Terrane Map of Northeast Asia: Principles of Compilation and Major Subdivisions of the Legend

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ABSTRACT

A terrane map being compiled for Northeast Asia at a scale of 1:5,000,000 covers the territories of eastern and southern Siberia, Mongolia, northeast China, southern Russian Far East, South Korea and Japan. The compilation of the map is part of an international scientific project on metallogenesis and tectonics of the region. This paper discusses the principles and contents of terrane analysis on which the map is based; provides definitions of key terms such as craton, terrane, accretion, amalgamation, dispersion, etc.; describes different types of terranes, overlap and stitch assemblages that are classified on the basis of actualistic (tectonic) principles. A possibility of recognizing terranes within the Early Precambrian basement of cratons is also discussed.

INTRODUCTION

Studies in the 1970's, based on the new concepts of plate tectonics, established that ophiolites of orogenic belts are former fragments of oceanic crust that floored oceans, which subsequently disappeared. Also recognized within orogenic belts were fragments of island arcs, continents, and microcontinents. Also at this time, initial global and regional paleotectonic reconstructions were made. At the time, it seemed that the new paradigm would allow for quick resolution, because on the basis of relatively limited initial data, all the global problems would be quickly solved concerning the structure and evolution of Phanerozoic orogenic belts and the accretion of continents. Consequently, future generations of geologists would have little to accomplish (Howell, 1989).

However, detailed investigations carried out in the early 1980's, primarily, in Alaska and the North American Cordillera (Coney and others, 1980; Howell, 1985, 1989; Howell, and others, 1985; Jones and others, 1983; Wheeler and others, 1991), revealed that orogenic belts consist of a collage, or mosaic of fault-bounded crustal blocks known as terranes. Terranes are fragments derived from larger tectonic units, such as craton, passive and active continental margins, oceanic crust (ophiolites), intraoceanic assemblages of various types and island arcs. All these fragments are interpreted as having formed at distances of hundreds to thousands of kilometers from their present location, from each other, and from adjacent cratons. Accretion (collision) of these fragments onto continental margins produced orogenic belts and were accompanied by regional thrust and strike-slip faulting. These accretions caused dismembering of previously single tectonics units, their dispersion and formation of new tectonic fragments along orogenic continental margins. These fragments, now defined as a mosaic of terranes, defines the structure of orogenic belts in Alaska and the North American Cordillera (Coney and others, 1980; Howell, 1985, 1989; Howell, and others, 1985; Jones and others, 1983; Monger and Nokleberg, 1996). These studies clearly show that paleotectonic reconstructions must be preceded by hard work that consists of recognizing terranes, establishing their geodynamic nature, etc., a type of study now defined as terrane analysis. A terrane analysis, now accepted as an efficient method of regional tectonic study of orogenic belts, combines regional geological mapping and detailed scientific investigations (structural, geochemical, paleomagnetic, paleobiogeographic, etc.) with regional and global paleotectonic reconstructions based on plate tectonic models. Also linked to terrane analyses are metallogenic analyses of orogenic belts.

PREVIOUS REGIONAL TERRANE ANALYSIS STUDIES

In the 1980s, terrane maps of Alaska and North American Cordillera (Jones and others, 1987; Monger and others, 1987; Silberling and others, 1987; Wheeler and others, 1988), and other regions (Howell, 1985) were compiled and published. The terrane maps, in contrast to geodynamic maps that are similar to geologic maps, show a mosaic of major tectonic units in orogenic belts that formed by tectonic juxtaposition (accretion) of terranes.

One of the first terrane maps for the territory of Russia was compiled within the framework of an International Project on Metallogenesis and Tectonics and of the Circum-North Pacific (Parfenov and others, 1993; Monger and Nokleberg, 1996). The project was completed in the period from 1990 to 1998 by geologists of the Russian Academy of Sciences (Far Eastern and Siberian Branches) and the "Roskomnedra" (now Russian Ministry of Natural Resources) in cooperation with geologists from U.S. Geological Survey, the Geological Survey of Canada, the Alaska Division of Geological and Geophysical Surveys, and the Geological Survey of Japan. The results of the work were the terrane, mineral deposit, and metallogenic maps published at scales of 1:5,000,000 to 1:10,000,000 of the region and companion explanations (Nokleberg and others, 1994, 1997, 1998). The obtained data and interpretative analyses were reported and appreciated at many international meetings in Russia, Japan, Alaska, Canada, and the conterminous USA. As a successor to this first study, a new similar international project of type was started on the to metallogenesis and tectonics and of Northeast Asia (specifically Eastern and Southern Siberia, Mongolia, Northeast China, South Korea, and Japan. The terrane map discussed here is part of this new project that involves geologists from all these countries and the USA. The terrane map for the new project overlaps the western part of the former study, and a continuation of the previous project (Figure 1). The new project is scheduled to be completed in 5 years (1997-2002).

