telkwa Formation	Telkwa Formation	Telkwa Formation	Telkwa Formation	Telkwa Formation	Nilkitkwa Formation	Telkwa Formation
56.4	62	61.5	61.5	56.7	54.5	54.4	54.8	56.5	55.8	55.6	54.5
162.1	156	164.5	164	233.4	232.9	231.9	231.9	233.2	233.4	233.6	232.9
Late Creta- ceous	Middle Jurassic	Triassic- Jurassic	Early Creta- ceous	Late Permian	Early Jurassic	Early Jurassic	Early Jurassic	200	200	190	Early Jurassic
4	93		10		∞	10	9	20	28	37	∞
27.9	47.0	14	40.9	17.4	22.3	24.2	26.8	14.3	21.3	22.0	22.3
41.8	65.2	19	61.8	22.8	28.2	30.8	36.5	32.6	36.5	35.5	28.2
61.8	88.0	25	90.0	29.0	35.2	38.7	49.3	65.2	60.2	55.4	35.2
84	42	43	61	40	54	-11	27	40	17	70	54
76	130	304	225	123	109.9	193	169	144	185	57	109.9
6.5	22.4	9.5	27.4	25	10	Ξ	15	34	26	23	10
7.2	20.8	5.5	25		6	7	=	23	19	16	6
Pechersky and Shapiro, 1996	Perchersky, 1970	Heiphitz and others, 1994	Perchersky, 1970	Irving and Monger, 1987	Vandall and Palmer, 1990	Vandall and Palmer, 1990	Vandall and Palmer, 1990	Monger and Irving, 1980	Monger and Irving, 1980	Monger and Irving, 1980	Vandall and Palmer, 1990
>	В	В	С	A	В	≻	В	С	С	С	В

Map unit, OVERLAP ASSEMBLAGE, Geographic area	ROCK UNIT	LAT	LONG	AGE	NUMBER OF SITES	-dl	PALEOLATITUDE di LAT +d	Hdl +dl	LAT	PALEOPOLE LONG a95, dm		a95, dp	REFERENCE	NCE
PE, Peninsular sequence, Wrangellia superterrane, Alaska Peninsula	Chignik/Hoodoo	56	200	Late Creta- ceous	47	18.0	25.0	33.6	40	96	12	∞		Stone and Packer, 1979
Same	Chignik	56	200	Late Creta- ceous	24				39	343	=		(A)	Stone and Packer, 1977
Same	Naknek/Chitina	58	205	Late Jurassic	∞	22.8	31.7	43.2	34	290	15	10	7	Packer and Stone, 1974, Stone and others, 1982
WR, Wrangellia sequence, Wrangellia superterrane, McCarthy Quadrangle	MacColl Ridge Formation	62.1	217.7	Late Creta- ceous	14	24.2	31.7	40.9	13	180	10		P	Panuska, 1985
Vancouver Island	Westcoast Complex	50	234	Jurassic(?	39	33.6	38.7	44.5	79	301	∞	7	_s	Symons, 1985a
Vancouver Island	Bonanza Group	50.5	232	200	13	20.0	24.2	29.0	22	154	9	6	~5	Irving and Yole, 1987
McCarthy Quadrangle	Nikolai Greenstone	61.5	217.5	Triassic	50	7.1	10.3	13.7	2	146	2		_H	Hillhouse, 1977
Healy & Mt. Hayes Quadrangles	Nikolai Greenstone	63.1	214	Triassic	46						14		10H	Hillhouse and Gromme, 1984
Clearwater Mountains	Nikolai Greenstone	63.1	212.6	Triassic	9	13.1	18.0	23.5	4	158	∞		a #	Hillhouse and Gromme, 1984
Clearwater Mountains	Nikolai Greenstone	63.1	212.9	Triassic	7	10.9	17.4	25.0	37	85	∞		_ O H	Hillhouse and Gromme, 1984
Ampitheater Mountains	Nikolai Greenstone	63.1	213.7	Triassic	6	4.0	10.3	17.4	7	133	∞		_	Hillhouse and Gromme, 1984
Rainy Mountain	Nikolai Greenstone	63.3	214.1	Triassic	9	0.0	3.5	7.1	æ	122	6		H	Hillhouse and Gromme, 1984
Slana River	Nikolai Greenstone	63.1	215.6	Triassic	6	8.7	16.1	25.0	22	120	24		_ O H	Hillhouse and Gromme, 1984
Slana River	Nikolai Greenstone	63	215.7	Triassic	∞	1.5	14.3	31.7	30	108	24		10 ^E	Hillhouse and Gromme, 1984

Map unit, OVERLAP	ROCK UNIT	LAT	LONG	AGE	NUMBER	PAI	PALEOLATITUDE	TUDE	- 1	PALEOPOLE	- 1		REFERENCE	RANK
area					OF SILES	<u></u>	LAI	<u> </u>	12.1	a95, dm	-	a75, up		
Viend	V	n	32.4		36	3		3	3	3	`			•
A WILCOUACT TRIMIN	Formation	Ç	5+54	Hassic		į	10.0	22.0	23	70	d		others, 1980; Yole and Irving, 1980; Irving and Wynne, 1990	
Skolai Creek	Hasen Creek	61.7	217.7	Permian	11	2.5	7.1	12.0	15	359	7		Panuska, 1984	С
Skolai Creek	Station Creek	61.7	217.7	Pennsyl- vanian	10	-2.0	5.6	13.7	14	359	12		Panuska and Stone, 1981; Panuska, 1984	В
WSA, West Sakhalin terrane, Sakhalin Island		47.3	142.4	Late Creta- ceous	6	34.5	40.9	48.3	73	246	9	7	Perchersky, 1970	С
Same, Primorye		46.5	138.5	Late Creta- ceous	S	27.4	36.5	48.3	68	245	14	10	Nevolina and Sokarev, 1986	С
Same		46.5	138.5	Late Creta- ceous	4	32.6	43.2	57.0	83	20	12	&	Nevolina and Sokarev, 1986	С

APPENDIX 1. DESCRIPTIONS OF GEOLOGY, CORRELATIONS, AND LINKAGES OF MAJOR TERRANES AND OVERLAP ASSEMBLAGES AROUND THE CIRCUM-NORTH PACIFIC

This appendix provides a detailed descriptive and interpretative section on the geology, correlations, and tectonic linkages of terranes and overlap assemblages for the Circum-North Pacific. In this appendix, units are described and interpreted in the following order: (1) continental margin and cratonal terranes; (2) Late Paleozoic through mid-Cretaceous island arc terranes of the Wrangellia superterrane; (3) Triassic through mid-Cretaceous continental margin arcs, island arcs, and tectonically paired subduction zones; (4) Late Cretaceous and Early Cenozoic continental margin arcs, island arcs, and tectonically paired subduction zones; (5) Middle and Late Cenozoic continental margin arcs and tectonically paired subduction zones; and (6) linkages between belts of anatectic-related igneous rocks and accretion of terranes. For each of these six groups, the descriptions of correlations, linkages; and alignments of terranes and overlap assemblages are presented in a counter-clockwise order, starting with Russian Southeast and ending with Southeastern Alaska and the southern Canadian Cordillera. Summary tables of correlations and linkages of terranes and overlap assemblages for the Circum-North Pacific are also provided in Table 2.

CRATONS, CRATONAL TERRANES, PASSIVE CONTINENTAL MARGINS, AND PASSIVE CONTINENTAL MARGIN TERRANES

The eastern part of the North Asian Craton (NSC) and the western part of the North American Craton (NAC) bound the western and eastern parts of the Circum-North Pacific, respectively (Figures 1, 3). Adjacent to these cratons are two major passive continental (craton) margins, the North Asian Craton Margin (Verkhoyansk fold and thrust belt, unit NSV) to the west, and the North American Craton Margin (NAM) to the east (Figures 1, 3). Adjacent to the passive continental margins are a wide collage of terranes that were accreted to the craton margins principally during the Mesozoic and Cenozoic (Figures 1, 3). More descriptions of, and stratigraphic columns for these 167 accreted terranes, and cratons and craton margins are provided by Nokleberg and others (1994a). The growth of the continental margins by terrane accretion is an amazing facet of the tectonic history of the region. Most of the accreted terranes are herein interpreted as derived from various parts of the cratons, craton margins, or from fringing island arcs and companion subduction zone complexes.

Continental Margin and Cratonal Terranes in the Russian Southeast

A complex suite of continent-related terranes in the Russian Southeast are interpreted as tectonically derived from various parts of either the North Asian Craton and North Asian Craton Margin (units NSC, NSV) (Figure 1), the North China Craton (not shown in Figure 1), or the Sino-Korean craton. These terranes, mainly of Archean, Late Proterozoic, and (or) early Paleozoic age, consist of the Argun, Baladek (BL), and Gonzha cratonal terranes, the Ayansk (AY), Khanka passive continental margin superterrane, and Oldoi

(OL) passive continental margin terrane, and the Bureya (BU) and Mamyn (MM) continental margin arc terranes (Figure 1). This suite of continent-related terranes has a complicated origin. Varying interpretations are proposed by Khanchuk and others (1996) and by Natal'in (1991, 1993), Sengör and others (1993, 1994), Sengör and Natal'in (1996).

Origin of Khanka Passive Continental-Margin Arc Superterrane and Laoelin-Grodekovo Island Arc Terrane

The Khanka passive continental-margin arc superterrane (KH), composed mainly of fragments of a Late Proterozoic and Paleozoic continental-margin arc and one accretionary-wedge complex occurs in the southern part of the Russian Far East (Figure 1). Adjacent to the Khanka superterrane is the Permian Laoelin-Grodekovo island arc terrane (Figure 1). The Khanka superterrane consists a series of related, early and middle Paleozoic, continental-margin arc and accretionary-wedge terranes, including the Kabarga, Sergeevka, and Voznesenka continental-margin arc terranes, and the Spassk accretionary wedge terrane (predominantly turbidites) (Nokleberg and others, 1994a; Khanchuk and others, 1996). The Khanka superterrane also includes overlapping units of Devonian and Mississippian continental-rift-related volcanic and sedimentary rocks, middle Paleozoic granitic rocks, late Paleozoic granitic rocks, and Permian back-arc-rift-related volcanic rocks.

The Voznesenka terrane, that forms the southern part of the Khanka superterrane, is interpreted as part of an early Paleozoic continental-margin arc or passive continental margin that was part of the Gondwanaland supercontinent (Khanchuk and others, 1996). Archaeocyatheans from Cambrian limestone in the Voznesenka terrane belong to the Australian paleobiogeographic province (Belyaeva, 1998). To the north of the Voznesenka terrane are the early and middle Paleozoic Sergeevka and Kagbarga continentalmargin arc terranes. These two terranes, and the Bureya continental-margin arc superterrane farther north (Figure 1), also of early and middle Paleozoic age, are all interpreted as parts of a single continentalmargin arc (Khanchuk and others, 1996) that formed along the margin of the Paleo-Asian Ocean along the Gondwanaland margin in the eastern Precambrian and Cambrian (Coleman, 1994). The Spassk accretionary wedge terrane, containing mainly early and middle Paleozoic oceanic rocks and turbidite deposits, also part of the Khanka superterrane, is interpreted as a subduction zone complex that was tectonically linked to the arc.

The Khanka superterrane is interpreted as having been rifted from the Gondwanaland supercontinent in the Devonian, resulting in the formation of bimodal volcanic rocks. The Permian marine and non-marine volcanic and terrigenous deposits that overlie most of the various terranes of the Khanka superterrane are interpreted as forming in a back-arc basin adjacent to the Permian island arc of the Laoelin-Grodekovo terrane, in a tectonic setting similar to that of the modern Sea of Japan (Khanchuk and others, 1996).

These data and interpretations indicate that the Khanka superterrane is a complex unit formed of fragments of diverse tectonic settings (Khanchuk and others, 1996), and is not a part of the Sino-Korean Craton (as interpreted by Sengör and Natal'in, 1994, 1996).

In contrast, the Khanka continental margin terrane (KH) in the southern part of the Russian Southeast is interpreted by other workers (Natal'in 1991, 1993; B.A. Natal'in Nokleberg and others, 1994a) as derived from part of the Sino-Korean Craton on the Korean Peninsula (not depicted in Figure 1) where similar Lower Cambrian shelf carbonates occur and was tectonically separated from this region during Mesozoic strike-slip faulting.

The Permian Laoelin-Grodekovo island arc terrane (LD), that occurs west the Khanka superterrane (Figure 1), is tectonically linked to various Permian accretionary-wedge terranes to the south, southwest, and southeast (Khanchuk and others, 1996). These accretionary-wedge terranes include the Chongjin terrane (out of the area of Figure 1), that extends westward from the Japan Sea coast (Chongjin city area) into probably southern Mongolia, in the area between the Khanka superterrane and Sino-Korean Craton. The Chongjin terrane contains large blocks of middle and late Paleozoic ophiolites, bedded cherts, and limestones is interpreted as forming in a subduction zone. Collision of the Sino-Korean Craton and Khanka superterrane and closing of the ocean between the two terranes is interpreted as occurring in the Early Triassic (Zonenshain and others, 1990).

Origin of Argun, Baladek, and Gonzha Cratonal Terranes, Ayansk (AY) and Oldoi (OL) Passive Continental Margin Terranes, and Mamyn (MM) and Bureya Continental Margin Arc Terranes

Three major groups of cratonal, passive continental margin, and continental margin arc terranes, of mainly Archean and Proterozoic age (cratonal terranes), and of mainly early and middle (continental-margin arc and passive continental margin terranes), occur in the northern part of the Russian Southeast. Following are interpretations for the origin of each of the three groups. (1) The Argun (AU) and Gonzha (GN) cratonal terranes, the early and middle Paleozoic Oldoi (OL) passive continental margin terrane, and the Proterozoic to Lower Cambrian part of the Mamyn continental margin arc terrane (MM), are interpreted as rifted fragments of the southern part of the North Asian Craton and Craton Margin (NSC, NSV) (Natal'in, 1991, 1993; Sengör and others, 1993, 1994; Sengör and Natal'in, 1996) (Figure 1). Rifting of this collage of terranes, as well as formation of similar tectonic units in the Transbaikal region of Southern Siberia and in Northern Mongolia, is interpreted as occurring in the latest Proterozoic. (2) Similarly, the Baladek (BL) cratonal and the Paleozoic Ayansk (AY) passive continental margin terrane, on the basis of similar stratigraphy and rock lithologies, are also interpreted as displaced fragments of the North Asian Craton and North Asian Craton Margin (NSC, NSV), respectively (Natal'in, 1991, 1993; Sengör and others, 1993, 1994; Sengör and Natal'in, 1996) (Figure 1). And (3) the early Paleozoic and older Bureya continental-margin arc terrane (BU) and similar tectonic units in Northeastern China and Inner Mongolia are interpreted as dismembered parts of the Manchurid orogenic system that formed along the north margin of the North China Craton (Natal'in 1991, 1993; Sengör and others, 1993; Sengör and Natal'in, 1994, 1996).

Both the early Paleozoic and older Mamyn (MM) and Bureya (BU) continental-margin arc terranes, that occur in the Russian Southeast, are interpreted as parts of one or more continental margin arcs that were active at various times in the Paleozoic (as discussed by B.A. Natal'in in Nokleberg and others, 1994a). occurrence of large, poorly dated, early and late Paleozoic granite and granodiorite intrusions in all three terranes, suggests to some researchers that these terranes were part of a single arc (Parfenov and Natal'in 1985, Parfenov, 1984, Zonenshain and others, 1990; Khanchuk, 1993; Natal'in, 1993; Sengör and Natal'in, 1996). However, differences in stratigraphy, and palinspastic reconstruction for the Mamyn (MM) and Bureya (BU) continental-margin arc terranes indicate these terranes are fragments of distinct arcs. The Mamyn (MM) continental margin arc terrane, and the associated Gonzha (GN) and Argun (AU) cratonal terranes, and the Oldoi (OL) passive continental margin terranes, are all interpreted as a dismembered parts of the Altaid orogenic system (Natal'in, 1991, 1993; Sengör and others, 1993; Sengör and Natal'in, 1994, 1996). In contrast, the Bureya continental margin arc terrane (BU), that locally contains Late Proterozoic to early Paleozoic igneous arc rocks, is interpreted as forming along the north margin of the North China craton as part of the Manchurid orogenic system (Natal'in, 1991, 1993; Sengör and others, 1993; Sengör and Natal'in, 1994, 1996). Disintegration of both the Altaid and Manchurid orogenic systems into terranes occurred mainly in the Mesozoic during tectonic escape that was initiated by the convergence of North Asian (Siberia) and North China Cratons (B.A. Natal'in in Nokleberg and others, 1994a; Sengör and Natal'in, 1996).

Correlation of Passive Continental Margin Terranes in the Russian Northeast, Alaska, and Canadian Cordillera and Linkage to North American Craton

Around the Circum-North Pacific a suite of passive continental margin terranes are correlated and interpreted as derived from the North American Craton Margin (NAM). These units are the Chukotka terrane (CH) (Russian Northeast), Arctic Alaska superterrane (AA) (Alaska), and the Cassiar terrane (CA) (Canadian Cordillera) (Figures 1, 2).

Eastern Part of Chukotka Terrane and Arctic Alaska Superterrane

Stratigraphic analysis of the North Slope terrane of the Arctic Alaska superterrane (approximately the equivalent of the Arctic composite terrane of Plafker and Berg, 1994), and the eastern part of the Chukotka terrane (Wrangell subterrane of the Chukotka terrane, Nokleberg and others, 1994a), and the Cassiar terrane (Nokleberg and others, 1994a) reveal that these units, and adjacent passive continental margin terranes constitute a long-lived Late Proterozoic, Paleozoic, and early Mesozoic, Atlantic-type passive continental margin that faced towards the Ancestral Pacific Ocean (Monger and others, 1992; Moore and others, 1994b).

This long-lived continental margin included two periods of continental-margin arc activity, one in the Late Proterozoic, currently recognized only in Northern Alaska, and another in the Devonian and Mississippian, recognized in both Northern Alaska and the Russian Northeast. In the Russian Northeast, the Chukotka terrane contains a Boreal fauna of Permian, Triassic, and Jurassic age (Dagis and others, 1979; Dagis and Dagis, 1984; Zakharov and others, 1984).

The regional correlation of these passive continental margin terranes is based on (Nokleberg and others, 1994a): (1) similar geologic positions around the Circum-North Pacific (before opening of the Canada Basin, these terranes are interpreted by most workers as part of the passive continental margin adjacent to the North American Craton (NAC) (Parfenov and others. 1993a, b; Monger and others, 1994, and Plafker and Berg, 1994; Monger and Nokleberg, 1996; Parfenov, 1997); and (2) on a regional basis, similar stratigraphy. This grouping of these terranes represents the extension of the Paleozoic North American continental margin into the Chukotka region of the Russian Northeast. The Arctic Alaska superterrane and Chukotka terrane were displaced by counterclockwise rotation, rifting, and (or) lateral translation associated with the Early Cretaceous opening of the Canada Basin (Lawver and Scotese, 1990; Grantz and others, 1991; Moore and others, 1994a; Lane, 1994, 1997). Recent detrital zircon isotopic studies in northeastern Alaska contradict the stratigraphic relations correlations of Proterozoic strata required by the rotation model, but are compatible with a transitional model involving rifting of Alaska and translation along a major transform (McClelland, 1997).

Cassiar Terrane

The Cassiar terrane (CA) was part of the western Canadian margin that was displaced 450 or more km northwards by dextral movement on the Tintina-Northern Rocky Mountain Trench fault system in the Late Cretaceous and Early Tertiary (Gabrielse, 1985). The most complete rock sequences in these terranes are similar to those of the North American margin, namely Late Proterozoic, clastic-dominated strata, Cambrian through Devonian carbonate rock and shale, and Devonian-Mississippian to (locally) Triassic Jurassic clastic rocks with lesser carbonates. Magmatic rocks are rare, but include late Proterozoic and Devonian granitic plutons and mafic and felsic volcanic arc rocks. Northward displacement of the Cassiar terrane for greater than 2000 km, mostly in the Permian and Triassic, from a source in present-day Idaho has been suggested by Pope and Sears (1997).

Correlation of Metamorphosed Continental Margin Terranes in the Russian Northeast, Alaska and Canadian Cordillera and Linkage to the North American Craton

Along the margin of North American Cordillera and the northern part of the Russian Northeast, outboard of the passive continental-margin terranes described above, are a group of metamorphosed continental margin terranes of Late Proterozoic and Paleozoic age that are linked to the North American Craton (NAC). The terranes are the Seward (SD)

Coldfoot (CO), Ruby (RB), Yukon-Tanana (YT), Kootenay (KO) terranes (Figures 1, 2). These terranes are correlated because of possessing similar ages, craton-derived quartz-rich clastic sedimentary units, Late Devonian and Early Mississippian continental-margin arc sequences (Nokleberg and others, 1994a; Rubin and others, 1991). These terranes are interpreted as having been displaced by a combination of strike-slip and thrust movement from loci along the North American continental margin. These terranes exhibit broadly similar stratigraphy, structure, metamorphism, and geographic position between inboard passive continental margins terranes and outboard island arc and subduction zone terranes (Mortensen, 1992; Gehrels and Berg, 1994; Moore and others, 1994b; Foster and others, 1994; Patton and others, 1994; Till and Dumoulin, 1994) (Figures 1, 2). The Seward terrane occurs on both sides of the Bering Straits and forms a major link from the Russian Northeast into northwestern Alaska (Figures 1, 2). An exception is a long prong of the Yukon-Tanana terrane that extends southeastward from the western Yukon Territory to latitude 52° N within the Canadian Coast Mountains (Figure 2). Most of these terranes were multiply penetratively deformed and metamorphosed from the middle Paleozoic through the Mesozoic. The Yukon-Tanana terrane exhibits several periods of regional deformation and metamorphism that range in age from the late Paleozoic through the mid- to Late Cretaceous (Mortensen, 1992). The Late Jurassic to the mid-Cretaceous events are interpreted as having occurred during accretion of outboard oceanic terranes, such as the Stikinia, Quesnellia, and Cache Creek terranes, and the Wrangellia superterrane.

The metamorphosed continental margin terranes are composed mainly of clastic-dominated successions containing mafic to felsic volcanic rocks, coeval granitic plutons, and local marble, whose protolith ages are mainly early and middle Paleozoic, but locally may be as old as Late Proterozoic and as young as Triassic. However, their facies, and ages of detrital zircons from clastic deposits within them, strongly suggest they are distal, i.e., oceanward, equivalents of continental margin (Smith and Gehrels, 1991). Devonian-Mississippian granitic plutons are widely distributed within the metamorphosed continental margin terranes whereas coeval volcanic successions are more restricted in occurrence. Scattered Permian granitic plutons occur locally along with Devonian-Mississippian and Permian-Triassic magmatism, deformation, and metamorphism (Mortensen, 1992; Smith and Gehrels, 1992), and are reflected in North American Craton Margin deposits to the east by coeval clastic wedge deposits and by local tuff horizons in Devonian carbonate rocks (Richards and others, 1994).

Correlation of Part of Taymyr Peninsular Collage with Verkhoyansk Fold Belt (North Asian Craton Margin)

The Taymyr Peninsula occurs west of the western Russian Northeast, out of the field of view of Figure 1. The collage is herein described because it constitutes part the tectonic history of the Circum-North Pacific. The Taymyr Peninsula consists of a collage of Late Proterozoic through Mesozoic terranes and overlap assemblages (Zonenshain and others, 1990; Vernikovskiy and others, 1998). The major tectonic

units in the region (from south to the north)are as follows. (1) The Byrranga fold and thrust belt contains Ordovician to Jurassic sedimentary rocks formed in a passive continental margin setting and contains Ordovician to middle Carboniferous carbonate shelf deposits, Late Carboniferous to Lower Permian clastic shallow marine deposits, and Late Permian to Early Triassic continental clastic coal-bearing deposits. On the basis of similar Siberian fauna and stratigraphy, the Byrranga belt is correlated with the Verkhoyansk fold belt (North Asian Craton Margin, NSV) Middle Triassic to Jurassic sedimentary rocks occur at the eastern Taymyr Peninsula and consist of marine clastic rocks that are also similar to those of the Verkhoyansk belt. (2) The Central Taymyr superterrane consists of the Fadeev and Mamont cratonal terranes, the late Precambrian Kossovsk miogeoclinal (passive continental margin) terrane, and the late Precambrian Shrenk island arc terrane. The Kossovsk and Shrenk terranes are composed of Lower and Middle Riphean units. The areas of formation of the units in the Central Taymyr superterrane are unknown. All the terranes in the Central Taymyr superterrane are overlapped by Late Riphean to Early Carboniferous deposits, including Late Riphean to Cambrian carbonate rocks and Ordovician to Lower Carboniferous deep-water black shale. And (3) the Karsk continental margin or turbidite terrane consists of Riphean to Ordovician turbidite. The area of formation of the Karsk terrane is unknown. All terranes of Taymyr Peninsula collage are intruded by Permian to Triassic granite with isotopic ages of 240-280 Ma. This relation and age provide a minimum age of accretion of terranes within the collage. Because of being an on-strike extension, the Byrranga fold and thrust belt is correlated with the Verkhoyansk fold and thrust belt.

Correlation of Passive Continental Margin Terranes in Russian Northeast from the Verkhoyansk Fold and Thrust Belt

The Kular-Nera (KN), Omulevka (OV), Prikolyma (PR), and Viliga (VL) passive continental margin terranes occur as widely separated fragments in the central part of the Russian Northeast and (Figure 1). These terranes are enclosed in a collage of accreted oceanic and island arc terranes, indicating rifting and migration away from a continental margin. These terranes share similar stratigraphy and fauna with each other and with the North Asian Craton Margin (Verkhoyansk fold and thrust belt, NSV), and are interpreted by most workers as derived from the North Asian Craton Margin (NSV) (Nokleberg and others, 1994a; Parfenov, 1984, 1991, 1995a, b., c; Parfenov and others, 1986, 1993a, b; Sengor and Natal'in, 1996a, b).

The North-Asian Craton Margin (Verkhoyansk fold and thrust belt) (NSV) consists chiefly of a thick wedge of craton margin deposits up to 20 km thick that is composed mainly of Carboniferous, Permian, Triassic, and Jurassic clastic rocks, marine-littoral, deltaic, and shelf deposits that prograde eastward (Natapov, 1984; Parfenov, 1984, 1985, 1987; 1991, 1994, 1995c; Parfenov and Prokopiev, 1993; Parfenov and others, 1995; Prokopiev, 1989). The fold belt is deposited on the passive margin of the North Asian continent. Major units grade successively eastward into turbidite deposits and deep-water black shale. The belt

contains local Middle to Late Devonian and Tournaisian, rift-related sedimentary units that are similar to those on Siberian platform. The belt contains local Early Triassic and Early Jurassic alkalic basalt flows and basalt dikes and sills. The northern and southern parts of fold belt contain thick shallow-marine carbonate and clastic deposits of Late Proterozoic and early Paleozoic age that become finer-grained and thicker to the east.

This Kular-Nera passive continental margin terrane (KN) occurs outboard of the Verkhoyansk fold and thrust belt (NSV), and is juxtaposed against the fold and thrust belt along the Adycha-Taryn fault 1) which exhibits older, large-scale (Figure overthrusting, and subsequent sinstral strike-slip displacements. The terrane consists of (Parfenov and others, 1988, 1989; Bychkov and Kiseleva, 1990): a thick assemblage of Permian, Triassic, and Lower Jurassic hemipelagic and pelagic mudstone, siltstone, and minor sandstone; and Permian and Lower Jurassic radiolarian chert and tuff. The Kular-Nera terrane is interpreted as a deep-sea-fan complex that contains interbedded with continental rise and marginal sea pelagic deposits that formed between the passive margin of the Siberian continent (North Asian craton margin, unit NSV) and the various parts of the Kolyma-Omolon superterrane to the east. The Kula-Nera terrane is weakly to highly metamorphosed and deformed, exhibits lower greenschist and locally epidote-amphibolite facies metamorphic assemblages, and is locally deformed into gently inclined appressed and superposed folds. The Kular-Nera terrane contains a Permian, Triassic, and Lower Jurassic Boreal fauna (Dagis and others, 1979; Dagis and Dagis, 1984; Zakharov and others, 1984), and is interpreted as a distal part of the passive continental margin of the North Asian Craton along which the proximal part is represented by the Verkhoyansk fold and thrust belt. Both parts of the passive continental margin were overthrust and displaced along the craton margin during Late Mesozoic deformation (Parfenov, 1984, 1997; Zonenshain and others, 1990).

The Omulevka passive continental margin terrane (OV) consists chiefly of five units (Bulgakova, 1986; Natapov and Surmilova, 1986; Parfenov, 1991, 1995c; Neustroev and others, 1993): (1) presumed Late Precambrian marble, schist, and metavolcanic rocks; (2) an unconformably overlying thick unit (up to 1700 m thick) of boulder conglomerate that contains pebbles of native and exotic rocks; other units consist of marble with Middle and Upper Cambrian fossils, schist, metarhyolite, and quartzite; (3) a thick sequence of Ordovician. Silurian. Devonian, and Carboniferous fossiliferous carbonate rocks, including limestone, dolomite, and marl, and sparse sandstone, siltstone, mudstone, and (Devonian) volcanic rocks; (4) Carboniferous and Permian fossiliferous tuff, chert, shale, limestone, siltstone, and sandstone; and (5) Triassic fossiliferous siltstone, mudstone, marl, and shaley limestone.

The Prikolyma passive continental margin terrane (PR) consists chiefly of several major units (Tret'yakov, 1989; Natapov and Shul'gina, 1991; Beus and Miledin, 1990): (1) a basal unit of high-grade gneiss and schist, metamorphosed up to amphibolite facies, interpreted either as late Precambrian to early Paleozoic, Pre-Vendian, or Early Precambrian; (2) Riphean, Vendian, and Cambrian shallow-marine

clastic and carbonate rocks in the central part of the terrane: (3) Ordovician and Lower Silurian shallowmarine carbonate and clastic rocks in the southwestern part of terrane; (4) Devonian and Lower Carboniferous shallow water limestone, dolomite, marl, sandstone, siltstone, and conglomerate; (5) in the central and eastern parts of the terrane, abundant Upper Devonian to late Paleozoic conglomerate, and a thick marine sequence of mainly thin-bedded clastic, volcaniclastic rocks, and subordinate carbonate rocks of Late Devonian to Middle Carboniferous and locally Lower Permian age; (6) Upper Carboniferous and Lower Permian rift-related alkalic basalt flows and tuff, and alkalic gabbro sills, stocks, and dikes (Chakhadanskaya Formation); and (7) Upper Triassic and Lower Jurassic shallow-marine shale, siltstone, sandstone, and tuff in the southwestern part of the terrane.

The Viliga passive continental margin terrane (VL) consists chiefly of a thick sequence of Carboniferous, Permian, Triassic, and Jurassic marine clastic rocks that ranges up to 10 km thick (Polubotko and others, 1977; Terekhov, 1979; Bychkov and Kiseleva, 1990). The major units are: (1) Lower sandstone Carboniferous and interbedded conglomerate, mafic tuff, and basalt flows; (2) Upper Carboniferous to Permian sandy argillite, siltstone, sandstone, tuff. chert, basalt, and shale that gradationally overlie the older units; (3) Triassic shale, siltstone, intermediate tuff, and limestone; and (4) Jurassic argillite, siltstone, intermediate tuff, sandstone, conglomerate.

Derivation of Passive Continental Margin Terranes in West-Central Alaska from the Verkhoyansk Fold and Thrust Belt in the Russian Northeast

A suite of passive continental margin terranes in West-Central Alaska consist of the Nixon Fork (NX), Dillinger (DL), and Mystic (MY) terranes (Figure 2) that are interpreted as subterranes of the larger Farewell terrane by Decker and others (1994), and as part of the Central composite terrane by Plafker and Berg (1994). These terranes occur within a collage of accreted oceanic and island arc terranes, indicating rifting and migration away from a continental margin.

