RUSSIAN ACADEMY OF SCIENCES
FAR EASTERN BRANCH

FAR EAST GEOLOGICAL INSTITUTE
PRIMORYE EXPLORATION AND MAPPING EXPEDITION

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GEOLOGY AND MINERAL DEPOSITS OF PRIMORSKY KRAI (TERRITORY)

Translated from Russian by *L.I.Kovbas*

Vladivostok
"Dalnauka"
1996

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Geology and Mineral Deposits of Primorsky Krai (Territory).

The book is an English translation of a sketch " Geologiya I Poleznye Iskopaemye Primorskogo Kraya", published by Dalnauka in 1995.

Geology and mineral deposits of Primorsky Krai (Territory) are discussed using the terrane concept as a method of regional tectonic analysis. Description of terranes, classified magmatic complexes, and metallogenic belts is given. Every economic coal and lode deposit discovered in Primorsky Krai is briefly described.

Color map of terranes, maps of the distribution of coal and lode deposits and metallogenic belts are enclosed.

The book could be of interest for regional, mapping, and economic geologists.

Reviewed by Dr. L.N.Khetchikov

Published by the decision of the Learned Council of the Far East Geological Institute

ISBN 5-7442-0864-X Dalnauka, 1996

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PREFACE

Primorsky Krai (Primorye) is characterized by abundant geological data. Substantial geological and mineral surveys have been completed because the mining industry is very important for the economy of the region. Large fluorite, boron, lead, zinc, tungsten, and other mines are in operation. Many known deposits have not been developed yet and there are promises for discoveries of new deposits, including new types for Primorye.

This book presents a synthesis on geology and mineral resources of Primorsky Krai. It is a geologically unique area, where we observe a juncture of young geologic units of the north-south-trending Pacific belt with older eastwest-trending units which extend from inland Asia to the Pacific coast. In a relatively small area, you can encounter sedimentary rocks of every geologic age along with various igneous rocks. Varied geology resulted in a unique variety of mineral deposits. This is the first attempt to describe every known economic ore deposit, some non-metal deposits, and coal deposits.

Metallogenic studies show that discoveries of new deposits are possible, including large gold deposits. The Sergeevka metallogenic belt is very promising in this respect.

This study is a joint effort of field geologists of the Primorsky Mapping-and-Exploration Expedition and scientists of the Far East Geological Institute of the Russian Academy of Sciences. The authors appreciate the assistance of Dr. V.K.Popov and Dr. S.A.Korenbaum in describing volcanic rocks and granites. Special thanks go to Dr. Steven Nelson, U.S.Geological Survey, Alaskan Branch, who carefully reviewed the English version of the manuscript.

The study discussed in the book was partly financed by the International Science Foundation Grants no RJ 1000 and no RJ 1300).

INTRODUCTION

This study uses the terrane concept as a method of regional tectonic analysis, which interprets large geologic areas as a collage of tectono-stratigraphic terranes, each of which has its own history. Some of them are relatively autochthonous, others traveled together with the oceanic lithosphere for thousands kilometers and accreted to the continental margin due to subduction. Within Primorsky Krai, we define several terranes, volcaniclastic overlap assemblages and "welding" intrusive complexes. The origin of some terranes is interpreted, others need further studies. Geodynamic classification of terranes, overlap, and intrusive complexes is based on a standard plate tectonic approach, that distinguishes rock assemblages of divergent and convergent plate margins and within-plate geodynamic setting. Regional geologic data suggest a recognition of rock assemblages of within-plate geodynamic setting with "mixed" magmatic series related to the intrusion of deep mantle plumes into collision and suprasubduction zones of the continental crust. The heating of the lithosphere prior to the intrusion of plumes presumably caused active mixing of the lower mantle magma with upper mantle and the crustal material during collision or subduction. This resulted in the origin of bimodal volcanic and plutonic syenitic rocks. A deep source for the primary magma is identified from low silica and high titanium, zirconium, niobium, phosphorus, and other elements typical of within-plate ultramafic-to-mafic rocks. Volcanic and plutonic rocks related to mantle plumes at the convergent plate boundaries are generally post-collision or post-subduction.

The following definitions are used in this work.

Accretion. Tectonic juxtaposition of a terrane(s) to a continental margin.

Accretion system. Two or more terranes juxtaposed during a single geologic time unit.

Within-plate geodynamic setting. A setting resulted from deep processes beneath the lithosphere plates.

Collision. A collision of terranes or a terrane and a continent during accretion accompanied by melting and anatectic granites and metamorphism.

Overlap and "welding" assemblages. Assemblages of sedimentary and/or intrusive rocks that overlap or intrude into two or more adjacent terranes.

Subduction volcano-plutonic assemblages. Igneous rocks that formed over subduction zones.

Subterrane. A fault-bounded fragment of a terrane that exhibit similar but not identical geologic history relative to another fault-bounded units in the same terrane

Tectono-stratigraphic terrane. A fault-bounded geologic unit of regional extent characterized by a geologic history different from that of neighboring terranes. Constitutes a fragment of an accretionary wedge, continental margin, island arc, etc.

Accretionary wedge (prism). A complex of rocks of different ages and geneses that formed during subduction. Characterized by the presence of turbidite deposits and fragments of the oceanic crust.

Metallogenic belt. A geologic unit (area) that either contains or is favorable for a group of coeval and genetically related significant lode and placer deposits.

Pre-accretion metallogenic belt. A geologic unit that contains deposits genetically related to pre-accretion or pre-accretionary wedge sedimentation, volcanism, or intrusive magmatism. Pre-accretionary metallogenic belts of ferrous and base metals deposits hosted in sedimentary, volcanic, and plutonic rocks constitute either the whole or a part of a belt and never extend beyond its boundaries.

Syn-accretion metallogenic belt. A geologic unit that contains metamorphic-related veined and veinlet deposits of gold, silver, arsenic, antimony, and other elements, resulting from the migration of ore constituents due to low-temperature greenschist metamorphism during the formation of accretionary wedges. Also metallogenic belts that contain deposits related to the intrusions of collision granitoids. Accretionary metallogenic belts commonly correspond completely to accretionary wedges and/or their fragments.

Post-accretion metallogenic belt. A geologic unit that contains magmatic (and telethermal) ore deposits which formed after accretion predominantly due to subduction and within-plate magmatism. Deposits are hosted in both rocks that constitute the terrane and overlap volcanic and sedimentary units. The boundaries of the belts are controlled by post-accretion igneous rocks and deep faults. Post-accretion subduction metallogenic belts generally do not exceed the terrane boundaries. Greisens, skarns, and low-to-medium temperature metasomatic veins of noble, base, and other metals predominate.

GEOLOGY (TERRANES)

The Laoelin-Grodekov composite terrane and Khanka and Sikhote-Alin superterranes are recognized within Primorye Krai. The location of terranes is shown on colored tectonic map of Primorye, and their composition is shown in stratigraphic columns.

THE LAOELIN-GRODEKOV COMPOSITE TERRANE

A fragment of the terrane outcrops in the southwestern Primorye, along the border with China from Khanka Lake to Hasan Lake. The relations between the constituting terranes need further studies.

One of these constituent terranes is formed by the Early Silurian sedimentary and volcaniclastic Kordonkinsky Formation (graptolite and brachiopod fossils). The formation of a visible thickness of over 200 m consists of clastic siltstone, shale, less common sandstone and conglomerate, mafic and intermediate lava and tuffs, siliceous tuffites, and cherts. Volcanic rocks are interpreted as within-plate mixed series.

The Kordonkinsky Formation forms three generally north-south- (locally northwest) trending lenticular blocks. The largest block, about 30 km long and up to 8 km wide, occurs to the south of the settlement of Pogranichnoe. It is bounded by faults, which are presumably thrusts transformed into left-lateral strike-slip faults. The formation is deformed into a system of closely spaced folds, the fold system level steeply plunges to the west.

Younger rocks of the composite terrane include Lower and Upper Permian terrigenous and island-arc intermediate and felsic volcanic rocks and tuffs and scarce limestone blocks. Large tonalite-plagiogranite intrusions that contain small granitized gabbroic units are also of island arc origin. The Urals-Alaskan type zoned dunite-clinopyroxenite intrusions with high-chromium spinel, typical of oceanic island arcs, were observed.

A rock unit between the Tumannaya River and Zarubino Peninsula consists of metamorphosed Permian basalts, limestone, clastic rocks, serpentinite, gabbro, gabbrodiorite, and numerous of diorite, granodiorite, and granite intrusives including leucocratic two-mica varieties. The composition of rocks suggests a fragment of the Permian accretionary wedge and island arc (or continental margin), intruded by Triassic (?) collision-related granites.

THE KHANKA ACCRETIONARY SYSTEM

The Khanka accretionary system consists of four terranes of different geodynamic origin: the Matveevka-Nakhimovka, Spassk, Voznesenka, and Sergeevka terranes. Late Silurian amalgamation of these terranes accompanied by the intrusion of the Shmakovka and Grodekov collisional granites.

The Matveevka-Nakhimovka terrane

The Matveevka-Nakhimovka terrane consists of Precambrian and Early Paleozoic mostly metamorphic rocks; three subterranes are distinguished: Matveevka, Nakhimovka, and Kabarga. The Alchansky Fault, a major branch of the Tan-Lu marginal continental left-lateral strike-slip system, is the northwestern boundary of the terrane. The northeastern and southeastern boundaries are covered by the overlap assemblage. In the south, the terrane is bounded by the eastwest-, locally northwest-trending Spassky Faults, along which rocks of the terrane thrusted over the Spassk terrane.

The Matveevka subterrane consists of Precambrian crystalline rocks. Diopside-calcite, less common forsterite-calcite and calcite-dolomite graphite-bearing marbles interlayered with gneisses (the Ruzhinsky Formation, over 1000 m thick) occur at the base of the visible section. They are overlain by biotite-sillimanite and garnet-biotite-cordierite gneisses, and hypersthene-magnetite and fayalite quartzite interlayered with marble (the Matveevsky Formation, about 3000 m) thick. Garnet-cordierite and orthoclase-biotite-sillimanite metamorphic phases of moderate pressures are distinguished. The upper part of the section consists of biotite-amphibole schist and gneisses, amphibolite, and marble (the Turgenevsky Formation, about 4300 m thick).