PURPOSE OF THE MAP

This paper discusses the principles of compilation of terrane maps in connection with development of the legend of the terrane map of Northeast Asia at a scale of 1:5,000,000. This discussion is particularly important, because in Russian geological literature, such terms and concepts such as terrane and terrane analysis are understood differently than in North American (Gusev and Khain, 1995).

The terrane map of Northeast Asia is based on the principles developed for the prior project on the Circum-North Pacific (Nokleberg and others, 1994, 1997, 1998) and on previously published terrane maps of other regions (Jones and others, 1987; Monger and Berg, 1987; Silberling and others, 1987; Wheeler and others, 1988). At the same time, additional development of the legend is needed. These additions are required, on the one hand, by the necessity of further refining the principles and methods of tectonic cartography and, on the other hand, by a great variety and complexity of tectonic structures for the new project area. For instance, the Circum-North Pacific terrane map only delineates Mesozoic and Cenozoic orogenic belts, whereas the new map will include, in addition to Mesozoic and Cenozoic orogenic belts of Sikhote-Alin, Japan and Russian Northeast, the various Paleozoic orogenic belts of Central Asia, the Taimyr Peninsula, as well as the whole of the Siberian platform and part of the North China platform. These areas contain extensive outcrops of Early Precambrian crystalline rocks. The legend of the previous map must be substantially supplemented to describe ancient Archean and Proterozoic craton and young platform covers, Early Precambrian cratonal formations, magmatic rocks of cratons, and granitoids and metamorphic rocks within variously-aged orogenic belts.

The 1:5,000,000 terrane map of Northeast Asia is planned as a major source of information on the geology and tectonic structures of the region. Within the limits of the project, the map will serve as a tectonic basis for analyzing the occurrence and formation of mineral resources and metallogenesis of the region. The map may also be used for other purposes, including regional tectonic analyses as well as analysis of neotectonics, seismicity, recent volcanism, etc. The terrane map will serve as a basis for paleotectonic reconstructions, showing ancient continents, their passive and active margins, ancient oceans, island arcs, microcontinents, and other intraoceanic formations.

Within the framework of the new project, regional problems and fundamental geologic, tectonic, and metallogenic problems will be addressed. These problems include: (1) comparatively analyzing the structure, paleogeodynamics and metallogenesis of Mesozoic-Cenozoic, Paleozoic and Late Precambrian orogenic belts in relation to the opening and evolution of the Pacific and Paleoasian oceans; (2) analyzing the tectonics and metallogenesis of Precambrian and Phanerozoic rocks within the limits of ancient platform shields; (3) recognizing specific events of metallogenesis and crustal formation; (4) determining the origin and evolution of major sedimentary basins within ancient platforms and in variously-aged orogenic belts on the periphery of the Pacific and Arctic oceans; and (5) determining the nature of magmatic activity and associated mineralization within platforms.

TERRANE ANALYSIS CONCEPTS

Terrane analysis includes the following concepts: (1) recognition of terranes, their overlap units (sedimentary and volcanic-sedimentary) and "stitching" assemblages (magmatic and metamorphic); (2) definition of terrane boundaries and types (thrust, strike-slip, or normal faults); (3) classification of terranes and their overlap and "stitching" assemblages on an actualistic or tectonic basis (island-arc formations, accretionary wedge complexes, active and passive continental margins, fragments of oceanic crust, etc., and magmatic formations related to rifting, collision, subduction, and other processes); (4) recognition and classification of post-accretionary faults that formed after the accretion of terranes to a continental margin and which caused dismembering and dispersion of terranes; and (5) analysis of paleobiogeographic and paleomagnetic data to clarify the origin of terranes.

KEY TERMS FOR TERRANE ANALYSIS

Key terms of terrane analysis are craton, tectonostratigraphic terrane (or simply "terrane"), accretion, amalgamation, dispersion, overlapping and "stitching" assemblages.