The Nixon Fork passive continental margin terrane (NX) (Palmer and others, 1985; Babcock and Blodgett, 1992; Decker and others, 1994; Patton and others, 1994; Blodgett, 1998; Fryda and Blodgett, 1998) consists of: (1) Late Precambrian basement consisting mainly of pelitic and calcareous schist with minor marble, quartzite, and felsic metavolcanic rocks; (2) unmetamorphosed sedimentary rocks of probable Late Proterozoic age that consist of interbedded sandstone, siltstone, and carbonate rocks, and two dolostone units (Babcock and others, 1993); (3) Middle Cambrian limestone and chert; (4) Upper Cambrian to Lower Ordovician platy limestone (possibly part lower part of Novi Mountain Formation); (5) Lower Ordovician thick and platy limestone (Novi Mountain Formation); (6) Ordovician to Middle Devonian carbonate-platform rocks (Telsitna, Paradise Fork, and Whirlwind Creek Formations, and Cheeneetnuk Limestone (R.B. Blodgett, written commun., 1993); and (7) Permian, Triassic, and Cretaceous fossiliferous sedimentary rocks, mainly calcareous sandstone, siltstone, conglomerate, and sparse chert. The Late Proterozoic stratified rocks are intruded by Middle

Proterozoic metagranitic rocks that yield a discordant U-Pb zircon age of 1.27 Ga, and capped by Late Proterozoic metavolcanic rocks that yield a discordant U-Pb zircon age of 850 Ma. The middle Paleozoic strata grade laterally into deep-water strata equivalent to the Dillinger terrane.

The Dillinger passive continental margin terrane (DL) consists of (Bundtzen and Gilbert, 1983; Gilbert and Bundtzen, 1984; Blodgett and Clough, 1985; Decker and others, 1994; Patton and others, 1994; Churkin and Carter, 1997; Blodgett, 1998; Fryda and Blodgett, 1998): (1) Cambrian and Ordovician basinal limestone, banded mudstone, and silty limestone turbidite deposits; (2) Ordovician graptolitic shale and associated(?) pillow basalt; and (3) Upper Silurian through Middle Devonian, unnamed, shallowmarine limestone and dolomite. The terrane is unconformably overlain by sedimentary rocks of the Cretaceous Kuskokwim Group (kw). South of Denali fault, the terrane consists chiefly of: (1) Cambrian(?) to Ordovician calcareous turbidites, shale, and minor greenstone; (2) Lower Ordovician to Lower Silurian graptolitic black shale and chert; (3) Lower to Middle Silurian laminated limestone and graptolitic black shale; (4) Middle to Upper Silurian sandstone turbidite deposits and shale; and (5) Upper Silurian to Lower Devonian limestone, breccia, sandstone, and shale.

The Mystic passive continental margin terrane (MY) consists of a complexly deformed but partly coherent, long-lived stratigraphic succession of (Gilbert and Bundtzen, 1984; Blodgett and Gilbert, 1992; Decker and others, 1994; Patton and others, 1994; Blodgett, 1998; Fryda and Blodgett, 1998): (1) Silurian massive limestone; (2) Upper Devonian sandstone, shale, conglomerate, and limestone that comprise the informally named Yentna limestone of Fernette and Cleveland (1984); (3) uppermost Devonian to Pennsylvanian radiolarian chert; (4) Pennsylvanian siltstone, sandstone, and conglomerate; (5) Pennsylvanian(?) and Permian flysch, chert, argillite, and conglomerate (locally plant bearing); and (6) Triassic(?) pillow basalt and gabbro.

Origin of Nixon Fork, Dillinger, and Mystic terranes

Debate exists about the origin of the Nixon Fork, Dillinger, and Mystic passive continental margin terranes that occur within a collage of accreted oceanic and island arc terranes, far removed from a craton margin (Figure 2). Two widely different tectonic origins are proposed. Studies by T.K. Bundtzen (oral commun., 1994) suggest derivation from similar strata that occur in the North American Craton Margin (NAM) in the northern Canadian Cordillera. This interpretation requires tectonic transport of these terranes by several hundred kilometers on dextral-slip faults such as the Denali (DE), Kaltag (KA), Tintina (TI), and related dextral-slip faults (Figure 4). Alternatively, several recent studies early to middle Paleozoic faunal suggest these faunas are typical of taxa that occur in similar age units in the Kolyma region, and that these three terranes were rifted from the Siberian continent (North Asian Craton Margin) (Blodgett and Brease, 1997; Blodgett, 1998; Fryda and Blodgett, 1998; Dumoulin and others, 1998). These terranes also exhibit stratigraphy that is similar to the North Asian Craton Margin (NSV) and are herein interpreted as being derived that unit (Nokleberg and others, 1994a). This interpretation requires rifting of these terranes from the North Asian Craton Margin (NSV) in the Late Devonian or Mississippian or earlier, and tectonic transport by several hundred kilometers to the east (present-day coordinates) (Figure 5).

Derivation of Kilbuck-Idono Cratonal Terrane from North Asian Craton

The Kilbuck-Idono cratonal terrane (KI) occurs in Western Alaska in two fault-bounded fragments about 330 km apart (Figure 1). The terrane consists chiefly a unit of metamorphosed diorite, tonalite, trondhjemite, and granite orthogneiss, subordinate amphibolite, and minor metasedimentary rocks (Hoare and Coonrad, 1978, 1979; Box and others, 1990, 1993; Miller and others, 1991). The metasedimentary rocks are mainly quartz-mica schist, marble, garnet amphibolite, and banded iron formation of the informally named Kanektok metamorphic complex of Hoare and Coonrad (1979). The metaplutonic rocks yield Early Proterozoic (2.06 to 2.07 Ga) U-Pb zircon ages of emplacement. Nd-Sm isotopic analyses indicate a 2.5 Ga (Archean) crustal component. The terrane is metamorphosed to amphibolite facies with retrograde greenschist-facies metamorphism, possibly in the late Mesozoic. A southern fragment constitutes the Kilbuck terrane of Box and others (1990, 1993); a northern fragment constitutes Idono Complex of Miller and others (1991). The Kilbuck-Idono terrane is interpreted as a highly displaced cratonal fragment; no known correlative cratonal rocks in Alaska and or the Canadian Cordillera (Miller and others, 1991; Box and others, 1993). The terrane is herein interpreted as derived from the closest craton, i.e., the North Asian Craton (NSC) (Figure 5). The stratigraphy of the Kilbuck-Idono terrane is also broadly similar to the older parts of the Okhotsk and Omolon cratonal terranes (described below) in the Russian Northeast that are interpreted as being derived from the North Asian Craton. In addition, both the Kilbuck-Idono and Omolon terranes contain similar suites of ironstone (Superior Fe) deposits (Nokleberg and others, 1996, 1997c).

Derivation of Okhotsk and Omolon Cratonal Terranes from Devonian and Older Parts of North Asian Craton

The Okhotsk (OK) and Omolon (OM) cratonal terranes occur in the central part of the Russian Northeast, either adjacent to, or as part of the Kolyma-Omolon superterrane (Figure 1). The Okhotsk cratonal terrane (OK) consists of (Avchenko, 1977; Chikov, 1978; Verzkhovskaya and Krichevets, 1987; Pavlov, 1993): (1) large blocks of Archean to Early Proterozoic gneiss and schist with a U-Pb age of 3.7 Ga; Middle and Upper Proterozoic shallow-marine clastic and carbonate rocks; (2) Lower Cambrian limestone, marl, and sandstone; (3) Lower Ordovician conglomerate, limestone, marl, and sandstone with macrofossils; (4) unconformably overlying Middle Devonian limestone, sandstone, shale, conglomerate; and Upper Devonian rhyolite, ignimbrite, andesite, dacite, and tuff that are interlayered with nonmarine sandstone, siltstone, and conglomerate; and (5) mainly nonmarine clastic rocks of Carboniferous, Permian, Late Triassic, and Early and Late Jurassic age.

The Omolon cratonal terrane (OM) consists of (Bibikova and others, 1981; Terekhov and others, 1984; Khramov, 1986; Zhulanova, 1990; Natapov and Shul'gina, 1991): (1) a poorly exposed Archean to Early Proterozoic crystalline basement metamorphosed at granulite and amphibolite facies with U-Pb ages of 2.8 to 3.4 Ga and a Rb-Sr age of 3.85 Ga; (2) unconformably overlying gently dipping low-grade Proterozoic conglomerate, sandstone, and siltstone that grade upward into limestone, quartzite, siltstone, and marl, and Vendian dolomite; (3) unconformably overlying rift-related Cambrian units that consist of nonmarine sandstone, conglomerate, siltstone, and alkalic basalt, local dolomite, limestone, sandstone, and siltstone, and widespread sills and stocks of Middle Cambrian rift-related layered gabbro; in several small tectonic blocks; (4) Lower and Middle Ordovician shallow-marine fossiliferous limestone, dolomite, sandstone, and conglomerate; and (5) unconformably overlying Middle and Upper Devonian calc-alkalic lava, rhyolite tuff, trachyte, trachyandesite, granitic plutonic rocks, and basalt, interlayered nonmarine sandstone, conglomerate, and siltstone, and rare shallow-marine sedimentary rocks. deposits.

Origin of Okhotsk and Omolon Terranes

The Okhotsk and Omolon terranes are correlated on the basis of (Nokleberg and others, 1994a): (1) similar Early Ordovician brachiopods and trilobites that also occur in the North Asian (Siberian) Craton (NSC) (Oradovskaya, 1974). (2) similar Boreal faunas of Carboniferous, Permian, Triassic, and Jurassic age (Korol'kov and Korol'kova, 1974); and (3) similar suites of Devonian igneous arc rocks (Umitbaev, 1976; Lychagin, 1978; Nokleberg and others, 1994a). The Okhotsk and Omolon terranes are interpreted as being derived from the North Asian Craton (NSC) because of similar Early Ordovician fauna (Oradovskaya, 1974).

CORRELATION, LINKAGE, AND ALIGNMENT OF LATE PALEOZOIC THROUGH MID-CRETACEOUS ISLAND ARC TERRANES OF THE WRANGELLIA SUPERTERRANE

Sequences of Wrangellia Superterrane

The Wrangellia island arc superterrane occurs in Southern Alaska and the Canadian Cordillera and contains a long succession of four island arcs that are preserved in combinations of sequences that comprise the superterrane. The four arcs, that range in age from Devonian through mid-Cretaceous, are the Devonian Sicker, the late Paleozoic Skolai, the Late Triassic and Early Jurassic Talkeetna-Bonanza, and the Late Jurassic through mid-Cretaceous Gravina (Nokleberg and others, 1994a, b). The Devonian Sicker arc occurs in the Alexander and Wrangell sequences of the superterrane and is best defined in the Wrangellia sequence on Vancouver Island the southern Canadian Cordillera. In this region, the arc consists of the Sicker Group that contains Upper Devonian arc-related volcanic and sedimentary strata, that yield a U-Pb zircon age of 367 Ma (Sicker Group), and coeval intrusions (Muller, 1980; Parrish and others, 1992). Possibly correlative middle Paleozoic arc rocks also

occur in the other sequences of the superterrane (Nokleberg and others, 1994b). The late Paleozoic Skolai arc occurs mainly in the Wrangellia sequence in Eastern-Southern Alaska (Nokleberg and others, 1994b). Correlative units also occur in the Peninsular sequence on the Alaska Peninsula. The Late Triassic and Early Jurassic Talkeetna-Bonanza arc occurs mainly in the Peninsular sequence in Western-Southern Alaska, and in the Wrangell sequence and in the Canadian Cordillera (Muller, 1977; Nokleberg and others, 1994a, b; Jones and others, 1977). The Late Jurassic through mid-Cretaceous Gravina arc occurs mainly in the Wrangell and Alexander sequences, In addition to the arc sequences, the Wrangellia superterrane also contains a major sequence of Late Triassic basalt and coeval gabbro dikes, sills, and small plutons in the Nikolai Greenstone and correlative units in Southern Alaska, and in the Karmutsen Formation and correlative units in the southern Canadian Cordillera that are interpreted as forming at a paleolatitude near the Triassic equator (Hillhouse, 1977; Hillhouse and Gromme, 1984).

Stratigraphic Succession of Late Paleozoic and Mesozoic Arcs of Wrangellia Superterrane

distinct sequences, Alexander, Three the Peninsular, and Wrangellia sequences, comprise the superterrane and contain various combinations of Paleozoic and Mesozoic island arcs. Initial analysis of terranes in Southern Alaska interpreted these three sequences as separate terranes (Jones and others, 1981), whereas more recent analyses indicates that the three sequences represent various stratigraphic levels within a large superterrane (Nokleberg and others, 1994b). The reasons for the initial interpretation was that that each sequence is dominated by one of the three arcs. The Alexander sequence, which occurs mostly in Southeastern Alaska, is mainly an early and middle Paleozoic volcanic arc, possibly a precursor to the Sicker arc, with generally only a local expression of the late Paleozoic and early Mesozoic units of the Wrangellia superterrane. Similarly, the Wrangellia sequence, which occurs mainly in Eastern-Southern Alaska and the Southern Canadian Cordillera, consists mainly of a late Paleozoic Skolai arc sequence and the Nikolai Greenstone, one of the back arc units for the Late Triassic and Early Jurassic Talkeetna-Bonanza arc. Similarly, the Peninsular sequence, that occurs principally in Western-Southern Alaska, consists mainly of the Late Triassic and Early Jurassic Talkeetna-Bonanza arc. Only locally does a small part of the Peninsular sequence exhibit either: (1) the volcanic and sedimentary rocks of the late Paleozoic Skolai island arc and the Late Triassic rift or oceanic flood basalt that form the major part of the Wrangellia sequence; or (2) possible fragments of metamorphosed Paleozoic or older metasedimentary and metavolcanic rocks that might be the early and middle Paleozoic part of the Alexander sequence. Pre-late Paleozoic basement rocks, possibly of the Alexander sequence, also occur in the Wrangellia sequence in Eastern-Southern Alaska.

The above relations indicate that, from east to west, the Alexander, Wrangellia, and Peninsular sequences exhibit successively higher levels of a structural-stratigraphic succession. The oldest part of the succession is mainly to the east in the

predominantly early and middle Paleozoic Alexander sequence; the middle part of the succession in the central part of the predominately late Paleozoic and early Mesozoic Wrangellia sequence; and the youngest part of the succession is to the west in the predominantly middle and late Mesozoic Peninsular sequence. Despite these relations, substantial tectonic imbrication has occurred within the Wrangellia superterrane (Plafker and others, 1989; Nokleberg and others, 1994a, b). The abrupt termination of the Talkeetna-Bonanza arc and associated plutonic rocks in the eastern Peninsular sequence structurally against the very minor occurrence of this arc in the Wrangellia sequence requires extensive post-Middle Jurassic tectonic displacement of the Wrangellia sequence relative to the Peninsular sequence. Timing of the suggested strike-slip displacement between the Peninsular and Wrangellia sequences cannot be constrained more closely than the Late Jurassic to Late Cretaceous (Nokleberg and others, 1994b).

CORRELATION, LINKAGE, AND ALIGNMENT OF TRIASSIC THROUGH MID-CRETACEOUS CONTINENTAL MARGIN ARCS, ISLAND ARCS, AND TECTONICALLY PAIRED SUBDUCTION ZONES

During the Triassic through mid-Cretaceous, ten major igneous arcs are herein recognized around the Circum-North Pacific. These arcs are: (1) the Jurassic Monakin arc in the Primorski region of the Russian Southeast and the Jurassic and Cretaceous Eastern China-Korean igneous arc in Korea and China, both part of the Great Hingan arc; (2) the Jurassic and Early Cretaceous Umlekan arc in the Russian Southeast, (3) the Early and mid-Cretaceous Khingan arc in the Russian Southeast; (4) the Late Jurassic and Early Cretaceous Uda arc in the central part of the Russian Far East; (4) the Late Jurassic and Early Cretaceous Kony-Murgal Arc in the Russian Northeast; (5) the Late Jurassic through Mid-Cretaceous Mainitskiy Arc in the Russian Northeast; (6) the Late Jurassic and Early Cretaceous Uyandina arc in the Russian Northeast; (7) the Late Triassic and Early Jurassic Alazeya island arc in the Russian Northeast; (8) the Late Jurassic through mid-Cretaceous Nutesyn-Koyukuk Arc in the Russian Northeast and Western Alaska; (9) the Late Jurassic through mid-Cretaceous Gravina Arc in Southern Alaska and the Canadian Cordillera; and (10) the Late Triassic and Early Jurassic Talkeetna-Bonanza Arc in Southern Alaska and the Canadian Cordillera.

Middle and Late Jurassic Monakin Arc in Russian Southeast

The Monakin arc is defined as a Middle and Late Jurassic suite of igneous and associated sedimentary rocks that occur in the Russian Southeast (Figure 3). The arc consists chiefly of sedimentary and volcanic rocks of the Monakin volcanic-plutonic belt and the Umlekan-Ogodzhin volcanic-plutonic belt that both occur in the Russian Southeast (Figure 3). The Monakin volcanic-plutonic belt (mo) overlies the Sergeevka terrane of the Khanka superterrane, and in the western part, consists of dacite and rhyolite flows and tuffs, and continental flora-bearing clastic rocks (Oleinikov and others, 1990; Decisions of the Fourth

Interdepartmental Regional Meeting on Precambrian and Phanerozoic of the Far East and Eastern Baikal Regions, 1994). In the eastern part, the arc consists of basalt, andesite, and tuff that are interlayered with shallow-marine deposits containing a bivalve-mollusk fauna. The Monakin arc and the underlying Sergeevka terrane, both too small to depict on Figures 1 and 3, occur in the extreme south part of the Russian Southeast.

Subduction Zone Terranes in Russian Southeast and Hokkaido Island Tectonically Linked to Jurassic Monakin Arc and Correlative Igneous Arcs in Korea and China

Tectonically linked to the Jurassic Monakin arc in the Russian Southeast was a discontinuous collage of accretionary wedge terranes that occur in northern Japan and in the southern part of the Russian Far East. The accretionary wedge terranes, composed mainly of Paleozoic and early Mesozoic oceanic crustal and upper mantle rocks, and turbidite deposits, consist of the Badzhal (BD), Khabarovsk (KB), and Samarka (SMA) accretionary wedge terranes (Figure 3). These terranés are also tectonically linked to the Umlékan arc and are described below. The Badzhal, Khabarovsk, and Samarka accretionary wedge terranes share (Natal'in, 1993; Nokleberg and others, Khanchuk and others, 1996; Sengör and Natal'in, 1996): (1) similar ages of deformation(s) and melange, formed mainly during Late Triassic through Early Cretaceous subduction; and (2) a similar tectonic position and occurrence as a series of narrow, discontinuous, and long tectonic lenses that occur outboard of the Umlekan-Ogodzhin volcanic-plutonic belt (uo) of mainly Late Jurassic and Early Cretaceous age that intrudes and overlies the Bureya continental margin arc terrane (BU) (Figure 3)

Tectonically linked to the Jurassic and Cretaceous Eastern China-Korean igneous arc in Korea and China, coeval units with respect to the Monakin arc, are the Taukha and Oshima terranes that are correlated with the Hern Chichibu terrane in southeastern Japan (Faure and Natal'in, 1992; Kojima, 1989; Natal'in and Faure, 1991; Kojima and others, 1991; Mizutani and Kojima, 1992; Golozubov and Khanchuk, 1996).

The Taukha accretionary wedge terrane (TU) occurs in the southern Russian Far East and consists chiefly of an Early Cretaceous accretionary complex composed of two main units (Golozubov and Melnikov, 1986; Mikhailov and others, 1986, 1987, 1989; Khanchuk and others, 1988; Rudenko and Panasenko, 1990; Natal'in, 1991; Golozubov and others, 1992; Kemkin and Khanchuk, 1993; Golozubov and Khanchuk, 1996): (1) A western, structurally lower unit contains oceanic basalt overlain by Callovian to Tithonian radiolarian chert, Berriasian siliceous mudstone, and Neocomian turbidite deposits, about 3,500 m thick, that contain ammonites and pelecypods; and (2) an eastern, structurally higher unit of turbidite and olistostrome deposits that contain abundant Valanginian to Hauterivian radiolaria and a Neocomian flora. The Takuha terrane also contains tectonic inclusions of oceanic intraplate basalt and chert with limestone caps (paleoguyots) that range up to several thousand meters wide and up to 10 km long, with local Tethyan fauna. And (2) Late Triassic clastic rocks. Formation of the Taukha accretionary wedge terrane is interpreted as ending during the Valanginian to Hauterivian with subsequent offset along transpressional sinistral-strike-slip faults (Natal'in, 1991; Natal'in and Faure, 1991; Golozubov and Khanchuk, 1996) (Figure 10).

The Oshima accretionary wedge terrane (OS) occurs on Hokkaido Island in northern Japan and consists chiefly of flysch and melange (Kato and others, 1990; Minoura, 1990; Natal'in, 1991, 1993; Natal'in and Faure, 1991). The melange is composed of blocks of basalt, limestone, chert, siliceous shale, and sandstone that occur in a shale matrix (Matsumae, Tamdrigawa, and Kamiiso Groups). Carboniferous fusulinids occur in the limestone blocks. Carboniferous to Permian radiolarians occur in the chert blocks, Triassic conodonts and radiolarians occur in limestone and chert blocks, and Upper Jurassic to Lower Cretaceous radiolarians are present in chert and siliceous shale blocks. The blocks were tectonically mixed during the Late Jurassic to the Early Cretaceous.

The Taukha. Oshima, and Tamba-Mino accretionary wedge terranes are interpreted as part of a Jurassic and Early Cretaceous subduction zone that formed along the eastern Asia margin (Taira and Tashiro, 1987; Ichikawa and others 1990; Natal'in, 1991, 1993; Natal'in and Faure, 1991; Faure and Natal'in, 1992; B.A. Natal'in Nokleberg and others. 1994a). This subduction zone was tectonically paired to the Jurassic granitic rocks in Korea to the southeast. (Lee, 1987; Cluzel, 1991; Cluzel and others, 1991) and to the Monakin arc in the Russian Southeast (Khanchuk and others, 1996). These Jurassic igneous granitic rocks in Korea are connected by magmatic anomalies with a Jurassic to Cretaceous volcanicplutonic belt of southeastern China. During the Cretaceous and early Cenozoic, dextral-slip on numerous Cretaceous strike-slip faults northward tectonic transport of these accretionary wedge terranes with respect to the magmatic arc. This Eastern China-Korean igneous arc and tectonically paired accretionary wedge terranes are the continuation of the Great Hinggan arc (Natal'in, 1991, 1993; Natal'in and Faure, 1991; Faure and Natal'in, 1992; B.A. Natal'in Nokleberg and others, 1994a).

Jurassic and Early Cretaceous Umlekan Arc in Southern Part of Russian Far East

The Umlekan arc is defined as a Jurassic and Early Cretaceous continental margin igneous arc in the Russian Southeast (Natal'in 1991, 1993, Natal'in and Faure 1991, Faure and Natal'in 1992, Natal'in et al., 1995; Khanchuk and others, 1996). Remnants of the arc are preserved in the Umlekan-Ogodzhin volcanic-plutonic belt (uo) and coeval Late Jurassic and Early Cretaceous granitic plutons that overlie or intrude various terranes in the Russian Southeast and the North Asian Craton (NAC) (Figure 3). The igneous rock units of the arc and tectonically linked subduction units occur inland from, and parallel to the coast of the Russian Southeast for about 1000 km (Figure 3).

Igneous Rock Units of Umlekan Arc

The Umlekan-Ogodzhin volcanic-plutonic belt (uo) consists chiefly of (Volsky, 1983; Kozlovsky, 1988): (1) Lower Cretaceous sandstone, conglomerate, and mudstone with sparse flora and freshwater fauna;

(2) Lower Cretaceous calc-alkalic andesite, dacite, and tuff that yield K-Ar ages of 112-135 Ma; and (3) Upper Cretaceous alkalic basalt and rhyolite. The belt is intruded by coeval Early Cretaceous granite, granodiorite, diorite, and monzodiorite. Some granitic plutons are probably Late Jurassic, or older because their detritus were shed into the Early Cretaceous part of section. The belt is deposited on the Gonzha terrane, and on the Mamyn and Turan terranes of Bureya superterrane after collision of these terranes with the Tukuringra-Dzhagdinsk terrane.

Subduction Zone Linked to Umlekan Arc

Tectonically paired to the Umlekan arc was a subduction zone now preserved in a discontinuous collage of subduction zone and accretionary wedge terranes in the southern part of the Russian Far East. These terranes, composed mainly of Paleozoic and early Mesozoic oceanic crustal and upper mantle rocks, and turbidite deposits, consist of the Badzhal (BD), Khabarovsk (KB) (older Jurassic part), and Samarka (SMA) accretionary wedge terranes (Figures 1, 3) (Natal'in, 1993; Nokleberg and others, 1994a; Khanchuk and others, 1996; Sengör and Natal'in, 1996).

The Badzhal accretionary wedge terrane (BD) consists chiefly of Paleozoic limestone olistoliths in a clastic matrix; Permian and Triassic chert lenses; Late Triassic through Late Jurassic turbidite deposits; chert and siliceous shale; and small lenses of mafic volcanic rocks (Shevelev and Kuzmin, 1990; Natal'in, 1991, 1993; Zablotsky and others, 1990). The terrane is interpreted as a Triassic to Middle Jurassic accretionary wedge complex that is composed of tectonically intermixed oceanic and continental slope deposits. Limestone units, which contain Carboniferous and Permian Tethyan fauna, are interpreted as the caps to seamounts.

The Khabarovsk accretionary wedge terrane (KB) consists chiefly of a Jurassic and Early Cretaceous melange with variously sized fault-bounded lenses and slices of Triassic chert, Lower to Middle Jurassic siliceous shale, hemipelagic sedimentary rocks, mafic volcanic rocks, and gabbro, Upper Carboniferous, Permian, and Upper Triassic limestone, and schist and metasandstone of unknown age (Natal'in and Alekseenko, 1989, Natal'in and Zyabrev, 1989, Shevelyov, 1987). The Upper Paleozoic limestone locally contains volcanic rock layers and a Tethyan fauna, and is interpreted as a reef caps on seamounts.

The Samarka accretionary wedge terrane (SMA) consists chiefly of a Middle and Late Jurassic accretionary wedge complex that contains tectonic sheets and lenses, olistostromes, and melange inclusions that are composed of Carboniferous and Permian reef limestone, Upper Triassic pelagic limestone, and interlayered Upper Devonian, Carboniferous, Permian, and Triassic chert, Lower Jurassic siliceous shale, and Permian and Triassic clastic marine rocks (Golozubov and Melnikov, 1986, Vrublevsky and others, 1988, Khanchuk and others, 1988, Natal'in, 1991).

Origin of Umlekan Arc

The continental margin Umlekan arc is interpreted as forming from subduction of part of the Ancestral

Pacific that is now preserved as tectonically fragments of the Badzhal interwoven Khabarovsk (KB), Samarka (SMA) terranes. This tectonic pairing is based on: (1) occurrence of the accretionary wedge terranes outboard (oceanward) of the Umlekan arc (Figure 3); (2) formation of melange structures during the Jurassic and Early Cretaceous (Nokleberg and others, 1994a; Khanchuk and others, 1996); and (3) where not disrupted by extensive Cretaceous and early Cenozoic movement along the Central Sihote-Aline strike-slip fault (CA), dipping of melange structures and bounding faults towards and beneath the igneous units of the arc. Subduction is generally interpreted as ending in the late Early Cretaceous when extensive sinstral faulting occurred long the subduction zone (Khanchuk and others, 1996).

Early and Mid-Cretaceous Khingan Arc in Russian Southeast

The Khingan arc is defined as an Early and mid-Cretaceous, continental-margin igneous arc in the Russian Southeast (Natal'in 1991, 1993, Natal'in and Faure 1991, Faure and Natal'in 1992, Natal'in et al., 1995; Khanchuk and others, 1996; (Figure 3). The Khingan arc consists of the Khingan-Okhotsk volcanic-plutonic belt (ko) that occurs as a chain of Early and mid-Cretaceous volcanic fields with similar age, lithology, and stratigraphy (Figure 3). The belt consists of (Sukhov, 1975; Scheglov, 1984; Natal'in, 1991, 1993): mainly of Barremian to Cenomanian (mid-Cretaceous) andesite and minor basalt, with coeval gabbro, diorite, and granodiorite. The belt overlies and intrudes the Badzhal (BD), Bureya (BU), and Ulban (UL) terranes (Figure 3).

Tectonically paired to the Khingan continental margin arc was a subduction zone now preserved in a discontinuous collage of accretionary wedge terranes in the Russian Southeast. These terranes, composed mainly of Paleozoic and early Mesozoic oceanic crustal and upper mantle rocks, and turbidite deposits, consist of the Amur River (AM), Khabarovsk (KH), and Kiselevka-Manoma (KLM) accretionary wedge terranes (Figures 1, 3) (Natal'in and Alexeenko; 1989, Natal'in and Zyabrev, 1989; Khanchuk and others, 1994).

The Amur River terrane (AM) consists chiefly of abundant Cretaceous turbidite deposits (Largasinsk, Uktursk, Pionersk, and Pivansk suites), subordinate Late Jurassic hemipelagic siliceous shale that occur in an imbricate stack of southeast-verging thrust sheets and slices (Natal'in and Aleseenko, 1989, Krasny, 1966). The Kiselevka-Manoma terrane (KLM), too small to depict on Figures 1, 3, occurs in a narrow band along the northeastern edge of the Amur River terrane, and contains Jurassic and Lower Cretaceous ribbon chert, siliceous shale. Cretaceous flysch, Jurassic basalt and Lower Jurassic limestone in an Early Cretaceous olistostrome (Filippov, 1988, Kuzmin and Kaidalov, 1990; Shevlyov, 1987, Natal'in, 1991; Khanchuk and others, 1994).

The Khabarovsk terrane (KB) consists chiefly of a Jurassic and Early Cretaceous melange with variously sized fault-bounded lenses and slices of Triassic chert, Lower to Middle Jurassic siliceous shale, hemipelagic sedimentary rocks, mafic volcanic rocks, and gabbro, Upper Carboniferous, Permian, and Upper Triassic limestone, and schist and metasandstone of unknown age (Shevelyov, 1987; Natal'in and Alekseenko, 1989; Natal'in and Zyabrev, 1989). The Upper Paleozoic limestone locally contains volcanic rock layers and a Tethyan fauna, and is interpreted as a reef caps on seamounts.

Origin of Khingan Arc

The continental margin Khingan arc is interpreted as forming from subduction of the Ancestral Pacific Ocean plate. Fragments of this plate are interpreted as occurring in tectonically interwoven fragments of the Amur River (AM), Khabarovsk (KH) (younger Early and mid-Cretaceous part), and Kiselevka-Manoma (KLM) accretionary wedge terranes (Figure 11) (Natal'in, 1991, 1993; Nokleberg and others, 1994a; Sengör and Natal'in, 1996). This tectonic pairing is based on: (1) occurrence of accretionary wedge terranes outboard (oceanward) of, and parallel to the various parts of the Khinghan arc (Figure 3); (2) formation of melange structures during the Early and mid-Cretaceous (Natal'in, 1991; Nokleberg and others, 1994a; Vrublevsky and others, 1988; Nechaev and others, 1996); and (3) where not disrupted by extensive Cretaceous movement along the Central Sihote-Aline strike-slip fault (CA), dipping of melange structures and bounding faults towards and beneath the igneous units of the arc (Natal'in, 1993). The Khabarovsk terrane (KB), interpreted as having formed during subduction in the Jurassic through Early Cretaceous (Natal'in and Zyabrev, 1989) is herein linked to both the Early and mid-Cretaceous Khingan arc and to the Late Jurassic and Early Cretaceous Umlekan arc described below. Formation of the Khingan arc and associated subduction is generally interpreted as ending in the late mid-Cretaceous when oblique subduction changed into sinistral-slip faulting along the outboard margin of the arc.