The Nakhimovka subterrane also consists of Precambrian crystalline rocks. Biotite and biotite-amphibole gneisses with lenses of marble and amphibolite occur at the lower part of the section (the Nakhimovsky Formation, over 1000 m thick, analog of the Turgenevsky Formation). They are overlain by biotite, diopside, and muscovite-graphitic schists (the Tatyanovsky Formation, about 2500 m).

Rb-Sr dates of Nakhimovka rocks yield 1517 Ma age.

Metamorphic rocks form two domes separated by the eastwest-trending Kabarga subterrane. Highly metamorphosed rocks outcrop in the core of these domes, and schist outcrop in limbs. The domes are deformed into brachyanticlines and synclines 5 to 20 km wide, elongated to the northeast and eastwest.

The Kabarga subterrane is a eastwest-trending band 10 to 25 km wide, where Late Proterozoic and Early Paleozoic rocks outcrop. Micaceous schist interlayered with quartzite (the Spassky Formation) occur at the base; they are overlain by less metamorphosed graphite-muscovite schists interlayered with amphibolite and limestone (the Mitrophanovsky Formation), with a sequence of phyllite and sandstone resting upon them (the Kabarga Formation and jaspilite sequence). The total thickness of these deposits is 2700 to 3000 m. Carbonate rocks of the Smolninsky and Rudonosny Formations that rest upon the Kabarga Formation make up the upper part of the Kabarga subterrane. The Smolninsky Formation consists of dolomite and limestone interbedded with siliceous and clay rocks. The overlying Rudonosny Formation is subdivided into three layers. The lower layer (80 m thick) of shale and graphitic schist; the intermediate ore-bearing layer (10-100 m thick) consists of jaspilite, ferromanganese, manganese, phosphorite siliceous ore and gangue quartzite; and the upper layer (10-300 m thick) consists of shale interbedded with dolomite and limestone. The sequence of carbonate rocks, 700 m thick, is limestone and dolomite, intercalated with shale. The age of the Rudonosny Formation is assumed to be Early Cambrian, by analogy with similar deposits of the Maly Khingan Ridge, dated by fossils. The Smolninsky Formation is presumably of the same age, they are spatially associated - the Rudonosny Formation lies conformably over the Smolninsky Formation. All these formations are deformed into a system of closely spaced folds of eastwest, less common northwest and northeast trends.

The Silurian Tamginsky Formation (4600 m thick) fills a north-south trough in the east of the Matveevka subterrane and consists of clastic rocks and phyllites interlayered with limestone; it is tentatively including into the Matveevka-Nakhimovka terrane.

The Matveevka-Nakhimovka terrane contains Proterozoic intrusions, which consist of: 1) older ultrametamorphic anatectic and metasomatic granitoids (granitic gneisses, alaskite, pegmatite, and porphyroblastic granites), gabbro, and gabbronorite, known only in the Proterozoic sequences of the Matveevka subterrane; and 2) younger muscovite, two-mica tourmaline granites and pegmatites, which intrude Late Proterozoic deposits. Rb-Sr dates of the second group yield 984 Ma. age.

The Spassk terrane

The Spassk terrane consists of three lithologic groups: 1) a sandy-schist sequence; 2) the Prokhorovsky Formation; and 3) the Dmitrievsky, Merkushevsky, and Medvezhinsky Formations. The third group includes Cambrian ophiolites. The contacts between them are faults. The sandy-shale assemblage carrying Tommotian archaeocyathean is commonly placed at the base of the stratigraphic section. However, the fossils were found only in limestone blocks, which are inserted in massive clay matrix and associated with ribbon cherts, which is common in olistostromes; olsitostrome-bearing clastic deposits have typical of turbidites graded bedding. The Prokhorovsky Formation consists of limestone and in the middle part of the section of schists and shales. The age was determined by archeocyathea as Atdabanian. The Dmitrievsky Formation consists of limestone in its lower part and limestone interbedded with shale in the upper part. The age of limestone is Botomian (archaeocyathean). The Dmitrievsky Formation is overlain by conglomerates of the Merkushevsky Formation. Pebbles contain up to 90% of Dmitrievsky limestone; limestone-siliceous rocks, sandstone, and siltstone are subordinate. Fragments of hematite-schist, ultramafic, and mafic rocks are very scarce. No fossils were found in the Merkushevsky Formation, and it was dated as Early to Middle Cretaceous by analogy with the clastic Medvezhinsky Formation (trilobites).

Ophiolitic rocks are hosted in carbonate deposits of the Dmitrievsky Formation. Ophiolitic rocks are represented by a sequence of mafic volcanic and volcaniclastic rocks interlayered with clay limestone and by serpentinite melange with blocks of apoharzburgite serpentinite and talc-magnesite rocks, gabbro, and gabbro diabase.

In the south of the Spassk terrane, Silurian (?) coarse clastic rocks fill an almost isometric basin (the Rettikhovsky and Daubikhezsky Formations).

Early to Middle Cambrian rocks form blocks and panels elongated to the northwest and limited by faults, generally thrusts. Within the blocks, small folds, generally recumbent to the southwest, alternate with the flat-lying areas ($30\text{-}40^{o}$).

In the basin, filled with Silurian deposits, simple folds, dipping $30\text{-}50^{o}$ at the limbs are observed.

Melange, turbidites, ophiolites, and serpentinites in the Spassk terrane and its imbricate structure suggest that it is a fragment of a pre-Devonian accretionary wedge.

The Voznesenka terrane

The Voznesenka terrane outcrops in the southwest of the Khanka superterrane. It is mostly covered by an overlap assemblage. Its western boundary is inferred along a tectonic line, presumably a thrust, separating the amalgamated Grodekov granites from the westward-lying Laoelin-Grodekov composite terrane.

Terrigenous carbonate rocks predominate. Two deposit types are distinguished from west to east. The first type is represented by the Nasyrovsky and Lusanovsky (Vendian or Lower Cambrian), Dalzavodsky, Pervomaisky, and

Berezyansky (Lower Cambrian) Formations. The Nasyrovsky Formation, more than 1000 m thick, consists of multicolored sandstones and quartz-sericite-hematite, sericite, and graphitic schists. The Dalzavodsky Formation, more than 650 m thick, is formed by sandstone and siltstone interlayered with limestone. In the upper part of the Dalzavodsky Formation, felsic ash layers are described. The Pervomaisky Formation, 500-600 m thick, consists of limestone and dolomite. The upper-lying Berezyansky Formation, about 1000 m thick, is alternating siltstone and sandstone. In the second Lower Cambrian deposit type, limestone interbedded with schists predominate. They form the Novoyaroslavsky (up to 900 m thick) and Volkushinsky (450-850 m thick) Formations, which grade upwards into clastic rocks of the Kovalenkovsky Formation, up to 700 m thick. Intrusive rocks are gabbro dated as Early Cambrian and Yaroslavka biotite granite, Rb-Sr age of which yielded 470-450 Ma.

The Voznesenka lithium-fluorine granites with Rb-Sr age of 384 Ma are within-plate "mixed" assemblages.

Stratified complexes of the terrane form a system of closely spaced, often recumbent folds of northwest trend. Presumably syn-folding thrusts and nappes are common. Left-lateral strike-slip faults of north-west trend are generally younger than thrusts.

The Voznesenka terrane is presumably a fragment of the forearc active continental margin.

The Sergeevka terrane

The Sergeevka terrane that forms the southeastern part of the Khanka superterrane includes pre-Devonian rocks of the southern Primorye and similar rocks of its northern part, occurring as nappes and wedges over the Jurassic accretionary wedge. In the Partizanskaya and Kievka Rivers divide, the allochthonous character of the terrane is emphasized by two antiforms of the northeastern strike, the cores of which contain rocks of Jurassic accretionary wedge. The Central Sikhote-Alin fault is the eastern boundary of the terrrane. Blocks of gabbro and metamorphic rocks that occur to the east of the Central fault in the Bikin River basin are presumably the northward projection of the Sergeevka terrane. "Sergeevka" gabbro make up about 80% of the terrane area, which also includes Tafuin biotite-muscovite and Taudemi biotite anatectic granites.

The oldest rocks of the Sergeevka terrane are high- and middle-temperature metamorphic rocks.

High-temperature metamorphic rocks occur as clearly limited lenticular and block-like pinnacles in the Sergeevka gabbro from a few tenths to hundred m in size. They consist of two rock assemblages: 1) clinopyroxene marble, calciphyre, garnet-quartz schists, and amphibolite; and 2) amphibolite, garnet amphibolite, and quartzite. Xenoliths of gneissic biotite-amphibolite and garnet-biotite are less common. Middle temperature metamorphic rocks are muscovite schist.

Traces of shearing and recrystallization of greenschist metamorphic facies are common in the Sergeevka gabbro. Similar schistosity arrangement in blastomylonitic retrograde gabbro and in younger metamorphic rocks suggest that these gabbro were altered by later processes. In areas, where these processes were weak, gabbroic rocks have a fabric of gabbro-amphibolite and gneissic gabbro.

U-Pb dates of zircon from Sergeevka gabbro yielded 528+/-3 Ma for gneissic gabbro; 504+/-2.6 Ma for gneissic diorite, and 493+/-12 Ma for Taudemi granites (with relic cores of 1742+/-5 Ma). ^{40}Ar-^{39}Ar age of muscovite from Tafuin granites is 492+/-2 Ma.

THE SIKHOTE-ALIN SUPERTERRANE

It includes the Middle Jurassic-to-Berriasian Samarka accretionary wedge terrane, Neocomian Taukha accretionary wedge terrane, Early Cretaceous Zhuravlevka terrane of strike-slip turbidite basin, and Aptian-to-Albian Kema island-arc terrane.