Craton is defined as a large (several million sq. km), rigid part of the continental crust that formed in the Precambrian (e.g., North Asian, Sino-Korean, and North American Cratons). A craton includes ancient platform and outer zones (fold-and-thrust belts) of contiguous orogenic belts. The platform and outer zones of orogenic belts have the same Precambrian crystalline basement, and thick, deformed sedimentary sequences that overlap the basement of the outer zones that laterally grade into synchronous formations of the ancient platform cover. For example, North Asian Craton (Kosygin and others, 1964) includes the Siberian Platform and variously-aged, marginal fold- and thrust-belts, including the Verkhoyansk, Baikal-Patom, Yenisey Ridge and Southern Taimyr fold- and thrust-belts. The outer zones of orogenic belts are separated from the platform by frontal thrusts or frontal monoclines. The character of deformations within the outer zones of orogenic belts is defined by thrusts, including regional tectonic decollements (sedimentary sequences detached from the crystalline basement), and by major folds. These zones are called "miogeoclines" (Dietz and Holden, 1966) because their stratigraphic section and thickness increase with distance from the front of the orogenic belt and "fold-and-thrust belts". Paleotectonically, a craton with a miogeoclinal margin corresponds to a continent with the miogeocline corresponding to passive margins of the modern continents. A craton (continent) increases in size with time due to attachment (accretion) of various terranes.

Tectonostratigraphic terrane (terrane) occurs beyond a craton margin and is defined as a fault-bounded body of the Earth's crust, large enough to be mapped at a scale of 1:5,000,000, that greatly differs in its geologic history from that of adjacent terranes. A combination of terranes with complex structural relationships comprises an entire orogenic belt. Recognition of a terrane is based not on the idea of possible large horizontal movements, but on the analysis of stratigraphic, paleontologic, structural, magmatic and metamorphic data that indicate a difference in geologic history compared to that of adjacent terranes.

The term "tectonostratigraphic terrane" implies that terranes recognized in Phanerozoic orogenic belts are characterized first of all as a distinctive stratigraphy and stratigraphic sequence of geologic complexes that formed in specific geodynamic settings (geodynamic complexes), as well as by the time and peculiarities of deformational, metamorphic, and magmatic events. A terrane may include one or more geodynamic complexes. In the explanatory note to the Circum-North Pacific terrane map (Nokleberg and others, 1994) each terrane is illustrated by a tectonostratigraphic column that portrays a sequence of geodynamic complexes, major stratigraphic breaks and unconformities, fossils (macrofauna, microfauna, or flora), isotopic ages, and age of deformational, metamorphic, and magmatic events. Terranes in many of the orogenic belts are interpreted as having migrated several thousands of kilometers before accretion to a continent, and having traveled on "the back" of oceanic lithosphere that was subducted beneath a continental margin or an island arc. Such terranes are called **exotic**. Examples of such terranes are those occurring in the Koryak Highland and Sikhote-Alin regions of the Russian Far East, as well as the Wrangellia, Quesnellia, and Stikinia terranes of southern Alaska and the western Canadian Cordillera. All contain remnants of late Paleozoic and early Mesozoic Tethyan fauna. In general, all recognized terranes must be checked for the degree of exotic nature by examining paleomagnetic and paleobiogeographic data. Sometimes such terranes are called "suspect" (Howell, 1989).

In addition, some terranes may have been fragments of larger tectonic units that disintegrated and were dispersed during accretion and post-accretion faulting. Such dispersal may create a collage of terranes derived from many various tectonic origins, including cratonal, miogeoclinal (passive continental margins), continental margin magmatic arc (active continental margins), island-arc, accretionary wedge, oceanic environments. Some terranes include geologic formations of various geodynamic or tectonic nature, i.e., different geodynamic complexes. For example, a terrane may consist of a continental-margin-arc or rift-volcanic sequence that formed an Early Precambrian crystalline basement. In this case the nature of a terrane is defined by the upper (younger) geodynamic complex (tectonic environment).