The Khingan arc is interpreted as forming after collision of the Anui microcontinent with the Samarka terrane (Natal'in 1991, 1993, Natal'in and Faure 1991, Faure and Natal'in 1992, B.A. Natal'in in Nokleberg and others, 1994a; Natal'in and others, 1995). The Anui microcontinent is now preserved within the Samarka subduction zone terrane in a small tectonic window as the Anui metamorphosed continental margin terrane. Xenoliths of metamorphic rocks, interpreted as fragments of the Anui terrane, are widespread in similar granitic rocks in the Central Sikhote-Alin region, and suggest that the Anui terrane occurs regionally underneath the Samarka terrane. The Khor continental margin arc terrane, too small to depict on Figures 1, 3) occurs in a narrow tectonic lens along the Central Sikhote-Aline fault (CA) and is correlated with the Khanka terrane (Khanchuk and others, 1996).

Mid-Cretaceous Kema Island Arc Eastern Part of Russian Southeast

The Kema arc is defined as a suite of mainly mid-Cretaceous igneous rocks units in the Eastern Sikhote-Alin area and on Sakhalin Island (Nokleberg and others, 1994; Khanchuk and others, 1996). These igneous-arc rocks were originally defined as part of the mid- and Late Cretaceous East Sikhote-Alin continental margin arc (Parfenov and Natal'in, 1986) or as part of the Samaka island arc (Simanenko, 1986).

However, the Late Cretaceous volcanic rocks of the East Sikhote-Alin arc disconformably overly the igneous arc rocks of the Kema terrane, thereby indicating, along with other field relations, that the Kema arc occurs in a separate terrane (Nazarenko and Bazhanov, 1986; Khanchuk and others, 1996).

Igneous Rock Units of Kema Arc

The Kema island arc terrane consists chiefly of a chain of predominantly volcanic rocks with a western unit volcaniclastic deposits. The volcanic rocks consists of lava, hyaloclastic rocks, and marine tuff that are composed of basalt, basaltic andesite, and andesite. These units occur in flows that vary from a few m to a few tens m thick. Also occurring are terrigenous volcanic deposits, flysch composed of fine-grained sandstone, siltstone, and distal turbidite-type argillite alternates with beds of volcaniclastic rocks. Thick layers of basaltic andesite also occur. Sedimentary rocks contain Aptian to Albian bivalves. In the lower part of the section, flysch consists of alternating, medium-grained sandstone, tuffaceous sandstone, with typical turbidite graded bedding, and abundant siltstone fragments. The sandstone is arkosic and medium-grained (Nazarenko and Bazhanov, 1986; Simanenko, 1986; Khanchuk and others, 1996).

Subduction Zone Related to Kema Arc

Tectonically linked to the Kema arc was an elongated, transpressional subduction zone that is now preserved in a discontinuous and disrupted collage of terranes in the Sakhalin and Hokkaido Islands. The terranes are the older part of the Aniva (ANV) subduction zone terrane on Sakhalin Island, and the Kamuikotan subduction zone terrane (KK) on Hokkaido Island (Figure 1). The older part of the Aniva subduction zone terrane consists chiefly of a melange unit with a matrix of mid-Cretaceous turbidite that encloses bodies of serpentinite melange, ophiolite, blueschist, and greenschist (Richter, 1986). The Kamuikotan subduction zone terrane consists chiefly of high-pressure metamorphic rocks, serpentinite melange and ophiolite. K-Ar ages of the ophiolite range from 100-125 ma (Kato and Nakagawa, 1986; Ichikawa and others, 1990).

Origin of Kema Arc

The Kema arc is interpreted as forming from subduction of part of the Ancestral Pacific Ocean plate that is now preserved as tectonically interwoven fragments of the Aniva and Kamuikotan subduction-zone terranes. Volcanic rocks of the Kema arc correlate with the Early and mid-Cretaceous volcanic rocks that disconformably overly the Oshima (OS) accretionary-wedge terrane on the Hokkaido Island and volcanic rocks of the northeastern Honshu Island (Kiminami and Kontani, 1983; Ichikawa and others, 1990). The Early and mid-Cretaceous Kema arc is similar in nature to the modern Aleutian-Wrangell arc.

Late Jurassic and Early Cretaceous Uda Arc in Central Part of Russian Far East

The Uda igneous arc is defined as a suite of mainly Late Jurassic and Early Cretaceous, and lesser

Late Triassic to Middle Jurassic igneous rock units in the central part of the Russian Far East (Parfenov and Natal'in, 1985, 1986 Parfenov, 1984; Natal'in, 1993; B.A. Natal'in in Nokleberg and others, 1994a; Sengör and Natal'in, 1996). Remnants of the arc are preserved in the Uda volcanic-plutonic belt (ud), the Univa-Bom turbidite basin terrane (UB), the Umlekan-Ogodzhin volcanic-plutonic belt (uz), and the Upper Amur sedimentary assemblage (ua) (Figure 3). The Uda arc was deposited on, adjacent to, and intruded into the North Asian Craton (NSC), the Stanovoy block of the North Asian Craton (NSS), and the Okhotsk terrane (OH), and formed as part of the Mongol-Okhotsk active continental margin. Farther south, the magmatic equivalents of the Uda arc occurs in the Great Hinggan Mountains of northeastern China (Natal'in, 1993; B.A. Natal'in in Nokleberg and others, 1994a; Sengör and Natal'in, 1996). The various igneous-related units of the Uda arc (Uda volcanic-plutonic belt, Univa-Bom turbidite basin terrane, Umlekan-Ogodzhin volcanicplutonic belt, and Upper Amur sedimentary assemblage) are grouped into a single arc on the basis of similar age, similar arc origin, geographical proximity, and simplicity.

Igneous Rock Units of Uda Arc

The Uda volcanic-plutonic belt (ud) consists chiefly of basalt, andesite-basalt, andesite, and tuff that are interlayered with nonmarine sandstone, siltstone, conglomerate, and coal with a Late Jurassic and Early Cretaceous flora (Sosunov and others, 1982; Filatova, 1979, 1988; Lebedev and others, 1989; Zmievsky and others, 1990). The belt also contains Jurassic granitic rocks, including granodiorite, diorite, and granite, that extend to the west along the southern margin of the North Asian Craton (NSC). The granitic rocks of the belt yield reliable isotopic ages that range from 130 to 200 Ma. The Uniya-Bom turbidite basin terrane (UB) consists chiefly of a tectonic sheet that is composed of Upper Triassic to Lower Jurassic turbidite deposits and interbedded olistostromes (Kirillova and Turbin, 1979, Natal'in and others, 1985). The turbidite deposits contain lenses of greenstone and chert that are typical of the Tukuringra-Dzhagdi terrane. Sandstone and conglomerate clasts were derived in part from North Asian Craton. The terrane is intensively deformed and contains a penetrative stretching lineation that formed by ductile deformation during strike-slip tectonic transport. The Umlekan-Ogodzhin volcanic-plutonic belt (uz) consists chiefly of (Volsky, 1983; Kozlovsky, 1988): (1) Lower Cretaceous sandstone, conglomerate, mudstone, calcalkalic andesite, dacite, and tuff with K-Ar ages of 112-135 Ma; (2) Upper Cretaceous alkalic basalt and rhyolite; (3) Early Cretaceous and granodiorite, diorite, and monzodiorite. The Upper Amur sedimentary assemblage (ua) consists chiefly of Upper Jurassic shallow-marine sandstone, siltstone. and shale, and nonmarine Lower Cretaceous clastic rocks with coal (Kirillova and Turbin, 1979). The structural thickness of the sedimentary rocks is about 3,000 m.

Subduction Zone Linked to Uda Arc

Tectonically paired to the Uda continental margin arc was a subduction zone that is now preserved in a

discontinuous collage of terranes in the central part of the Russian Far East. These terranes, composed mainly of Paleozoic and early Mesozoic oceanic crustal rocks, upper mantle rocks, and turbidite deposits, consist of the Tukuringra-Dzhagdinsk subduction zone, Galam accretionary wedge, and Ulban accretionary wedge terranes (Figure 3) (Parfenov and Natal'in, 1985, 1986; Parfenov, 1984; Natal'in and Borukavev, 1991; Natal'in, 1991, 1992, 1993; Natal'in and Faure, 1991, Faure and Natal'in, 1992; Natal'in, 1993; Khanchuk, and others, 1996; B.A. Natal'in in Nokleberg and others, 1994a; Sengör and Natal'in, 1996). These subduction zone terranes occur along splays of the Mongol-Okhotsk fault (MO), along which substantial middle Mesozoic through early Tertiary sinistral-slip faulting has occurred.

The Turkuringra-Dzhagdi accretionary wedge terrane (TD) consists chiefly of fault-bounded units of tectonic lenses or olistoliths of Upper Proterozoic limestone. Silurian and Devonian mafic volcanic rocks and chert, Carboniferous and Permian sandstone. siltstone, shale, and turbidites, flysch, greenstone, chert, and limestone with Permian Tethyan fusulinids, and a narrow tectonic lens of ophiolite (Pikansk complex) along the southern margin of the terrane that consists of gabbro, amphibolite pyroxenite, serpentinite, and plagiogranite (Natal'in and others, 1985, Kozlovsky, 1988). The Galam accretionary wedge terrane (GL) consists chiefly of Cambrian and Lower Ordovician limestone olistoliths in a flysch matrix, and Silurian to Lower Carboniferous and Upper Permian turbidite deposits, and lesser mafic volcanic rocks, chert, siliceous shale, pelagic shale, and fine-grained graywacke that are included in widespread olistostrome deposits. Oceanic chert, mafic volcanic rocks, and clastic rocks of Silurian to Late Permian age are also occur in local tectonic slices (Kirillova and Makhinin, 1983, Roganov and others, 1986, Natal'in and Popeko, 1991). Along the boundary with Baladek cratonal terrane are fault slices of harzburgite, dunite, and websterite. The Ulban accretionary wedge terrane (UL) consists chiefly of Early and Middle turbidite deposits and unconformably Jurassic overlying Callovian turbidite deposits (Maibroda and Sharuyeva, 1979; Natal'in, 1991). The turbidite deposits contain local tectonic lenses of oceanic crustal rocks which include chert, siliceous shale, and mafic volcanic rocks.

Origin of Uda Arc

The continental margin Uda arc is interpreted as forming from the subduction of the Mongol-Okhotsk Ocean that is now preserved as tectonically interwoven fragments of the Turkuringra-Dzhagdi, Galam, and Ulban subduction zone and accretionary wedge terranes (Figures 7-10) (Natal'in, 1993; B.A. Natal'in in Nokleberg and others, 1994a; Sengör and Natal'in, 1996). This tectonic pairing is based on: (1) occurrence of these accretionary wedge terranes outboard (oceanward), southward of (in present-day coordinates), and parallel to the various parts of the Uda arc (Figure 3); (2) formation of melange structures during the Jurassic and Early Cretaceous (Nokleberg and others, 1994a); and (3) where not disrupted by extensive Cretaceous and early Cenozoic dextral slip along the Mongol-Okhotsk fault (MO) (Figure 3), dipping of melange structures and bounding faults

towards and beneath the igneous units of the arc. Subduction is generally interpreted as ending in the Early to mid-Cretaceous during final closure of the Mongol-Okhotsk Ocean.

Late Triassic to Early Cretaceous Kony-Murgal Arc in Russian Northeast

Remnants of the Kony-Murgal continental margin and island arc are preserved in the Kony-Murgal (KM) and West Pekul'ney (WP) island arc terranes that occur in the eastern part of the Russian Northeast (Figure 1). These terranes consist of an extensive suite of coeval Late Jurassic through mid-Cretaceous volcanic arc and related rocks (Parfenov and others, 1993a, b; Parfenov, 1984; Nokleberg and others, 1994a; Sokolov, 1992; Sokolov and Byalobzheskiy, 1996; Khudoley and Sokolov, 1998). The Kony-Murgal terrane occurs along the northwestern margin of the Sea of Okhotsk, southeast of the Kolyma-Omolon superterrane; the West Pekulney terrane occurs along strike to the northeast (Figure 1). Together, these two island arc terranes extend along strike for about 1,400 km. The Kony-Murgal arc is the eastern extension of the mostly coeval Uda arc.

Igneous Rock Units of Kony-Murgal Arc

The Konv-Murgal continental margin and island arc terrane (KM) consists chiefly of Upper to Hauterivian folded, calc-alkaline, continental and island arc volcanic and sedimentary rocks (Belyi, 1977; Parfenov, 1984; Nekrasov, 1987; Filatova, 1979, 1988). The volcanic units are mainly basalt, andesite-basalt, andesite, and tuff, and local shallow-marine and nonmarine volcaniclastic rocks. The terrane also contains Late Jurassic and Early Cretaceous (pre-Albian) granodiorite, tonalite. plagiogranite, and quartz diorite and locally Late Permian though Middle Jurassic shale, siltstone, sandstone, conglomerate, tuff, and basalt.

The West Pekul'ney island arc terrane (WP) consists of various tectonic sheets composed of (Nekrasov and Sumin, 1987; Zhulanova and Pertsev, 1987): (1) thick, folded sequences of flows and volcaniclastic rocks of intermediate, mafic, and sparse felsic compositions, argillite, siltstone, sandstone, grit and rare limestone with Buchia of Berriasian and Valanginian age and Aucelline of Aptian to Albian age; (2) Hauterivian to Barremian olistostrome with gabbro. ultramafic rock, jasper, and basalt fragments; (3) Early Cretaceous plagiogranite and gabbro; amphibolepyroxene schist and olivine gabbro with Pb-Pb isotopic ages of 1,200 to 2,900 Ma; and (4) layered gabbro, pyroxene-amphibole gabbro, and amphibole microgabbro.

Subduction Zone Units Linked to Kony-Murgal Arc

Tectonically linked to the Kony-Murgal arc was a subduction zone now preserved in the discontinuous collage of the Talovskiy (TL) subduction zone, and Penzhina-Anadyr (PA) accretionary wedge. These terranes occur outboard (oceanward) of, and parallel to the Kony-Murgal arc (Figure 1), and consists mainly of Paleozoic and early Mesozoic oceanic crustal rocks, upper mantle rocks, and turbidite deposits (Figure 1)

(Parfenov and others, 1993a, b; Nokleberg and others, 1994a).

The Talovskiy terrane (TL) consists chiefly of (Khanchuk and others, 1990; Sokolov, 1990, 1992, 1992; Vishnevskaya and others, 1992; Heiphitz and others, 1994b; Sokolov and Byalobzheskiy, 1996; Khudoley and Sokolov, 1998): (1) tectonic sheets of Bathonian and Tithonian ophiolite and serpentinite melange with blocks of ultramafic rock, gabbro, plagiogranite, oceanic dike suites; amphibolite, and glaucophane schist; (3) island arc and forearc andesite, dacite, tuff, sedimentary rocks; and (3) the Kuyul subduction-zone melange composed of Upper Jurassic and Lower Cretaceous turbidite deposits.

The Penzhina-Anadyr terrane (PA) consists chiefly of (Sokolov, 1992; Khanchuk and others, 1992; Sokolov and Byalobzheskiy, 1996; Khudoley and Sokolov, 1998): (1) thrust slices of serpentinite melange; (2) an ophiolite sequence that is depositionally overlain by Devonian and Carboniferous chert, calcareous sandstone, tuff, and limestone; (3) younger diabase, plagiogranite, and diorite dikes with K-Ar ages of 180 to 304 Ma; (4) shallow-marine sandstone and siltstone and interlayered conglomerate; and (5) Late Jurassic to Early Cretaceous sandstone, siltstone, and mudstone).

Origin of Kony-Murgal Arc

The Kony-Murgal arc is interpreted as forming from subduction of part of the Ancestral Pacific Ocean plate (Parfenov and Natal'in, 1985, 1986; Filatova, 1988; Zonenshain and others, 1990; Sokolov, 1992; Parfenov and others, 1993a, b; Nokleberg and others, 1994a; Zonenshain and others, 1990) that is preserved in the Talovskiy (TL) subduction zone, Penzhina-Anadyr (PA) accretionary wedge, and Pekul'ney subduction zone terranes (Figures 7-10). This tectonic pairing is based on: (1) occurrence of these subductionrelated terranes outboard (oceanward or to the east using present-day coordinates), and parallel to the various parts of the igneous rock units of the Kony-Murgal arc (Figure 1); (2) formation of melange structures during the Jurassic and Early Cretaceous (Nokleberg and others, 1994a); and (3) dipping of melange structures and bounding faults towards and beneath the igneous units of the arc, where not disrupted by displacement along Cretaceous and early Cenozoic northwest-striking, strike-slip faults (Figure 1). Subduction is generally interpreted as ending in the Early to mid-Cretaceous during final closure of the Mongol-Okhotsk Ocean and the accretion of the Kony-Murgal island arc onto the Northeast Asian continental margin (Stavsky and others, 1988; Zonenshain and others, 1990; Sokolov, 1992).

Late Jurassic through Mid-Cretaceous Pekul'ney Arc in Russian Northeast

Remnants of the Pekul'ney island arc terrane are preserved in the West Pekul'ney island arc terrane (WP) that occurs in the eastern part o the Russian Northeast (Figure 1). The West Pekul'ney island arc terrane (WP) consists of various tectonic sheets composed of (Nekrasov and Sumin, 1987; Zhulanova and Pertsev, 1987): (1) thick, folded sequences of flows and volcaniclastic rocks of intermediate, mafic, and sparse felsic compositions, argillite, siltstone,

sandstone, grit and rare limestone with *Buchia* of Berriasian and Valanginian age and *Aucelline* of Aptian to Albian age; (2) Hauterivian to Barremian olistostrome with gabbro, ultramafic rock, jasper, and basalt fragments; (3) Early Cretaceous plagiogranite and gabbro; amphibole-pyroxene schist and olivine gabbro with Pb-Pb isotopic ages of 1,200 to 2,900 Ma; and (4) layered gabbro, pyroxene-amphibole gabbro, and amphibole microgabbro.

Subduction Zone Units Linked to Pekul'ney Arc

Tectonically linked to the Kony-Murgal arc was a subduction zone now preserved in the discontinuous collage of the Pekul'nev subduction zone terrane that occurs outboard (oceanward) of, and parallel to the Pekul'ney arc (Figure 1) (Parfenov and others, 1993a, b; Nokleberg and others, 1994a). The Pekul'ney terrane (PK) consists of (Nekrasov and Sumin, 1987; Markovsky and Bogdanov, 1985; Zhulanova and Pertsey, 1988) western and eastern units. The western unit consists of: (1) a basal serpentinite matrix melange that contains fragments of metamorphic rocks, including greenschist, glaucophane schist, and picritic basalt; (2) a metamorphic complex that is composed of amphibolite and schist that are derived from dunite, spinel peridotite, clinopyroxenite and that yields Pb-Pb isotopic ages of 1,600 to 1,800 Ma, and eclogite inclusions that yield isotopic ages of 2,400-1,900 Ma; and (3) the Upper Jurassic and Lower Cretaceous Pekulneyveem suite which is composed of basalt, tuff, chert, hyaloclastite, radiolarian siltstone, sandstone. The eastern Televeem unit consists of thick flysch of Early Cretaceous (Aptian to Albian) and Upper Cretaceous (Cenomanian to Turonian) age.

Origin of Pekul'ney Arc

The Pekul'ney arc is interpreted as forming from subduction of part of the Ancestral Pacific Ocean plate (Parfenov and Natal'in, 1985, 1986; Filatova, 1988; Zonenshain and others, 1990; Sokolov, 1992; Parfenov and others, 1993a, b; Nokleberg and others, 1994a; Zonenshain and others, 1990) that is preserved in the Pekul'ney subduction zone terrane (PK) (Figures 9-10). This tectonic pairing is based on: (1) occurrence of subduction-related terranes (oceanward), east of (in present-day coordinates), and parallel to the various parts of the igneous rock units of the arc (Figure 1); (2) formation of melange structures during the Jurassic and Early Cretaceous (Nokleberg and others, 1994a); and (3) dipping of melange structures and bounding faults towards and beneath the igneous units of the arc, where not disrupted by displacement along Cretaceous and early Cenozoic northwest-striking, strike-slip faults (Figure 1). Subduction is generally interpreted as ending in the Early to mid-Cretaceous during accretion of the island arc onto the Northeast Asian continental margin (Stavsky and others, 1988; Zonenshain and others, 1990; Sokolov, 1992).

Late Jurassic through Mid-Cretaceous Mainitskiy Arc in Russian Northeast

Remnants of the Mainitskiy arc are preserved in the Mainitskiy island arc terrane that occurs in the eastern part of the Russian Northeast (Figure 1)

(Stavsky and others, 1988; Zonenshain and others, 1990: Parfenov and others, 1993a, b: Nokleberg and others, 1994a; Bogdanov and Tilman, 1992 Sokolov, 1992; Sokolov and Byalobzheskiy, 1996). The Mainitskiy island arc terrane (MAI) consists of two sequences (Stavsky and others, 1989; Shmakin, 1991; Vishnevskaya and others, 1991; Sokolov, 1992; 1993: Didenko and others, Sokolov Byalobzheskiy, 1996). An older sequence consists of a lower unit of serpentinite and serpentinite melange that contain fragments of late Paleozoic and early Mesozoic ophiolite with Middle and Upper Jurassic radiolarians, and an upper Berriasian and Valanginian unit of graywacke, siltstone, tuff, bedded chert. Local olistoliths are common and are composed of ophiolite. limestone with Permian and Triassic foraminifera, plagiogranite, andesite, and rhyolite. A younger sequence consists of a thick assemblage of Upper Jurassic and Lower Cretaceous island arc volcanic and sedimentary rocks composed of tholeitic basalt, andesitic basalt, rhyolite, tuff, breccia, chert, siltstone, and sandstone with Callovian to Kimmeridgian, and Tithonian to Hauterivian radiolarians. The Mainitskiy terrane also contains a complex series large tectonically imbricated nappes of disrupted ophiolite (Yagel melange) of Late Jurassic to Early Cretaceous (Callovian to Hauterivian) age, and several tectonic sheets of dunite, harzburgite, gabbro, and ultramafic rocks that are structurally overlain by island arc volcanic rocks. The Mainitskiy terrane is interpreted as a fragment of a Late Jurassic to mid-Cretaceous island arc that is underlain by a basement of oceanic crust and primitive island arc rocks of Triassic to Early Jurassic

Subduction Zone Unit Linked to, and Origin of Mainitskiy Arc

Tectonically linked to the Mainitskiy arc was a subduction zone now preserved in the discontinuous collage of the Alkatvaam accretionary wedge terrane (AV) (Figure 1) (Sokolov, 1992; Didenko and others, 1993; Parfenov and others, 1993a, b; Nokleberg and others, 1994a; Sokolov and Byalobzheskiy, 1996; Khudoley and Sokolov, 1998). The Alkatvaam accretionary wedge terrane (AV) consists chiefly of an intensely deformed, thick assemblage of clastic flysch, tuffaceous, and clastic deposits with local coeval intercalated Upper Triassic, Upper Jurassic, Cretaceous, and Paleocene island-arc volcanic and pyroclastic rocks (Pushcharovskiy and Til'man, 1982; Kazimirov, 1985; Grigor'yev and others, 1987). A basal unit consists of serpentinite melange contains fragments of late Paleozoic and Triassic ophiolite and metamorphic rocks.

The Mainitskiy arc is interpreted as forming from subduction of part of the Ancestral Pacific Ocean plate (Stavsky and others, 1988; Zonenshain and others, 1990; Parfenov and others, 1993a, b; Nokleberg and Sokolov, 1992; 1994a; others, Sokolov Byalobzheskiy, 1996) that is partly preserved in the Alkatvaam accretionary wedge terrane (VT) (Figure 10). This tectonic pairing is based on: (1) the occurrence of the Alkatvaam terrane outboard of, and parallel to the various island arc terranes that comprise the arc (Figure 1); (2) coeval, Late Jurassic and Early Cretaceous and accretion of units in the Alkatvaam terrane. Subduction is generally interpreted as ending in the mid-Cretaceous with the accretion of the Mainitskiy arc and associated subduction zone, and subsequent outboard (oceanward) stepping of subduction to form the Okhotsk-Chukotka igneous arc (Parfenov and others, 1993a, b; Nokleberg and others, 1994a; Sokolov and Byalobzhesky, 1996).

Late Jurassic and Early Cretaceous Uyandina Arc in Russian North East

The Uyandina igneous arc is defined as the suite of igneous rocks units of the Uyandina-Yasachnaya volcanic belt that forms part of the Indigirka-Oloy sedimentary-volcanic-plutonic assemblage that occurs along the western and southwestern margins (presentday coordinates) of the Kolyma-Omolon superterrane in the central part of the Russian Far East (Figure 3) (Parfenov, 1984, 1991, 1995a, b; Sosunov, 1985; Nokleberg and others, 1994a). The Indigirka-Oloy contains the Uyandina-Yasachnaya assemblage volcanic belt, the Zyryanka sedimentary basin, the small Ainakhkurgen, Umkuveem, and Upper Penzhina basins, and the North Omolon basin. The Uyandina-Yasachnaya volcanic belt occurs in the southwestern part of the Indigirka-Oloy assemblage (Chersky Range).

Igneous Rock Units of Uyandina Arc

sedimentary-volcanic-Indigirka-Olov plutonic assemblage (io) consists chiefly of shallowmarine and nonmarine late Middle Jurassic to Precambrian, Neocomian formations overlying Paleozoic, and early Mesozoic rocks of the Kolyma-Omolon superterrane(Figure 3) (Parfenov, 1984, 1991, 1995a, b; Archegov and others, 1987; Gaiduk, 1988; Gaiduk and others, 1989, 1993f; Shul'gina and others, 1990). The assemblage consists of mainly sandstone, siltstone, shale, conglomerate, volcanic rocks of varying composition, and lesser granitic plutonic rocks. The assemblage is weakly deformed and contains large, doubly plunging anticlines and synclines. The Indigirka-Oloy assemblage consists of the following distinct volcanic belts and sedimentary basins. Three other units of sedimentary and igneous rocks also occur in the Indigirka-Oloy sedimentary-volcanic-plutonic assemblage. (1) The Zyryanka sedimentary basin is located in a 60-km-wide and 550-km-long basin, in the central part of the Indigirka-Oloy assemblage, and contains Upper Jurassic through Upper Cretaceous marine clastic rocks. The Zyryanka basin is interpreted as forming in the back-arc region of the Uyandina-Yasachnaya arc (Parfenov, 1984, 1991, 1995a, b). (2) The small Ainakhkurgen, Umkuveem, and Upper Penzhina basins occur along the southeastern margin of the assemblage and contain Late Jurassic and Neocomian graywacke and shale. And (3) the North Omolon basin occurs in the central part of the Kolyma-Omolon superterrane and contains shallow marine and nonmarine Late Jurassic and Neocomian sandstone, shale, conglomerate, and alkalic basalt.

The Uyandina-Yasachnaya volcanic belt occurs consists of calc-alkalic basalt, andesite, and rhyolite interlayered with shallow-marine and nonmarine sandstone, siltstone, shale, and conglomerate of Oxfordian, Kimmeridgian and Early Volgian age. The

belt is intruded by granitic rocks with Ar-Ar and K-Ar ages of 120 to 144 Ma (Fujita and others, 1997).

Subduction Zone Linked to Uvandina Arc

The subduction zone was tectonically linked to the Uyandina arc is assume to have been located along the southwestern and northwestern margins of the Kolyma-Omolon superterrane (Parfenov 1984; 1991, 1995b). Along these margins are the In'vali-Debin and Polousny synclinoria that are composed of highly deformed, Late Jurassic flysch. These deposits are interpreted as representing the forearc basin of the Uyandina arc. Near the Charky-Indigirka thrust, that separates the synclinoria from the Kular-Nera terrane, is the Chersky Range ophiolite belt containing the Garbyn'ya and Debin ophiolite complexes of unknown age (Oxman and others, 1995) (Figure 1). These ophiolites are herein interpreted as the subducted remnants the Oimyakon Ocean that formed between the North Asian Craton Margion and the Kolyma-Omolon superterrane (Oxman and others, 1995; Parfenov and others, 1996). The backarc basin of the Uyandina arc is interpreted as located northeastward from the arc and is represented by Kimmeridgan and Volgian black shales of the Ilin-Tas anticlinorium and Zyryanko Basin. An alternate interpretation is that the subduction zone linked to the Uyandina arc was located to the northeast of the arc (Zonenshain and others, 1990). With this interpretation, the black shale deposits of the Ilin-Tas anticlinorium represent the Uyandina-Yasachnaya forearc, and the flysch deposits in the In'yali-Debin and Polousny synclinorium represent the backarc.

Origin of Uyandina Arc

The Uyandina arc is interpreted as forming from convergence between the Kolyma-Omolon superterrane and the North Asian Craton Margin (Verkhoyansk fold and thrust belt) (NSV), and closing of the relatively small Oimyakon Ocean (Parfenov, 1984, 1995b, 1997). This ocean is interpreted as opening in the Late Devonian to Early Carboniferous as a result of rifting of the Omulevka terrane from the North Asian Craton. The collision of the Kolyma-Omolon superterrane and the North-Asian Craton resulted in the formation of (Trunilina and Orlov, 1997): (1) the collisional Main batholith granite belt that extends along the southwest margin of the superterrane; and (2) the Northern granite belt along the northwest margin of the superterrane. ³⁹Ar -⁴⁰Ar data indicate the Main granite belt formed at 144 to 134 Ma, and the Northern granite belt formed at 127-120 Ma (Fujita and others, 1997). These data and relations indicate that the Uyandina arc and associated subduction as ending in the Early Cretaceous with accretion of the Kolyma-Omolon superterrane to the North Asian Craton Margin (Parfenov, 1991, 1995a, b, 1997; Nokleberg and others, 1994a; Parfenov and others, 1986, 1993a, b). Much of the data supporting this interpretation is derived from the northwestsoutheast-trending part of the Kolyma structural loop of Zonenshain and others (1990).

Late Jurassic and Early Cretaceous Oloy and Svyatoy Nos Arcs Russian North East

The Olov and Svvatov Nos continental margin arcs are defined as suites of igneous rocks of the Oloy and Svyatoy Nos volcanic belts that occur along the eastern and northeastern margins (present-day coordinates) of the Kolyma-Omolon superterrane in the central part of the Russian Far East (Figure 3) (Parfenov, 1984, 1991, 1995a, b; Sosunov, 1985; Nokleberg and others, 1994a). The Late Jurassic-Neocomian Oloy volcanic belt occurs along the northeastern margin of the Kolyma-Omolon superterrane, crosses the Kolyma River, and extends into the inner part of the superterrane. The belt consists of shallow-marine and nonmarine mafic, intermediate, and siliceous volcanic rocks and tuff, and associated sedimentary rocks, and small plutons of granite, granodiorite, and monzongranite (Shul'gina and others, 1990; Natapov and Shul'gina, 1991). The Late Jurassic Svyatoy Nos volcanic belt extends in a north-south direction across the Svyatoy Nos Cape, and according to aeromagnetic data, can be traced northward into the eastern part of the Laptev Sea. The belt contains mainly shallow-marine, andesite, rhyolite, and tuff with interlayered sandstone, conglomerate, and siltstone.

Subduction Zone Linked to, and Origin of Svyatoy Nos and Oloy Arc

Tectonically linked to the Oloy and Svyatoy Nos volcanic belts was a subduction zone now preserved in the South-Anyui terrane (SA) (Figure 1) (Parfenov, 1984; this study). The South Anyui subduction zone terrane (SA) consists of thrust slices of (Natal'in, 1984: Savostin and Drachev, 1988; Dudko and Spektor, 1989; Lychagin and others, 1991; Drachev and Savostin, 1992): (1) tectonic sheets of serpentinized peridotite; and Permian to Triassic turbidite deposits; (2) highly deformed, Carboniferous (in part) MORB-type pillow lavas; (3) interlayered MORB-type pillow basalt and Middle and Late Jurassic graywacke, slate, and chert; and (4) local glaucophane schist; and Berriasian through Hauterivian turbidites.