The Samarka terrane

The Samarka terrane extends along the edge of the Khanka accretionary system; in the south it is concealed by rocks of the Sergeevka terrane. The large left-lateral Arsenyevsky and Central Sikhote-Alin strike-slip faults form its northwestern and southeastern boundaries.

Terrane matrix consists of alternating turbidite and melange (olistostrome) sequences, up to few thousand m thick; genetically different syn-sedimentation tectonic inclusions of different ages are of predominant oceanic origin. Turbidites and mudstone matrix of melange contain Middle Jurassic (Callovian)-to Early Cretaceous radiolarians.

Allochthons occur as blocks and panels, few cm (olistoliths) to few km long. The contacts of allochthons with matrix (where not affected by later movements) are welded, with clearly different lithologies, and signs of siltstone matrix pressed into fractures of the lower part of panels, and deposition over the panels. Large panels are generally underlied by olistostromes. Chert panels often occur among turbidites, some look like alternation. Allochthonous inclusions are: 1) fragments of complete ophiolitic assemblage with Upper Devonian (?)-to-Lower Permian cherts and Carboniferous-to-Permian limestones resting upon basalts. K-Ar age of hornblende in pegmatoid gabbro is 41-+/-9 Ma; 2) basalts and overlying Upper Permian cherts; 3) Middle-to (less common) Upper Triassic cherts, locally associated with basalts; 4) Lower Jurassic siliceous and clay deposits presumably a part of Triassic chert section; 5) Upper Permian and Triassic-to-Jurassic sandstone and Upper Jurassic picrites and basalts, which are the fragments of the Sergeevka terrane nappe; 6) metamorphic rocks of greenschist and epidote-amphibolite facies over ophiolitic assemblage; 7) green and glaucophane schists that formed over metapelite and high-titanium metabasites, occurring in the upper part of the tectonostratigraphic section of the Samarka terrane, at the base of the Sergeevka terrane nappe. K-Ar dates of mica in metapelite yield 290+/-7 and 255+/-9 Ma.

The distribution of these blocks and panels follows a certain pattern - blocks of certain age and composition occur at a certain level. On the whole, the terrane is a packet of thrust sheets, 800 m to few km thick, each thrust sheet differs in the composition of matrix or the presence of exotic blocks. For example, in the lower part of the section, olistostrome layers are rare. Lower Mesozoic chert beds conformably overlain by fine clastic, normally-bedded turbidites occur repeatedly in the section. In the middle part, olistostrome members with blocks of Upper Paleozoic limestone, basalt, and cherts, Triassic cherts, and with panels of Middle Paleozoic ophiolites are common. In the upper part, there are packets of bedded flysch and virtually no olistostrome.

This sequence, not less than 15 thousand m thick, filled presumably subduction-related wrench-faulted basin. During Early Cretaceous, apparently Hauterivian, the unit was deformed into a system of northeast-trending folds. Axes of folds occur at an acute angle to the western boundary of the terrane, which is common in folding formed during left-lateral movement along the faults in the basement. From the southern end of the visible part of the terrane to the latitude, at which the settlement of Kavalerovo occurs, the fold system level plunges to the northwest.

The Taukha terrane

Three rock complexes are distinguished: 1) Silinsky, 2) Gorbushinsky, and 3) Ustinovsky. The outcrops of the lower Silinsky complex are traced along the western margin of the terrane. The Gorbushinsky complex tectonically overlap the Silinsky complex, and rocks of the Gorbushinsky complex rest upon it.

The Silinsky complex is formed by a coupled section of Upper Jurassic basalts and siliceous rocks, overlain with a gradual transition by Berriasian-to-Valanginian turbidites. The Gorbushinsky complex contains 3-5 panels, forming a continuous section of Triassic cherts, Jurassic siliceous and clay rocks, and Berriasian-to-Valanginian turbidites, angular pebbles, and sedimentary breccia. The Ustinovsky complex occurs over olistostromes that overlap the Gorbushinsky complex and is identified by olistoliths consisting of conglomerate in the lower part and Berriasian-to-Valanginian turbidite in the upper part, which represent canyon facies at the slope of a deep trench. Olistostromes that separate the three complexes contain limestone blocks - fragments of Late Devonian-to-Triassic guyots, Permian basalts and cherts, late Middle and Late Triassic shelf sandstone, and Late Jurassic cherts. Turbidites of matrix carry Valanginian-to-early Barremian radiolarians.

These three overlying complexes form a tectonostratigraphic unit about 13 thousand m thick. During the Late Albian, this unit was deformed into a system of northeast-trending folds, which are obliquely cut by terrane-bounding faults. The fold system level plunges very gently to the southeast.

The Zhuravlevka terrane

It consists of Early Cretaceous clastic rocks, greater than 10,000 m thick. The Central Sikhote-Alin Fault forms the western boundary. Berriasian-to-Valanginian rocks overlying Upper Jurassic oceanic basalts and cherts in the Taukha terrane (along the boundary with the Zhuravlevka terrane) and occurrences of Late Jurassic siliceous rocks and basalts within Berriasian-to-Valanginian deposits in the Zhuravlevka terrane suggest that Berriasian-to-Valanginian deposits of the Zhuravlevka terrane overlap Late Jurassic oceanic crust rocks.

The terrane section is clearly divided into two sections, one Berriasian-to-Valanginian and the other Hauterivian-to-Albian. The Berriasian-to-Valanginian section consists of predominant mudstone with beds of melange. Exotic limestone blocks, are very scarce. Valanginian high-titanium picrites and basalts are of within-plate type. The Hauterivian-to-Albian section consists of sandstone with numerous beds of flysch.

Early Cretaceous deposits of the terrane formed at the continental slope and fan under the conditions of sinistral movement of the oceanic crust.

During the Late Albian, these deposits were deformed into closely spaced northeast-trending folds. The folding was accompanied by sinistral movements along bounding and newly-formed faults within the terrane. The fold system generally plunges to the southeast.

The Kema terrane

The Kema terrane consists of Aptian-to-Albian island arc rocks overlain unconformably by Upper Albian volcaniclastic deposits of the Sikhote-Alin volcanic belt. The Kema terrane is thrusted over the Zhuravlevka terrane.

A chain of predominantly volcanic rocks, which is surrounded on the west by volcaniclastic deposits, is distinguished. Volcanic rocks are lava, hyaloclastic rocks, and marine tuffs of basalt, basaltic andesite, and andesite compositions; they form flows few m to few tens m thick. In terrigenous volcanic deposits, flysch of fine-grained sandstone, siltstone, and distal turbidite-type argillite alternates with beds of volcaniclastic rocks. Thick beds of basaltic andesite are also observed. Sedimentary rocks carry Aptian-to-Albian bivalves. In the lower part of the section, flysch alternates with medium-grained sandstone and tuffaceous sandstone with typical graded bedding of turbidite flows and abundant siltstone fragments. Flysch sandstone is arkosic, and medium-grained sandstone is graywacke.

Common closely spaced, generally recumbent to the northwest folds are often complicated by syn-folding thrusts which plunge to the southeast.

Volcanic rocks of the Kema terrane are tholeiitic and calc-alkalic series typical of epicontinental island arcs. The Kema island arc part of the terrane presumably formed near the continental margin. The Zhuravlevka and Kema terranes are interpreted as a marginal sea - island arc system.

OVERLAP AND WELDING ASSEMBLAGES

These rock complexes formed in different geodynamic settings during different time, thus they occur in every terrane although they vary in composition. Paleozoic and Triassic-to-Jurassic overlap assemblages, occur in the western Primorye up to the West Sikhote-Alin suture, which is the boundary between the Khanka and Sikhote-Alin superterranes. Mesozoic and Cenozoic overlap assemblages occur in every accretionary system. Several types are distinguished

1) intracontinental basins

2) continental passive margins

3) subductional

4) collisional

5) within-plate "non-mixed" series

6) within-plate "mixed" series - post-collisional and post-subductional

1. Rock complexes of intracontinental basins are Lower Cretaceous. Lower-to-Upper Cretaceous. and Paleogene-to-Neogene in age

Lower Cretaceous continental clastic coal-bearing deposits of the Suchansky and Nikansky Formations (Hauterivian-to-Albian). 1200 to 1400 m thick. fill the Partizansky-Yakovlevka and Razdolnensky basins in the southern and western Khanka accretionary system.

The Lower-to-Upper Cretaceous and Upper Cretaceous clastic continental sequences. more than 2500 m thick. fill the same basins.

Terrigenous complexes of the basins are deformed into wide northeast-trending folds with rather gently-dipping limbs (30 to 40^{0}); some folds. predominantly anticlines. are closely spaced. steeply dipping. and have a more complex structure due to thrusts and strike-slip faults

Paleogene-to-Neogene deposits fill numerous small and large basins. presumably fault-related. These are continental predominantly coarse clastic deposits. coal-bearing in some basins. and virtually flat-lying. Coal seams are abundant in the Uglovsky (Paleogene). Pavlovsky (Oligocene-to-Miocene) and Ust'-Davydovsky (early Miocene) Formations.

2. Rock complexes of continental passive margins consist of Permian continental and shallow-marine sandstone. siltstone. conglomerate and coaly argillite interbedded with limestone. Triassic continental clastic rocks are shallow-marine sequences with limestone and are coal-bearing.

Jurassic clastic rocks with admixture of tuff material and rare limestone lenses are known only in the southern part of the Khanka accretionary system

All these complexes are rather poorly dislocated and deformed into open generally brachyaxial folds with gently-dipping limbs (up to 45^{0}). near large left-lateral strike slip faults of north-north-east trend. closely spaced northeast-trending folds are observed. Permian and younger (to Early Cretaceous) sequences are dislocated in a similar way.

3. Subduction-related complexes. Cenomanian-to Maastrichtian subduction-related volcaniclastic and volcanic rocks form the East Sikhote-Alin marginal continental volcanic belt, which overlaps Paleozoic Sergeevka and other terranes of the Khanka system and Mesozoic Kema, Zhuravlevka, and Taukha terranes.

