DESCRIPTION OF MAJOR PHANEROZOIC METALLOGENIC AND TECTONIC EVENTS FOR CIRCUM-NORTH PACIFIC

Abstract

The Phanerozoic metallogenic and tectonic evolution of the Russian Far East, Alaska, and the Canadian Cordillera is recorded in the cratons, craton margins, and 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 and contained metallogenic belts that are composed of fragments of igneous arcs, accretionary-wedge and subduction-zone complexes, passive continental margins, and cratons. The collages of terranes are overlapped by continental-margin-arc and sedimentary-basin assemblages and their contained metallogenic belts. The metallogenic and geologic history of terranes, overlap assemblages, cratons, and craton margins is highly complicated because of post-accretion dismemberment and translation during strike-slip faulting that occurred subparallel to continental margins.

Six processes overlapping in time were responsible for most of metallogenic and geologic complexities of the region. (1) In the Late Proterozoic, Late Devonian, and Early Carboniferous, major periods of rifting occurred along the ancestral margins of present-day Northeast Asia and northwestern North American. The rifting resulted in fragmentation of each continent, and formation of cratonal and passive continental-margin terranes that eventually migrated and accreted to other sites along the evolving margins of the original or adjacent continents. The rifting also resulted in formation of various massive-sulfide metallogenic belts. (2) From about the Late Triassic through the mid-Cretaceous, a succession of island arcs and contained igneous-arc-related metallogenic belts, and tectonically paired subduction zones formed near continental margins. (3) From about mainly the mid-Cretaceous through the present, a succession of igneous arcs and contained metallogenic belts, and tectonically paired subduction zones formed along the continental margins. (4) 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 cratons that have become Northeast Asia and the North America. The oblique convergences and rotations resulted in the fragmentation, displacement, and duplication of formerly more-continuous arcs, subduction zones, passive continental margins, and contained metallogenic belts. These fragments were subsequently accreted along the margins of the expanding continental margins. (5) From the Early Jurassic through Tertiary, movement of the upper continental plates toward subduction zones resulted in strong plate coupling and accretion of the former island arcs, subduction zones, and contained metallogenic belts to continental margins. Accretions were accompanied and followed by crustal thickening, anatexis, metamorphism, formation of collision-related metallogenic belts, and uplift. The accretions resulted in the substantial growth of the North Asian and North American continents. (6) In the middle and late Cenozoic, oblique to orthogonal convergence of the Pacific Plate with present-day Alaska and Northeast Asia resulted in formation of the modern-day ring of volcanoes and contained metallogenic belts 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

The following summary of the major Phanerozoic metallogenic and tectonic events for the Circum-North Pacific is adapted from a study of the metallogenesis of the Russian Far East, Alaska, and the Canadian Cordillera (Nokleberg and others, 1993, 1994a, b, 1996a, b, 1997a, b, 2001). Because of a lack of abundant Proterozoic and older rock units, exterior to the craton margins, the model starts with the Devonian. For various published tectonic reconstructions for the Proterozoic, which illustrate highly different global interpretations, the studies of Daziel (1991), Hoffman (1989, 1991), Moores (1991), Ross and others (1992), Scotese (1997), Unrug (1997), and Karlstrom and others (1999) are recommended. The tectonic part of the dynamic computer model on this CD-ROM is derived from a major analysis of the tectonic evolution of the Circum-North Pacific (Nokleberg and others, 2001) which is also contained on this CD-ROM in directory \tectevol.