About twenty terranes occur within the Mesozoic orogenic belts of the Russian Northeast on the Circum-North Pacific terrane map (Nokleberg and others, 1994, 1997) with each terrane defined by a unique name and map unit, and a distinct geologic history. The terranes vary in size from several kilometers to 350 km across. The smallest are ophiolite sheets, representing fragments of oceanic crust and lithosphere. Most of the terranes are rather large (tens to hundreds of kilometers across) and are variously shaped. In plan view, there exist equidimensional terranes, e.g., Okhotsk (300 by 350 km) and Omolon (250 by 350 km) cratonal terranes; narrow (several tens of kilometers) linear terranes that extend for many hundreds of kilometers, e.g., the South-Anyui accretionary wedge terrane, Koni-Murgal island-arc terrane, Omulevka miogeoclinal (passive continental margin) terrane and others. Terranes are subdivided into subterranes defined as fault-bounded parts of terranes with similar but not identical geologic history (Nokleberg and others, 1994).

In the analysis of orogenic belts in the context of plate tectonics the term "suture" (or "suture zone") is widely used and is defined as a tectonic expression of the zone of collision (Howell, 1989). A suture zone normally includes ophiolites and (or) high-pressure metamorphic rocks. On the Circum-North Pacific terrane map, ophiolites and high-pressure metamorphic rocks with glaucophane and lawsonite comprise parts of some accretionary wedge terranes. Many of these terranes, with a ribbon-like plan view, are described in the literature as suture zones, e.g., the Angayucham terrane in Alaska, the South-Anyui terrane in Chukotka, and the Tukuringra-Djhagdi terrane in the Mongol-Okhotsk belt. Consequently, no need exists to separately delineate suture zones as independent tectonic units. In the past, many of the terranes were separated by vast expanses of oceanic crust.

Consequently, ophiolites, and sometimes high-pressure metamorphic rocks tend to occur at the boundaries of many terranes; however this occurrence is not a necessary condition for defining terranes boundaries. Rather the boundaries of the terranes are marked by major thrust, strike-slip, and, less frequently, by normal faults, and tectonic melange zones.

Some authors criticize the term "terrane" without apparent good basis. Sengör (1990, 1991) expresses concerns that the term "terrane" might be emasculated and reduced to a tectonic nappe or even smaller tectonic units. In fact, it is difficult to set size limits of a terrane. Recognition of a terrane must be guided by the ultimate aim of research which is to make global and regional paleotectonic reconstructions on the basis of a terrane map. These aims include reconstructions of an orogenic belt as a whole, e.g. North American Cordillera, or those of a number of orogenic belts, e.g. in the Russian Northeast. In this case, recognition of numerous, small terranes is not useful. It should be noted that in his works devoted to tectonic evolution of Asia, Sengör (1990, 1991 presents "a generalized tectonic map" showing present location of "the first-order tectonic units" (Figure 2 in (Sengör and others, 1993)). Subsequent paleotectonic reconstructions are based on these first-order tectonic units from which island arcs, microcontinents, etc. are reconstructed. As can be easily seen, these first-order tectonic units are the same as terranes.

Accretion is defined as tectonic attachment of one or more terranes to a craton (continent) margin. It is a cardinal event in tectonic evolution of a terrane and a craton margin. Geologic assemblages that formed before the accretion are defined as preaccretion assemblages, whereas those that formed afterwards as postaccretion assemblages. Accretion may result from subduction, for example collision of an island arc with a passive or active continental margin, from obduction of oceanic crust onto a continent, or from large strike-slip motions parallel to a continent margin.

Amalgamation is defined as tectonic combination of two or more terranes into a single larger tectonic unit prior to their attachment to a craton. Amalgamation produces either a composite terrane or a superterrane or. A composite terrane consist of terranes of the same nature, say, two or more island arc terranes. A superterrane includes terranes of different nature such as island-arc, passive continental margin, oceanic terranes, etc. For example, the Mesozoic Kolyma-Omolon superterrane in the Russia Northeast includes the Omolon cratonal terrane, the Omulevka and Prikolyma miogeoclinal (passive continental margin) terranes, the Alazeya, Khetachan, and Oloy island-arc terranes, the Munilkan oceanic terrane, etc. The superterrane formed as a single unit in the late Middle Jurassic. Upper Jurassic rocks rest with an angular unconformity on different-aged deposits of terranes making up the superterrane. According to paleomagnetic data, the superterrane was at a distance of 1,500-2,000 km from the North Asian craton in the early Late Jurassic. The superterrane accreted to the craton margin only in the late Late Jurassic to Early Cretaceous as indicated by the formation of collisional granites of 140-130 Ma as dated by incremental Ar techniques.