Tuffaceous conglomerate, tuffite, and tuff and lavas of basaltic andesite, andesite, and less common basaltic composition of the Cenomanian-to-Turonian Sinanchinsky Formation occur at the base of the section. Extrusions and dikes of pyroxene-hornblende andesites are spatially related to volcanic rocks. Intrusives rocks form small gabbro-diorite and diorite bodies. Volcanic rocks are typical calc-alkaline series. Compared with island-arc calc-alkaline series they have higher lanthanum, cerium, and niobium contents. Intrusive rocks are characterized by higher alkalinity of mafic and intermediate rocks and low titanium content.

The greatest part of the belt consists of areal section of tuff and rhyolite ignimbrite fields and comagmatic shallow diorite-granite intrusions, which are classified as Turonian-to-Campanian Primorsky volcano-plutonic complex. Petrochemically, the rocks are of calc-alkaline series. Extrusive rocks are of normal alumina and alkali contents, with high potassium. Intrusive rocks have porphyritic texture, locally grading from granite to granite porphyry at the apex of plutons. Petrochemistry of igneous rocks of the complex suggests its interpretation as a marginal continental-type subduction volcano-plutonic assemblage.

Maastrichtian-to-Danian igneous rocks, which lie at the top of the volcanic section are interpreted as the same type. They form the Samarginsky and Bogopolsky volcano-plutonic assemblages.

The Samarginsky assemblage consists of intermediate (the Samarginsky Formation) and moderately felsic (the Siyanovsky Formation) volcanic rocks: lava and pyroclastic fields of two-pyroxene andesite, dacite, and ignimbrite of rhyodacite. Locally, lava of basaltic andesite is observed in the section. In chemical composition, the rocks are of high-alumina calc-alkaline series, with higher alkalinity in some volcanic edifices. Intrusive rocks cut cover facies and often form the middle parts of volcanic edifices (eroded magma chambers) as stocks, which are classified as differentiated gabbro-granite series with increased basic and alkaline components.

Unlike areal plateau-ignimbrite of the Primorsky complex, felsic volcanic rocks of the Bogopolsky volcano-plutonic assemblage are more local, they fill grabens and volcanic calderas, which are confined to eastwest- and northwest-trending faults. Volcanic cover rocks are tuff, less common ignimbrite, rhyolite, and rhyodacite. In volcanic vents, volcanic glass (perlite) and ultrafelsic lava of fluidal rhyolite predominate. Volcanic rocks of the Bogopolsky Formation belong to high-alumina calc-alkaline series; they are characterized by ultrafelsic composition and increased K content. At late stages of volcanism, higher basic and alkaline extrusions (trachyandesite and trachydacite) formed, they have high contents of alkalies and REE: strontium, barium, zirconium, yttrium, niobium, lanthanum, and cerium. Intrusions consist of hypabyssal porphyritic leucogranite. Some researchers classify alkali rocks of the Sanchazsky gabbro-monzonite-syenite massif that intrude extrusive rocks of the Bogopolsky Formation to the Bogopolsky volcano-plutonic assemblage. Presumably, the Bogopolsky Formation belongs to the within-plate "mixed" series.

We interpret Middle-to-Late Jurassic felsic volcanic rocks within the Sergeevka terrane (the Monakinsky Formation) and Jurassic-to-Early Cretaceous extrusive rocks in the northern part of the Khanka accretionary system, where they form the eastern boundary with the Matveevka-Nakhimovka terrane, as the subductional type. According to Yu.Oleinik, it is the Verkhne Kabarginsky complex, which consists of a sequence of biotite and biotite-hornblende rhyolite and sequences of terrigenous and volcanic rocks. It is closely related to granitoids of the Troitsky complex, Rb-Sr age of 120 Ma. Granites are high-alumina, contain increased silica and alkalies, and enriched in volatiles.

4. Paleozoic and Mesozoic collision-related complexes are distinguished. Late Silurian (up to the beginning of the Devonian) Grodekov and Shmakovka granitoids "welded" terranes of the Khanka accretionary system. Early Cretaceous complexes "welded" the terranes of the Khanka and Sikhote-Alin superterranes. Collision assemblages are exclusively intrusive rocks, no extrusives are known.

Late Silurian granodiorite-granite batholiths (the Grodekov and Shmakovka complexes) intrude Cambrian and Lower Silurian deposits and are overlain by Devonian sequences. Large plutons seem "to consume" crystalline rocks of the Matveevka-Nakhimovka terrane that resulted in granitoids grading into gneissic granites with numerous xenoliths of wall rock at the endocontacts, and intrude poorly metamorphosed deposits of the Voznesenka and Spassk terranes, forming typical intrusive contacts with signs of thermal metamorphism in host rock.

Rock-forming minerals of granitoids are plagioclase, microcline, quartz, biotite, and less common muscovite. Hornblende is observed at the margins of intrusions and clinopyroxene in hybrid rocks. Accessory garnet, ilmenite, and zircon are common.

Ordovician lithium-fluorine granites of the Voznesenka and Tafuin complexes, which occur in the Voznesenka and Sergeevka terranes respectively, are interpreted as collision-related, formed directly after the formation of the Spassk accretionary wedge during the collision of the Matveevka-Nakhimovka terrane with the Voznesenka terranes.

Early Cretaceous granitoids form the Hungari and Tatibi assemblages. Hauterivian Hungari granitoids occur within the Samarka terrane, predominantly its Bikin part, few plutons are known within the Central Sikhote-Alin Fault. They have increased alumina content; granites carry cordierite. Medium-to-coarse-grained biotite and two-mica granites predominate.

Aptian-to-Albian Tatibi granitoids are common within the Samarka and Zhuravlevka terranes, in the vicinity of the Sikhote-Alin Fault. Individual intrusions are known within the Khanka accretionary system, along the western boundaries of the Matveevka-Nakhimovka and Spassk terranes.

Tatibi intrusions form mostly hypoabyssal batholiths, which consist of 1) amphibole-biotite granodiorite and adamellite; 2) amphibole-biotite and biotite granites; and 3) biotite leucocratic granites.

Tatibi granitoids form a continuous petrochemical series from quartz diorite to granodiorite to granite to leucogranite. They are potassic-sodium and potassic. Garnet is common, locally cordierite is observed. Proper cordierite-bearing granites are classified to the Sandinsky assemblage and are known in the northeast Primorye, within the Zhuravlevka terrane.

5. Within-plate assemblages of "non-mixed" series

Late Jurassic-to-Early Cretaceous plutonic and Neogene volcanic assemblages are distinguished.

Several Late Jurassic-to-Early Cretaceous plutons occur in the Samarka accretionary wedge (the Ariadnensky, Koksharovsky, etc.) and small intrusives in the Sergeevka terrane. They consist of alkalic mafic and ultramafic rocks up to Nb-Ta-bearing nepheline syenite. Ultramafic rocks of this assemblage have increased contents of alkalies, titanium, zirconium, niobium, and other compatible elements.

Within-plate volcanic assemblages are common in the south (the Shkotovo and Shufansky plateaus) and north (the Bikin and Nelminsky plateaus) of Primorye. The sections of volcanic rocks of the Shufansky and Shkotovo plateau consist of thick lava flows of tholeiitic basalts, similar in composition to trap rocks. Alkali basalts occur locally; they form small volcanic edifices protruding into plateau basalts and basement rocks.

Basalts of the Sovgavansky Formation form the Bikin and Nelminsky plateaus. Petrochemically, they belong to olivine alkali basalts of continental rifts - they are highly basic and alkaline, with high titanium and alkali-earth elements.

6. Within-plate assemblages of "mixed" series are subdivided into post-collisional and post-subductional.

A. Paleozoic and Mesozoic post-collisional assemblages occur within the Khanka accretionary system.

Paleozoic assemblage consists of Devonian, Carboniferous, and Late Permian volcano-plutonic rocks. Devonian and Carboniferous rocks occur locally within the Sinegorsky basin.

Devonian-to-Middle Carboniferous (plant and animal fossils) volcanic rocks are predominantly felsic, from rhyolite to dacite; few basalts contain up to 1.7% of titanium dioxide.

Devonian-to-Carboniferous plutons are mostly basic and felsic hypabyssal intrusions and dikes. Large Devonian plutons consist of differentiated olivine gabbro, hornblende diorite, and granite. Gabbroic rocks contain up to 6% of titanium dioxide, which is together with high titanium content in mafic minerals evidences for within-plate nature of Devonian-to-Carboniferous magmatism. Carboniferous intrusions consist of subalkaline leucocratic granites.

The upper Lower and Upper Permian volcanic rocks occur at the western margin of the Khanka system. They consist of basalt, andesite, dacite, rhyolite, and rhyolitic tuff, formed in shallow-water marine and continental environments. Basalts contain up to 2% of titanium dioxide.

Common, generally hypabyssal Late Permian intrusions are closely related to volcanic rocks. Like in extrusive rocks, mafic and felsic rocks predominate in intrusions, with rather few granodioritic rocks. Petrochemically, Late Permian granites are interpreted as granitoids related to the opening of back-arc basins.

Vast Mesozoic volcanic Alchansky fields in the Alchansky basin are moderately felsic, less common felsic

B. Post-subductional Cenozoic volcanic assemblages. The Paleogene bimodal assemblage occurs locally within the eastwest-trending vast volcanotectonic depressions and complex ring structures. In the southern and southwestern Primorye, Paleogene depressions are generally filled with coal-bearing deposits of the Uglovsky, Nadezhdinsky, and Pavlovsky Formations. In basins filled with volcanic and clastic rocks, sedimentary deposits alternate with mafic and felsic volcanic rocks.

Mafic bimodal assemblages of the Kuznetsovsky, Suvorovsky, and Zaisanovsky Formations are tuffs and lava of basalt and andesite with highly subordinate extrusive dacite and rhyolite. Rocks are classified as high-alumina calc-alkaline series. Basalts have increased content of titanium. potassium, strontium, and LREE.