The Svyatoy Nos and Oloy volcanic belts are interpreted as parts of a continental margin igneous arcs that formed during closure of different parts of the South Anyui Ocean (Figures 11-12). This tectonic pairing is based mainly on the occurrence of the South Anyui terrane outboard of, and parallel to the newly formed continental margin of Northeast Asia, and parallel to the Oloy and Svyatoy Nos volcanic belts (Figure 3). Subduction is generally interpreted as occurring in the Late Jurassic and Early Cretaceous, the time of activity in the arcs (Parfenov 1984; 1991, 1995b; Parfenov and others, 1993a, b).

Late Paleozoic to Early Jurassic Alazeya Island Arc in Russian Northeast

Remnants of the mainly Late Triassic and Early Jurassic (and possibly Late Paleozoic) Alazeya island arc are preserved in the Alazeya (AL) and Khetachan (KT) island arc terranes in the Russian Northeast within the Kolyma-Omolon superterrane (Figure 3) (Parfenov, 1984, 1991, 1995a, b; Sosunov, 1985;

Nokleberg and others, 1994a). These terranes consist of an extensive suite of mainly Late Triassic and Early Jurassic volcanic rocks and granitic plutonic rocks, and extend for a distance of only about 150 km (Figure 1). In addition to Late Triassic and Early Jurassic igneous arc rocks, the Alazeya island arc terranes also contains middle and late Paleozoic igneous arc rocks that may correlate with the Carboniferous Skolai island arc of the Wrangellia superterrane (Nokleberg and others, 1994a).

Igneous Rock Units of Alazeva Arc

The Alazeva island arc terrane (AL) consists chiefly of (Rusakov and others, 1975, 1977; Grinberg and others, 1981): (1) an intensely deformed tectonic melange composed of deep-water basalt, chert, graywacke, glaucophane schist, and greenschist of unknown age; and (2) a thick sequence of Carboniferous to Lower Jurassic littoral-marine and shallow-marine tuff of intermediate, mafic, graywacke, composition, conglomerate with rare lava horizons. The Khetachan island arc terrane (KT) consists chiefly of (Afitsky and Lychagin, 1987; Natapov and Shul'gina, 1991): (1) strongly deformed thick Late Triassic to Early Jurassic volcanogenic sandstone, grit, and conglomerate and lesser mafic to intermediate tuff and calc-alkalic volcanic flows, and interbedded siltstone, argillite and limestone; and (2) Lower Jurassic siltstone, and volcaniclastic sandstone and conglomerate, interbedded basaltic and andesitic tuff and flows; and Late Triassic syenite and diorite.

Subduction Zone Units Linked to Alazeya Arc

Tectonically linked to the Alazeva arc was probably an elongate subduction zone that is only preserved as a small remnant in the Aluchin subduction zone terrane (AC) that occurs at the eastern end of this chain of island arc terranes (Figure 1). The Aluchin subduction zone terrane (AC) consists chiefly of (Lychagin and others, 1989; Byalobzhesky and others, 1990; 1990): Seslavinskiy and Ged'ko, dismembered ophiolites of presumed middle Paleozoic age, including harzburgite, pyroxenite, dunite, lherzolite, gabbro, plagiogranite, a mafic dike suite, basalt, and local glaucophane schist; (2) tectonic lenses of Middle Carboniferous to Lower Permian island arc clastic-tuffaceous deposits, basalt, and andesitic basalt that are intruded by diorite and tonalite; and (3) unconformably overlying Late Triassic (Norian) shallow-marine volcanic and sedimentary rocks, and Lower Jurassic clastic deposits that contain pebbles of the underlying diorite and tonalite. In the inner part of the Kolyma-Omolon Superterrane, the subduction zone linked to the Alazeya arc can be traced beneath Cenozoic deposits along a horseshoe-like magnetic high (Parfenov, 1991).

Origin of Alazeya Arc

The Alazeya arc is interpreted as forming from subduction of the Aluchin subduction zone terrane (Figures 6-8) (Parfenov, 1991, 1995a, b; Nokleberg and others, 1994a; Parfenov and others, 1986, 1993a, b). This tectonic linkage is based mainly on the occurrence of the Aluchin subduction zone terrane

parallel to the arc (Figure 1). Subduction ended in the Early to Middle Jurassic with accretion of the arc and subduction zone to other parts of the Kolyma-Omolon superterrane, including the Omolon, Prikolyma, and Omulevka terranes (Parfenov, 1991, 1995a, b; Nokleberg and others, 1994a; Parfenov and others, 1986, 1993a, b).

Late Jurassic through mid-Cretaceous Nutesyn-Koyukuk Arc in Russian Northeast and Western Alaska

The Nutesyn-Koyukuk igneous arc is herein defined as a discontinuous suite of mainly Late Jurassic through mid-Cretaceous igneous rock units in the Russian Northeast and Western Alaska (Parfenov and others, 1993a, b; Parfenov, 1995a, b, 1997; Nokleberg and others, 1994a, b; Plafker and Berg, 1994; Monger and Nokleberg, 1996). The arc consists of an extensive suite of mainly turbidites, volcaniclastic rocks, volcanic rocks, and plutonic rocks. From west to east (present-day coordinates), remnants of the arc are preserved in the Nutesyn (NU), Koyukuk (KY), Nyac (NY), and Togiak (TG) island arc terranes (Figures 1, 3). The various units of the Nutesyn-Koyukuk arc occur along an east-west trend for about 2,000 km (Figures 1, 3), and are grouped as parts of a single arc on the basis of similar age, similar lithologies, geographical proximity, and simplicity. The Nutesyn part of the arc is interpreted as a continental-margin arc (Parfenov and others, 1993a, b, Parfenov, 1995a, b, 1997) whereas the onstrike Koyukuk arc is interpreted by most workers as an island arc that formed near the passive continental margin of North America (Nokleberg and others, 1994a, b; Patton and others, 1994; Plafker and Berg, 1994; Monger and Nokleberg, 1996). In Western Alaska, the original linear arrangement of these terranes has been extensively disrupted by Late Cretaceous and Cenozoic dextral-slip faulting along the Kobuck (KO), Kaltag (KA), and Denali (DE) faults (Figures 1, 3).

Igneous Rock Units of Nutesyn-Koyukuk Arc

The Nutesyn continental margin terrane (NU) consists chiefly of (Sizykh and others, 1977; Natal'in, 1984): (1) a basal unit of serpentinite and serpentinized peridotite and metagabbro; and (2) an upper unit of Upper Jurassic and Lower Neocomian basalt, andesitic basalt, and andesite, tuff, hypabyssal dacite, rhyodacite bodies, volcaniclastic sandstone, conglomerate, and shale. Basalt and limestone containing Lower Carboniferous corals occur at the base of the Upper Jurassic volcanic rocks.

The Koyukuk island arc terrane (KY) consists of consists of northern and southern sequences (Patton, 1973; Box and Patton, 1989; Patton, 1991; Patton and others, 1994). The northern sequence, north of Kaltag fault, contains chiefly of basalt, voluminous Lower Cretaceous (Neocomian) andesite flows, tuff, breccia, conglomerate, tuffaceous graywacke, mudstone, and bioclastic limestone with fossil and isotopic ages of Late Jurassic through Early Cretaceous (Berriassian to Aptian). The southern sequence, south of Kaltag fault, contains: (1) Middle and Late Jurassic tonalite and trondhjemite plutonic rocks that locally intrude the Angayucham terrane which in this area may form the stratigraphic basement of the Koyukuk terrane; and (2)

a sequence of Upper Jurassic to Lower Cretaceous volcanic and related rocks that are associated with, and unconformably overlie the tonalite and trondhjemite. The Koyukuk terrane is generally structurally underlain, and possibly locally stratigraphically underlain by the Angavucham terrane.

The Nyac island arc terrane (NY) consists chiefly of Middle and Upper Jurassic andesite and basalt flows, breccia, tuff, and interbedded shallowmarine volcaniclastic rocks; and Early Cretaceous gabbroic and granitic rocks (Hoare and Coonrad, 1978; Box, 1985b, c; Box and others, 1993). The Togiak island arc terrane (TG) consists chiefly of two major sequences (Hoare and Coonrad, 1978; Box, 1985b, c; Coe and others, 1985: Box and others, 1993): (1) a lower ophiolite sequence at the southwestern end of the terrane that contains Upper Triassic midocean-ridge pillow basalt, diabase, gabbro, and ultramafic rocks; and (2) a coherent upper sequence of Lower Jurassic to Lower Cretaceous marine volcaniclastic sandstone, conglomerate. shale, tuffaceous chert, argillaceous limestone, and marine to nonmarine andesite and basalt flows and flow breccia, and tuff.

Subduction Zone Linked to Nutesyn-Koyukuk Arc

Tectonically linked to the Nutesyn-Koyukuk arc was an elongate subduction zone that is now preserved in a discontinuous and disrupted collage of terranes in the Russian Northeast and Western Alaska. The terranes are the Velmay (VE), Angayucham (AG), and Goodnews (GD) subduction zone terranes (Figures 1, 3) (Parfenov and others, 1993a, b; Parfenov, 1995a, b, 1997; Nokleberg and others, 1994a, b; Plafker and Berg, 1994; Monger and Nokleberg, 1996):. These terranes occur: (1) outboard of, and are thrust over major, partly coeval, passive continental margin, including the Chukotka (CH) terrane and Arctic Alaska superterrane (AA); (2) outboard of and are thrust over metamorphosed continental margin terranes, including the Seward (SD), Coldfoot (CO), and Ruby (RB) terranes (Figures 1, 3); and (3) inboard of the island arc terranes of the Nutesyn-Koyukuk arc. In Western Alaska, the original linear arrangement of these terranes has been extensively disrupted by Late Cretaceous and Cenozoic dextral-slip faulting along the Kobuck (KO), Kaltag (KA), and Denali (DE) faults (Figure 3).

The Velmay subduction zone terrane (VE) consists chiefly of a suite of Triassic silicic volcanogenic rocks that are composed of metamorphosed Triassic basalt, tuff, chert, siliceous and argillaceous slate, graywacke, and tectonic blocks of serpentinized harzburgite, pyroxenite, gabbro, and plagiogranite (Voevodin and others, 1978; Tynankergav and Bychkov, 1987).

The Angayucham subduction zone terrane (AG) consists of three thrust panels (Jones and others, 1988; Pallister and Carlson, 1988; Pallister and others, 1989; Patton and others, 1977, 1992, 1994; Patton, 1992a, b). The lower panel consists chiefly of phyllonite, melange, and sedimentary broken formation. The sedimentary rocks are mainly thin-bedded, quartz- and chert-rich graywacke turbidite deposits of continental derivation, chert, phyllite, and slate. The panel contains local tectonic blocks of volcanic rocks, chert, limestone turbidite, chert-pebble conglomerate, and shallow-marine clastic deposits. The middle thrust panel

consists chiefly of structurally interleaved diabase, pillow basalt, tuff, chert, graywacke, argillite, minor limestone, and volcanogenic sandstone, conglomerate, and tuff. Locally abundant gabbro and diabase. The cherts range in age from Late Devonian to Early Jurassic. The upper thrust panel consists chiefly of serpentinized pyroxenite, harzburgite, dunite, wehrlite, cumulate gabbro, non-cumulate gabbro, and diabase. The basal contact of ophiolite locally marked by amphibolite metamorphosed at the time of structural emplacement in the Middle Jurassic (Boak and others, 1987). The upper thrust panel is interpreted as the basal part of an ophiolitic assemblage that was emplaced during Middle or Late Jurassic onto the unrelated middle thrust panel may be the root of the Kovukuk island arc (Patton and others, 1994). Local blueschist metamorphism occurs in the Angayucham and structurally subjacent terranes, including the southern margin of the Arctic Alaska superterrane, and the Coldfoot and Ruby terranes (Moore and others, 1994a, b). The occurrence of blueschist facies minerals in units beneath the oceanic rocks of the Angayucham terrane is generally interpreted as forming during subduction of a passive continental margin (Moore and others, 1994a, b; Plafker and Berg, 1994).

The Goodnews subduction zone terrane (GD) consists chiefly of a disrupted assemblage of pillow basalt, diabase, gabbro, chert, argillite, minor limestone, volcanogenic sandstone, and ultramafic rocks (Hoare and Coonrad, 1978; Box, 1985b, c; Box and others, 1993; Patton and others, 1994). Sedimentary rocks range from Ordovician to Jurassic. The terrane displays prehnite-pumpellyite, greenschist, and blueschist metamorphic mineral assemblages (Dusel-Bacon and others, 1992).

Origin of Nutesyn-Koyukuk Arc

The Nutesyn-Koyukuk island arc is herein interpreted as forming in response to Late Jurassic mid-Cretaceous subduction Angayucham and Goodnews Ocean plates. Remnants of these oceanic plates are now preserved in the discontinuous fragments of the Velmay, Angayucham, and Goodnews subduction zone terranes (Figures 9-10) (Nokleberg and others, 1994a, b). This tectonic pairing is based on (Parfenov and others, 1993a, b; Parfenov, 1995a, b, 1997; Nokleberg and others, 1994a, b; Plafker and Berg, 1994; Monger and Nokleberg, 1996): (1) occurrence of these accretionary wedge and subduction zone terranes adjacent and parallel to island arc terranes (Figures 1, 3); (2) formation of melange structures during the Jurassic through mid-Cretaceous; (3) formation of blueschist facies minerals in the subduction zone units and in structurally subjacent terranes; and (4) dipping of melange structures and bounding faults towards and beneath the Nutesyn-Koyukuk arc. Subduction is interpreted as generally ending by mid-Cretaceous, depending on the area, with accretion and obduction of the oceanic and ophiolite terranes onto adjacent continental margin terranes. Most of the oceanic and ophiolite terranes exhibit older periods of Jurassic and locally older (Permian) blueschist facies metamorphism that is linked to subduction. In Northern and Western Alaska, many of the terranes exhibit a younger period of generally Cretaceous greenschist facies metamorphism that some workers have linked to extension that occurred after

accretion (Miller and Hudson, 1991; Moore and others, 1994b; Patton and others, 1994).

Late Jurassic through mid-Cretaceous Gravina Arc in Southern Alaska and the Canadian Cordillera

The Gravina igneous arc (Gravina-Chisna and Chitina arcs of Plafker and Berg, 1994) is defined as a suite of mainly Late Jurassic through mid-Cretaceous igneous rock units in Southern Alaska and the Canadian Cordillera (Plafker and others, 1989; McClelland and others 1991, 1992a, b; Nokleberg and others, 1994a, b; Plafker and Berg, 1994; Monger and Nokleberg, 1996). The arc consists of an extensive suite of mainly turbidites, volcaniclastic rocks. volcanic rocks, and plutonic rocks. Remnants of the arc are preserved in (Figure 4): (1) the Kahiltna sedimentary and volcanic assemblage (kh) in Southern Alaska; (2) the Gravina-Nutzotin-Gambier volcanicplutonic-sedimentary belt (gg) in eastern-Southern Alaska, Southeastern Alaska, and the western Canadian Cordillera; and (3) the Cadwallader (CD) (younger part), Methow (MT), Izee (IZ), and Wallowa (WA) island arc and turbidite basin terranes, Spences Bridge volcanic-plutonic belt (sb), and Tahtsa-Twin Sisters-Francois Lake magmatic assemblage (tt) in the southern part of the Canadian Cordillera (Figure 4). In Southern Alaska and the western parts of the Canadian Cordillera, the Gravina arc consists of igneous-arcrelated units (Kahiltna assemblage and Gravina-Nutzotin-Gambier belt) that occur along the entire length of the Wrangellia superterrane (WR) for about 2,400 km (Figure 4) (McClelland and others, 1991, 1992a, b). In the southern part of the Canadian Cordillera, the equivalent part of the arc consists of four small terranes, the Cadwallader (CD) island arc (younger part), Izee (IZ) turbidite basin, Methow (MT) turbidite basin, and Wallowa (WA) island arc terranes that were founded mostly on late Paleozoic and early Mesozoic oceanic basements, and juxtaposed with one another by the mid-Cretaceous (Monger and others, 1994; Monger and Nokleberg, 1996). The various igneous-related units of the Gravina arc are grouped into a single arc on the basis of similar age, similar lithologies and geographical proximity. The Gravina arc is generally interpreted by some workers as an island arc that formed on the Wrangellia superterrane during migration towards North America (Plafker and others, 1989; Nokleberg and others, 1994a, b; Plafker and Berg, 1994; Monger and Nokleberg, 1996).

Igneous Rock Units of Gravina Arc

The Kahiltna sedimentary and volcanic assemblage (kh) consists chiefly of structurally disrupted, deep marine, partly volcaniclastic, graywacke, argillite, and flysch with minor amounts of chert, limestone, conglomerate, and andesite (Bundtzen and others, 1988; Wallace and others, 1989). The assemblage is mainly Early Cretaceous, but includes rocks ranging in age from Late Jurassic to early Late Cretaceous. The assemblage is interpreted to have originally stratigraphically overlain Peninsular sequence on Alaska Peninsula and is thrust over older rocks of the Wrangellia superterrane in central Alaska Range.

The Gravina-Nutzotin-Gambier volcanicplutonic-sedimentary belt (gg) ranges in age from Middle Jurassic (ca. 167 Ma) to Early Cretaceous (about 110 Ma) (Wheeler and McFeely, 1991; Woodsworth and others, 1992; Monger, 1991, 1993; McClelland and others, 1991, 1992a, b; Haeussler, 1992; Cohen and Lundberg, 1993). The belt consists of mainly of argillite, graywacke, and conglomerate, with lesser andesitic and basaltic volcanic and volcaniclastic rocks, and an extensive suite of plutons in the southwestern Canadian Coast Mountains, Southeastern Alaska, and Southern Alaska. These magmatic units terminate abruptly on the coast of southwestern British Columbia near latitude 48° 50' N. In Southeastern and Southern Alaska, these volcanogenic strata were deposited in the intra- and back-arc Gravina, and Nutzotin basins and in the Kahiltna basin to the west (Cohen and Lundberg, 1993; Nokleberg and others, 1994b). No direct evidence exists that the Gravina-Nutzotin-Gambier belt was deposited on the Yukon-Tanana and Stikinia terranes to the east (Monger and Journeay, 1994; Monger and others, 1994). A major thrust fault system separates the Gravina-Nutzotin-Gambier belt from units to the east in the Canadian Cordillera (Figure 4), and petrologic studies indicate that detritus in the Gravina basin was derived almost entirely from the arc (Cohen and Lundberg, 1993). Within the Nutzotin part of the belt are detrital zircons that may be derived from units to the east (Gehrels and others, 1991).

The Cadwallader island arc terrane consists of Permian oceanic rocks, Triassic arc rocks, and Jurassic clastic deposits (Vallier and Brooks, 1994; Rusmore, 1987). The Izee turbidite basin terrane consists chiefly of thick, mainly flyschoid, clastic sedimentary rocks and subordinate volcaniclastic rocks of Late Triassic through Middle Jurassic (Callovian) age (Brooks and Vallier, 1978; Dickinson, 1979; Silberling and others; 1984; Vallier, 1995). Local unconformities and abundant facies changes indicate a long-lasting and complex depositional basin. The Izee terrane is interpreted as a suite of forearc deposits for an island arc. The Methow turbidite basin terrane (forearc deposits) consists of Triassic basalt and associated ultramafic rocks, Jurassic arc-related clastic deposits, and Lower Cretaceous forearc basin strata. The Wallowa island arc terrane (Vallier, 1977; Vallier and others, 1977; Brooks and Vallier, 1978; Dickinson and Thayer, 1978; Ma; Lund and Snee, 1988; Hillhouse and Gromme, 1982; Harbert and others, in 1990; Vallier, 1995) consists chiefly of: (1) Pennsylvanian tuff and sandstone; (2) Lower Permian sequence of silicic volcaniclastic rocks; (3) Permian through Upper Triassic (Carnian) volcanic and volcaniclastic sedimentary rocks; (4) abundant Middle and Upper Triassic (Ladinian and Carnian) island-arc tholeiites and associated rocks; (5) massive carbonate rocks and flysch of Late Triassic (Norian) and Early Jurassic age; (6) Middle and Upper Jurassic alluvial fan, braided stream, and marine sandstone sequences that compose fault-bounded inliers; and (7) Permian and Triassic plutonic rocks. At the southern end of the Canadian Cordillera, the Wallowa island arc terrane, and adjacent Baker, Izee, and Olds Ferry terranes (Figure 4) are intruded by Late Jurassic and Early Cretaceous granitic plutons that are herein interpreted as part of the Gravina arc.

Coeval with the Kahiltna assemblage and Gravina-Nutzotin-Gambier belt to the west and north are two coeval, overlap arc assemblages that occur in the southern part of the Canadian Cordillera. The Spences

Bridge volcanic-plutonic belt (sb) (Thorkelson and Smith, 1993; Monger and others, 1994) contains: (1) a lower part composed chiefly of intermediate, locally felsic, calc-alkalic, continental-margin arc volcanic and lesser plutonic rocks of mid-Cretaceous age (105 Ma); and (2) an upper part composed of mafic andesites that are possibly rift related. The Tahtsa-Twin Sisters-Francois Lake magmatic assemblage (tt) consists chiefly of Middle and Late Jurassic and Cretaceous plutonic rocks (Wheeler and McFeely, 1991; van der Heyden, 1992; Woodsworth and others, 1992; Monger and others, 1994). The occurrence of coeval volcanic and plutonic rocks of the Spences Bridge volcanicplutonic belt and the Tahtsa-Twin Sisters-Francois Lake magmatic assemblage in the southern part of the Canadian Cordillera in an area of previously accreted terranes suggests that the Late Jurassic to mid-Cretaceous Gravina arc associated with the Kahiltna assemblage and Gravina-Nutzotin-Gambier extended onto the North American continent in this area.

Back-Arc Units Linked to Gravina Arc

Two major sequences of Late Triassic tholeittic pillow basalt and associated units form distinctive parts of the Wrangellia superterrane. In South-Central Alaska, the Nikolai Greenstone constitutes a major unit of Upper Triassic (Norian) subaerial and marine tholeiitic pillow basalt and lesser argillite and associated mafic intrusions, that is thousand meters thick (Nokleberg and others, 1994b). On Vancouver Island in the southern Canadian Cordillera, the Karmutsen Formation constitutes a coeval and distinctive Middle(?) to Upper Triassic tholeiitic basalt and associated mafic intrusions. The units are interpreted as major back-arc sequences with respect to the coeval Talkeetna-Bonanza arc (Barker and others, 1989; Monger and Nokleberg, 1996; Nokleberg and others, 1994b; Plafker and Berg, 1994). Alternatively, the mafic magmatism may have formed in a short-lived mantle plume setting similar to that in Java (Richards and others, 1991; Lassiter and others, 1994).

Subduction Zone Linked to Gravina Arc

Tectonically linked to the Gravina arc was an elongate subduction zone that is now preserved in a discontinuous and disrupted collage of terranes in Southern Alaska and the western Canadian Cordillera. These terranes, mainly of Late Triassic, Jurassic, and Early Cretaceous age, are the Chugach (CG), Pacific Rim (PR), Bridge River (BR), and Baker (BA) subduction zone and accretionary wedge terranes (Figure 4). These terranes exhibit (Nokleberg and others, 1994a; Plafker and Berg, 1996; Monger and Nokleberg, 1996): (1) rare tectonic lenses of mainly limestone with Tethyan faunas; (2) similar ages of deformation(s) that are generally interpreted as occurring during mainly Middle Jurassic to Early Cretaceous subduction (Plafker and Berg, 1995; Plafker and others, 1989, 1994; Monger and Nokleberg, 1996); and (3) local blueschist facies metamorphism.

The Chugach accretionary wedge and subduction zone terrane (CG) consists of a compound, complexly deformed, accretionary wedge and subduction zone complex of Late Triassic to Late

Cretaceous melange, flysch, and oceanic rocks (Plafker and Berg, 1994; Nokleberg and others, 1994a). The major units of the Chugach terrane are (Plafker and others, 1989, 1994): (1) a northern boundary unit of blueschist dated as mainly Late Triassic to Early Jurassic; (2) the McHugh Complex, a Late Triassic through mid-Cretaceous melange composed mainly of argillite, chert, basalt, greywacke, melange, with rare limestone blocks containing Permian Tethyan fusulinids; and (3) the Valdez Group, an accretionary complex composed mainly of Late Cretaceous greywacke and argillite. The terrane forms a long, narrow belt that extends for several thousand kilometers along the southern rim of Alaska (Figures 2, 4). The eastern part of the Chugach terrane in Southern Alaska contains a large zone of upper amphibolite facies metamorphic rocks and associated anatectic granitic rocks of early Tertiary age (Plafker and others, 1989, 1994; Plafker and Berg, 1994). This zone is interpreted as forming during underplating of a part of the Kula-Farallon oceanic ridge under the Chugach terrane in the Eocene (Plafker and others, 1989; Sisson and others, 1989; Harris and others, 1996).

The Pacific Rim accretionary wedge and subduction zone terrane (PR) consists of Upper Triassic to Lower Jurassic arc-related volcanic rocks, and unconformably overlying, disrupted graywacke, argillite, conglomerate, chert, and tuff of mainly Late Jurassic (late Kimmeridgian and early Tithonian) to Early Cretaceous (mid-Valanginian) age (Muller, 1977; Brandon, 1989). The Bridge River accretionary wedge and subduction zone terrane (BR) consists of disrupted Mississippian to early Late Jurassic chert, pelite, basalt and ultramafic rocks, and rare Triassic blueschist. These units are gradationally overlain by a clastic succession whose upper parts are Early Cretaceous. Rocks in the northwest Cascade Ranges that are possibly correlative with the younger part of the Bridge River terrane, contain Jurassic and Cretaceous blueschist (Journeay and Northcote, 1992; Cordey and Schiarizza, 1993; Garver, 1992; Mahoney and Journeay, 1993; F. Cordey, written commun., 1994; Monger and others, 1994). The Baker accretionary wedge terrane (BA) consists chiefly of disrupted late Paleozoic and Triassic oceanic and island arc volcanic and plutonic rocks with deep-marine sedimentary rocks (Burnt River Schist, Mine Ridge Schist, Elkhorn Ridge Argillite, and Nelson Marble), and mélange with serpentinite matrix and tectonic blocks (Vallier, 1977, 1995; Vallier and others, 1977).

Origin of Gravina Arc

The Gravina island arc is interpreted as forming during Late Jurassic through mid-Cretaceous subduction of the Farallon Ocean plate along the margin of the Wrangellia superterrane and outboard of the Cadwallader and Methow terranes to the south (Figure 3). This oceanic plate is now preserved in discontinuous fragments in the younger parts of the Chugach, Bridge River, and Baker terranes, and in the Pacific Rim terrane (Plafker and others, 1989; Nokleberg and others, 1994a, b; Plafker and Berg, 1994; Monger and Nokleberg, 1996). This tectonic pairing is based on (Plafker and others, 1989; Nokleberg and others, 1994a, b; Plafker and Berg, 1994; Monger and Nokleberg, 1994): (1) occurrence of these accretionary wedge and subduction zone terranes

outboard (oceanward), southward (in Alaska) or westward (in the Canadian Cordillera) (in present-day coordinates), and parallel to the various parts of the arc (Figure 4); (2) formation of melange structures during the Jurassic through mid-Cretaceous; (3) where not disrupted by Late Cretaceous and Cenozoic dextral slip along the Denali fault (DE) and companion faults (Figure 4), and (4) dipping of melange structures and bounding faults towards and beneath the igneous units of the arc. Subduction is generally interpreted as ending in the Late Jurassic to mid-Cretaceous when the Wrangellia superterrane was accreted to North America continental margin.

Late Triassic and Early Jurassic Talkeetna-Bonanza Arc in Alaska and the Canadian Cordillera

The Talkeetna-Bonanza arc occurs discontinuously in Southern Alaska and the Canadian Cordillera (Plafker and others, 1989; Nokleberg and others, 1994a, b; Plafker and Berg, 1994; Monger and Nokleberg, 1996). The arc consists mainly of an extensive suite of volcanic rocks, volcaniclastic rocks, turbidites, and plutonic rocks. Remnants of the arc are preserved in (Figure 4): (1) the Peninsular sequence of the Wrangellia superterrane (WR) in Southern Alaska; (2) the Bonanza Volcanics in the Canadian Cordillera (part of an overlap assemblage on the Wrangellia superterrane); and (3) the older parts of the Cadwallader island arc (CD), and Methow turbidite basin (MT) terranes (Figure 2). The various igneousrelated units of the Talkeetna-Bonanza arc are grouped into a single arc on the basis of similar age, similar arc origin, geographical proximity, and simplicity. The Talkeetna-Bonanza arc is interpreted by most workers as an island arc that formed on the Wrangellia superterrane during migration towards North America (Plafker and others, 1989; Nokleberg and others, 1994a, b; Plafker and Berg, 1994; Monger and Nokleberg, 1996).

Igneous Rock Units of Late Triassic and Early Jurassic Talkeetna-Bonanza Arc

In Southern Alaska, the Peninsular sequence (western part of WR in Alaska) (Figure 2) consists mainly of an areally extensive Jurassic island arc volcanic and plutonic sequence, that constitute the Talkeetna arc, and younger sedimentary units (Jones and others, 1981; Pavlis, 1983; Plafker and others, 1989; Nokleberg and others, 1994a, b; Detterman and others, in press; Wilson and others, in press). The volcanic part of the Talkeetna arc consists mainly of Upper Triassic (Norian) and Lower Jurassic andesitic flows, breccia, and volcaniclastic siltstone and sandstone of the Talkeetna Formation. The plutonic part of the Talkeetna arc consists of Jurassic batholithic granitic rocks. Overlying the volcanic units are Middle Jurassic to Cretaceous arc-derived clastic rocks (Shelikof and Chinitna Formations, Tuxedni Group, and Kialagvik, Naknek, Staniukovich, and Herendeen Formations), and bioclastic limestone with Boreal fauna (Nelchina Limestone). Unconformably overlying units are Cretaceous to lower Tertiary progradational marine and nonmarine sandstone, shale, and minor conglomerate (Matanuska, Hoodoo, Chignik, and Kaguyak Formations). The southern part of the

Peninsular sequence, adjacent to the Denali fault. consists of the Early Jurassic Border Ranges ultramafic-mafic assemblage (BRUMA) which is interpreted as the mafic and ultramafic roots of the Talkeetna arc (Burns, 1985; DeBari and Coleman, 1989; Plafker and others, 1989). In the Canadian Cordillera, the Bonanza Formation (southern part of WR) consists of Lower Jurassic volcanic arc rocks and Middle Jurassic arc rocks comprised of volcanic units ranging from basalt to andesite and interlayered with mainly fine-grained clastic rocks and intruded by the coeval Island intrusions. These units extend into the Coast Mountains to the east and are equivalent to the Bowen Island Group and the Harrison Lake Volcanics (Monger and Journeay, 1994). Also occurring in the region are coeval Early and Middle Jurassic granitic intrusions (Parrish and McNicoll, 1992; Monger, 1991; Grantz and others, 1991; Parrish and McNicoll, 1992; van der Heyden, 1992). The Cadwallader island arc terrane and the Methow turbidite basin terrane, also interpreted as part of the Talkeetna-Bonanza arc, are described above in the section on the Gravina arc.

Subduction Zone Linked to Talkeetna-Bonanza Arc

Tectonically linked to the Talkeetna-Bonanza arc was the older part of an elongate subduction zone that is now preserved in a discontinuous and disrupted collage in Southern Alaska and the western Canadian Cordillera. These terranes, mainly of Late Triassic, Jurassic, and Cretaceous age, consist of the Chugach (CG), Bridge River (BR), and Baker (BA) subduction zone and accretionary wedge terranes (Figure 2). The basis for correlating these terranes and descriptions of these terranes are given in the above section on the Gravina arc. The Permian Tethyan faunas occur mainly in shallow water carbonate rocks locally in the inner Chugach terrane (McHugh Complex) are obviously exotic faunas, and are generally interpreted as being derived from the late Paleozoic and early Mesozoic Tethys region of the Mediterranean region, Middle East, Himalayas, Southeast Asia, eastern China, Russian Southeast, and Japan (Monger and Ross, 1971; Monger and others, 1972; Stevens and others, 1997).