Methodology of Metallogenic and Tectonic Analysis

The methodology for the analysis of the complex metallogenic and tectonic history of the Russian Far East, Alaska, and the Canadian Cordillera consists of the following steps. (1) The major lode deposits are described and classified according to defined mineral deposit models. Description of the mineral deposit models applied to the region, and descriptions of the 1079 significant lode deposits and 161 placer districts of the region are contained in Nokleberg and others (1996a, b, 1997a); (2) Metallogenic belts are delineated (Nokleberg and others, 1997a). (3) Tectonic environments for the cratons, craton margins, orogenic collages of terranes, overlap assemblages, and contained metallogenic belts are assigned from regional compilation and synthesis of stratigraphic, structural, metamorphic, isotopic, faunal, and provenance data (Nokleberg and others, 1997b, 2001). The tectonic environments include cratonal, passive continental margin, metamorphosed continental margin, continental-margin arc, island arc, transform continental-margin arc, oceanic crust, seamount, ophiolite, accretionary wedge, subduction zone, turbidite basin, and metamorphic (Nokleberg and others, 1997a, 2001). (4) Correlations are made between terranes, fragments of overlap assemblages, and fragments of contained metallogenic belts. (5) Coeval terranes and their contained metallogenic belts are grouped into a single metallogenic and tectonic origin, for instance, a single island arc or subduction zone. (6) Igneous-arc and subduction-zone terranes, which are interpreted as being tectonically linked, and their contained metallogenic belts, are grouped into coeval, curvilinear arc-subduction-zone-complexes. (7) By use of geologic, faunal, and paleomagnetic data, the original positions of terranes and their metallogenic belts are interpreted. (8) The paths of tectonic migration of terranes and contained metallogenic belts are constructed. (9) The timings and nature of accretions of terranes and contained metallogenic belts are determined from geologic, age, and structural data; (10) The nature of collision-related geologic units and their contained metallogenic belts are determined from geologic data. (11) The nature and timing of post-accretionary overlap assemblages and contained metallogenic belts are determined from geologic and age data.

Middle through Late Devonian (387 to 360 Ma)

The first (Middle through Late Devonian) stage of the dynamic model shows the location of two major cratons and craton margins, the North American Craton and Craton Margin on the right side of the diagram, and the North Asian Craton and Craton Margin on the upper central edge of the diagram. For understanding the rational for these loci, the reader is referred to the detailed companion report on the tectonic evolution of the region (pp1626.pdf).

During the Middle to Late Devonian (387 to 360 Ma), the major metallogenic-tectonic events were: (1) formation of a discontinuous continental-margin arc (Kedon arc in Russian Northeast) and contained metallogenic belts, and associated subduction zone along the North Asian and North American Craton Margins; (2) in the late Late Devonian, inception of rifting of the North Asian and North American Cratons and Craton Margins, resulting in formation of new terranes and associated metallogenic belts; and (3) formation of the Sicker arc and contained metallogenic belts, and associated subduction zone in the Wrangellia superterrane. Sedimentation continued along the North Asian and North American Craton Margins. Out of the field of view of was formation of the Yaroslavka (YA) belt that contains F and Sn greisen deposits. The belt is hosted in the Voznesenka terrane in the Khanka continental-margin arc superterrane and is interpreted as forming during anatectic granitic plutonism that occurred during accretion of the Voznesenka terrane with other parts of the Khanka superterrane in the early Paleozoic.

Mississippian (360 to320 Ma)

During the Mississippian (360 to 320 Ma), the major metallogenic-tectonic events were: (1) separation of North Asian and North American Cratons and Cratons Margins along a series of oblique-sinistral rifts; (2) ending of rifting of fragments from cratons and craton margins and formation of associated metallogenic belts; (3) continuation of the Sicker arc and associated subduction in the Wrangellia superterrane. Sedimentation continued along the North Asian and North American Craton Margins.

Pennsylvanian (320 to286 Ma)

During the Pennsylvanian (320 to 286 Ma), the major metallogenic-tectonic events were: (1) inception of the older parts of Stikinia-Quesnellia arc (Stikinia and Quesnellia terranes) and associated subduction zone in the Yukon-Tanana (YT) and Kootenay (KO) terranes in an area offshore of the North American Craton Margin (NAM); and (2) formation of the Skolai island arc and associated metallogenic belt, and associated subduction zone in the Wrangellia superterrane. Sedimentation continued along the passive continental margins of North Asia and North America. Out of the field of view was formation of the Laoelin-Grodekovsk (LG) metallogenic belt, that contains granitic-magmatism-related deposits and that formed in the Laoelin-Grodekovsk island-arc terrane.

Late Triassic (230 to 208 Ma)

During the Late Triassic (Carnian to Norian - 230 to 208 Ma), the major metallogenic-tectonic events were: (1) inception of continental-margin arcs and associated subduction along the North Asian Craton Margin; (2) continued formation of the Stikinia island arc and inception of subduction-related Talkeetna and Bonanza island arcs and associated metallogenic belts offshore of the North American Craton Margin; and (3) beginning of sinistral-slip imbrication of the Stikinia-Quesnellia island arc and metallogenic belts, and associated subduction zones. Sedimentation continued along the passive continental margins of North Asia and North America.