Felsic bimodal extrusives of the Verkhnekedrovsky Member and Novopos'etsky Formation occur within ring structures with common alternation of mafic and felsic volcanic rocks, which evidences for their simultaneous deposition. Tuff and lava predominate among felsic extrusive rocks. Lava generally consists of fluidal and spherulitic rhyolite and volcanic glass. In chemical composition, felsic volcanic rocks are classified as potassium series; they show a succession of eruption from rhyolite and trachyrhyolite to ultrapotassic rhyolite and latite-type trachydacite.

Eocene-to-Oligocene andesite and basaltic andesite of the Salibezsky sequence, petrochemically similar to andesite of the initial stage, occur in the upper part of the section of Paleogene bimodal assemblage.

Oligocene-to-Miocene plateau basalts, basaltic andesite, and andesite of the garnet sequence and Kizinsky Formation have a similar origin and are classified as calc-alkaline rock series with normal content of alumina and alkalies, that occur in the northern Primorye.

MINERAL DEPOSITS OF PRIMORSKY KRAI

Pre-, syn-, and post-accretion metallogenic belts are classified. Their location is shown on the metallogenic maps. Major ore deposits are briefly described in Appendix 1.

PRE-ACCRETION METALLOGENIC BELTS

The Voznesenka metallogenic belt of massive sulfide deposits in carbonate rocks

The Voznesenka belt is hosted in the Voznesenka terrane (a fragment of an active continental margin arc) and Spassk terrane, which carry numerous large olistoliths of Cambrian carbonate rocks. Clastic calcareous shelf sequences emplace polymetallic (predominantly Zn) stratiform sedimentary-exhalative deposits in the Voznesenka terrane. The massive sulfide ore bodies occur conformably to hosting organic, bituminous limestone near the contact with overlying clastic clayey sequences. Abundant sedimentary-exhalative siliceous rocks in the ore-bearing sections have anomalously high F, B, and Zn values, 5 to 10 times exceeding crustal abundance . Banded magnetite ore associated with algae bioherms is a peculiarity of Voznesenka stratiform deposits. The deposits were interpreted as skarns and were not properly studied. The area has not been prospected for stratiform deposits.

The best prospected Voznesenka stratiform zinc deposit occurs within the Voznesenka fluorite open pit; at present, zinc ore is being stockpiled until its processing methods are determined.

The Kabarga metallogenic belt of sedimentary-exhalative ironstone (with manganese) deposits

The Kabarga metallogenic belt is hosted in the Riphean-to-Early Paleozoic syn-sedimentation depression, the Kabarga subterrane of the Matveevka-Nakhimovka terrane. Ironstone deposits occur in a sequence of Early Cambrian clastic carbonate rocks. They consist of beds of magnetite- and hematite-magnetite-bearing quartzite of sedimentary-exhalative origin interbedded with dolomite. Few thin beds consist of oxidized manganese ore. The deposits are not mined because of small ore reserves; ore is hard to concentrate, although it is quite possible to mine some deposits (Kazennoe) for local demands.

The Laoelin-Grodekov metallogenic belt of Late Paleozoic copper and gold deposits

The belt is located within the Laoelin-Grodekov composite terrane. The metallogeny is poorly studied. The age and genesis of the few discovered deposits is questionable. The principal epithermal gold-silver deposits are associated with intrusions of Permian rhyolite (Komissarovskoe). Accumulation of a thick Permian marine sequence of felsic and mafic volcanic rocks is favorable for undiscovered Kuroko massive sulfide deposits. The belt was not studied for this type deposits, although there are small lenses of sphalerite ore that occur conformable to hosting shales. Dunite-clinopyroxenite-gabbro intrusions in Permian rocks may be favorable for undiscovered Ural-Alaskan type platinum deposits.

SYN-ACCRETION METALLOGENIC BELTS

The Yaroslavka metallogenic belt of greisen deposits

The deposits occur in granitic plutons that intrude Cambrian clastic carbonate sequences of the Voznesenka terrane. Granitoids are interpreted as forming during the collision of the Voznesenka and Matveevka-Nakhimovka terranes during the Early Paleozoic, after the formation of the Spassk accretionary wedge.

The intrusions consist of predominant Silurian-to-Early Devonian biotite granite and Ordovician alaskite lithium-fluorine granites (Rb-Sr dates), formed by within-plate magmatic processes almost simultaneous to the Early Paleozoic collision.

The leucogranites host large and rich Voznesenka and Pogranichnoe fluorspar deposits. Ore bodies occur above the apex of intrusions and consist of zones of fluorite-micaceous aggregate replacing limestone. Fluorite also occur in topaz-fluorite greisens in the apex of the ore-bearing intrusion.

The large size of fluorite deposit, comparable with the size of the ore-bearing intrusion, suggests that the source for fluorine was Precambrian fluorite deposit located at the depth where magmatic melt was contaminated with crustal material.

Isotopic analyses of boron in tourmaline from leucogranite suggests that evaporites were the source for the boron (11B=+24.0%).

In addition to fluorite ore, the leucogranites of the Voznesenka and Pogranichnoe deposits host Ta-Nb ore. They occur in the zone of quartz-topaz greisens. Tabular ore bodies occur below the apex of the intrusion.

Tin veins are hosted in the intrusions of biotite granites. They occur as vein greisens with cassiterite spatially associated with the apex of the intrusion. Greisen veins carry abundant fluorite and tourmaline.

The Prigranichny metallogenic belt of gold and arsenic deposits

The belt is hosted in the Laoelin-Grodekov terrane, but because it is poorly studied its classification is tentative. The metallogenic belt contains small occurrences of gold-quartz veins with pyrite in dynamothermally metamorphosed Permian rocks. A metamorphic origin for the deposits is based on the lack of intrusive bodies. A similar genesis is proposed for the

Slavyanskoe As deposit, which consists of quartz-arsenopyrite veins in schist.

Regional metamorphism associated with Triassic (?) collision is thought to have concentrated gold that was deposited initially during Permian marine volcanism.

Additional studies could substantiate an economic value to these gold deposits. Again, they are sources for placers.

The Samarka metallogenic belt of tungsten skarn deposits

The belt occurs in the Samarka accretionary wedge terrane. Collision-related, mainly S-type granitic rocks of the Early Cretaceous age that intruded olistostromes of large Carboniferous-to-Permian limestone bodies and calcareous shale in sections of the Jurassic sedimentary rocks formed a favorable setting for skarn deposits.

Tungsten skarn deposits are related to Hauterivian (Lermontovskoe) and Albian-to-Cenomanian (Vostok-2) aluminous biotite granites.

Ore bodies occur at the contacts of limestone (in olistoliths) and alumosilicate clastic rocks. Successive skarn and greisen alteration of limestone preceded the deposition of sheelite and other ore minerals, including gold and apatite (a few tens of percent) that can be easily concentrated.

In addition to sheelite skarn deposits, collisional granitoids host small tin and tin-tungsten quartz-cassiterite deposits.

The Ariadny metallogenic belt of magmatic titanium deposits

The zone contains Ti deposits, genetically related to zoned intrusions of ultramafic and gabbroic alkaline complex. According to V.V.Golozoubov, these intrusives intruded and metamorphosed turbidites of the Samarka accretionary wedge prior to the emplacement of collisional granites; although no direct relation between these intrusions and Early Cretaceous collision was observed.

Ore-hosting alkali gabbro and pyroxenite have abundant dissemination of ore minerals with abundant ilmenite. Titanium magnetite ore with abundant apatite dissemination are rare. Ore is PGE-bearing. Based on petrochemical features and mineral composition, ore-bearing intrusions are interpreted as within-plate alkali mafic-ultramafic complexes, similar to those, hosting the Kondyor platinum deposit.

The deposits are poorly studied, although they could be economic and are located in the areas with developed infrastructure.

POST-ACCRETION METALLOGENIC BELTS

The Sergeevka metallogenic belt of granitoid-related Au deposit

The Sergeevka metallogenic belts is hosted in the Sergeevka terrane, an active continental margin of the Cambrian age (according to A.I.Khanchuk) that consists of amphibolite, quartzite, and calciphyre, intruded by gneissic gabbro and diorite. Early Paleozoic rocks are imbricated and obducted onto Late Jurassic-to-Early Cretaceous turbidites and olistostromes of the Samarka terrane.

Gold deposits occur in the western part of the terrane in presumably autochthonous Cambrian rocks. The deposits are hosted in granitic plutons that intrude predominantly Early Paleozoic metamorphic rocks.

These Late Cretaceous intrusions are interpreted as post-accretion, however they could be older and related to Jurassic-to-Early Cretaceous subduction. Gold-bearing quartz veins occur in and near intrusions. The deposits are small, although they could be of economic interest, because they are located in inhabited areas with developed infrastructure. The belt also contains numerous small minable gold placers.

The Luzhki metallogenic belt of tin deposits

The Luzhki metallogenic belt is hosted in the southern part of the Zhuravlevka terrane, which consists of a sequence of Berriasian-to-Valanginian turbidite with olistostrome and Hauterivian-to-Albian flysch. The sequence formed during the Berriasian-to-Hauterivian sedimentation in the fan of the passive continental margin and in Aptian-to-Albian back-arc basin. The formation of this margin was synchronous to strike-slip faulting. In the eastern part of the metallogenic belt, the turbidite sequence is presumed to be overlapped by rocks of the Taukha accretionary wedge.

The belt comprises major tin deposits that formed 100 to 60 million years ago. The oldest (90-100 Ma) typical Sn greisen deposits are associated with lithium-fluorine granitic rocks. These Sn greisen deposits contain wolframite together with cassiterite, as at the Tigrinoe deposit, and occur in the western part of the belt, adjacent to the Samarka tungsten-bearing belt, which presumably caused higher tungsten content.

Tin polymetallic vein deposits that formed 75 to 85 million years ago in the eastern part of the belt are interpreted to have formed in andesite, monzodiorite, and granodiorite intrusions. In addition to high lead, zinc, and copper contents, they contain tin as cassiterite and stannite.