Origin of Talkeetna-Bonanza Arc

The Talkeetna-Bonanza arc is interpreted as forming from the Late Triassic and Early Jurassic subduction of part of the Cache Creek Ocean plate along the margin of the Wrangellia superterrane, and the geographically adjacent Cadwallader and Methow terranes (Figures 7-9). This plate is now preserved in discontinuous fragments in the older parts of the Chugach, Bridge River, and Baker terranes (Plafker and others, 1989; Nokleberg and others, 1994a, b; Plafker and Berg, 1994; Monger and Nokleberg, 1996). The younger parts of these terranes were also tectonically paired to the Gravina arc discussed above. This tectonic pairing is based on: (1) occurrence of these accretionary wedge and subduction zone terranes outboard (oceanward) and parallel to the various parts of the arc (Figure 2); (2) formation of melange structures during the Late Triassic through Early Jurassic; and (3) where not disrupted by Late Cretaceous and Cenozoic dextral slip along the Denali fault (DE) and companion faults (Figure 4), dipping of melange structures and bounding faults towards and

beneath the igneous units of the arc. Subduction is generally interpreted as ending in the mid-Cretaceous when a major change in direction of sea-floor spreading occurred.

Late Triassic and Early Jurassic Stikinia-Quesnellia Island Arc in the Canadian Cordillera and East-Central Alaska

Remnants of the Stikinia-Quesnellia island arc are preserved in the Stikinia (ST) and Quesnellia (QN) terranes in the Canadian Cordillera and in East-Central Alaska (Figure 2). (Monger and others, 1992; Mihalynuk and others, 1994; Plafker and Berg, 1994; Monger and Nokleberg, 1996). These terranes consists of an extensive suite of mainly Late Triassic and Early Jurassic volcanic and granitic plutonic rocks. The Stikinia terrane extends for distance of about 1,200 km, and the Quesnellia terrane extends for a distance of about 1,200 km (Figure 2). The Stikinia and Quesnellia terranes occur on opposite limbs of an apparent oroclinal warp that also includes, in a complex map pattern, the Yukon-Tanana and Cache Creek terranes (Figure 2). In the core of the warp is the Cache Creek subduction zone terrane. In successive sheaths towards the northwest are (Figure 2): (1) the Stikinia and Quesnellia island arc terranes; (2) Yukon-Tanana metamorphosed continental margin terrane; and (3) the Slide Mountain and Seventymile subduction zone and accretionary wedge terranes. These relations are interpreted by Mihalynuk and others (1994) as the result of counter-clockwise rotation in the Late Triassic and Early Jurassic of the Stikinia and Yukon-Tanana terranes to oroclinally entrap the Cache Creek terrane.

Igneous Rock Units of Stikinia-Quesnellia Arc

The Stikinia island arc terrane (ST) chiefly of (Monger and Ross, 1971; Monger, 1977; Monger and Irving, 1980; Monger and others, 1982; Symons, 1983; Wernicke and Klepacki, 1988; Anderson, 1989; Gehrels and others, 1990; Vandal and Palmer, 1990; Gabrielse, 1991; Evenchick, 1991; Nelson and Mihalynuk; 1993): (1) Lower Devonian, Mississippian, Upper Pennsylvanian, and Permian volcanic arc rocks (Stikine assemblage) that are interbedded with carbonate and fine-grained clastic rocks (Brown and others, 1991; (2) unconformably overlying Upper Triassic volcanic arc rocks and interfingering clastic rocks (Stuhini Formation and Takla Group), and coeval granitic rocks; and (3) unconformably overlying Lower Jurassic andesitic volcanic rocks and intercalated sedimentary rocks (Hazelton and Spatzizi Groups, and Takwahoni Formation) (Tipper and Richards, 1976; Monger, 1977; Anderson, 1989; Gabrielse, 1991). The basement of the Stikinia terrane is unknown. Suggestions have been made that it is underlain by the metamorphosed continental margin strata of the Yukon-Tanana terrane (Gehrels and others, 1990; McClelland, 1992). The Stikinia terrane is herein interpreted as occurring as most probably stratigraphically, rather than structurally above the Yukon-Tanana terrane. With this stratigraphic interpretation, the Stikinia terrane is interpreted as a fragment of an extensive early Mesozoic island arc that formed on rifted continental margin fragments of the Yukon-Tanana and Kootenay(?) terranes, similar to the modern day volcanic arcs of New Zealand and Japan.

Nd-isotopic studies from late Paleozoic through Jurassic units of the Stikinia terrane suggest a juvenile character (Sampson and others, 1991).

The Quesnellia island arc terrane (QN) consists chiefly of west-facing Upper Triassic to Lower Jurassic (Carnian to Sinemurian) volcanic arc rocks (Nicola Group, Rossland Formation), coeval calc-alkalic and alkalic plutons, and laterally equivalent clastic sedimentary rocks (Mortimer, 1987; Monger, 1989; Andrew and others, 1990; Parrish and Monger, 1992). In southwestern British Columbia, volcanic arc rocks are unconformably overlain by clastic rocks of the Pliensbachian to Callovian Ashcroft Formation. The early Mesozoic volcanic arc rocks overlie at least two basement complexes (Monger and Berg, 1987): Devonian through Permian chert, clastic rock, basalt, and ultramafic rocks of the oceanic Apex Mountain Complex and probably units of the Slide Mountain terrane; and coeval volcaniclastic rocks, pelite, and carbonate of the arc-related Harper Ranch Group. These Paleozoic strata were deformed and juxtaposed with one another, and possibly with parts of the Kootenay terrane, prior to the Late Triassic (Read and Okulitch, 1979; Klepacki, 1983; Orchard and Danner, 1991).

Subduction Zone Linked to Stikinia-Quesnellia Arc

Tectonically linked to the Stikinia-Quesnellia arc was a subduction zone now preserved in the discontinuous collage of the Cache Creek accretionary wedge and subduction zone terrane (CC), the Slide Mountain accretionary wedge terrane (SM), and the Seventymile subduction zone terrane (SV) (Figure 2). These terranes consist mainly of a complex assemblage of Mississippian through Triassic mafic and ultramafic rocks, chert, shale, and turbidite deposits, and volcanic arc rocks.

The Cache Creek accretionary wedge and subduction zone terrane (CC) ranges in age from Early Missisippian to Early Jurassic and consists of disrupted chert, pelite, basalt, ultramafic rocks, and local volcaniclastic rocks of arc origin, as well as distinctive large bodies of Late Mississippian to Triassic reefoidal limestone, with exotic Permian Tethyan faunas (Monger, 1977; Travers, 1978; Monger and Irving, 1980; Ross and Ross, 1983; Monger, 1985; Cordey and others, 1987; Mortimer, 1987; Gabrielse, 1991; Parrish and Monger, 1992; Nelson and Mihalynuk, 1993). The carbonate rocks consist of distinctive large bodies of upper Paleozoic or Triassic reefoidal rocks that at least locally overlie volcanic rocks. The Upper Triassic volcaniclastic rocks are of probable arc origin; in one locality, associated pelitic rocks are possibly as young as Pliensbachian (Lower Jurassic), and, to the south, the unit may be as young as Middle Jurassic (Monger, 1977; Cordey and others, 1987, 1991). Late Triassic blueschists occur locally in these terranes and in similar rocks in northern California (Nokleberg and others, 1994a; Monger and others, 1996). The occurrence of Permian Tethyan fauns in the Cache Creek terrane is similar to that in other parts of the Circum-Pacific region, including the Turkuringra-Dzgadi, Badzhal, Khabarovsk, and McHugh Complex (inner Chugach) terranes. This fauna occurs mostly in detached, shallowwater, tropical-origin limestone blocks in melange. In places, the limestone blocks cap volcanic seamounts (guyots).

The Slide Mountain accretionary wedge terrane (SM) consists chiefly of Upper Devonian to Permian oceanic rocks, but also contains structurally intermixed subordinate volcanic arc rocks, granitic rocks, and minor continent-derived clastic rocks (Struik and Orchard, 1985; Harms and others, 1988; Nelson and Bradford, 1989; Mortensen, 1992b; Richards and others, 1993; Roback and others, 1994). Substantial variation occurs within the terrane.

To the south, in the central and northern British Columbia, the Slide Mountain terrane consists of numerous fault-bound slices, each composed of one or several lithologies, including chert, pelitic rocks, basalt, diorite, gabbro, and ultramafic rocks, with minor volcanic arc and carbonate rocks (Struik and Orchard, 1985; Harms and others, 1988; Nelson and Bradford, 1989). Rarely can the stratigraphy be correlated between tectonic slices. Permian and Devonian to Carboniferous granitic rocks (Mortensen, 1992b) locally cut bounding faults. To the north, continent-derived clastic rocks are structurally imbricated within the Slide Mountain terrane and are possible lateral equivalents to late Paleozoic mafic volcanic rocks in the Kootenay terrane to the east (Klepacki, 1983; Roback and others, 1994). Permian plutons in the Yukon-Tanana terrane (Mortensen, 1992) crosscut thrust faults in the Slide Mountain terrane (Harms, 1986; Nelson, 1993), thereby indicating late Paleozoic juxtaposition of at least parts of the Yukon-Tanana and Slide Mountain terranes.

The Seventymile subduction zone terrane (SV) occurs as scattered remnants of three highly deformed and locally folded thrust sheets and several smaller klippen that structurally overlie the Yukon-Tanana and Stikinia(?) terranes in East-Central Alaska (Keith and others, 1981; Foster and others, 1987, 1994). The lower thrust sheet, interpreted as a fragment of an island arc, is composed chiefly of a structural melange undated metasandstone, metagraywacke, metaconglomerate, and metaandesite. The middle thrust sheet is composed chiefly of a structural melange of pillow basalt, basalt, mafic tuff, chert, argillite, and limestone of Mississippian, Permian, and Upper Triassic age. Rare glaucophane occurs in pillow basalt. The middle thrust sheet is interpreted as a subduction zone melange composed of late Paleozoic and early Mesozoic oceanic crust and seamounts. The upper thrust sheet is composed chiefly of harzburgite and peridotite with minor clinopyroxenite, and gabbro, and diabase with a local amphibolite sole. The upper thrust sheet is interpreted as the possible root to part of the Jurassic(?) Stikinia island arc.

Origin of Stikinia-Quesnellia Arc

The Stikinia-Quesnellia arc is interpreted as forming during the Permian, Late Triassic, and Early Jurassic subduction of part of the Cache Creek Oceanic Plate along one margin of the Stikinia and Quesnellia terranes, and from the Early Jurassic subduction of the Slide Mountain and Seventymile Oceanic Plate along the other margin of the Stikinia and Quesnellia terranes (Figures 7-8) (Mihalynuk and others, 1994; Plafker and Berg, 1994; Monger and Nokleberg, 1996). These plates are now preserved in discontinuous fragments in the Cache Creek, Slide Mountain, and Seventymile terranes (Plafker and others, 1989; Nokleberg and others, 1994a, b; Plafker and Berg, 1994; Monger and

Nokleberg, 1996). This tectonic pairing is based on: (1) occurrence of these accretionary wedge and subduction zone terranes adjacent to, and parallel to the various parts of the arc as reconstructed in the tectonic model below; and (2) formation of melange structures during the Late Triassic through Early Jurassic. Subduction is generally interpreted as ending in the Middle Jurassic when Stikinia, Quesnellia, Cache Creek, Slide Mountain, and Seventymile terranes were obducted onto the accretionary margin of the Canadian Cordillera and onto the North American Craton Margin (NAM) (Plafker and Berg, 1994; Mihalynuk and others, 1994; Monger and Nokleberg, 1996).

CORRELATION, LINKAGE, AND ALIGNMENT OF LATE CRETACEOUS AND EARLY CENOZOIC CONTINENTAL MARGIN ARCS, ISLAND ARCS, AND TECTONICALLY PAIRED SUBDUCTION ZONES

After the mid-Cretaceous, much of the Circum-North Pacific was uplifted along with formation of a series of continental-margin arcs and tectonically paired subduction zones. These arcs and subduction zones are the immediate ancestors of the current continental margin arcs and subduction zones the ring the Pacific Ocean. Consequently from the Late Cretaceous and onward, the major tectonic units of the Circum-North Pacific are more readily recognized and interpreted.

During the Late Cretaceous and early Cenozoic, four major igneous arcs are herein recognized around the Circum-North Pacific. These arcs are the East Sikhote-Alin arc in Russian Southeast, the Cretaceous and Early Tertiary Okhotsk-Chukotka Arc in the Russian Northeast, the Late Cretaceous and Early Tertiary Olyutorka Arc in the Russian Far East, and the Late Cretaceous and Early Tertiary Kluane and Coast Arcs in Southern Alaska and Canadian Cordillera (Figures 3, 4).

Cretaceous and Early Tertiary East Sikhote-Alin Arc in Russian Southeast

The East Sikhote-Alin arc is defined as a extensive suite of Late Cretaceous and early Tertiary volcanic and plutonic rocks that occur in the Russian Southeast along the present-day continental margin. Remnants of the arc are preserved in the East Sikhote-Alin (es) volcanic-plutonic belt, and in the Sorachi-Yezo (SY) and West Sakhalin (WSA) turbidite basin terranes (Figures 1, 3) (Natal'in, 1993; B.A. Natal'in and A.I. Khanchuk in Nokleberg and others, 1994a; Sengör and Natal'in, 1996; Khanchuk and others, 1996). These three igneous-related units form a major continental margin arc sequence that occurs along the entire length of the Russia Southeast for about 1,250 km, with an extension into the Okhotsk-Chukotka arc to the northeast (Figure 3). The various igneous-related units of the East Sikhote-Alin arc (East Sikhote-Alin volcanic-plutonic belt, and Sorachi-Yezo and West Sakhalin turbidite basin terranes) are grouped into a single arc on the basis of similar age, similar arc origin, geographical proximity, and simplicity. Both the Sorachi-Yezo and West Sakhalin turbidite basin terranes are interpreted as forearc basin units for the East-Sikhote-Alin arc.

Igneous Rock Units of East Sikhote-Alin Arc

The East Sikhote-Alin volcanic-plutonic belt (es) consists chiefly of (Nevolina and Sokarev, 1986; Nazarenko and Bazhanov, 1987): (1) Cenomanian rhyolite, dacite, basalt, and andesite; (2) thick Turonian to Santonian ignimbrite; (3) Maastrichtian to Danian basalt, andesite, and rhyolite; and (4) coeval, mainly intermediate-composition granitic plutons). Sorachi-Yezo turbidite basin terrane (SY) in northern Japan consists chiefly of (Kito and others, 1986; Kato and others, 1990): (1) an ocean floor basement assemblage of Tithonian to Barremian and Lower Cretaceous basalt, chert, siliceous shale, shale, sandstone, and limestone; (2) an overlying forearc basin assemblage of Aptian to Maastrichtian siltstone sandstone, conglomerate, and volcaniclastic rocks, deep-marine turbidites; (3) shallow-marine siltstone and sandstone; and (4) Aptian to Maastrichtian shallow marine sandstone and conglomerate. The West Sakhalin turbidite basin terrane (WSA) on Sakhalin Island consists chiefly of a basal sequence of Early Cretaceous volcanic rock, jasper, and pelagic rocks, and an upper sequence of Late Cretaceous clastic and tuffaceous clastic rocks (Parfenov, 1984; Zyabrev, 1984; Nevolina and Sokarev, 1986; Rozhdestvensky, 1987).

Subduction Zone Linked to East Sikhote-Alin Arc

Tectonically linked to the East Sikhote-Alin arc was a subduction zone now preserved in a discontinuous collage of terranes in the Russian Southeast and Northern Japan. These terranes, composed mainly of Paleozoic and early Mesozoic oceanic crustal and upper mantle rocks, and turbidite deposits, consist of the older part of the Hidaka accretionary wedge (HI), the younger part of the Aniva (ANV) subduction zone terrane, and Nabilsky (NAB), and Tokoro (TO) subduction zone terranes (Figure 3) (Natal'in, 1993; Nokleberg and others, 1994a; Sengör and Natal'in, 1996; Khanchuk and others, 1988; Khanchuk, 1993).

The Hidaka accretionary wedge terrane (HI) consists chiefly of flysch and melange of the Hidaka Group that includes blocks of basalt, chert, limestone, siliceous shale, and sandstone within a shale matrix (Sakai and Kanie, 1986; Iwata and Tajika, 1989; Kato and others, 1990). The basalt occurs both as blocks in melange and as lava flows within a sedimentary succession. The Hidaka Group contains Permian fusulinids and corals, Upper Triassic sponge spicules in limestone, Upper Jurassic to Lower Cretaceous radiolarians in chert, Lower Cretaceous nannofossils in limestone, and Lower Cretaceous to radiolarians in shale. The southwestern part of the Hidaka terrane includes high-T, low-P metamorphic rocks, metamorphosed from granulite to greenschist metamorphic The rocks include metamorphosed ophiolite succession that ranges from basal tectonites to an upper level dike complex.

The Aniva subduction zone terrane (ANV) consists chiefly of a melange composed of lenses of Middle Triassic, Jurassic, and Early Cretaceous oceanic high-titanium tholeiite, alkalic basalt, and chert; fragments of guyots with late Paleozoic and Late Triassic limestone caps; local exotic bodies of intensely metamorphosed ultramafic and mafic rocks; and a

matrix of Albian to Cenomanian turbidite and olistostromes (Dobretsov, 1978; Rikhter, 1986; Khanchuk and others, 1988; Bekhtold and Semenov, 1990). The terrane is complexly folded and faulted and metamorphosed to transitional blueschist-greenschist facies.

The Nabilsky subduction zone terrane (NAB) consists chiefly of a melange unit with a matrix of late Campanian to early Paleogene(?) turbidites and Campanian chert olistostromes that enclose bodies of Upper Jurassic and Lower Cretaceous radiolarian chert and basalt, and guyot fragments (Geology of the U.S.S.R., Sakhalin Island, 1970; Rikhter, 1986; Khanchuk and others, 1988). The guyots are capped by Upper Jurassic to Lower Cretaceous limestone that contains Tethyan reef corals. The melange also locally ophiolitic fragments, including harzburgite and lherzolite bodies, and sparse cumulative gabbro and sheeted dikes, and MORB seamount basalt. The Tokoro subduction zone terrane (TO) consists chiefly of a ultramafic cumulate rocks, diabase, pillow basalt, trachite, alkali rhyolite. volcaniclastic rocks, chert and limestone of Jurassic and Cretaceous age (K. Wakita in Nokleberg and others, 1994a).

Origin of East Sikhote-Alin Arc

The continental margin East Sikhote-Alin arc is interpreted as forming from subduction of part of the Ancestral Pacific that is now preserved as tectonically interwoven fragments of the Hidaka, Aniva, and Nabilsky accretionary wedge and subduction zone terranes (Figure 12) (Zonenshain and others, 1990; Natal'in, 1993; B.A. Natal'in and A.I. Khanchuk in Nokleberg and others, 1994a; Sengör and Natal'in, Khanchuk and others. 1988. Rozhdestvensky, 1993). This tectonic pairing is based on (Parfenov, 1984; Khanchuk and others, 1988; Natal'in, 1991, 1993; Parfenov, 1991; Parfenov and others, 1993a, b; Nokleberg and others, 1994a): (1) occurrence of these accretionary wedge terranes outboard (oceanward), southward of (in present-day coordinates), and parallel to the various parts of the East Sikhote-Alin arc (Figure 3); (2) formation of melange structures and blueschist metamorphism during the Late Cretaceous and early Tertiary (Nokleberg and others, 1994a); and (3) where not disrupted by extensive early Cenozoic slip along the Central Sikhote-Aline and companion faults (CA) (Figure 3), dipping of melange structures and bounding faults towards and beneath the igneous units of the arc. Subduction is generally interpreted as ending in the early Tertiary during strike-slip dismemberment of the Southeast and subsequent outboard (oceanward) stepping of subduction to form the East Japan and Kuril igneous arcs.

Cretaceous and Early Tertiary Okhotsk-Chukotka Arc in Russian Northeast

The Okhotsk-Chukotka arc is defined as an extensive suite of partly coeval Cretaceous and early Tertiary volcanic and plutonic rocks that occur along the continental margin in the Russian Northeast. Remnants of the arc are preserved in the Okhotsk-Chukotka volcanic-plutonic belt (oc) and the Penzhina sedimentary basin (pn), and a series of Late Cretaceous

and early Tertiary granitic plutons in Western Alaska (Figure 3) (Belyi, 1977, 1978; Filatova, 1988; Parfenov, 1984, 1991, 1995a, b; Parfenov and Natal'in, 1985; Sosunov, 1985; Stavsky and others, 1988; Zonenshain and others, 1990; Sokolov, 1992; 1994a; Sokolov Nokleberg and others. Byalobzheskiy, 1996; Bogdanov and Tilman, 1992). These three units of igneous-arc-related rocks constitute a major continental margin arc sequence that occurs for about 3,500 km along the entire length of the Russia Northeast and into Western Alaska. The Okhotsk-Chukotka arc was deposited on, or intruded into the North Asian Craton (NSC), North Asian Craton Margin (NSV), Kolyma-Omolon superterrane (KO), Chukotka terrane, Seward terrane, and many adjacent, smaller terranes (Figure 3). The various igneous-related units of the Okhotsk-Chukotka arc (Okhotsk-Chukotka volcanic-plutonic Penzhina sedimentary basin) are grouped into a single arc on the basis of similar age, similar arc origin, geographical proximity, and simplicity. The Penzhina sedimentary basin is interpreted as a forearc basin unit for the arc.

Igneous Rock Units of Okhotsk-Chukotka Arc

The Okhotsk-Chukotka volcanic plutonic belt (oc) consists of Early Cretaceous and Late Cretaceous, locally Paleocene gently dipping basalt, andesite-basalt, andesite, dacite, rhyolite, tuff, rare beds of nonmarine clastic rocks, with conglomerate, grit, and sandstone at the base. Local widespread silicic volcanic rock (mainly ignimbrites) (Belyi, 1977, 1978; Filatova, 1988; Lebedev and others, 1989; Bakharev, 1976; Zagruzina, 1977; Parfenov, 1984). The Penzhina sedimentary basin (pn) consists chiefly of Albian to Late Cretaceous littoral-marine, nonmarine clastic rocks, and coal that occur in a northeast-striking trough about 90 km wide and 500 km long (Parfenov, 1984). The clastic rocks consist chiefly of volcanic and polymictic sandstone, conglomerate, siltstone, argillite, and local tuff, with mollusks and plant fossils.

Subduction Zone Linked to Okhotsk-Chukotka Arc

Tectonically linked to the Okhotsk-Chukotka arc was a subduction zone now preserved in a discontinuous collage of terranes in the Russian Northeast. These terranes are the West-Kamchatka (WK), Ekonay (EK), Yanranay (YN) accretionary wedge terranes (Figure 3) (Khanchuk and others, 1990; Sokolov, 1990, 1992; Parfenov and others, 1993a, b; Nokleberg and others, 1994a; Sokolov and Byalobzkeskiy, 1996; Khudoley and Sokolov, 1998). The West-Kamchatka, Ekonay, and Yanranay terranes are extensively overlapped by the West Kamchatka sedimentary basin (wk), the Central Kamchatka volcanic belt (kc), and the East Kamchatka volcanic belt (ek) (Figure 3).

The West Kamchatka accretionary wedge terrane (WK) consists chiefly of intensely deformed pillow and massive basalt interlayered with siliceous, argillaceous, carbonate rocks, and tuff of Jurassic and Early Cretaceous age; turbidite deposits (mainly graywacke, arkose, and lesser subarkose), of Late Cretaceous (Santonian to Maastrichtian) and early Paleogene age, and local olistostrome layers (Shantser and others, 1985; Bondarenko and Sokolkov, 1990;

Sokolov, 1990, 1992). The terrane is generally

complexly folded and imbricately thrusted.

The Ekonay accretionary wedge terrane (EK) consists chiefly of (Byalobzhesky and others, 1986; Bychkov and others, 1990; Sokolov, 1990; Didenko and others, 1993): (1) serpentinized ultramafic rocks, layered gabbro, and ultramafic rock complex; leucocratic gabbro, gabbro-diabase, diabase, and plagiogranite; and (2) upper Paleozoic to Triassic volcanic-sedimentary assemblage (spilite, basalt and rarely andesite and plagiorhyolite; various tuff, cherty, biogenic, tuffaceous and clastic rocks; subordinate carbonate and clastic rocks, argillite, volcaniclastic siltstone and sandstone). The volcanic-sedimentary assemblage includes tectonic fragments Carboniferous to Triassic units with Tethyan foraminifers, radiolarians, and conodonts.

The Yanranay accretionary wedge terrane (YN) consists chiefly of (Byalobzhesky and others, 1986; Grigoriev and others, 1987b; Sokolov, 1992): (1) Upper Jurassic and Cretaceous (as young as Campanian) oceanic, MORB-type basalt, pelagic sedimentary rocks, chert, and rare carbonate rocks with a condensed section of radiolarite and jasper with radiolarians of Tithonian, Berriasian and Valanginian ages; and (2) Lower and Upper Cretaceous argillite, siltstone, sandstone, and associated rocks. Also occurring is a local Senonian olistostrome composed of fragments of Paleozoic to early Mesozoic and Upper Jurassic to Lower Cretaceous sedimentary and volcanic rocks in a siltstone matrix. The terrane is highly deformed into folds, thrusts, imbricated fault slices, and duplex structures, and is exposed in tectonic windows beneath the Ekonay terrane.

Origin of Okhotsk-Chukotka Igneous Arc

The continental margin Okhotsk-Chukotka igneous arc is interpreted as forming from subduction of part of Ancestral Pacific Ocean plate that is now preserved as the West-Kamchatka, Ekonay, and Yanranay accretionary wedge terranes (Figures 11-13). This tectonic pairing is based on (Stavsky and others, 1988; Parfenov, 1984, 1991; Parfenov and Natal'in, 1985; Filatova, 1988; Zonenshain and others, 1990; Parfenov and others, 1993a, b; Nokleberg and others, 1994a): (1) occurrence of these accretionary wedge terranes outboard (oceanward), southward of (in present-day coordinates), and parallel to the various parts of the Okhotsk-Chukotka arc (Figure 3);. (2) formation of melange structures during the Late Cretaceous and early Tertiary (Nokleberg and others, 1994a); and (3) where not disrupted by extensive early Cenozoic slip along northwest-striking faults (Figure 3), dipping of melange structures and bounding faults towards and beneath the igneous units of the arc. Subduction is generally interpreted as ending in the early Tertiary with accretion of the Kula Ocean Plate and subsequent outboard (oceanward) stepping of subduction to form the Kuril and Kamchatka igneous arcs (Scholl and others, 1992, 1994).

The igneous units of the Okhotsk-Chukotka arc, the Okhotsk-Chukotka volcanic-plutonic belt and Penzhina sedimentary basin, and related units, are interpreted by most workers as various parts of a long continental-margin arc that was active in the Cretaceous and early Tertiary along the eastern margin of the Russian Northeast and Western Alaska (Parfenov and others, 1978; Parfenov and Natal'in, 1985; Zonenshain and others, 1990; Stavsky and

others, 1990; Parfenov, 1991, 1994; Bogdanov and Tilman, 1992; Parfenov and others, 1993a, b; Nokleberg and others, 1994a). The arc overlaps the previously accreted Kolyma-Omolon superterrane and adjacent terranes in the Russian Northeast, and previously accreted terranes in Western Alaska (Figures 3, 4).

Late Cretaceous and Early Tertiary Olyutorka Arc in Russian Far East

Remnants of the Late Cretaceous and early Tertiary Olyutorka arc are preserved, from north to south, in the Olyutorka-Kamchatka (OK), Iruneiskiy (IK), Kronotskiy (KRO), Shmidt (SHT), Terpeniya (TR), and Nemuro (NE) island arc terranes that occur in the central and southern parts of the Russian Far East (Figure 3) (Rikhter 1986; Tsukanov 1991; Zinkevich and Tsukanov, 1992, 1993; Sokolov, 1992; Chekhovich 1993; Nokleberg and others, 1994a; Sokolov and Byalobzhesky, 1996). These terranes constitute an extensive suite of coeval Late Cretaceous and early Tertiary island arc volcanic and related rocks that occur along strike for about 2,700 km (Figure 1). The island arc terranes occur on the Kamchatka Peninsula, Sakhalin island, and in the southern Kuril Islands.

Igneous Rock Units of the Olyutorka Arc

The Olyutorka-Kamchatka island arc terrane (OK) consists of (Kovalenko, 1992; Tsukanov, 1991; Zinkevich and Tsukanov, 1992, 1993; Zinkevich and others, 1993; Heiphitz and others, 1994a): (1) a local unit of serpentinite melange that is composed of blocks of mid-Cretaceous jasper, basalt, gabbro, and ultramafic rock; (2) late Campanian to early Maastrichtian island arc deposits (Hapitskiy complex) that are composed of basalt, andesite flows and tuff, tuffaceous siltstone, volcaniclastic sandstone, and tuffaceous jasper; and (3) an upper part of Maastrichtian to Paleocene volcanic and clastic island arc deposits. The terrane is locally intruded by zoned intrusives range from dunite to clinopyroxenite to gabbro (Kepezhinskas and others, 1993).

The Iruneiskiy island arc terrane (IK) consists chiefly of several tectonic sheets and overlying Cretaceous clastic deposits (Shantser, and others, 1985; Zinkevich and Tsukanov, 1992, 1993): (1) pillow basalt, siliceous shale, tuff, and jasper of Albian to Cenomanian age with structurally overlying Upper Cretaceous tuff and jasper, and coarse-grained, mafic, and intermediate composition volcanic breccia; and (2) fine-grained silicic, fine-tuffaceous deposits, and coarse-clastic tuffaceous deposits with Upper Cretaceous basalt, and overlying tuff-breccia and calcalkalic volcanic rocks with tuffaceous-sedimentary lenses that grade into Maastrichtian siliceous siltstone.

The Kronotskiy island arc terrane (KRO) consists chiefly Conacian to early Paleocene island-arc basalt, lava and tuff breccia that contain hyaloclastite fragments of mafic and silicic volcanic rocks in a coarse-grained tuff, and chert (Mys Kamenistyi complex and Kronotskaya suite) (Khubunaya, 1981; Tsukanov, 1991; Bazhenov and others, 1992). Also locally occurring is a serpentinite melange with ophiolite fragments.

The Shmidt island arc terrane (SHT) consists chiefly of three units (Geology of the U.S.S.R., Sakhalin Island, 1970; Raznitsin, 1982; Yurkova, 1991). A lower unit of serpentinite melange, interpreted as a subduction zone complex, is composed of harzburgite, cumulate gabbro, high-Ti mafic dikes, basalt, and Upper Jurassic to Lower Cretaceous radiolarian chert (Tominskia sequence). intermediate unit consists of bimodal sheeted dikes and flows, siliceous tuff that yield mid-Cretaceous (Albian to Cenomanian) radiolarians, and plagiogranite. The bimodal igneous rocks are geochemically similar to primitive island arcs. The upper unit consists of basalt, andesite, tuff, argillite, and sandstone that yield Cenomanian to Santonian Inoceramus (Slavyansk sequence)

The Terpeniya island arc terrane (TR) consists chiefly of a thick tectonic melange composed of deepmarine and terrestrial Santonian to Campanian volcanic and sedimentary rocks (Berozovskaya, Rakitinskaya, and Bogatinskaya sequences) (Geology of the U.S.S.R.; Sakhalin Island, 1970; Khanchuk and others, 1988). The volcanic rocks consist of island-arc tholeiitic, calc-alkalic, and shoshonite rocks. Abundant peridotite-pyroxenite-gabbroic and gabbroplagiogranite intrusions are interpreted as the magmatic part of the island arc. The terrane is structurally disrupted and strongly folded.