Early Jurassic (208 to193 Ma)

During the Early Jurassic (Hettangian to Pleinsbachian - 208 to 193 Ma), the major metallogenic-tectonic events were: (1) continuation of continental-margin arcs and associated subduction near the North Asian Craton in the Russian Far East; (2) beginning of assembly of previously rifted cratonal, passive continental-margin, and island-arc terranes between that craton and the ancestral Pacific Ocean to form the Kolyma-Omolon superterrane; (3) continuation of the Talkeetna, Bonanza, and Stikinia-Quesnellia arcs and associated metallogenic belts, and formation of companion subduction zones; (4) continued sinistral-slip imbrication of the Stikinia-Quesnellia island arc, contained metallogenic belts, and associated subduction zones during oblique-sinistral convergence between the ancestral Pacific Ocean plate and the North American Craton Margin; 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. Sedimentation continued along the passive continental margins of North Asian and North American Cratons.

Middle Jurassic (193 to163 Ma)

During the Middle Jurassic (Toarcian through Callovian - 193 to 193 Ma), the major metallogenic-tectonic events were: (1) continuation of continental-margin arcs and associated subduction near the North Asian Craton in the Russian Far East; (2) beginning of assembly of previously rifted cratonal, passive continental-margin, and island-arc terranes between that craton and the ancestral Pacific Ocean to form the Kolyma-Omolon superterrane; (3) continuation of the Talkeetna, Bonanza, and Stikinia-Quesnellia arcs, associated metallogenic belts, and formation of companion subduction zones; (4) continued sinistral-slip imbrication of the Stikinia-Quesnellia island arc and associated subduction zones during oblique-sinistral convergence between the ancestral Pacific Ocean plate and the North American Craton Margin; 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. Sedimentation continued along the passive continental margins of North Asian and North American Cratons.

Late Jurassic (163 to 144 Ma)

During the Late Jurassic (Oxfordian through Kimmeridgian) (163 to 144 Ma), the major metallogenic-tectonic events were: (1) beginning of accretion of the Bureya superterrane against the North Asian Craton along the Mongol-Okhotsk suture and formation of associated metallogenic belts; (2) establishment of a series of continental-margin arcs, and formation of associated metallogenic belts companion subduction-zones around the Circum-North Pacific; (3) initiation of rift grabens that subsequently formed the Amerasia and Canada Basins; (4) obduction of the Stikinia-Quesnellia arc and associated terranes onto the North American Craton Margin; and (5) ending of the previous long-lived period (Late Proterozoic through Early Jurassic) of passive sedimentation along the margins of the North Asian and North American Cratons.

Early Cretaceous (144 to 120 Ma)

During the Early Cretaceous (Neocomian - 144 to 120 Ma), the major metallogenic-tectonic events were: (1) completion of accretion of the Bureya superterrane against the North Asian Craton along the Mongol-Okhotsk suture and formation of associated metallogenic belts; (2) continuation of the continental margin and island arcs, and formation of associated metallogenic belts and companion subduction zone assemblages around the Circum-North Pacific; (3) accretion of the major Kolyma-Omolon superterrane and formation of associated metallogenic belts in the Russian Northeast; (4) initiation of obduction of Angayucham subduction-zone terrane onto the North American Continental Margin; (5) continuation of opening of the Amerasia, Canada, and Eurasia Basins in response to sea-floor spreading in the Arctic Ocean; (6) the beginning of accretion of the Wrangellia superterrane in the Southern Canadian Cordillera; and (7) around the Circum-North Pacific, continued sinstral transpression between oceanic plates and continents.