In addition to "accretion" and "amalgamation", terrane analysis involves such terms as "collision" and "docking". The term "collision" is used in the English geologic literature in a general sense as "impact". This may explain its absence in the basic Glossary of Geology edited by Bates and Jackson (1990). One can speak of collision of terranes with one another or with a craton, collision of continents, island arcs, etc. The term "docking" denotes attachment of terranes to a craton (continent) (Twiss and Moores, 1992) and is synonymous with "accretion".

Dispersion is defined as tectonic dismemberment of previously accreted or amalgamated terranes and occurs in three different ways (Howell, 1989):

(1) By translation of terrane fragments along major strike-slip faults over a distance of hundreds to thousands of kilometers; (2) By rifting leading to divergence of fragments of previously single terrane or terranes; the amount of displacement may be very large if rifting develops into the opening of a new ocean; And (3) by dismembering of terranes by deep-seated thrusting that causes sheets of lower crustal (or even upper mantle) rocks coming to the surface. One example of a terrane dispersion as a result of strike-slip tectonics is the Wrangellia terrane in North American Cordillera which was accreted to the continent in the mid-Cretaceous (Monger and Nokleberg, 1996). Subsequently in the Late Cretaceous and Cenozoic the terrane was dismembered into fragments and was dispersed over a distance of 24° of latitude as a result of large-scale strike-slip faults that occur parallel to the continent margin. Another example is the San Andreas fault in California along which dispersion of terranes on the continent margin occurred over the last several million years and continues to the present (Crowell, 1985). Similar examples are known from eastern Asia (the Tanlu fault in China and the Central Sikhote-Alin fault, each with displacements of hundreds of kilometers). The Avekova terrane within the Mesozoic rocks of northeast Asia, which is comprised of Early Precambrian metamorphic rocks, is an example of terranes detached from the structurally similar Omolon terrane. Detachment is interpreted as occurring in the Late Paleozoic due to rifting that formed the so-called Gizhiginsk fold zone that separates the two terrane (Parfenov, 1984). Examples of deep thrusts are known from the southern Alps and the Grenville province in the Canadian shield (Howell, 1989). **Terrane fragments** are parts of terranes that formed by dispersion.

Overlap and stitch assemblages form after the accretion and amalgamation of terranes and define the maximum age limit of such events.

Overlap assemblages consist of sedimentary, volcanic-sedimentary and volcanic rocks that accumulated after amalgamation or accretion of terranes. These assemblages stratigraphically overlie two or more adjacent terranes or a terrane and a craton margin. Overlap assemblages include ancient and young platform covers, marginal and intermontane basins, molasses, etc. Stitch assemblages are represented by plutonic rock belts or dike swarms and metamorphic belts of various geodynamic nature that pierce the adjacent terranes and a craton (continental) margin.

Stitch assemblages may form during accretion and amalgamation of terranes, rifting, subduction, or other processes. Plutonic rocks may be genetically related to volcanic rocks overlying terranes. An example in the Russian Northeast is the granitoids of the Cretaceous Okhotsk-Chukotka continental-margin volcanic-plutonic belt. As with terranes, overlap and "stitch" assemblages are classified on the basis of actualistic principles.

Key terms of terrane analysis are schematically illustrated in Figure 2A where an orogenic belt, formed of terranes 1, 2, 3, and 4, occurs between two cratons (A and B). A corresponding tectonostratigraphic diagram (Figure 2-B) shows ages of rocks comprising terranes, and postamalgamation and postaccretion overlap and stitch assemblages. As seen from the diagram, terranes 3 and 4, that formed after intrusion by pluton **a** of Early Jurassic age, formed a single tectonic unit, superterrane I, that was accreted to craton B in Middle Jurassic time, as indicated by the age of the lower horizons of their overlying deposits **b**. Terranes 1 and 2 were amalgamated into superterrane II in Late Jurassic time, and subsequently, in the early Cretaceous, were accreted to craton B. Formation of an orogenic belt in the Cenozoic occurred as a result of collision of cratons A and B. In the Cretaceous time, accretion of superterrane II to craton B was followed by dispersion of terranes 2 and 4 along a strike-slip fault.