The Nemuro island arc terrane (NE) consists chiefly of two subterranes (Parfenov and others, 1983; Grapes, 1986, Okada and others, 1989; Kato and others, 1990; Goloionko, 1992; Bazhenov and Burtman, 1996). (1) A northern subterrane is composed of a monoclinal sequence of conglomerate, breccia, grit, sandstone, massive calc-alkalic pillow basalt, andesitic basalt, and basalt agglomerate and tuff. The basaltic rocks contain Campanian Inoceramus and a K-Ar age of 88 Ma. The basaltic rocks are unconformably overlain by tuffaceous flysch with layers of alkalic pillow basalt, diabase, and shoshonite sills that yield K-Ar ages of 65 to 89 Ma. and that contain Campanian to Maastrichtian Inoceramus. And (2) a southern subterrane is composed of folded continental and shallow-marine lava, breccia, and andesite-basalt tuff, basalt, rare andesite that yields K-Ar ages of 69 to 82 Ma, and local layers of sandstone. grit, cherty siltstone with wood and plant detritus. The subterrane is intruded by local gabbro and sheeted dikes.

Subduction Zone Linked to Olyutorka Arc

Tectonically linked to the Olyutorka arc was a subduction zone now preserved in the discontinuously exposed Vetlovskiy accretionary wedge terrane (VT) (Sokolov, 1992; Zinkevich and Tsukanov, 1992, 1993; 1994a; Nokleberg and others, Sokolov Byalobzhesky, 1996) (Figure 1). The Vetlovskiy terrane (VT) occurs in thin thrust sheets that are composed mainly of volcanic and sedimentary rocks, deep-water chert, mudstone, and carbonate rocks, and midocean ridge basalt (Vetlovskiy complex) (Fedorchuk and others, 1990; Zinkevich and Tsukanov, 1990, 1992, 1993; Tsukanov, 1991). The volcanic and sedimentary rocks range from Maastrichtian to lower Eocene.

Origin of Olyutorka Igneous Arc

The Olyutorka arc was is interpreted as forming from subduction of part of the Ancestral Pacific Ocean plate (Bogdanov 1988; Zonenshain and others, 1990; Sokolov, 1992; Zinkevich and Tsukanov, 1992, 1993; 1994a Nokleberg and others. Sokolov Byalobzhesky, 1996; Khudoley and Sokolov, 1998) that is partly preserved in the Vetlovskiy accretionary wedge terrane (VT). This tectonic pairing is based on: (1) the occurrence of the Vetlovskiy terrane outboard of, and parallel to the various island arc terranes that comprise the arc (Figure 1); (2) coeval, Late Cretaceous and early Tertiary deformation and accretion of units in the Vetlovskiy terrane. Subduction is generally interpreted as ending in the early Tertiary with accretion of the Olyutorka arc and associated subduction zone, and subsequent outboard (oceanward) stepping of subduction to form the Kuril and Kamchatka igneous arcs (Zinkevich and Tsukanov. 1992, 1993; Sokolov and Byalobzhesky, 1996; 1994a; Nokleberg and others, Sokolov Byalobzhesky, 1996; Khudoley and Sokolov, 1998).

Late Cretaceous and Early Tertiary Kluane and Coast Arcs in Southern Alaska and Canadian Cordillera

The Kluane arc is defined an extensive suite of coeval Late Cretaceous and early Tertiary volcanic and plutonic rocks that occur in Southern and Eastern Alaska. Remnants of the arc are preserved in the Kuskokwim Mountains sedimentary, volcanic, and plutonic belt (km), the Alaska Range-Talkeetna Mountains volcanic-plutonic belt (at) (Figure 4), and various coeval granitic plutons (too small to depict on Figure 4) (Plafker and others, 1989; Nokleberg and others, 1994a, b; Plafker and Berg, 1994; Monger and Nokleberg, 1996). Similarly, remnants of the Coast arc are preserved in the Coast-North Cascade plutonic belt (cn) and in the Kamloops magmatic belt (ka) in the Canadian Cordillera. These volcanic-plutonic belts form a major continental margin arc sequence that occurs along the entire length of Southern Alaska and the Canadian Cordillera for about 3,000 km. The various, igneous-related units of the Kluane and Coast arcs are grouped into a single arc on the basis of similar age, similar arc origin, geographical proximity, and simplicity. The Kluane and Coast arcs overlap the Wrangellia superterrane and adjacent, previous-accreted inboard units, including the Stikinia, Quesnellia, Cache Creek, and Yukon-Tanana terranes (Figures 2, 4). The Kluane and Coast arcs are interpreted as having formed immediately after accretion of the Wrangellia superterrane in the Late Jurassic to mid-Cretaceous (Plafker and others, 1989; Plafker and Berg, 1994; Nokleberg and others, 1994a, b; Monger and Nokleberg, 1996). Both the Kluane and Coast arcs are extensively disrupted by dextral slip movement that occurred from the Late Cretaceous through the present on the Denali (DE), Tintina (TI), and companion faults.

Igneous Rock Units of Kluane Arc

The Kuskokwim Mountains sedimentary, volcanic, and plutonic belt (km) consists chiefly of volcanic rocks and minor interlayered tuffaceous

sedimentary rocks (Moll-Stalcup, 1990, 1994; Miller and Bundtzen, 1993; Moll-Stalcup and others, 1994). The belt also includes minor conglomerate to coarsegrained sandstone turbidite deposits deposited in deeplesser sandstone marine conditions, and deposited shallow-marine conglomerate in nonmarine conditions along the flanks of the unit. Volcanic rocks consist chiefly of rhyolite and dacite domes, flows, and tuff, and dacite, andesite, and basalt flows with isotopic ages of 58 to 77 Ma, and contains numerous related volcano-plutonic complexes, dikes, and plutons that exhibit a wide compositional range, gabbro, quartz diorite, granodiorite, including monzonite, and syenite. The Alaska Range-Talkeetna Mountains volcanic-plutonic belt (at) consists chiefly of large and small volcanic fields composed of calcalkalic rhyolite, dacite, and andesite flows, pyroclastic rocks, and interlayered basalt and andesite flows (Moll-Stalcup, 1994; Moll-Stalcup and others, 1990, 1994; Plafker and others, 1989). Isotopic ages range mainly from 50 to 75 Ma. The belt also contains numerous related diorite, quartz diorite, granodiorite, and granite and locally monzonite and syenite plutons.

Igneous Rock Units of Coast Arc

The Coast-North Cascade plutonic belt (cn) forms a major granitic plutonic belt that extends the length of the Canadian Cordillera and into East-Central Alaska. The belt consists chiefly of quartz diorite, granodiorite, and locally more mafic or felsic plutons (Rubin and others, 1991; Gehrels and others, 1990; Wheeler and McFeeley, 1991; van der Heyden, 1992; Woodsworth and others, 1992; Journeay and Friedman, 1993). Crystallization ages are generally younger toward the east. In the central and southern parts of the belt, age zonation permits division into three subbelts: (1) mid-and Late Cretaceous plutons (about 96-70 Ma); (2) plutons that straddle the Cretaceous-Tertiary boundary (70 to 60 Ma); and (3) early Tertiary plutons (60-40 Ma). Early Late Cretaceous through early Tertiary intrusions were emplaced concurrently with structures formed sequentially during contraction, local(?) dextral transpression and transtension, and accompanied by regional metamorphism (Rubin and others, 1991; Journeay and Friedman, 1993). The Kamloops magmatic belt (ka) consists chiefly of 55-46 Ma, calc-alkalic to alkalic felsic, intermediate and mafic volcanic and sedimentary strata, and comagmatic granodiorite, syenite, and quartz monzonite plutonic rocks (Ewing, 1980; Parrish and others, 1988; Symons and Wellings, 1989). The volcanic rocks may be surface equivalents of early Tertiary plutonic rocks in the eastern Coast Belt (youngest part of Coast-North Cascade belt). In parts of south-central British Columbia and northeastern Washington, the belt is typically alkalic, and emplacement was concurrent with widespread basin-and-range style extension.

Subduction Zones Linked to Kluane and Coast Arcs

Tectonically linked to the continental-margin Kluane arc were the younger parts of the Chugach terrane (the Late Cretaceous accretionary wedge Valdez Group), and the older part of the Prince William accretionary-wedge terrane (Figure 4). Both terranes occur in a similar tectonic position, occurring as a series of narrow, discontinuous, and long tectonic

lenses located outboard of the igneous-arc-related units of the Kluane arc (Figure 4). Tectonically linked to the Coast continental-margin arc was the Pacific Rim subduction zone and accretionary wedge terrane that occurs outboard of the igneous-arc-related units of the Coast arc in the Canadian Cordillera (Figure 4). The Chugach and Pacific Rim terranes, described in the above section on the Gravina arc, were long-lived subduction zone and accretionary wedge complexes of the Chugach terrane that were formed from the Late Triassic through Late Cretaceous (Nokleberg and others, 1994a; Plafker and Berg, 1994), and from the Late Jurassic though mid-Cretaceous for the Pacific Rim terrane (Nokleberg and others, 1994a; Monger and Nokleberg, 1996).

The Prince William accretionary-wedge terrane (PW) consists chiefly of a complexly folded and faulted, thick assemblage of graywacke, argillite, minor conglomerate, pillow basalt, basaltic tuff, sills, dikes, and mafic and ultramafic rocks (Orca Group, Sitkalidak Formation, and Ghost Rocks Formation) (Moore and others, 1983; Nelson and others, 1985; Dumoulin, 1987, 1988; Plafker and others, 1989b; Bol and others, 1992; Nelson, 1992; Bol, 1993). The terrane includes the Upper Cretaceous and early Tertiary Ghost Rocks terrane of Jones and others (1987), and contains rare mega- and microfossils of Paleocene and Eocene age. On Resurrection Peninsula and on Knight Island, the terrane contains a local ophiolite that is interpreted as slabs of oceanic basement.

Origin of Kluane and Coast Arcs

The igneous units that define the Kluane and Coast arcs are interpreted by most workers as various parts of a long continental-margin arc that was active in the Late Cretaceous and early Tertiary (Figure 12) (Plafker and others, 1989; Nokleberg and others, 1994a, b; Plafker and Berg, 1994; Monger and Nokleberg, 1996). The arcs are interpreted as forming in response to subduction of part of the Kula Ocean Plate. During subduction, substantial accumulations of igneous-arcderived flysch (some from erosion of the Kluane arc) were deposited into a continental margin trench bordering Southern Alaska. These deposits were underthrust along a major, north-dipping subduction zone (present-day coordinates), and underplated into a large accretionary wedge complex of the Valdez Group of the southern Chugach terrane (Nokleberg and others, 1989; Plafker and others, 1989; Plafker and Berg, 1994). Subduction is generally interpreted as ending in the early Eocene with accretion of the Kula Ocean Plate and Kula Ridge, and subsequent outboard (oceanward) stepping of subduction to form the modern-day Aleutian-Wrangell arc and Cascade arc (Plafker and others, 1989; Scholl and others, 1992, 1994; Plafker and Berg, 1994).

CORRELATION, LINKAGE, AND ALIGNMENT OF MIDDLE AND LATE CENOZOIC CONTINENTAL MARGIN ARCS AND TECTONICALLY PAIRED SUBDUCTION ZONES

From about the early Eocene or Miocene through the present, three continental margin arcs have been and still are active around the Circum-North Pacific. These arcs are (Figures 3, 4): (1) the Northeast Asia arc consisting of the East Japan volcanic-plutonic belt, Central Kamchatka volcanic belt, Central Kamchatka volcanic and sedimentary basin, East Kamchatka volcanic belt, Eastern Sakhalin sedimentary basin (esa), and the West Kamchatka sedimentary basin; (2) the Aleutian-Wrangell arc consisting of the Aleutian volcanic belt (al) and the Wrangell volcanic field; and (3) the Cascade arc consisting of the Cascade volcanic-plutonic belt volcanic belt.

Northeast Asia Arc

The Northeast Asia arc is a major continental margin igneous arc that has been active in Northeastern Asia since inception in the early Eocene to Miocene. The arc is being preserved in the East Japan volcanic-plutonic belt (ej), Central Kamchatka volcanic belt (kc), Central Kamchatka volcanic and sedimentary basin (ck), East Kamchatka volcanic belt (ek), Eastern Sakhalin sedimentary basin (esa), and the West Kamchatka sedimentary basin (wk) (Figure 3) (Shahiro and others, 1987; Nokleberg and others, 1994a). This arc occurs along the entire length of Northern Japan and the southern and central parts of the Russian Far East for about 2,500 km. The Northeast Asia arc overlaps all previously accreted inboard terranes in the region (Figures 1, 3).

Igneous Rock Units of Northeast Asia Arc

The East Japan volcanic-plutonic belt (ej) consists chiefly of Neogene to Holocene large andesite and rhyolite and lesser basalt volcanoes, dacite to andesite and lesser basalt lava, tuff, breccia, volcanic avalanche deposits and domes, and minor intermediate-composition plutons (Koji Wakita in Nokleberg and others, 1994a). Major modern volcanoes occur at Oshima-oshima, E-san, Komagatake, Kariba, Raiden, Niseko, Toya, Usu, Yotei, Shikotsu, Tarumae, Tokachi, Daisetsu, Akan, Kutcharo, Masyu, and Shiretoko. The East Japan belt is coeval with the volcanic part of the Kuril arc to northeast. The belt overlies many terranes of Hokkaido Island, including the Oshima, Sorachi-Yezo, Kamuikotan, Hidaka, Tokoro and Nemuro terranes (Figures 1, 3).

The Central Kamchatka volcanic belt (kc) consists chiefly of late Tertiary and Quaternary, thick, gently dipping andesite, dacite, and rhyolite strata interlayered with sandstone, siltstone, and conglomerate, and widespread large ignimbrite fields (Erlikh, 1973; Poplitove and Volynets, 1982; Shapiro and others, 1987). Shallow-marine deposits are predominant in the lower part and nonmarine deposits predominant in the upper part. Formation of the belt culminated with eruptions of Pliocene to Quaternary plateau basalts that are associated with stratovolcanoes.

The Central Kamchatka volcanic and sedimentary basin (ck) consists chiefly of late Pliocene and Quaternary volcanic and sedimentary rocks up to 6 km thick and ranges from 20 to 70 km wide and 350 km long (Vlasov, 1964; Shapiro and others, 1987). The basin contains mainly shallow-marine sedimentary rocks and widespread tuff, basalt, and basaltic andesite. The basin overlies deformed Late Cretaceous to early Tertiary sedimentary rocks and is interpreted as a forearc unit for central Kamchatka volcanic belt.

The East Kamchatka volcanic belt (ek) consists chiefly of a major chain of modern volcanoes of Pliocene and younger age. The main lithologies are basalt, andesite-basalt, rare dacite, and tuff (Vlasov, 1964; Erlikh, 1973; Shapiro and others; 1987; Volynets and others, 1990). The belt is the northward continuation of modern Kuril volcanic arc which started to form in the Neogene.

The Eastern Sakhalin sedimentary basin (esa) consists chiefly of an Oligocene to Quaternary sedimentary basin that is up to 8,000 m thick (Baboshina and others, 1984, 1985; Kosygin, 1985). Seismic-reflection data suggest late Miocene to Quaternary marine clastic and siliceous sedimentary rocks form most of basin.

The West Kamchatka sedimentary basin (wk) consists chiefly of thick, gently folded, littoral-marine and nonmarine Cenozoic coal-bearing deposits up to 6-km thick (Vlasov, 1964, 1977). The basin contains major, linear, en-echelon folds that occur diagonal to general strike of basin. The basin is interpreted as an oblique-slip backarc basin for the central Kamchatka volcanic belt to east.

Subduction Zone Linked to Northeast Asia Arc

Tectonically linked to the Northeast Asia continental-margin arc is the Kuril-Kamchatka accretionary wedge and subduction zone terrane (kuk) that occurs outboard of the arcs in the Northern Japan and the Russian Far East (Figure 3). The terrane is forming along the Kuril-Kamchatka megathrust (Nokleberg and others, 1994a) and consists chiefly of three major units (Gnibidenko and others, 1980; Seliverstov, 1987; Lomtev and Patrikeev, 1989). (1) A structurally lower unit is composed of bedded turbidites of Quaternary to Pliocene age and underlying oceanic crust. The turbidites generally range from about 100 to 500 m thick, but are as thick as 1,000 m thick near the junction of the Kuril-Kamchatka and Aleutian trenches. Seismic-reflection surveys indicate the turbidites unconformably overlie oceanic crust. The turbidites are folded and deformed near the continental slope, and can be traced below the accretionary wedge unit at an angle of 5 to 15°. (2) A structurally emplaced upper unit consists of accretionary wedge deposits that occur in a series of overthrusts that enclose fragments of the deformed bedded turbidites. Rocks dredged from the accretionary deposits consist of turbidites that contain Pliocene diatoms, Upper Cretaceous oceanic chert that contains radiolarians, and basalt. And (3) as determined from seismic-reflection surveys, an older, structurally higher part of the accretionary wedge consists of units bounded by numerous thrust faults. Rocks dredged from that part of the trench slope consist of turbidites that contain Miocene to Pliocene diatoms, and volcanic rocks that are metamorphosed to greenschist facies. Locally along the northwestern margin, this older part of the accretionary wedge occurs in a depression up to 20 km wide and consists of well-stratified turbidite deposits that range from 1.5 to 2.5 km thick. Transverse canyons occur along the trench and are filled with Miocene to Quaternary turbidite deposits up to 3 km thick.

Back-Arc Units Linked to Northeast Asia Arc

Also tectonically linked to the Northeast Asia continental-margin arc are the Sea of Japan (sj), Sakhalin-Primorye volcanic belt (sp), and the Kuril back-arc units (kur) (Figure 3). These three units consist of mainly alkalic or MORB-type basalt and related rocks and all occur inboard (continentward) from the Northeast Asia arc (Figure 3) (Ueda 1986; Bogdanov, 1988; Tamaki, 1988; Tatsumi and others, 1989).

The Sea of Japan back-arc unit (sj) consists chiefly of volcanic rocks ranging from MORB-type basalt to trachyrhyolite as dredged from seamounts and ridges (Bersenev and others, 1987; Ingle and others, 1975). Tholeitic basalt forms about 80-90% of total dredged material, along with sparse clinopyroxene-olivine ferrobasalt. The basalt commonly contains lehrzolite xenoliths with a predominant olivine-plagioclase assemblage and subordinate chromium clinopyroxene and chrome spinel. The age of basalt is tentatively estimated as 0 to 15 Ma from interpretation of the time of opening of the Japan Sea, as determined by paleomagnetic data (Table 3). The basalts are overlapped by a sedimentary cover up to 2 km thick.

The Sakhalin-Primorye volcanic belt (esa) consists chiefly of late Cenozoic basalt that occurs in relatively small eruptive fields that are closely associated with grabens and bounding faults (Semenov 1982; Nakamura and others, 1990; Martynov and Okamura, 1993; Martynov, 1994). The basalt ranges from quartz tholeiite to olivine nephelenite and basanite that locally contain xenoliths of spinel and garnet peridotite, pyroxenite, and harzburgite. Alkali basalt is predominant in the continental area of eastern China, whereas tholeiite, with an unusually low K2O content (less than 0.25%), occurs in the East Sikhote-Alin region adjacent to the rift basin of the Sea of Japan. On Sakhalin Island, the belt consists mainly of: (1) Miocene subalkalic andesite-basalt, basalt, and rare rhyolite; (2) Late Miocene to early Pliocene trachybasalt, trachydiabase, subvolcanic intrusions of monzonite, essexite, and other alkalic rocks; and (3) Pliocene olivine basalt and diabase, and rare andesite and dacite.

The Kuril back-arc unit (kur) consists of (Gnibidenko and Svarichevsky, 1984; Sergeev and Krasny, 1987; Zonenshain and others, 1990; Maeda, 1990): (1) a central and northern part that is interpreted as Oligocene to Miocene oceanic crust with an average seismic velocity of 6.7 to 7.0 km/s, a thickness of 12-13 km, and a thin upper layer of sedimentary rocks on the basis of inferred slow sedimentation rates (Zonenshain and others, 1990) and heat flow values that are 2 to 2.5 times higher than in modern oceans: and (2) a southern part that is interpreted as a back-arc unit that started to form at about 15 Ma. Local, partly buried volcanic cones are overlain by sedimentary rocks. Direct data on nature and age of this back-arc unit are absent. Dredging from the eastern part of the unit on the western slope of Kuril island arc yields granitic rocks, ranging in age from 94 to 219 Ma, and granitic clasts in conglomerate interlayered with Paleogene volcanic rocks.

Origin of Northeast Asia Arc

The igneous-rock-related units that define the Northeast Asia arc are interpreted by most workers as various parts of a major active that occurs along the northeastern margin of Asia. The arc is interpreted as forming in response to subduction of part of the Pacific Oceanic Plate and formation of the Kuril-Kamchatka accretionary wedge and subduction zone terrane (Figures 13-15) (Parfenov and others, 1978; Parfenov, 1984; Parfenov and Natal'in, 1985; Bogdanov, 1988; Zonenshain and others, 1990). Subduction is herein interpreted as commencing in about the Eocene after accretion of the Olyutorka arc and associated subduction zones to the Northeast Asian margin, and outward stepping of subduction. Also associated with the Northeast Asia arc are three major back-arc units, the Sea of Japan back-arc unit, Sakhalin-Primorye volcanic belt, and the Kuril back-arc unit that occur inboard of the arc (Figure 3). The three back-arc units are interpreted as the result of back-arc rifting. The major rift basins that contain these units are interpreted as the loci of extension and thinning of previously accreted terranes, and the loci of migration of the arc oceanward or away from the Northeast Asia continental margin (Figure 14) (Ueda, 1986; Bogdanov, 1988).

Aleutian-Wrangell Arc in Southern Alaska

The Aleutian-Wrangell arc is a major intraoceanic (western part) and continental margin (eastern part) igneous arc that continues that started formation in the early Eocene to Miocene and is continuing through the present. The arc is being preserved in the Aleutian volcanic belt (al), and the Wrangell volcanic field (wr) (Figure 4) (Moll-Stalcup, 1990, 1994; Nokleberg and others, 1994a; Plafker and others, 1994; Vallier and others, 1994). This arc occurs along the entire southern edge of the Bering Sea and Southern Alaska for about 4,000 km. The Aleutian-Wrangell arc overlap all previous-accreted inboard terranes in the region (Figures 2, 4).

Igneous Rock Units of Aleutian-Wrangell Arc

The Aleutian volcanic belt (al) consists three parts (Harbert, 1987; Tsvetkov and others, 1990;. Moll-Stalcup, 1990, 1994; Bazhenov and others, 1992; Vallier and others, 1994). (1) The extreme western part of the arc in the Komandorsky Islands consists of Eocene and Miocene volcanic, tuffaceous, and sedimentary deposits including basalt, andesite-basalt and andesite and interbedded tuff. The sedimentary rocks include sandstone, conglomerate, clay mudstone, unconformably diatomite. overlying, subalkalic basalt and alkalic basal, middle Miocene tuff and tuffaceous siltstone, cross-bedded sandstone and gritstone, and extensive interlayered Quaternary and Holocene glacial deposits. (2) The western part of the arc in the Aleutian Islands is subdivided into a lower (37 to 55 Ma), middle (5.3 to 37 Ma), and upper series (5.3 Ma to Holocene) (Scholl and others, 1992; Miller and Richter, 1994; Vallier and others, 1994). The lower series forms the base of the arc and consists predominantly of flows and volcaniclastic rocks. Igneous composition ranges from basalt to rhyolite, but is mainly calc-alkalic basalt and andesite. Also occurring are local hypabyssal and plutonic rocks. The

middle series is predominantly volcanic flows, volcaniclastic rocks, conglomerate, and dolomite. Locally abundant sills, dikes, plugs, and large quartz diorite and granodiorite plutons also occur. The upper series is predominantly sedimentary and volcanic strata that occur mainly in offshore basins and along the flanks of volcanoes. The early Tertiary part of arc, named the Meshik arc on the Alaska Peninsula, consists chiefly of andesite and dacite flows and volcaniclastic rocks. The younger, middle Tertiary through Holocene part of the arc consists of about 37 subaerial stratocones composed predominantly of calcandesite to dacite flows, tuffs, and alkalic volcaniclastic rocks. And (3) the eastern part of the arc on the Alaska Peninsula and in the Alaska Range overlaps the Peninsular sequence of the Wrangellia superterrane and consists of the 50 to 55 Ma Teklanika Formation, the 37 to 45 Ma Mount Galena, Sheep Creek, and Post River volcanic complexes, and associated unnamed units that range in composition from basalt to rhyolite.

The Wrangell volcanic field (wr) consists chiefly of andesite and lesser basaltic andesite shield volcanoes, satellitic cones, and andesite and lesser dacite flows, tuff, breccia, volcanic-avalanche deposits, mudflows, and domes of 0 to 20 Ma age (Miller and Richter, 1994). The volcanic field also includes lesser rhyolite and rhyodacite flows and domes, and basalt and basaltic andesite cinder cones, and associated flows and dikes. Pyroclastic rocks are mainly lithic and crystal tuff with lesser agglomerate and ash. Local associated shallow andesite plutons, dikes, dike swarms, and plugs also occur. The volcanic field overlies mainly the Wrangellia superterrane in Eastern-Alaska, and is locally extensively interlayered with Quaternary and Holocene glacial deposits.

Subduction Zone Units Linked to Aleutian-Wrangell Arc

Tectonically linked to the Aleutian-Wrangell continental-margin arc is the western part (Attu Island part) of Prince William accretionary wedge terrane, that constitute the younger part of the Prince William accretionary wedge terrane (Nokleberg and others, 1994b), and the Yakutat terrane (accretionary-wedge and subduction-zone complexes), and the modern-day subduction-zone complex that is forming inboard of the Aleutian megathrust (Plafker and others, 1994) (Figure 4).

The Attu Island part of Prince William accretionary wedge terrane (western part of PW) consists predominantly of early Tertiary trench sedimentary rocks accreted to hanging wall of the subduction zone (Cooper and others, 1987, 1992; Scholl and others, 1992; Plafker and others, 1994; Scholl and Hart, 1994). The terrane is exposed on lower landward trench slope near Attu and Kodiak Islands. The Prince William accretionary wedge terrane (PW) is describe in the above section on the Kluane arc

The Yakutat accretionary wedge terrane (YA) is a composite terrane that consists of the Mesozoic Yakutat Group in the eastern part, and Eocene oceanic crust in the western part (Jones and others, 1981; Plafker, 1987; Plafker and others, 1994). Both the eastern and western parts are overlain by younger

Cenozoic sedimentary and volcanic rocks. The Yakutat Group is divided into: (1) melange facies, chiefly basalt, chert, argillite, tuff, and sandstone of Upper Jurassic(?) and Early Cretaceous age, and exotic blocks of Permian and Upper Triassic carbonate rocks, and Middle and Late Jurassic tonalite; and (2) flysch facies, chiefly Upper Cretaceous volcanic sandstone, siltstone, and minor conglomerate with structurally interleaved lenses of disrupted chert, argillite, and volcanic rocks. The Yakutat Group is metamorphosed from zeolite to lower greenschist facies and is intruded by Eocene granitic plutons. The Yakutat terrane is interpreted as a fragment of Chugach terrane (Yakutat Group) and Eocene oceanic crust that, together with overlying, pre-Miocene sequence, was displaced at least 600 km northward along the Fairweather transform fault since the early Miocene. Isotopic studies by Heller and others (1992) suggest formation of the Cenozoic sedimentary rocks of the Yakutat terrane in a basin offshore of the USA Pacific Northwest with subsequent northward tectonic migration of about 600 km (Plafker and Berg, 1994).

Origin of Aleutian-Wrangell Arc

The igneous units that define the Aleutian-Wrangell arc are interpreted by most workers as various parts of an elongate continental-margin arc that has been active since inception in the late Eocene (Figures 13-15) (Plafker and others, 1989; Scholl and others, 1992; Nokleberg and others, 1994a, b; Plafker and Berg, 1994; Plafker and others, 1994; Monger and Nokleberg, 1996). The arc is interpreted as forming in successive, response to oblique subduction (combination of dextral slip and underthrusting) of three major units along the continent-ward-dipping Contact fault (CO), the Aleutian Megathrust, and parallel intervening faults (Figure 4): the younger, Paleocene and Eocene part of the Prince William wedge terrane, the Yakutat and accretionary with accretionary wedge terrane, underthrust sedimentary rocks as young as Eocene, and part of the Pacific Oceanic Plate. In contrast to the Northeast Asia arc, described above, with three major back-arc units, and to the Cascade arc, described below, with one major back-arc unit, the Aleutian-Wrangell arc is not associated with any prominent back-arc unit.

Cascade Arc in Southern Part of Canadian Cordillera and U.S.A. Pacific Northwest

The Cascade arc is a major continental margin igneous arc that continues to be active since inception in the early Eocene. The arc is being preserved in the Cascade volcanic-plutonic belt (ca) (Figure 4) (Wells and Heller, 1988; England and Wells, 1991; Goldfinger and others, 1996, 1997; Fleuh and others, 1997). The Cascade arc overlap all previous-accreted inboard terranes in the region (Figures 2, 4).

The Cascade volcanic-plutonic belt volcanic belt (ca) consists of Canadian and U.S.A. parts (Vance and others, 1987; Wells, 1990; Walker and MacLeod, 1991; Smith, 1993). In the Canadian Cordillera, the belt consists of Pleistocene and Holocene basalt, andesite, and dacite eruptive centers, and late Eocene(?), Oligocene, and Miocene plutons (Chilliwack and Mount Barr batholiths). The belt includes age-equivalent, possibly unrelated volcanic

rocks (Masset Formation) on the Queen Charlotte Islands. In U.S.A. Pacific Northwest, the belt consists of volcanic rocks of stratovolcanoes, mostly andesite but ranging from basalt to rhyolite. The belt includes interbedded fluvial and lacustrine deposits and minor tonalite to granodiorite plutons. In Washington, parts of belt are included in the Ohanapecosh, the Fifes Peak, and the Northcraft Formations (Vance and others, 1987; Smith, 1993). The Oregon parts of the belt are included in many formations and informal units, listed in Walker and MacLeod (1991). The youngest active volcanoes in the belt are Mount Jefferson, Mount Hood, Mount Adams, Mount St. Helens, and Mount Rainier.

Subduction Zone and Back-Arc Units Linked to Cascade Arc

Tectonically linked to the Cascade continentalmargin arc are, from inboard to outboard, the Siletzia subduction zone terrane (SZ), and the Olympic Core (OC) and Hoh (HO) accretionary-wedge terranes, and an unnamed, modern-day subduction complex forming along the Cascadia megathrust (Nokleberg and others, 1994a, 1997; Goldfinger and others, 1996, 1997; Fleuh and others, 1997) (Figure 4).