Younger deposits are tin veins, composed of cassiterite and silicate minerals. They are often spatially related to older tin polymetallic deposits and formed simultaneously with lead-zinc deposits (70-60 Ma) of the Taukha metallogenic belt to the east. These deposits are related to the formation of subduction volcanic rocks, mostly dikes of ultrapotassic rhyolite, any relation to intrusions is obscure.

This relation to volcanic edifices is most clear in porphyry copper deposits, occurring in the north of the metallogenic belt. These deposits are spatially related to Maastrichtian-to-Danian volcanic vents (65 Ma) and formed immediately during volcanic activity. Explosive breccias carry disseminations and veins of cassiterite and sulfides (galena, sphalerite, and chalcopyrite). Large cassiterite-polymetallic veins occur generally near vents with ore dissemination.

Young (50-60 Ma) tin deposits are related to local greisen zones within older deposits and are not economic.

Most cassiterite-silicate greisen and vein deposits of the Luzhki belt are active mines. Mining of tin-polymetallic vein deposits is hampered by technological problems of ore processing. Porphyry tin deposits are underestimated, although they are promising economically.

In addition to tin deposits, there are several small porphyry copper deposits in the Luzhki belt. They are associated with Cenomanian-to-Turonian monzodiorite in the western part of the belt adjacent to the Samarka terrane. These are not-typical for the belt and presumably reflect the anomalous Cu-rich characteristics of the Samarka metallogenic belt.

The Taukha metallogenic belt of skarn and vein boron and lead-zinc deposits

The metallogenic belt is hosted in the Taukha accretionary wedge terrane, which consists of Neocomian turbidites and olistostromes with allochthonous Paleozoic and Mesozoic guyots (limestone "caps" with basalts in the basement), Carboniferous-to-Jurassic cherts, Berriasian-to-Valanginian turbidite, and Triassic and Berriasian-to-Valanginian shelf sandstone.

The deposits are mainly skarns and veins that are related to the formation of suprasubduction Late Cretaceous-to-Paleogene East Sikhote-Alin volcanic belt.

The largest in the region Dalnegorsk boron skarn deposit is interpreted as forming early in the history of the East Sikhote-Alin volcanic belt, from about

70 to 90 Ma, when part of the Taukha terrane was overlapped by ignimbrite sequences. Triassic limestone enclosed in Neocomian olistostrome were altered into skarns. Skarn zones do not show any visible relation to intrusions, although they are intruded by granites, K-Ar age of which is about 64 Ma. Isotopic studies of B from ore minerals indicate that granitoid intrusions occurring far from the skarn alteration zones were the source for boron. Wollastonite, hedenbergite, and garnet predominate in skarns. The first stage of limestone alteration resulted in grossular-wollastonite skarns, thin-banded datolite-hedenbergite-wollastonite kidney-like masses and coarse-crystalline danburite deposited in hydrothermal cavities. The second stage resulted in the alteration of remaining limestone relics into garnet-hedenbergite skarns, and datolite was completely replaced by newly-formed aggregate of garnet, hedenbergite, orthoclase, quartz, and calcite. Remobilized boron was deposited as datolite and axinite associated with quartz and calcite.

Datolite is the major economic mineral. The Dalnegorsk deposit is prospected to the depth of 1 km and is the only source for boron in Russia.

Detailed study of the Zayavochnoe deposit showed that zones of Pb-Zn (with Sn) disseminated and veined deposits with tourmaline and chlorite alteration of host rocks are economic for open pit mining. The origin of these zones is interpreted as related to large volcanic edifices of the Primorsky stage of the post-accretion volcanic belt (70 to 90 Ma). Boiling solutions in caldera lakes deposited ore on the floor and particularly 100 to 200 m below the floor of the lakes simultaneous to volcanism. Notable copper content in addition to zinc and lead in the Zayavochnoe deposit make these type deposits promising for mining in the nearest future.

Lead-zinc skarn deposits occur like borosilicate deposits in the middle part of the belt, within the Dalnegorsk ore district, where Neocomian olistostrome enclose numerous olistoliths of limestone. Lead-zinc (galena-sphalerite) ore bodies are associated with hedenbergite and garnet-hedenbergite skarns at the contacts of these olistoliths with hosting clastic rocks or overlying post-accretion volcanic rocks. Lead-zinc skarns formed after the early borosilicate skarns during a later stage of post-accretion volcanism (70 to 60 Ma) that was dominated by rhyolite and dacite. Granitic intrusions of intermediate volcanic center located not less than 300 m from the skarns were the source of ore-bearing solutions. Skarn deposits are the major source for lead and zinc in the Russian Far East.

Pb-Zn polymetallic deposits are coeval with the Pb-Zn skarn deposits, but occur only in the areas with no allochthonous limestone bodies. Unlike the skarn deposits, the polymetallic vein deposits contain much tin as stannite, and lesser cassiterite. Some deposits hosted in clastic rocks, are associated with granodiorite intrusions, K-AR age of which is 60 to 65 Ma. Some ore bodies, as at Lidovskoe deposit, occur in the apices of the intrusions, forming saddle-shaped deposits. The polymetallic vein deposit at Krasnogorskoe is associated with volcanic breccias that are spatially related to a volcanic vent. The breccias also contain disseminated galena, sphalerite, pyrite, and cassiterite. This relation suggests the interpretation of these deposits as porphyry tin-polymetallic deposits. The age of hosting volcanic rocks is 60 to 65 Ma.

Other type deposits that occur in the belt are of lesser importance. Sparse disseminated and porphyry Cu deposit, as at Plastun, occur in Maastrichtian-to-Danian volcanic rocks. A silver sulfosalt occurrence is hosted in Paleocene rhyolite.

The Kema metallogenic belt of epithermal gold-silver deposits

The metallogenic belt occurs in the island-arc Kema terrane, characterized by Aptian-to-Albian basaltic andesite volcanism. The epithermal Au-Ag deposits are mostly hosted in subduction-related volcanic rocks that overlie the terrane. Adularia-quartz veins are mostly spatially related to Maastrichtian-to-Danian extrusions, and less common in granodiorite intrusions. At Tayozhnoe deposit, which was best studied, silver-bearing veins also discovered among Early Cretaceous clastic rocks, overlapped by post-accretion volcanic rocks. According to P.I.Logvenchev, these volcanic rocks affected ore deposition as a screen.

Concentrations of Ag are much greater than Au, and Ag/Au ratios generally are greater than 200. Silver sulfosalt minerals (pyrargirite, stephanite) predominate; in the depth they are substituted by argentite.

A favorable geologic setting and numerous occurrences of Au-Ag epithermal ore suggest that the Kema metallogenic belt is very promising economically. Mining of the Tayozhnoe silver deposit shows profitable, even when the concentrate is shipped to the central Russia or abroad, because there is no smelters in the Far East Russia.

The Daubikhe metallogenic belt of polymetallic and tin deposits

The Daubikhe metallogenic belt is an eastern margin of the Khanka accretionary system. It consists exclusively of overlap assemblages, mostly

Permian-to-Triassic terrigenous and Permian volcanic rocks. All known tin, tungsten, and lead-zinc deposits are associated with subduction-related Jurassic-to-Early Cretaceous granite. These are predominantly garnet-pyroxenite, and garnet-pyroxene-wollastonite skarns, locally with vesuvianite. Virtually all skarns contain magnetite; tungsten occurs as sheelite. Deposits have different sizes: from 60 to 500 m long, and 0.5 to 70 m thick. Contents of ore minerals also vary: few hundredth to 1.5% WO_3, and few hundredth to 3.8% Sn.

Tin and tungsten skarns contain low contents of polymetallic ore. Small Kabarginskoe and Kurkhanskoe deposits consist of skarns at the contacts of Proterozoic marble with Paleozoic granites in collapsed roof of granites. The deposits are genetically related to Early Cretaceous granites. Skarn deposits are 40 to 700 m long, and 2 to 15 m thick. Skarns consist of garnet-pyroxene with vesuvianite. Lead content varies from 2.0 to 22.0%, and zinc from 2.0 to 29.0%. At the margin of the Kabarginskoe deposit, garnet-magnetite skarns carry few tenth to 1.2% tin, and fluorite veins occur.

In addition to skarns, the Daubikhe belt contains tin-tungsten ore as quartz veins and mineralized zones hosted in Early Cretaceous granite as at Troitskoe or in volcanic rocks as at Kirovskoe deposits.

COAL IN PRIMORSKY KRAI

The major economic coal-bearing formations are Mesozoic and Cenozoic. Cenozoic rocks hosting Paleogene coal deposits are common both in the south and north of Primorye. Again, coal occurs in intermontane valleys of the Arsenyev suture zone and few Sikhote-Alin basins. Mesozoic (Late Triassic and Early Cretaceous) coal deposits concentrate in the south and southwest Primorye.

Triassic hard coal makes up approximately 9% of the energy resources of Primorye, Cretaceous hard coal 23%, and Paleogene-to-Neogene lignite 68%. The rank of coal decreases from Triassic to Neogene. At present, Cretaceous and Paleogene-to-Neogene coal is of economic importance.

Paleogene-to-Neogene coal is hosted in Paleocene-to-Oligocene Uglovsky Formation, Oligocene-to-Miocene Pavlovsky Formation, and Early-to Middle Miocene Ust'-Davydovsky Formation. The formations contain 5 to 15 seams of high- to medium-ash lignite (rank 1B-3B, see the table). Coal is predominantly humic and clarain, with scarce sapropelic lenses and laminae at the base of lower seams. Paleocene-to-Neogene coal is mined by opencut and underground mining operations.

Mesozoic fields are predominantly related to Late Triassic (Carnian and Norian) and Early Cretaceous (Hauterivian-to-Albian and Turonian-to-Campanian) deposits.

The section of the Sadgorodsky Formation (Carnian stage) contains up to 20 hard coal seams and partings. All seams are highly variable and folded; they have been traced for 100 m maximum in strike and were not studied to depth.