TERRANES IN PRECAMBRIAN BASEMENT OF CRATONS

Early Precambrian structures in the basement of cratons which are exposed within the limits of shields represent a mosaic of blocks as large as hundreds of kilometers across that are separated and surrounded by linear belts of folded rocks that are metamorphosed to varying degrees (in some cases, up to granulite facies). The craton of the Canadian Shield is divided into provinces, subprovinces, orogenic, and granulite belts. The cratons of Africa and Australia are composed of granite-greenstone formations and mobile belts composed of granulite and amphibolite facies rocks. The Aldan Shield is described as fold areas, systems, and zones.

In recent years the term "terrane" has found wide use for describing these large Early Precambrian tectonic units or smaller structures within them (Dobretsov and others, 1997; Dook, 1989; Frost and others, 1997; Glover and Ho, 1992; Howell, 1989; Moscovchenko and others, 1993; Rosen and others, 1990). We find it reasonable to apply the term "terrane" to Early Precambrian fault-bounded tectonic units that differ in their geologic features and, hence, in their geologic history. Where not affected by high-grade metamorphism, a general mosaic pattern of Early Precambrian structures in many ways is similar to the structures of some Phanerozoic orogenic belts. An example is the Paleozoic structures of Central Kazakhstan or Mesozoic units of the Russian Northeast, that all exhibit a "block-mosaic" pattern. At first glance, plate tectonics models are also readily applicable for interpreting Early Precambrian structures of cratons, provided that original composition of high-grade rocks could be restored on the basis of geochemical and other data. However, it is not always possible to reconstruct unambiguously original composition of metamorphic rocks and, moreover, it is still unclear whether plate tectonics operated in the same sense in Early Precambrian time. Kevin Burke, former editor of "Tectonics" wrote, in the foreword to the book *Greenstone Belts*, that plate tectonics is a basic property of the present Earth and it would be interesting to know if the Earth was different during Archean times. Unfortunately this is not an easily answered question (Burke, 1997).

For compilation of the terrane map of Northeast Asia, we suggest that terranes be identified in the Early Precambrian cratons in a manner similar to that for Phanerozoic orogenic belts, i.e. as large (tens and first few hundreds of kilometers across) fault-bounded tectonic units differing in their geologic history, and classified on the basis of their rock composition. Unlike Phanerozoic terranes, Early Precambrian terranes can not be classified as stratigraphic sequences, in most cases, due to their high-grade metamorphism. In recognizing Early Precambrian terranes, the most important things to consider are the types and combination of their metamorphic and magmatic rocks, age of protolith, age and type of the main and superimposed metamorphism, and age of magmatic events.

Within the Aldan-Stanovoy Shield various Early Precambrian terranes have been recognized. These terranes include the Olekma and Batomga granite-greenstone terranes, the Nimnyr charnockite-granite gneiss terrane, the Seimsko-Sutam quartzite-paragneiss terrane, the Timpton-Uchur quartzite-carbonate-paragneiss terrane, the Tynda tonalite-trondhjemite terrane, and the Chogar amphibolite-diorite gneiss terrane. Just like in Phanerozoic orogenic belts, Early Precambrian terranes can amalgamate into a composite terrane or superterrane. For example, the Nimnyr and Seimsko-Sutamsk terranes comprise the Central-Aldan superterrane. The Seimsk thrust separating these two terranes is dated at 2.3 Ga which is much earlier than the time of accretion of the superterrane to the Olekma terrane to the west (1.85 Ga) and the time of accretion of the Timpton-Uchur terrane to the east (1.75 Ga). According to interpretations of Smelov (1996), the Central-Aldan superterrane is separated from adjacent terranes to the west, south, and east by wide (up to 100 km) zones of tectonic melange, respectively the Amga, Kalar and Tyrkanda tectonic melanges. Within these melange zones are tectonically juxtaposed sheets comprised of adjacent terranes and high-pressure granulites and anorthosites from the lower crustal levels. In the Anabar Shield, similar melange zones, up to several tens of kilometers wide, separate blocks (terranes) of compositionally various granulites, and are described as deeply eroded fault zones (Lutz and Oxman, 1990).