The Siletzia subduction zone terrane (SZ) consists chiefly of basalt and greenstone of the early middle Eocene Crescent and Metchosin Formations and the Siletz River Volcanics (Tabor and Cady, 1978; Mueller, 1980; Wells and others, 1984; Clowes and others, 1987; Silberling and others, 1987; Babcock and Engebretson, 1992, 1994). greenstone consists of metamorphosed tholeiitic pillow basalt, massive basalt, diabase, gabbro, tuff, and breccia. Intercalated with the greenstone are minor clastic rocks, ferruginous coccolithic limestone, and argillite. Total structural thickness of the terrane is over 16 km. On the Olympic Peninsula, the greenstone and basalt sequence appears to be stratigraphically underlain by continent-derived graywacke, argillite and minor conglomerate (Tabor and Cady, 1978). Deep seismic-reflection studies on Vancouver Island suggest that the Siletzia terrane was partly subducted beneath the Wrangellia superterrane (Clowes and others, 1987). The Siletzia terrane is stratigraphically overlain by middle and late Eocene turbiditic sedimentary rocks of

The Olympic Core accretionary-wedge terrane (OC) consists chiefly of broken formation and melange composed of marine clastic rocks (Needles-Graywolf, Grand Valley, Western Olympic, and Lithic assemblages) that form the core of the Olympic Mountains (Tabor and Cady, 1978; Clowes and others, 1987; M.T. Brandon, written commun., 1993). The marine clastic rocks are poorly dated but are probably mostly late Eocene to Oligocene in age; however, some imbricated Miocene rocks also occur (M.T. Brandon, written commun., 1993). The terrane includes the western Olympic assemblage of Tabor and Cady (1978), part of which may correlate with part of the Yakutat terrane in Southeastern Alaska (Heller and others, 1992). The Olympic Core terrane is interpreted as having been subducted under the Siletzia terrane along the Hurricane Ridge fault. Deep seismicreflection studies on Vancouver Island suggest that the Olympic core terrane forms the lowest of several northeast-dipping thrust sheets that form the crust of

the Northern Olympic forearc basin.

Vancouver Island, above the presently subducting Juan de Fuca plate (Clowe and others, 1987).

The Hoh accretionary-wedge terrane (HO) consists chiefly of middle Miocene to upper Oligocene melange and broken formation (Snavely and others, 1980; Clowes, and others, 1987; Silberling and others; 1987). Onshore, the terrane consists of sandstone and siltstone that occur in a sheared siltstone matrix on the western Olympic Peninsula (Snavely and others, 1980). Deep seismic reflection studies on Vancouver Island suggest that the Hoh terrane forms the lowest of the northeast-dipping thrust sheets that comprise the crust of Vancouver Island above the presently subducting Juan de Fuca Plate (Clowes, and others, 1987).

Also tectonically lined to the Cascade continentalmargin arc is a major back-arc rift unit represented by the Columbia River Basalt Group (cb). The group consists chiefly of thick flows of olivine tholeiite erupted as flood basalt, between middle and late Miocene (16.5 and 6 Ma), and minor interbeds of fluvial and lacustrine sedimentary rocks. The basalt in group has an estimated volume of 210 km² (Bevier, 1988; Mathews, 1988; Hooper and Conrey, 1989; Hooper 1982; Wells and others, 1989; Wheeler and McFeely, 1991). The group is an extensive unit in central Washington and northern Oregon. In the southern Canadian Cordillera, equivalent rocks of the group consist of the Chilcotin volcanic field of late Tertiary, mainly Oligocene(?), Miocene, and Pliocene age (16 to 2 Ma). The group consists mainly of subaerial, rarely subaqueous, olivine basalt flows, intercalated pyroclastic rocks, and local gabbroic and basaltic intrusions. The group also locally contains younger volcanic centers of intermediate to felsic composition, such as the plume-related(?) Anaheim volcanic rocks, and the rift-related Ediza volcanic rocks (Wheeler and McFeely, 1991).

Origin of Cascade Arc

The Cascade arc is a major continental-margin arc that has been active since the late Eocene (Wells and Heller, 1988; England and Wells, 1991; Goldfinger and others, 1996, 1997; Fleuh and others, 1997). The arc is interpreted as forming in response to successive, oblique subduction (combination of sinistral slip and underthrusting) four major units along the a series of continentward-dipping faults (Figures 13-15). From inboard to outboard, four successively younger units have been subducted and accreted during formation of the arc: the middle Eocene Siletzia subduction zone terrane, the late Eocene to Oligocene Olympic Core accretionary-wedge terrane, the middle Miocene to upper Oligocene Hoh accretionary-wedge terrane, and modern-day subduction unnamed, forming above the Cascadia Megathrust (CC). The Juan de Fuca Oceanic Plate is presently being subducted at the Cascadia Megathrust (Figure 4). Also associated with the Cascade arc is the Columbia River Basalt Group that is interpreted as forming from backarc rifting in the middle and late Miocene. Associated with back-arc rifting is extension and thinning of previously accreted terranes (Wells and Heller, 1988; England and Wells, 1991).

LINKAGES BETWEEN BELTS OF ANATECTIC-RELATED (COLLISONAL) IGNEOUS ROCKS AND ACCRETIONS OF TERRANES

Linkage of the Verkhoyansk Plutonic Belt with Accretion of Kolyma-Omolon Superterrane to North Asian Craton Margin

Characteristics of Verkhovansk Collisional Granite Belt. The Verkhovansk collisional granite belt (vk) occurs in the Russian Northeast consists chiefly of two major belts, the Main collisional granite belt of Late Jurassic to early Neocomian age, and the Northern collisional granite belt of Neocomian age. The Main collisional granite belt extends for about 1000 km along southwest border of the Kolyma-Omolon superterrane and stitches the superterrane to North Asian Craton Margin (NSV) (Verkhoyansk fold and thrust belt). The Main belt consists of inclined, sheetlike plutons, up to 200 km long, that are generally conformable with major fold axes. Ar-Ar ages of granitic rocks range from 144 to 134 Ma (Hackett and others, 1992; Layer and others, 1995; Fujita and others, 1997). Major lithologies in the Main belt are two-mica granite containing garnet, cordierite, and sillimanite, and biotite and biotite-amphibole granite (Shkodzinsky and others, 1992; Trunilina and Oplov, 1997). A few, unpublished initial Sr ratios for granites in the Main higher than 0.7060 range (personnel communication of A.G. Bakha to L.M. Parfenov, 1997). The regional metamorphism parts of the host Kular-Nera terrane, from lower greenschist to local epidote-amphibolite facies, is interpreted as forming during the collisional event.

The Northern collisional granite belt extends for about 600 km along northwestern margin of the Kolyma-Omolon superterrane. Ar-Ar ages of granitic rocks range from 127 to 120 Ma (Layer and others, 1995; Fujita and others, 1997). The Northern belt consists of inclined sheet-like plutons, up to 200 km long, that are generally conformable with major fold trends. Major lithologies are tonalite, granodiorite, and, less commonly, two mica leucogranite. (Shkodzinsky and others, 1992; Bakharev and others, 1988).

Collisional Origin of Verkhoyansk Granite Belt. The Verkhoyansk collisional granite belt (vk) extends for 1,300 km along the southwest and northwest margins of the Kolyma-Omolon superterrane (Figure 3). The granite plutons in the belt intrude several major faults and units, including the Adycha-Taryn and Charky-Indigirka thrust faults, and folds and faults within the Verkhoyansk fold and thrust belt (NSV), the Kular-Nera terrane (KN), and the In'yali-Debin and Polousny synclinoria, and the Uyandina-Yassachnaya volcanic arc (part of unit io) that formed on the margin of the Kolyma-Omolon superterrane (Figure 3) (Parfenov and others, 1993a, b; Nokleberg and others, 1994a, b; Parfenov, 1995a, b). These relations indicate that the Verkhoyansk granite belt formed during and immediately after collision of the Kolyma-Omolon superterrane to the east and the North Asian Craton Margin (Figure 10).

Linkage of Omineca-Selwyn Plutonic Belt to Mid-Cretaceous Accretion of Outboard Terranes Along the North American Continental Margin

Characteristics of Omineca-Selwyn Plutonic Belt. The Omineca-Selwyn plutonic belt occurs in the Canadian Cordillera, Alaska, and the northern part of the Russian Northeast for a strike length of about 4,000 km (Nokleberg and others, 1994a, 1997). The belt includes the easternmost magmatic rocks in the Canadian Cordillera, and the northernmost plutonic rocks in Interior and Northern Alaska and in the northern part of the Russian Northeast. In the Canadian Cordillera, the belt consists chiefly of granodiorite, granite, quartz syenite and minor syenite plutons of Early to mid-Cretaceous age (110-90 Ma) that form an extensive belt of discrete intrusions (Armstrong, 1988; Miller, 1989, 1994; Woodsworth and others, 1992). Many plutons exhibit S-type character. The belt ranges in age from 110 to 90 Ma and exhibits high initial Sr ratios (> 0.710) (Armstrong, 1988; Woodsworth and other, 1992). Extrusive equivalents, such as the South Fork volcanic rocks in the Yukon Territory, are rare.

In the Canadian Cordillera, various western Cordillera terranes (Slide Mountain and Quesnellia) were thrust over the distal, craton-margin Kootenay terrane in the Early to Middle Jurassic (at about 185 Ma). The overthrusting was accompanied by highgrade metamorphism and complex deformation of the Kootenay terrane. From 185 Ma, granitic rocks of the Omineca-Selwyn plutonic belt showing increasing evidence of crustal contamination. Precambrian zircons occur, and higher initial Sr ratios occur in the easternmost granites (Ghosh, 1995). In the mid-(Kootenay. terranes Cretaceous, the western Quesnellia, and Slide Mountain), were overthrust eastwards over the North American Craton Margin (NAM) and over the North American Craton (NAC) along with formation of the distinctive collisional granites of the Omineca-Selwyn plutonic belt. The position of the belt relative to west-dipping structures and isotopic geochemistry suggests it formed by partial anatectic melting of the structurally depressed continental crust. Alternatively, Armstrong (1988) interprets these rocks as the rear part of a single, Cordillera-wide, mid-Cretaceous arc.

In Interior and Northern Alaska, the Omineca-Selwyn belt consists of large plutons of mid-Cretaceous granite and lesser syenite and granodiorite that occur in an elongate trend that extends from East-Central to West-Central Alaska, the Seward Peninsula, and St. Lawrence Island. The belt includes the Ruby geanticline plutons of Central Alaska (Foster and others, 1987, 1994; Miller, 1989, 1994; Patton and others, 1994), and the mid- and early Late Cretaceous granitic plutons of the Yukon-Tanana Upland (Pavlis and others, 1993; Foster and others, 1994). In Interior Alaska, granitic plutons tend to be K-rich, are locally ultrapotassic and Na-depleted, and weakly moderately peraluminous, are locally part of the ilmenite series, and exhibit S-type characteristics. These plutons are interpreted as the product of melting or contamination of continental crust. In the Chukotka terrane in the northern part of the Russian Northeast, the Omineca-Selwyn belt consists of a suite of Early Cretaceous granitic rocks that are overlain by volcanic rocks of Okhotsk-Chukotka volcanic-plutonic belt (Sosunov and others, 1982; Sosunov, 1985).

Within the Verkhovansk fold and thrust belt (NSV), discrete granite plutons of mid-Cretaceous age occur in a linear belt in the West Verkhovansk granite belt. This belt of plutons extends for more than 1,000 km along a north-south strike (unit wvk, Figure 3) (Parfenov and others, 1996). These plutons consist of granodiorite, granite, monzonite, and quartz monzonite with initial Sr ratios of greater than 0.707. Ar³⁹-Ar⁴⁰ isotopic studies indicate ages of 120 to 90 Ma (Fujita and others, 1997). Locally these plutons are associated with regional metamorphism that ranges up to epidoteamphibolite facies, as in the South Verkhovansk region. Field relations suggest regional metamorphism occurred immediately before granite intrusion. The age of metamorphism and granite intrusion is correlated with the intense deformation of the Verkhoyansk fold and thrust belt in the mid- to Late Cretaceous (Parfenov and others, 1996; Fujita and others, 1997), perhaps during the same tectonic event that resulted in formation of the Omineca-Selwyn belt.

Collisional Origin of Omineca-Selwyn Belt. The Omineca-Selwyn plutonic belt (om) occurs in a linear zone of intense mid-Cretaceous deformation that occurs along the inboard part of the North American orogen, about 200 to 300 km continentward from the accretionary margin of the North American continent. The plutonic rocks of the belt were intruded during the late stages of a period of intense contraction that as associated with orthogonal convergence between the Farallon Oceanic Plate and North America (Englebretson and others, 1985; 1992), and subsequent regional extension (Pavlis and others, 1993). In the Canadian Cordillera, the mid-Cretaceous plutons of the belt exhibit a strong crustal inheritance that possibly reflects Andean-style back-arc thrusting and melting of the craton margin beneath the continental margin and accreted terranes during this episode of strong convergence (Monger and Nokleberg, 1996). The thrusting involved both craton margin deposits and the overlying Jurassic and Cretaceous clastic deposits derived from the orogen. Similarly in Interior Alaska, in both the Ruby geanticline and Yukon-Tanana Upland, the plutons belt intruded the sedimentary and volcanic rocks of the two terranes during the waning stages of a complex period of compression and thrusting followed by regional extension (Pavlis and others, 1993; Nokleberg and others, 1995). These geologic relations, and chemical and isotopic characteristics of the Omineca-Selwyn plutonic belt indicate genesis during anatexis associated with the late stages of, and immediately after major terrane collision and orthogonal compression along the North America Cordillera in a narrow linear zone that extended from the southern part of the Canadian Cordillera, across Interior Alaska and into the northern Russian Northeast (Figures 3, 4).

FIGURE CAPTIONS

1. Generalized terrane map for Russian Far East, Northern Japan, and adjacent offshore area. Map illustrates major terranes, major oceanic plates, major offshore faults, and tectonic environment. Adapted from Nokleberg and others (1994a, 1997a, b).

2. Generalized terrane map for Alaska, Canadian Cordillera, and adjacent offshore area. Map illustrates major terranes, major oceanic plates, major offshore faults, and tectonic environment. Adapted from Nokleberg and others (1994a, 1997a, b) and

Monger and Nokleberg (1996).

3. Generalized map of overlap assemblages and tectonically linked subduction zone terranes for Russian Far East, Northern Japan, and adjacent offshore area. Map illustrates overlap assemblages, tectonically linked subduction zones, major oceanic plates and rifts, and major faults. Adapted from Nokleberg and others (1994, 1997a, b).

 Generalized map of overlap assemblages and tectonically linked subduction zone terranes for Alaska, Canadian Cordillera, and adjacent offshore Map illustrates overlap assemblages, tectonically linked subduction zones, major oceanic plates and rifts, and major faults. Adapted from Nokleberg and others (1994a, 1997a, b) and Monger and Nokleberg (1996).

5. Plots of paleolatitude versus time for terranes and overlap assemblages in Russian Far East, Alaska, and the Canadian Cordillera. Time scale from Palmer (1983). Plots derived from Table 3 and cited references. Refer to section on Paleomagnetic

Variation Diagrams for explanation.

A. Plot of paleolatitude versus time for Kolymasuperterrane. Abbreviations: Khetachan; OV, Omulevka; OLE, Oloy-Eropol;

OLS, Oloy-Siverskiy; RA, Rassokha;

B. Plot of paleolatitude versus time for outboard terranes in Russian Northeast. Abbreviations: AV, Alkatvaam; EK, Ekonay; bs Aleutian Bowers-Shirshov; KOR, Kronitskiy; LY, Lyakhov; MAI, Mainitskiy; NE, Nemuro; OK, Olyutorka-Kamchatka; WSA, West Sakhalin; TL, Talovskiy; VL, Viliga; VT, Vetlovskiy.

C. Plot of paleolatitude versus time for Interior and Arctic Alaska. Abbreviations: AA, Arctic Alaska; KY, Koyukuk; NX, Nixon Fork; YT, Yukon-Tanana; bs, Bering Straits; yu, Yukon-Koyukuk

Basin.

D. Plot of paleolatitude versus time for South-Central Alaska. Abbreviations: CG, Chugach; PE, Peninsula; PMW, Pingston, McKinley, Windy; PW. Prince William: TG, Togiak; Wrangellia; al, Aleutian Islands.

E. Plot of paleolatitude versus time for Southeastern Alaska and Canadian Cordillera. Abbreviations: AX, Alexander; CC, Cache Creek; MT, Methow; QN, Quesnellia; SM, Slide

Mountain; ST, Stikinia.

6. Plots of paleolatitude versus time for North Asian and North American Cratons. Time scale from Palmer (1983). Plots derived from Table 3 and cited references. Refer to section on Paleomagnetic Variation Diagrams for explanation. A. Plot of paleolatitude versus time for North Asian Craton. B. Plot of paleolatitude versus time for North American Craton.

7. Middle through Late Devonian (387 to 360 Ma) stage of tectonic model. Refer to Tectonic Model section of text for explanation of tectonic events and to Figure 18 for explanation of abbreviations, symbols, and patterns.

8. Pennsylvanian (320 to 286 Ma) stage of tectonic model. Refer to Tectonic Model section of text for explanation of tectonic events and to Figure 18 for explanation of abbreviations, symbols, and patterns.

9. Carnian through Norian (230 to 208 Ma) stage of tectonic model. Refer to Tectonic Model section of text for explanation of tectonic events and to Figure 18 for explanation of abbreviations, symbols, and

10. Hettangian through Callovian (208 to 163 Ma) stage of tectonic model. Refer to Tectonic Model section of text for explanation of tectonic events and to Figure 18 for explanation of abbreviations,

symbols, and patterns.

11. Oxfordian through Kimmeridigian (163 to 144 Ma) stage of tectonic model. Refer to Tectonic Model section of text for explanation of tectonic events and to Figure 18 for explanation of abbreviations, symbols, and patterns.

12. Neocomian (144 to 120 Ma) stage of tectonic model. Refer to Tectonic Model section of text for explanation of tectonic events and to Figure 18 for explanation of abbreviations, symbols, and patterns.

13. Albian through Santonian (100 to 85 Ma) stage of tectonic model. Refer to Tectonic Model section of text for explanation of tectonic events and to Figure 18 for explanation of abbreviations, symbols, and patterns.

14. Campanian through Early Eocene (85 to 52 ma) stage of tectonic model. Refer to Tectonic Model section of text for explanation of tectonic events and to Figure 18 for explanation of abbreviations,

symbols, and patterns.

15. Middle Eocene through early Miocene (42 to 23 Ma) stage of tectonic model. Refer to Tectonic Model section of text for explanation of tectonic events and to Figure 18 for explanation of abbreviations, symbols, and patterns.

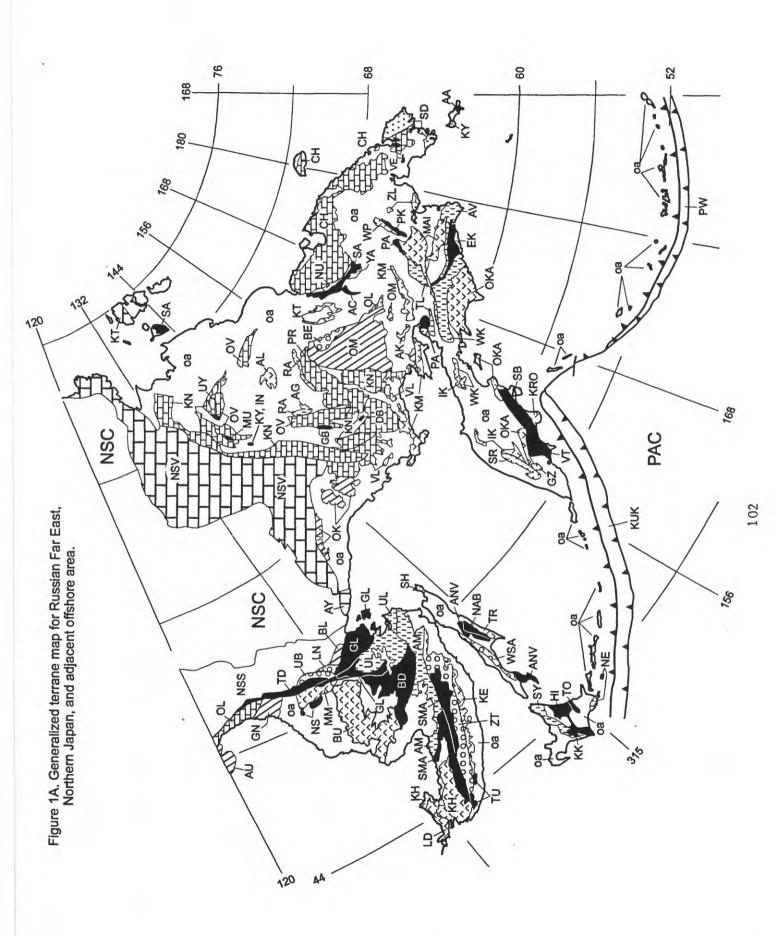
16. Miocene (20 to 10 Ma) (Figure 14) stage of tectonic model. Refer to Tectonic Model section of text for explanation of tectonic events and to Figure 18 for explanation of abbreviations, symbols, and

patterns.

17. Pliocene through Present (4 to 0 Ma) stage of tectonic model. Refer to Tectonic Model section of text for explanation of tectonic events and to Figure 18 for explanation of abbreviations, symbols, and

18. Explanation of abbreviations, symbols, and patterns for various times stages of tectonic model (Figures

7-17).



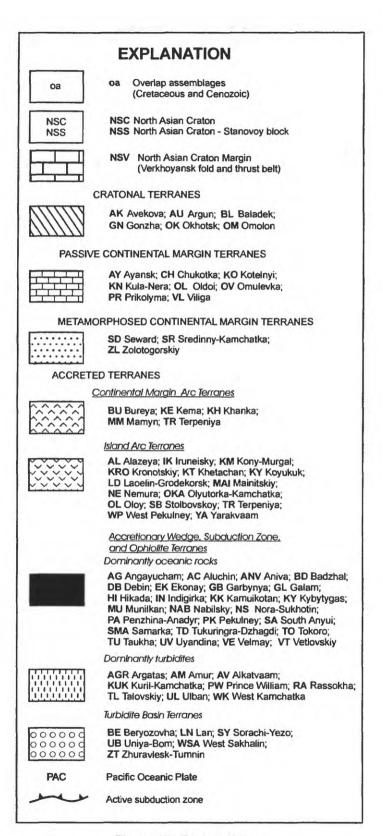
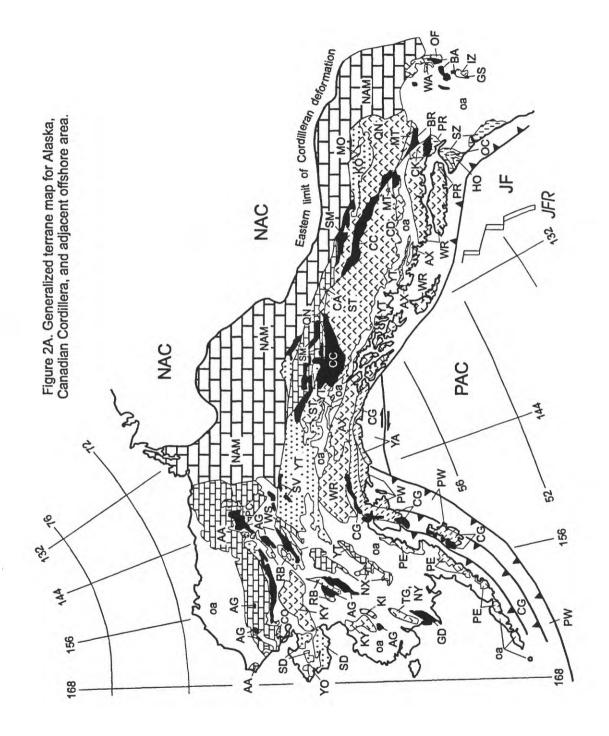


Figure 1B. Explanation.



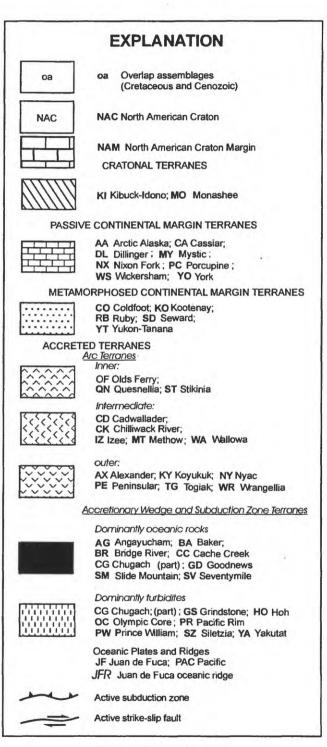
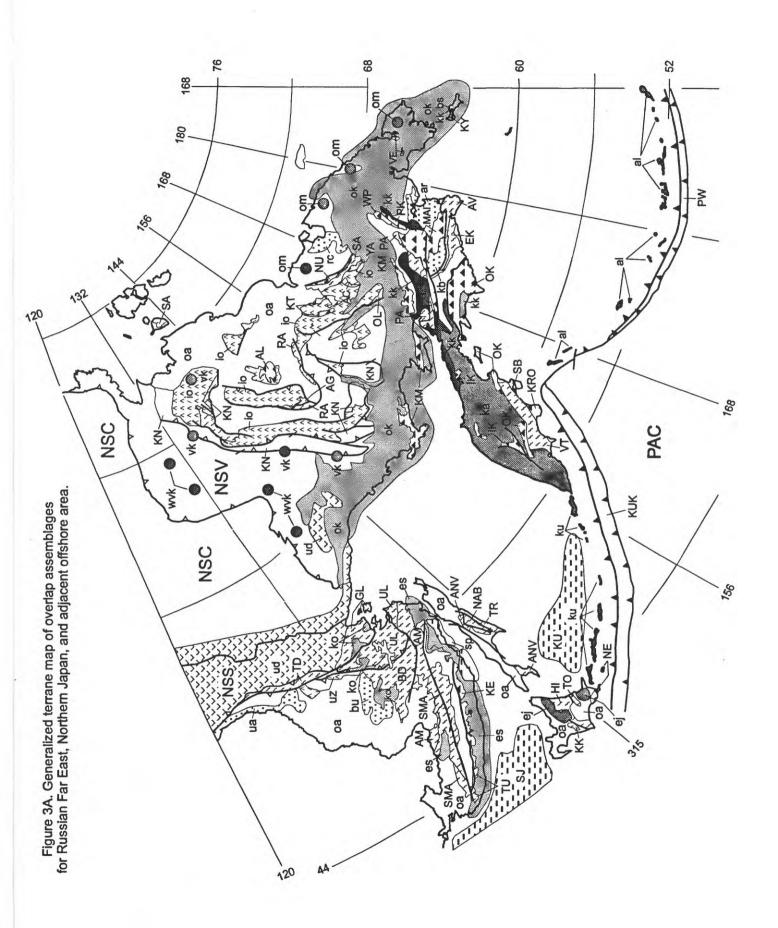


Figure 2B. Explanation.



EXPLANATION

oa

Cenozoic overlap sedimentary assemblages and undivided terranes

Overlapping Middle and Late Tertiary Magmatic Arcs; Emplaced across all major terranes



al Aleutian; ej East Japan; ka Kamchatka (includes east, central, western parts);

Middle and Late Tertiary back arc units



SJ Sea of Japan; KR Kurile;

Overlapping Early Tertiary Magmatic Arcs; Emplaced across all major terranes



kk Kamchatka-Koryak

Overlapping Cretaceous and Early Tertiary Magmatic Arcs; Emplaced across all major terranes



es East Sikhote-Alin; ko Khingan-Okhotsk; ok Okhotsk-Chukotka

Overlapping Middle Jurassic and Early Cretaceous Magmatic Arcs, and Fore-arc and Back-arc Basins



Emplaced across Kolyma-Omolon Superterrane io Indigirka-Oloy



Overlapping Jurassic Continental Margin Arc and Back-arc Basin; Emplaced across NSS

ud Uda; uz Umlekan-Ogodzhin

Jurassic and Cretaceous Island Arc Terranes



AL Alazeya; IK Iruneisky; KE Kema; KM Kony-Murgal; KRO Kronotskiy; KT Khetachan; KY Koyukuk; LD Laoelin-Grodekorsk; MAI Mainitskiy; OK Olyutorka-Kamchatka; OL Oloy; SB Stolbovskoy; WP West Pekulney; YA Yarakyaam

Jurassic, Cretaceous, and Tertiary Accretionary Wedge and Subduction Zone Terranes

Accretionary Wedge and Subduction Zone Terranes
Dominantly oceanic rocks



AG Angayucham; AC Aluchin; AGR Argatas; ANV Aniva; BD Badzhal; EK Ekonay; GL Galam; HI Hikada; KK Kamuikotan; NAB Navilsky; PA Penzhina-Anadyr; PK Pekulney; RA Rassokha; SA South Anyui; SMA Samarka; TD Tukuringra-Dzhagdi; TO Tokoro; TU Taukha; VE Velmay; VT Vetlovskiy

Dominantly turbidites

AM Amur; AV Alkatvaam; KN Kular-Nera; KUK Kuril-Kamchatka; PW Prince William; TL Talovskiy; UL Ulban; WK West Kamchatka

Clastic Sedimentary Basins

(Jurassic, J; Cretaceous, K; and Tertiary, T)



ar Anadyr (T); bu Bureya (JK); kb Kuibiveem (K); rc Raucha (JK); ua Upper Amur (J); Foreland basin on NSC

Craton and Craton Margin

NSC, NSS, NSV, KN NSC North Asian Craton; NSS North Asian Craton - Stanovoy Block; NSV North Asian Craton Margin (Verkhoyansk fold and thrust belt); KN Kular-Nera terrane



Verkhoyansk collisional granite belt



West Verkhoyansk collisional granite belt



Omineca-Selwyn collisional granite belt



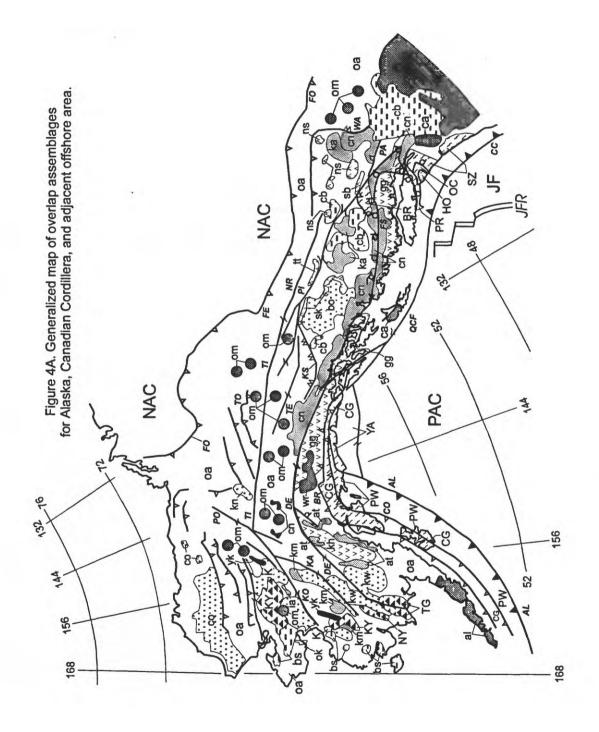
Pacific Oceanic plate

Active subduction zone
Thrust fault



Major mid-Cretaceous and younger strike-slip transform faults

Figure 3B. Explanation.



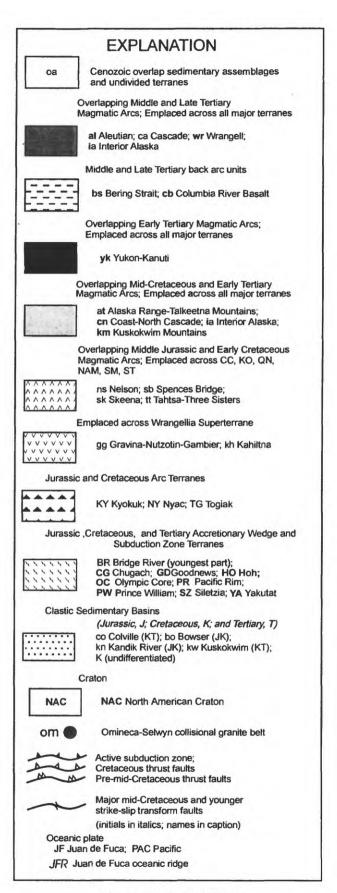


Figure 4B. Explanation.

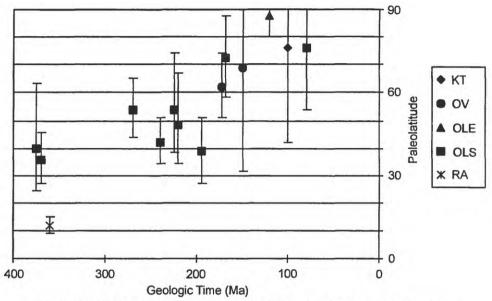


Figure 5A. Paleolatitude versus time for Kolyma-Omolon superterrane.