Triassic coal has high-ash content, which varies from 11 to 50 % in some beds, most common 30-40%. An average ash content in a seam is 40-45%, seldom 30% (in a simple seam). The coal ranks are gas, paralic fat, lean-baking, lean, and less common coking. At present, the coal is not mined.

Hauterivian-to-Albian coal is of economic value. It occurs in the Suchansky Group in the Partizansk coal basin, and in the Nikansky Group in the Razdolnoe basin.

The Nikansky Group consists of the Ussuriisky, Lipovetsky, and Galenkovsky Formations. Economic coal concentrates in the Lipovetsky Formation. Generally, the number of coal seams does not exceed 8, combined into four minable seams - Nizhni, Rabochi, Sredni, and Gryazny. The seams are of complex composition, the thickness of economic coal is 2.7 to 3.5 m, with up to 6 rock beds, 0.3 to 0.4 m thick. It is medium- to high-ash hard coal, rank D (long flame). Mining operations are both opencut and underground.

The Suchansky Group consists of the Starosuchansky and Novosuchansky Formations. The lower, Starosuchansky Formation contains 12 hard coal seams, including 9 economic. The upper, Novosuchansky Formation contains 23 seams, including 10 economic. Simple seams are 0.1 to 2.3 m thick, complex seams are up to 10 m thick.

Hard coal of the Partizansk basin is of various ranks - gas, fat, coking, semianthracite, and anthracite; low- and high-ash. Coal is mined by underground operations.

In the northern part of the Partizansk basin, 14 seams and laminae of hard coal were also discovered in the Turonian-to-Campanian Dostoevsky Formation. The seams are complex and nonpersistent in strike and dip. Coal is weathered, intensely broken, and highly contaminated with mineral matter; ash content varies from 2.9 to 58.8%. The coal is non-economic at present.

Data on coal deposits of Primorye are given in Appendix 2.

CONCLUSION

Primorsky Krai is located at the northwestern Pacific continental margin that formed during Middle Jurassic to Cretaceous accretion of different terranes to the Siberian craton. Destruction processes that resulted in the formation of epicontinental Japan Sea basin started about 15 million years ago.

The Paleozoic history of the Khanka superterrane is correlated with the history of the Paleoasian Ocean. The Matveevka-Nakhimovka terrane is presumably a part of Precambrian continental margin, with rift-type troughs with marine sedimentation during the Riphean and Cambrian (the Kabarga subterrane). The Spassk terrane of the Early Paleozoic accretionary wedge, in which allochthons of Early Cambrian ophiolites and radiolarian ribbon cherts are known, is a remnant paleo-oceanic basin, separating the Matveevka-Nakhimovka terrane of a passive continental margin from the Voznesenka and Sergeevka terranes of a Cambrian active continental margin. Juxtaposition of these terranes started during the Middle Ordovician and was completed at the time of formation of the Grodekov and Shmakovka anatectic granites at the end of the Silurian. Starting from the Silurian, the Khanka superterrane developed as a part of the continent. Devonian to Middle Carboniferous bimodal magmatism reflected epicontinental destructive processes. By mid-Permian, the Khanka system became a part of the active island-arc margin. The Laoelin-Grodekov terrane is a fragment of an island arc, and Permian deposits of the Khanka terranes are rocks of the back-arc rift basin. Permian deposits along the eastern margin of the Khanka system are comparable with the rocks of the volcanic belt and continental slope of the Japan Sea-type rift basin. At the end of the Permian, this island-arc system accreted to the Sino-Korean craton and became a part of the North-China-Amurian continent. Permian fossils and paleomagnetic data suggest that this accretion took place near the equator. Paleomagnetic data and changing composition of Triassic fossils from Tethian (Lower Triassic) in marginal continental deposits to boreal (Upper Triassic) show a gradual shift of the North-China-Amurian continent towards the Siberian craton and their Middle Jurassic collision. The Middle Jurassic is a crucial time in the evolution of the northwestern Pacific and its continental framework. A system of circum-Pacific subduction zones appeared. The Samarka terrane is a fragment of an accretionary wedge of Middle Jurassic to Berriasian subduction zone. Small outcrops of Middle to Late Jurassic felsic volcanic rocks in the Sergeevka terrane and of tentatively Early Cretaceous granitoids to the north of it presumably correspond to an suprasubduction magmatic arc.

The deposition of Early Cretaceous turbidites of the Zhuravlevka terrane on the continental slope and fan resulted from the change of subduction for sinistral sliding of the oceanic crust along the continental margin (California type setting) at the beginning of the Cretaceous, with typical manifestations of within-plate magmatism.

The Taukha accretionary wedge terrane is a fragment of the Neocomian subduction zone, which judging by Mediterranean fossils occurred to the south and probably on the projection of the Zhuravlevka transform margin. The Kema terrane is a fragment of the Aptian to Albian epicontinental island arc.

The collision of the Sikhote-Alin terrane, caused by the movement of the continental margin towards the ocean along the Tan-Lu strike-slip faults, started in Early Cretaceous (Hauterivian) and finished in Albian. The collision resulted in rapid thickening of the primary sedimentary and volcanic sequence. Marginal continental conditions during the formation of the Sikhote-Alin terranes explain accumulation of abundant clastic arkosic material, which later was melted forming anatectic granites (the Khungari and Tatibi complexes) during the growth of granitic metamorphic zone. The formation of the East Sikhote-Alin volcano-plutonic belt started at the end of the Albian, related to the subduction zone, outcrops of which are observed on Sakhalin Island. Post-subduction bimodal volcanic series with predominant basalts, which were presumably related to the emplacement of mantle plumes, formed during Paleogene. The Sikhote-Alin continental crust tension during that period formed the Japan Sea rift basin; during the Pliocene, mixed volcanic series were substituted for within-plate plateau basalts.

These main stages of the geologic evolution of Primorye territory are reflected in its mineralization.

The Khanka accretionary system is a lead, zinc, iron, tin, tungsten, niobium, tantalum, and fluorite province. During the Early Paleozoic (Cambrian), when it was a passive continental margin, stratiform deposits of zinc (hosted in carbonate rocks) and iron (hosted in clastic rocks) formed. During Early Paleozoic collision, metasomatic alteration of limestone related to Ordovician lithium-fluorine granites caused the formation of huge fluorite deposit and tantaloniobate deposits hosted in leucogranites. The emplacement of Early Devonian biotite granites generated medium size and grade tin veins. Younger deposits are related to the Jurassic to Early Cretaceous subduction of the oceanic plate beneath the Khanka sialic crust. As a result, subduction volcano-plutonic complexes formed at the eastern margin of the superterrane and Jurassic to Cretaceous accretionary wedge formed at the eastern boundary of the present superterrane. Small tungsten, tin, lead, and zinc deposits formed during Jurassic to Early Cretaceous subduction intrusions of granites.

The crucial events for the Laoelin-Grodekov composite terrane were: 1) pre-accretion evolution of its fragments as Late Paleozoic volcanic island arcs; and 2) Permian syn-accretion metamorphism. Epithermal Au-Ag deposits are related to Permian island-arc complexes. Permian mafic-ultramafic intrusions are presumably platinum-bearing. Sequences of Permian metamorphic sediments are promising for metamorphic gold lode deposits and related placers.

Tungsten, tin, lead, zinc, gold, silver, copper, and boron deposits formed in the Sikhote-Alin accretionary system during the Mesozoic.

Tungsten-bearing scheelite skarns are the oldest deposits. They formed in association with Early Cretaceous collisional high-alumina granites and emplaced in folded rocks of the Jurassic to Early Cretaceous Samarka accretionary wedge. They occur in olistostrome sequences with abundant allochthons of Permian limestones.

Late Cretaceous to Paleogene deposits are spatially and genetically related to volcano-plutonic subduction complexes of the post-accretion East Sikhote-Alin volcanic belt. Gold, silver, tin, lead, zinc, copper, and boron deposits formed during a small time interval of 90 to 60 Ma. The composition of terrane, which was overlapped or intruded by post-accretion igneous rocks clearly affects the location of post-accretion metallogenic belts.

Virtually all gold deposits are related to the Sergeevka metallogenic belt, in which pre-Upper Cretaceous basement consists of predominantly metamorphosed igneous rocks of mafic composition. Gold-silver deposits occur in post-accretion felsic volcanic rocks of the Kema metallogenic belt, which corresponds in area to the Kema island-arc terrane. The most part of its Aptian to Albian section consists of basaltic andesite. All significant in reserves and grades tin deposits form the Luzhki metallogenic belt within the boundaries of the Zhuravlevka terrane. Mesozoic folded rocks of the Zhuravlevka terrane are a many km thick flysch sequence of the fans formed at the base of continental slope. All economic lead and zinc skarns and veins concentrate in the Taukha accretionary wedge terrane. In addition to oceanic rocks, it contains panels of shelf quartz-feldspar sandstone among syn-sedimentary allochthons. Abundant unsorted clastic quartz-K-feldspar material in olistostrome matrix suggests the origin of this accretionary wedge on the continental slope.

Despite all differences between Paleozoic deposits in the Khanka system and Mesozoic deposits in the Sikhote-Alin system, both have similar geochemical characteristics. Taking into account the influence of the terrane composition on the emplacement of post-accretionary deposits, we suggest that for tin, tungsten, lead, and zinc deposits this was the influence of geochemical composition of sediments, the source for which in Mesozoic near-continental basins was cratonized Paleozoic units. Gold is an exception; its relative increase in Mesozoic ore corresponds to the relative increase of intermediate-to-mafic rocks in the composition of terranes that formed a basement for post-accretion volcanic belts.

A combination of mining industry (tungsten, lead, zinc, boron, and fluorite deposits) and high potential for coal in the region can be a basis for construction of processing plants in the southern Far East Russia.

Another goal is production of borides and carbides of metals, fluororganic compounds and metalloceramics, based on large deposits of non-metallic mineral deposits and coal.