Assuming plate tectonics operated in Early Precambrian time in a manner similar to modern plate tectonics, attempts can be made to find possible Phanerozoic analogs of geodynamic settings in which Early Precambrian terranes formed. For example, granite-greenstone terranes may be highly-metamorphosed units that formed from the island-arc or oceanic tectonic environments. Tonalite-trondhjemite terranes may be the highly-metamorphosed, root zones of continental-margin magmatic arc. Charnockite-granite gneiss terranes may be the highly-metamorphosed, miogeocline (passive continental margin), forearc or backarc basins of island arcs. Of course, these correspondences are highly speculative and many specialists of Early Precambrian geology would not agree to these interpretations. Because of these considerations, for compiling the Northeast Asia terrane map, we decided to classify Early Precambrian terranes on the basis of generalized compositional data and have map users formulate their interpretations of the nature of the terranes.

MAIN DIVISIONS OF MAP LEGEND

The legend of the 1:5,000,000 terrane map of Northeast Asia includes three divisions: (1) terranes, (2) overlap and "stitch" assemblages, and (3) other symbols.

Tectonic Environments for Terranes

Terranes of Phanerozoic and Late Precambrian orogenic belts are defined and interpreted as forming in the following tectonic environments (Nokleberg and others, 1994). Terranes are colored according to tectonic environment and not according to age.

Cratonal terrane is defined as a fragment of a craton, composed of Early Precambrian crystalline rocks, sometimes with a thin Late Precambrian and (or) Phanerozoic cover (e.g., Gardan terrane in Eastern Sayan region or Muya terrane in Transbaikal region (Parfenov and others, 1996)).

Miogeoclinal terrane is defined as a fragment of a miogeocline (passive continental margin), composed of thick shallow-water (shelf) sedimentary series deposited on a thinned continental crust (e.g., Omulevka and Chukotka terranes in Russian Northeast (Parfenov and others, 1993)).

Continental margin terrane is defined as a fragment of a continental slope and adjacent rise and is composed of distal turbidites and hemipelagic deposits formed deposited on a thinned continental or oceanic crust (e.g., Kular-Nera, Rassokha and West Kamchatka terranes in Russian Northeast (Parfenov and others, 1993)).

Continental margin arc terrane is defined as a fragment of an Andean-type continental margin arc and includes calc-alkaline volcanic and (or) plutonic rocks unconformably overlying or intruding units below the arc. This type of terrane may also include forearc basins represented by thick (measured in kilometers), deep-water, shallow-water, and continental deposits formed near of the front of a magmatic arc (e.g., Sergeevka and Kabarga terranes in Sikhote-Alin region (Nokleberg and others, 1994)).

Island arc terrane is defined as a fragment of a volcanic island arc and adjacent forearc basin, and is composed of island-arc volcanic-sedimentary and intrusive rocks. Various types of ophiolites, representing subjacent oceanic crust, may also occur (e.g., Alazeya and Khetachan terranes in the Russian Northeast, and the Iruneiskiy and Olyutorka-Kamchatka terranes in Kamchatka (Parfenov and others, 1993; Nokleberg and others, 1994), the Eravnya and Djida terranes in Transbaikal (Parfenov and others, 1996)).

Oceanic terrane is defined as a fragment of oceanic crust obducted onto continental crust and is composed of MORB-type ophiolites. This type of terrane may also include fragments of submarine volcanic islands, guyots, etc. (e.g., Munilkan and Econay terranes in the Russian Northeast (Parfenov and others, 1993)).

Accretionary wedge terrane (type A**)** is defined as a fragment of the accretionary wedge of a continental margin or island magmatic arc made mainly of turbidites with minor amounts of oceanic rocks or without them (e.g., Prince Williams terrane in southern Alaska (Nokleberg and others, 1994)).

***Accretionary wedge terrane (type* B)** is defined as a fragment of the accretionary wedge of a continental margin or island magmatic arc made chiefly of oceanic rocks with subordinate turbidites (e.g., South Anyui terrane in the Russian Northeast, and the Samarka terrane in the Sikhote-Alin region (Nokleberg and others, 1994)).

Flysch *or* ***turbidite basin terrane*** is defined as a fragment of thick flysch (turbidite) series of unclear origin. This type of terrane may form on a continental slope and its rise, or in forearc or backarc basins related to continental-margin or volcanic island arcs, or in narrow troughs in the front of advancing tectonic nappes (e.g., Beryozovka terrane in the Russian Northeast (Nokleberg and others, 1994), and the Barguzin terrane in Transbaikal (Parfenov and others, 1996)).