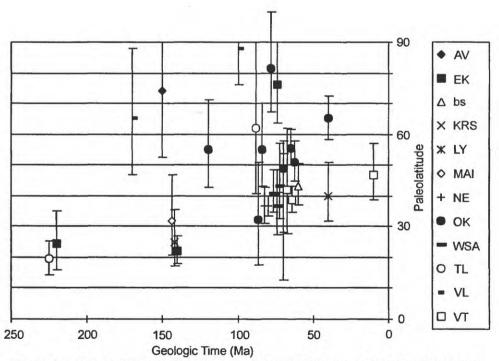


Figure 5B. Paleolatitude versus time for outboard terranes in Russian Northeast.

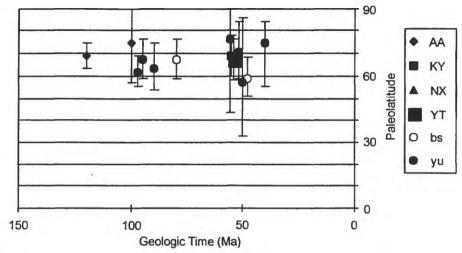


Figure 5C. Paleolatitude versus time for interior and Arctic Alaska.

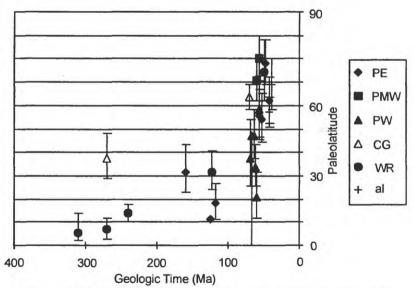


Figure 5D. Paleolatitude versus time for South-Central Alaska.

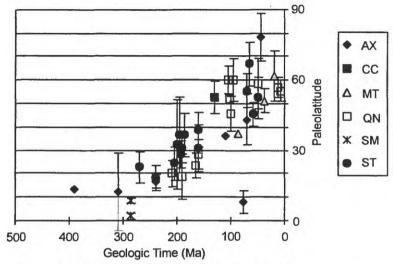


Figure 5E. Paleolatitude versus time for Southeastern Alaska and Canadian Cordillera.

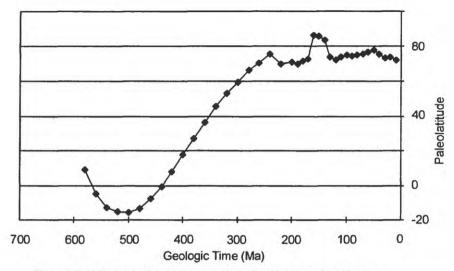


Figure 6A. Paleolatitude versus time for North Asian Craton.

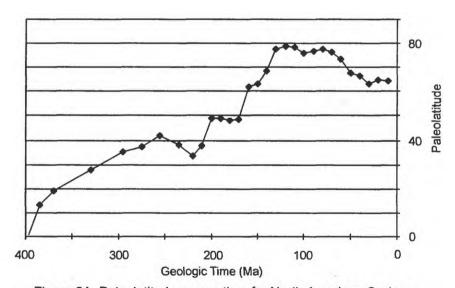
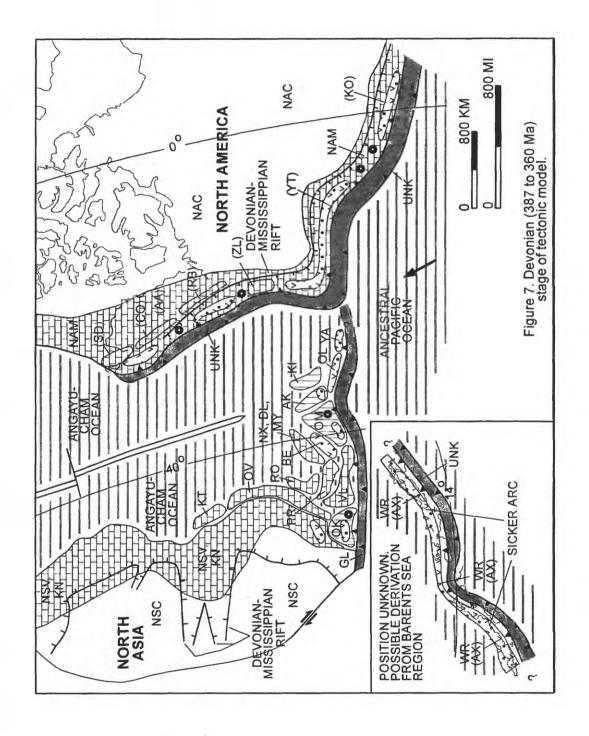
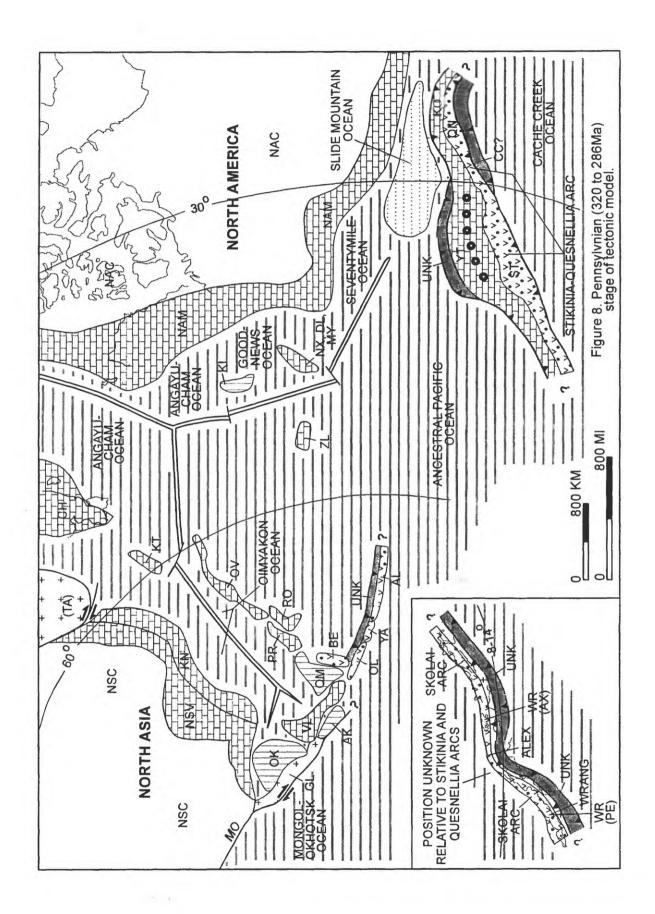
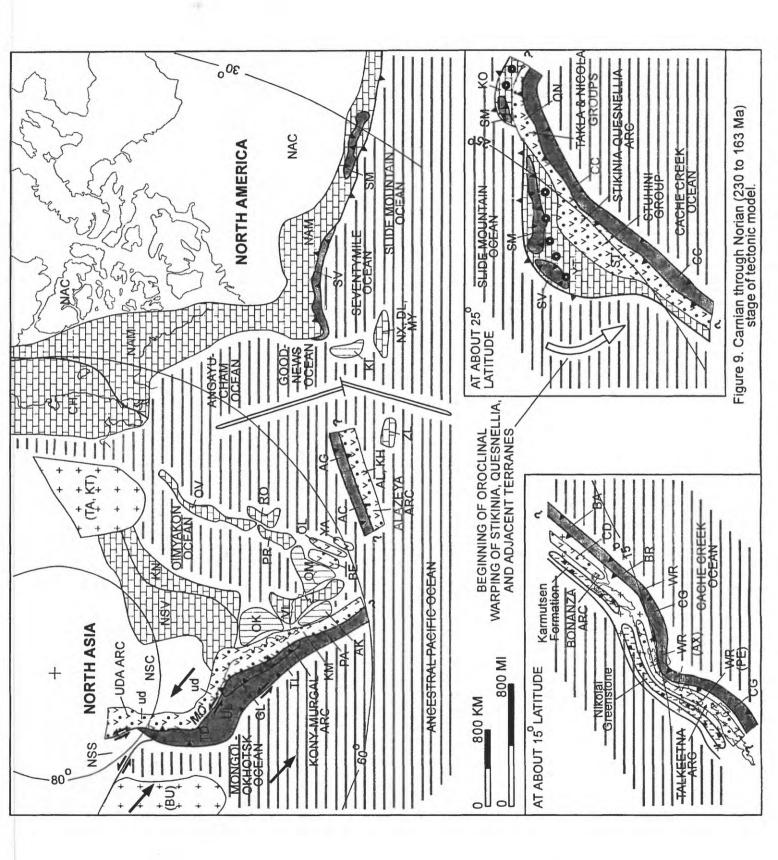
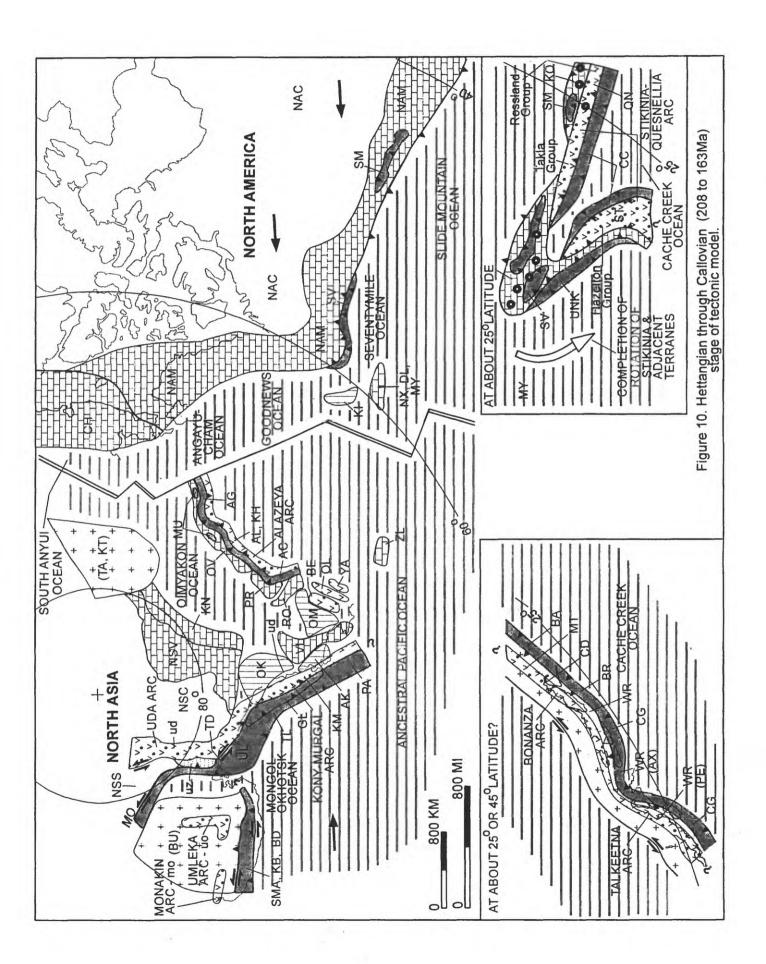


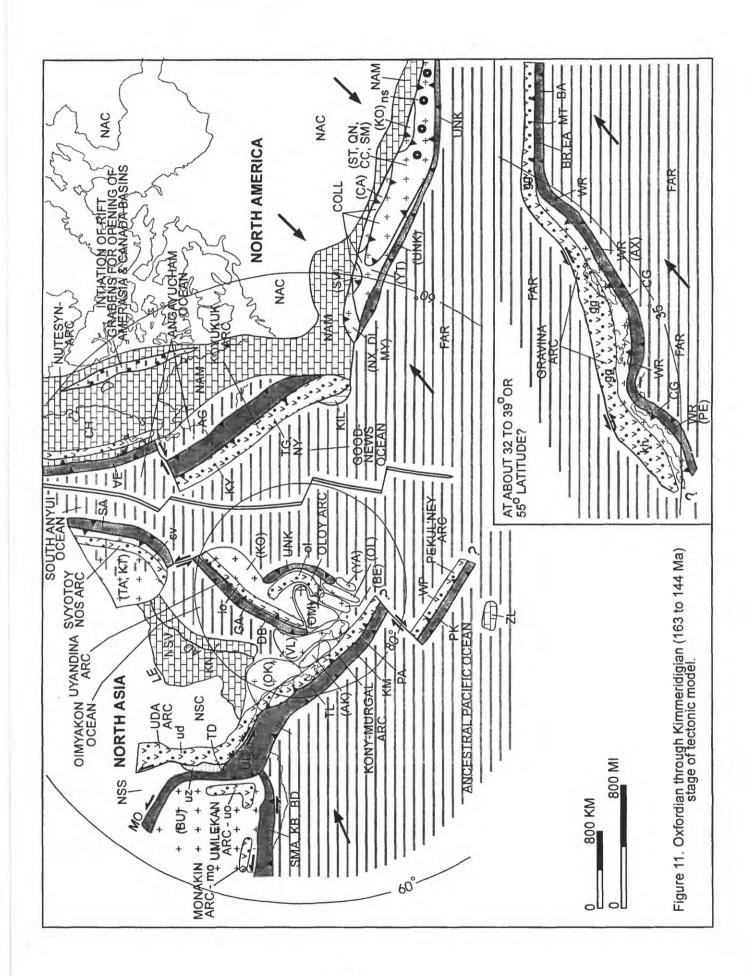
Figure 6A. Paleolatitude versus time for North American Craton.

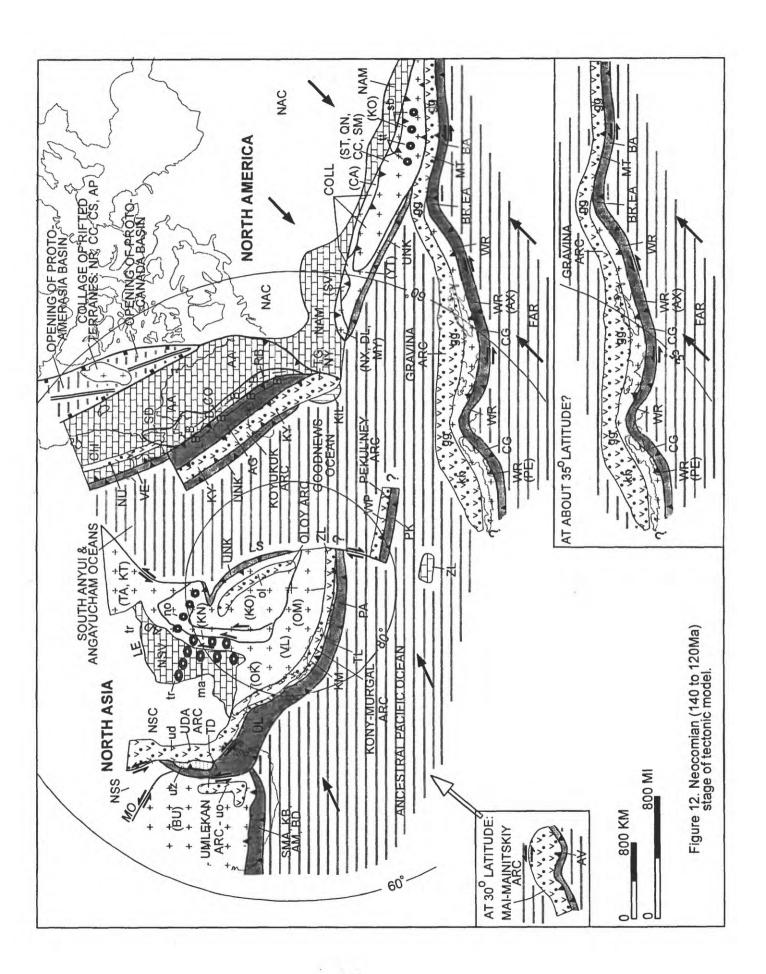


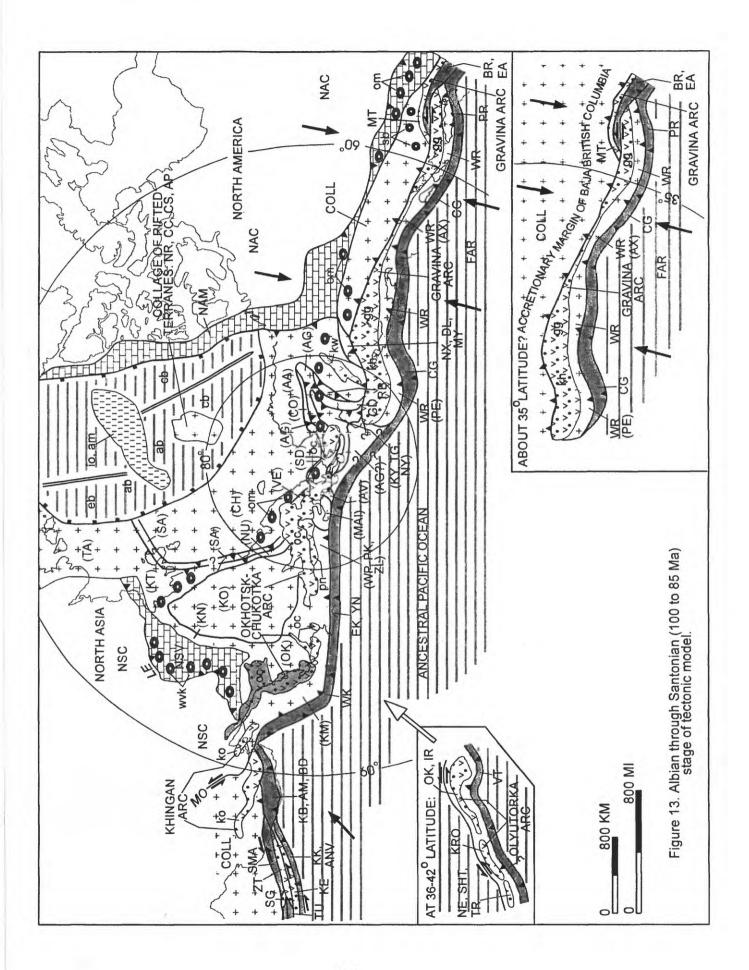


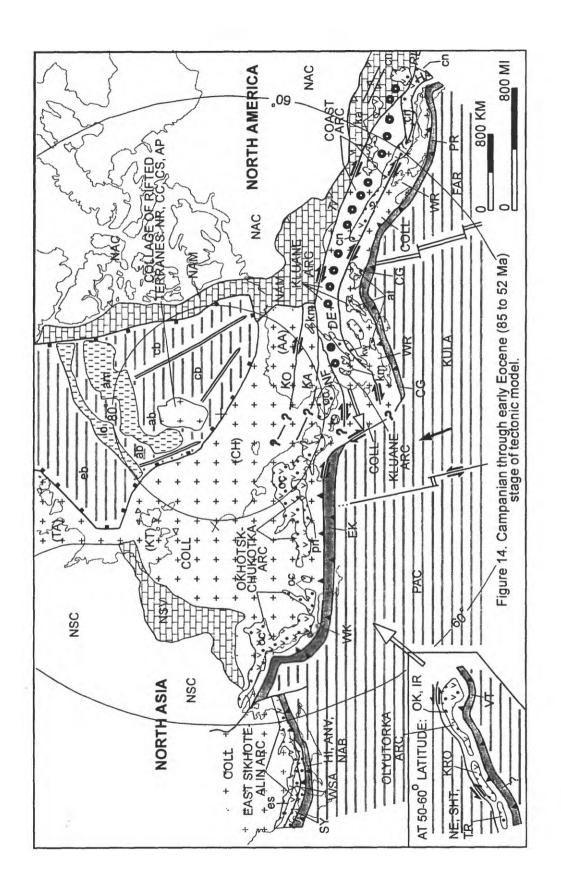


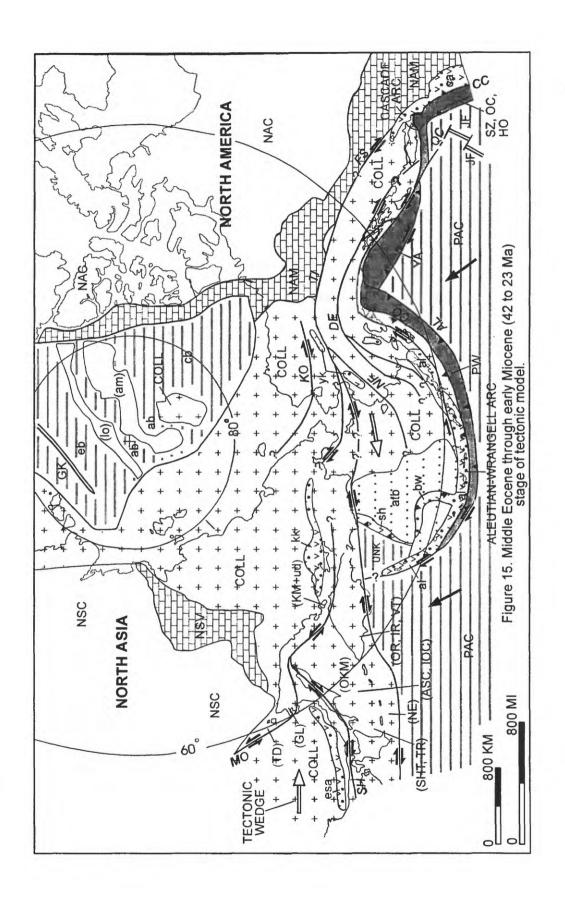


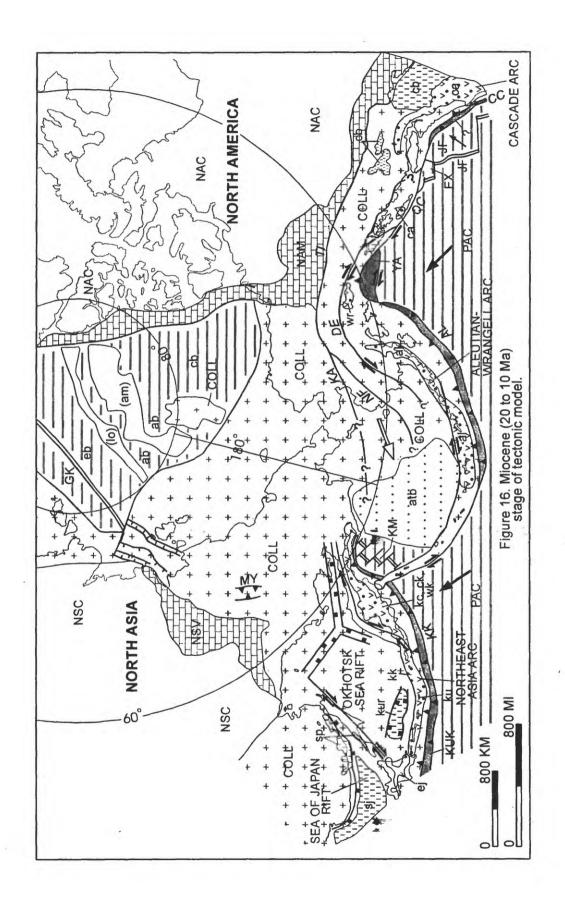


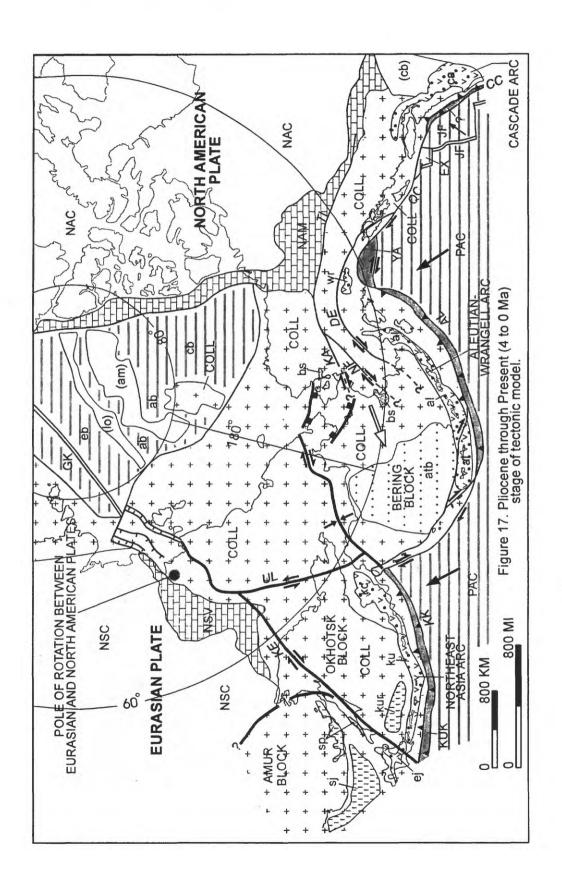












TECTONIC ENVIRONMENTS AND GEOLOGIC UNITS

CRATONAL

Cratons: NAC North American Craton; NSC North Siberian (No patterns) Cratonal Terranes (Vertical line pattern): AK Avekova; GN Gonzha; KI Kilbuck-Idono; Omolon OM

CRATON-MARGIN

Craton Margins: NAM North American; NSV North Asian (Verkhoyansk Foldbelt,

NSS North Asian Craton Margin (Stanovoy Block)
Passive Continental Margin Terranes (Derived from cation margins): AA Arctic Alaska
CA Cassiar, CH Chukchar, Chukchi Cap.; CO Coldocot: D. Dillinger, KN Kullar-Nera;
KO Kootenay, KT Kotelnyi, LO Lomonosov, OL Oldoi, MY Mystic, NR Northwind Ridge.
NX Nikon Fork, PC Porcupine, OV Omulevka, PR Prikolyma; RB Ruby, RO Rassokha;
SD Seward; SR Sredinny-Kamchataka; VL Viliga;WS Wickersham; YT Yukon-Tanana;
ZL Zolotogorskiy.

(Subduction-Related; Includes forearc & backarc, and related turbidite basin deposits) CONTINENTAL MARGIN ARC, ISLAND ARC, & TURBIDITE BASIN

Continental-Margin Arcs: at Alaska Range-Talkeetna Mountains; bw Bowers Ridge; ca Cascade; cn Coast-North Cascade; ej East Japan); esa East Sikhole-Alin; gg Gravina-Gambier-Nuclorin; oi Indigira-Oloy; ka Kamloops; kc Central Kamchatka; kk Kamchatka-Koyask; kh Kahilina; km Kuskokwim Mountains; ko Khingan-Okholsk; kw Kuniti, mo Monakin; oc Okholsk-Chukotka; ol Oloy; os Oloy-Svyotoy Nos; pn Penzhina;

ns Neison; sb Spences Bridge, sh Shirshov Ridge; sv Svydlov-Nos; ti Tahtsa-Three Sisters-Farois Lake, cut Uda; uo Umlekan-Ogodzhin;
Terranes: AL Alazeya; AX Alexander BE Beryozovkha; BU Bureya; CD Cadwallader;
CK Chilliwack River; If Linnelisky, IZ Lee, KE Kema; KH Khetachan; KM Kony-Murgal;
KM Konostky, KT, Kotelnyi; KY Koyukuk; LA Lan, LD Lacelin-Grodekorsk; MAI Mamitskiy;
MT Methow; NE Namuro; NI Nulesyn; NY Nyac; PE Peninsula; OF Olds Ferny;
OK Olyudorka-Kamchatka; OL Oloy; QN Quesnellia; SB Stobolvskoy; SG Sergeewa;
SH Shmidt; ST Stikinia; SY Sorechi-Yezo; TG Togiak; TR Terpeniya; UB Uniya-Bom;
NA Wallowa; WP Wast Pekulney; WR Wangellia; WSA West Sakhalin;

SUBDUCTION ZONE OR ACCRETIONARY WEDGE COMPLEX, AND OPHIOLITE



AG Angayucham; AM Amur; AC Aluchin; AGR Angatas; ANV Aniva; AV Alkatvaam; BA Baker: BD Badzhal; BR Bridge River; CC Cache Creek; CG Chugach; EA Easton; EK Ekoray; GD Goodnews; GL Galam; GS Grindstone; HI Hikada; HO Hoh; KB Khabarovsk; KK Kamuukodari, KLM Kiselyovka-Manoma; KN Kula-Nera; KUK Kuni-Kamotalka. MU Munikar; NAB Nabilsky; OC Olympic Core; PA Penzhina-Anadyr; PK Pekulney; PR Pacific Rim; PW Parnes William; RA Rassokha; AS Aouth Anyuj; SM Silea Mouraliai; SMA Samarka; SN Seventymile; SZ Siletiai: TD Turkuringa-Dzhagdi; T. Talvoskiy; TO Tokoro; TR Terpeniya; TU Taukha; UL Ulban; unk Unknown; VE Velmay; VT Vetlovskiy; WK West-

BACK-ARC SPREADING AND HOT-SPOT UNITS

am Alpha-Mendeleev Ridge; bs Bering Sea; cb Columbia River, kur Kuril; lo Lomonsov Ridge; am Alpha & Mendeleev Ridges; sj Sea of Japan; sp Sakhalin-Primorye;

DCEANIC

Plates: FAR Farallon; JF Juan de Fuca; KULA Kula; PAC Pacific; EX Explorer; Oceanic Ridge: GK Gakkel; JF Juan de Fuca; KOM Komandorsky; POST-ACCRETION OVERLAP SEDIMENTARY AND VOLCANIC UNITS,

SUBMARINE FAN, AND OCEAN BASIN DEPOSITS

ar Anadyr, as Amerasia Basin; bo Bowser,bu Buraya; cb Canada Basin; cf Cordilleran Foreland; co Colville; eb Eurasia Basin; gb Georgia; kb Kuibiveem; kn Kandik River, kw Kuskokwim; rc Raucha; ua Upper Amur, uz Uda-Zeya

COLLAGE OF PREVIOUSLY-ACCRETED TERRANES, AND EXTINCT TERRANES, OVERLAP ASSEMBLAGES, AND BACK-ARC UNITS (Names of Units in Parentheses)

COLL various collages of accreted terranes; KT Kotel'nyi; TA Taimyr Peninsula ÷- COLLISIONAL GRANITE BELTS

ma Main; om Omineca-Selwyn; tr transverse; ** Verkhoyansk; wvk West Verkhoyansk

CONTACTS, FAULTS, SYMBOLS

Dashed where concealed or approximately located)

Contact

Thrust fault, barbs on upper plate

1

^**~** ~ ~ ~

Oblique thrust fault, barb on upper plate Strike-slip fault

High- to low-angle normal fault of relatively downthrown block regional extent; barbs on

HA Harrison KA Kaltag KE Ketanga KK Kuril Kamchatka megathrust

KO Kobuk-South Fork

DE Denali FS Frasier Straight Creek

CO Contact

AD Adycha-Taryn AL Aleutian metathrust CC Cascadia megathrust

FAULTS

Boundary between North American and Eurasian plates and adjacent microplates

Subduction zone, barbs pointing towards subducting margin

ransform fault

LE Lena LS Lyakhov-South Anyui MO Mongol-Okhotsk MY Myatisk NF Nixon Fork NR Northern Rocky Mountain PA Pasayten

Boundary of neotectonic block defined by modern seismicity

SYMBOLS

SH Sahhalin-Hokkaido TE Teslin

RL Ross Lake QC Queen Charlotte

PI Pinchi PO Porcupine

Oceanic Ridge

Back-arc spreading, barbs on spreading basin

Zone of blueschist facies metamorphism Zone of active metamorphism and deformation of continental margin 8-8 555

Subduction-related continental margin plutonic rocks

Collisional granite belts

Relative direction and motion of oceanic plate and continental plates with respect to North America or Eastern Asia

Abbreviation for extensive extinct basin, previously accreted terranes, or inactive arcs (cp)

Abbreviation for fault name

DE

Direction of tectonic migration or major oroclinal bending

Figure 18. Explanation of abbreviations, symbols, and patterns for various time stages of tectonic model (Figures 7-17).