Late Early Cretaceous (120 to 100 Ma)

During the late Early Cretaceous (Aptian through Albian - 120 to 100 Ma), the major metallogenic-tectonic events were: (1) inception of the short-lived Khinghan continental margin arc, and formation of associated metallogenic belts and companion subduction zone in the Russian Southeast; (2) accretion of the Mainitskiy island arc and associated

Alkatvaam (AV) accretionary-wedge terranes to the active continental margin (by the beginning of the Albian); (3) completion of accretion of the major Kolyma-Omolon superterrane in the Russian Northeast and formation of associated metallogenic belts; (4) obduction of Angayucham subduction-zone terrane onto the Arctic Alaska terrane (rifted fragment of North American Continental Margin) and formation of metallogenic belts during extension that succeeded obduction; (5) continued opening of the Amerasia, Canada, and Eurasia Basins; and (6) continuation of the Gravina arc and formation of associated metallogenic belts during continuing accretion of the Wrangellia superterrane, and inception of collision-related metallogenic belts.

Early Late Cretaceous (100 to 84 Ma)

During the early Late Cretaceous (Cenomanian though Santonian - 100 to 84 Ma), the major metallogenic-tectonic events were: (1) establishment of a series of continental-margin arcs and associated metallogenic belts, and companion subduction-zone assemblages almost continuously around the Circum-North Pacific; (2) continued opening of an ocean that would become the Amerasia, Canada, and Eurasia Basins; (3) completion of accretion of the Wrangellia superterrane and formation of associated metallogenic belts; and (4) in the eastern part of the Circum-North Pacific, a change to orthogonal compression between the Farallon Ocean plate and North America.

Late Cretaceous and Early Tertiary (84 to 52 Ma)

During the Late Cretaceous and early Tertiary (Campanian though Early Eocene - 84 to 52 Ma), the major metallogenic-tectonic events were: (1) the continuation of a series of continental-margin arcs, associated metallogenic belts, and companion subduction-zone assemblages around the Circum-North Pacific; (2) completion of opening of the Amerasia, Canada, and Eurasia Basins; (3) completion of accretion of the Wrangellia superterrane; (4) a change to dextral transpression in the eastern part of the Circum-North Pacific between the Kula Ocean plate and the North American continental margin; (5) oblique subduction of the Kula-Farallon oceanic ridge under the margins of Southern and Southeastern Alaska, and formation of associated metallogenic belts, and (6) northward migration of previously accreted terranes along the margin of the North American Cordillera.

Early to Middle Tertiary (42 to23 Ma)

During the early to middle Tertiary (middle Eocene to the early Miocene - 42 to 23 Ma), the major metallogenic-tectonic events were: (1) continuation of a series of continental-margin arcs, associated metallogenic belts, and companion subduction-zone assemblages around the Circum-North Pacific; (2) continuation of sea-floor spreading in the Arctic and eastern Pacific Oceans; (3) establishment of a new continental margin in the northern and eastern parts of the Circum-North Pacific 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) continuation of dextral transpression between the Pacific Ocean plate (PAC) and the North American continental margin in the eastern part of the Circum-North Pacific; and (5) a change to orthogonal transpression between the Pacific Ocean plate and the Southern Alaska continental margin because of counterclockwise rotation of Western Alaska.

At about 50 Ma, the Gakkel Ridge (GK) (northern extension of the Atlantic mid-Ocean Ridge) was initiated and sea-floor spreading extended into the Eurasia Basin (eb) in the Arctic ocean, thereby resulting in the North American–Eurasia plate boundary in the Russian Northeast. The exact location of the Euler pole changed throughout the Cenozoic, thereby resulting in regional changes in the stress regime.

Middle Tertiary (20 to10 Ma)

During the middle Tertiary (Miocene - 20 to 10 Ma), the major metallogenic-tectonic events were: (1) continuation of a series of continental- margin arcs, associated metallogenic belts, and companion subduction-zone assemblages around the Circum-North Pacific; (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 Southern Alaska continental margin; and (5) continued sea-floor spreading in the Arctic and eastern Pacific Oceans.

Late Tertiary and Quaternary (4 to 0 Ma)

During the late Tertiary and Quaternary (Pliocene to the present - 4 to 0 Ma), the major metallogenic-tectonic events were and are: (1) continuation of a series of continental-margin arcs, associated metallogenic belts, and companion subduction-zone assemblages around the Circum-North Pacific; (2) continuation of opening of major sedimentary basins behind major arcs; (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; (4) a continuation of oblique-orthogonal transpression between the Pacific plate and the Southern Alaska; and (5) continuation of sea-floor spreading in the Arctic and eastern Pacific Oceans.

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