Rift terrane is herein defined as a fragment of a rift zone composed of sedimentary and magmatic rocks associated with regional normal faults and (or) basin and range structures in intracontinental rifting conditions. Such terranes were not recognized for the Circum-North Pacific; however, a careful investigation of Northeast Asia may reveal their presence.

Crystalline Cratonal Basement terranes of Early Precambrian age are classified on the basis of their generalized present-day rock composition. These terranes include granite-greenstone, charnockite-granite gneiss, quartzite-paragneiss, enderbite gneiss and other terranes.

Tectonic Environments for Overlap and Stitch Assemblages

Overlap and "stitch" assemblages are defined and interpreted as forming in the following tectonic environments (Nokleberg and others, 1994).

Continental margin and island arc assemblages (undifferentiated). These assemblages consist of which volcanic-plutonic belts, formations of backarc and forearc basins. Tectonically-linked (paired) and accretionary wedge or subduction zone assemblages are excluded. Examples of continental margin assemblages are; (1) the Cretaceous Okhotsk-Chukotka and East Sikhote-Alin volcanic-plutonic belts in which granitoids and volcanics are shown; (2) the adjacent Penzhina and West Sakhalin forearc basins; (3) the modern Kuril-Kamchatka volcanic arc with the associated South Okhotsk backarc basin and adjacent forearc basins on the Pacific side of the arc; and (4) the Kuril-Kamchatka arc composed of the Kuril Islands arc and the onstrike East Kamchatka volcanic belt that unconformably overlying previously accreted terranes.

Miogeoclinal (passive continental margin) assemblages.

Intracontinental assemblages. These assemblages include rifts, aulacogens, platform covers of different age, and magmatic formations (massifs, pipes, alkali ultramafic dike complexes, carbonatites, gabbros, alkali granites, kimberlites, plato-basalts, etc.).

Assemblages related to orogenic belts. These assemblages include foreland molasse, hinterland and intermountain basin deposits, collisional granite belts and dikes, and various metamorphic belts.

Assemblages related to large-scale transform motions of crustal blocks. These assemblages include fields and belts of bimodal volcanic rocks, alkali to subalkalic granites, mafic to ultramafic rocks, pull-apart sedimentary basins, etc).

Colors, symbols, and faults. Ages of overlap and "stitch" assemblages are colored by age whereas their geodynamic nature (tectonic environment) is indicated by patterns. Ancient and modern overlap assemblages (including modern-day island arcs, passive continental margins, etc.) are also defined as overlap assemblages. Overlap and stitch assemblages are marked by low-intensity yellow and light-brown colors that differ sharply from the intense red, green, violet, and blue colors of tectonic environments for terranes. This practice permits recognition of terranes and determination of the timing of accretion and amalgamation of terranes. Other symbols include stratoisohypses along the sole of platform covers, boundaries of major sedimentary basins, astroblemes, and faults. Faults are differentiated into terrane-bounding faults and postaccretion faults causing dispersion of terranes. Faults types are subdivided into thrusts, strike-slips, and normal faults.

CONCLUSIONS

The terrane map of Northeast Asia at a scale of 1:5,000,000 will display present-day locations of terranes, overlap and "stitch" assemblages within Cenozoic, Mesozoic, Paleozoic and Late Precambrian orogenic belts located along the margins of the North Asian and Sino-Korean cratons, and the Arctic and Pacific oceans. Both the terranes and their overlap and "stitch" assemblages are classified on the basis of the plate tectonic models. An effort has been made to recognize terranes in the Early Precambrian basement of cratons. These terranes are classified on generalized compositional data of crystalline rocks. By showing terranes and the overlap and "stitch" assemblages, the map will demonstrate major structures of orogenic belts and time of their formation, age of accretion, as well as postaccretion and postamalgamation modifications.

The map is a major prerequisite for performing a regional metallogenic analysis, for determining relationships of metallogenic belts and zones with geodynamic complexes of various type and geodynamic processes that have formed orogenic belts and contained mineral deposits. The map will also yield valuable initial information for palinspastic (tectonic) reconstructions that will also utilize paleomagnetic and paleobiogeographic data.

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FIGURE CAPTIONS

Figure 1. Areas covered by the previous project on metallogenesis and tectonics of the Circum-North Pacific and the new project on metallogenesis and tectonics of Northeast Asia.

Figure 2. Key concepts of terrane analysis.