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Lode deposits of Primorsky Krai

' on the Map	Deposit Name	Type. Major Metals	Major Minerals	Size and Grade	Stage of Development	Metallogenic belt
1	Yagodnoe	Epithermal vein; Au, Ag	Au-native, Ag-argentite	Small Au=4.2 g/t Ag=49.3 g/t	Undeveloped	10
2	Malakhitovoe	Porphyry Ñu-Mo; Cu, Mo	Cu-chalcopyrite Ìî-molybdenite	Small Cu-0.32% Mo=0.005%	Undeveloped	6
3	Burmatovskoe	Epithermal vein; Au, Ag	Au-native Ag-sulphosalts, argentite	Small Au=0.8-8.4 g/t Ag=10.0-61.0 g/t	Undeveloped	10
4	Glinyanoe (Primorskoe)	Epithermal vein; Au, Ag	Au-native Ag-argentite	Small Au=8.3 g/t Ag=122.3 g/t	Undeveloped	10
5	Lermontovskoe	Skarn; W	W-scheelite	Large $W0_3$=0.67-3.0%	Active mining	6
6	Vostok-2	Skarn; W	W -scheelite Cu-chalcopyrite Ð - apatite	Large WO_3=1.64% Cu=0.65% P_2O_5 = 3%	Active mining	6

7	Yantarnoe	Porphyry Sn; Sn,Pb,Zn,Cu	Sn-cassiterite Pb-galena Zn-sphalerite
8	Salyut	Epithermal vein; Au, Ag	Au-native Ag-argentite
9	Verkhnezolotoe	Porphyry Cu-Sn; Cu, Sn	Cu-chalcopyrite Sn-cassiterite
10	Zvezgnoe	Porphyry Sn; Sn,Pb,Zn,Cu	Sn-cassiterite stannite Pb-galena

Small Sn up to 7.30% Pb=0.03-1.02% Zn=0.7-2.22% Cu=0.10-2.17%	Undeveloped	8
Small Au=1.75 g/t Ag=242 g/t	Undeveloped	10
Small Ca=0.35-2.27% Sn = 0.26% Pb = 0.69% Au = 3 g/t Ag = 86 g/t	Undeveloped	8
Small Sn = 0.53% Pb = 2.56% Zn = 2.16% Cu=0.04-0.4%	Undeveloped	8

' on the Map	Deposit Name	Type, Major Metals	Major Minerals
11	Tigrinoe	Greisen; Sn, W	Sn-cassiterite W-wolframite
12	Goluboe	Vein; Sn	Sn-cassiterite
13	Arminskoe	Vein; Sn	Sn-cassiterite, stannite
14	Trapetsiya	Vein; Sn	Sn-cassiterite
15	Ternistoe	Vein; Sn	Sn-cassiterite Cu-chalcopyrite

Table 1 - continued

Size and Grade	Stage of Development	Metallogenic belt
Large Sn = 0.14% WO_3 = 0.045%	Undeveloped	8
Small Sn = 1.1% Pb = 1.63% Zn = 1.23%	Being mined by prospectors	8
Small Sn=0.25-0.65% Pb=1.47-2.17% Zn=0.1-1.53%	Undeveloped	8
Small Sn = 0.86%	Undeveloped	8
Medium Sn = 1.96% Cu = 0.39%	Active mining	8

16	Shirokodoloe	Vein; Sn	Sn-cassiterite Pb-galena Zn-sphalerite
17	Ust- Mikulinskoe	Vein; Sn, W	Sn-cassiterite W-wolframite
18	Gornoe	Vein; Sn	Sn-cassiterite
19	Zimneye	Vein; Sn,Pb,Zn	Sn-cassiterite, stannite Pb-galena Zn-sphalerite
20	Sredne- Mikulinskoe	Vein; Sn	Sn-cassiterite, stannite

Small Sn = 1.62% Pb =1.86% Zn = 0.48%	Undeveloped	8
Small Sn=0.04-3% $W0_3$ = 0.03%	Undeveloped	8
Small Sn-1.05-4.93%	Being mined by prospectors	8
Small Sn = 0.59% Zn = 4.09% Pb = 3.18%	Undeveloped	8
Cu=0.1-3.0% Ag=26.6-46.6 g/t		8
Small Sn=0.1-0.76% Pb = 1.13% Zn=0.01-16.4% Cu=0.28-1.85%	Undeveloped	8

on the Map	Deposit Name	Type, Major Metals	Major Minerals
21	Dalnetayozhnoe	Vein; Sn, Zn, Pb	Sn-cassiterite, stannite Zn-sphalerite Pb-galena
22	Glukhoe	Vein; Au	Au-native
23	Naumovskoe	Vein; Sn,	Sn-cassiterite
24	Zabytoe	Greisen; Sn, W	Sn-cassiterite W-wolframite
25	Lesovoznoe	Vein; Sn	Sn-cassiterite
26	Sukhoklyuchev-skoe	Vein; Sn	Sn-cassiterite
27	Avangardnoe	Vein; Sn	Sn-cassiterite

Table 1 - continued

Size and Grade	Stage of Development	Metallogenic belt
Small Sn = 0.53% Zn = 2.58% Pb = 1.53%	Undeveloped	8
Large Au=1.86 g/t	Undeveloped	8
Small Sn=0.31%	Undeveloped	8
Medium Sn=0.01-0.1% $W0_3$=0.01-12.61%	Undeveloped	8
Small Sn=0.1-2.0%	Undeveloped	8
Small Sn=0.18-0.66%	Undeveloped	10
Small Sn=0.001-1.68%	Undeveloped	8

28	Rudnoe	Vein; Sn	Sn-cassiterite
29	Tayozhnoe	Epithermal vein; Ag	Ag-sulphosalts, argentite
30	Group of Ussuriisk deposits	Stratiform; Fe	Fe-magnetite, hematite
31	Kabarginskoe	Skarn; Pb, Zn	Pb-galena Zn-sphalerite
32	Lysogorskoe	Vein; Sn, Pb, Zn	Sn-cassiterite Pb-galena Zn-sphalerite
33	Noyabr'skoe	Vein; Sn, Pb, Zn	Sn-cassiterite, stannite Pb-galena

Small Sn = 0.6%	Mined out by prospectors	8
Medium Ag = 400 g/t	Active mining	10
Small Fe=23.8-38.62%	Undeveloped	2
Small Pb=0.01-0.24% Zn=0.01-0.12%	Undeveloped	11
Small Sn = 1.47% Pb = 1.94% Zn = 4.74%	Mined out by prospectors	8
Small Sn = 0.46% Pb = 3.75%	Undeveloped	8

on the Map	Deposit Name	Type; Major Metals	Major Minerals
			Zn-sphalerite
34	Malinovskoe	Porphyry Cu; Cu, Au	Cu-chalcopyrite Au-native
35	Burnoe	Vein; Sn, W	W-wolframite Sn-cassiterite
36	Skrytoe	Skarn; W	W-scheelite
37	Oktyabr'skoe	Vein; Sn,	Sn-cassiterite
38	Nizhnemolodez-hnoe	Vein; Sn, Pb, Zn	Sn-cassiterite Pb-galena Zn-sphalerite

Table 1 - continued

Size and Grade	Stage of Development	Metallogenic belt
Zn = 3.78% Ag = 126 g/t		
Small Cu=0.42-4.50% Au=0.6-12.9 g/t	Undeveloped	8
Small WO_3=0.25-0.47% Sn=0.03-0.1%	Undeveloped	8
Small WO_3=0.1-0.88%	Undeveloped	6
Small Sn=0.12-0.59%	Mined out	8
Small Sn = 0.39% Pb=0.02-1.31% Zn=0.02-0.3%	Mined out	8

39	Dalneye	Vein; Sn, Pb, Zn	Sn-cassiterite, stannite Pb-galena Zn-sphalerite
40	Ariadnenskoe	Magmatic; Ti	Ti-ilmenite, kennedeite (?)
41	Komissarovskoe	Epithermal vein; Au, Ag	Au, Ag-electrum Ag-sulphosalts
42	Kirovskoe	Vein; Sn	Sn-cassiterite
43	Raspashnoe	Vein; Sn, Pb, Zn	Sn-cassiterite, stannite Pb-galena Zn-sphalerite
44	Vernoe	Vein; Sn, Pb	Sn-cassiterite Pb-galena

Medium Sn = 0.97% Pb = 17.04% Zn = 40.02%	Mined out	8
Large TiO_2=1.0-11.8% V_2O_5 = 0.086%	Undeveloped	7
Small Au = 1.92 g/t Ag = 49.51 g/t	Undeveloped	3
Small Sn=0.1-3.8%	Undeveloped	11
Small Sn=0.15-0.21% Pb = 1.49% Zn = 0.58	Undeveloped	6
Small Sn = 0.42% Pb = 1.34%	Undeveloped	8

on the Map	Deposit Name	Type, Major Metals	Major Minerals
45	Verkneussurskoe	Vein; Sn, Pb, Zn	Sn-cassiterite Pb-galena Zn-sphalerite
46	Cheremukhovoe	Vein; Sn, Pb, Zn	Sn-cassiterite, stannite Pb-galena Zn-sphalerite
47	Vstrechnoe	Vein; Sn, Pb, Zn, Ag	Sn-cassiterite Pb-galena Zn-sphalerite
48	Plastun	Porphyry Cu; Cu, Ag	Cu-chalcopyrite, Ag-sulphosalt

Table 1 - continued

Size and Grade	Stage of Development	Metallogenic belt
Small Sn = 0.6% Pb = 1.5% Zn = 2.5% Ag = 40 g/t	Partly being mined	8
Small Sn = 0.56% Pb = 4.08% Zn = 4.49% Ag = 140 g/t	Undeveloped	9
Small Sn = 0.39% Pb = 2.46% Zn = 2.48% Ag = 76 g/t	Undeveloped	8
Small Cu=0.3-0.8% Ag=30-350 g/t	Undeveloped	9

49	Yuzhnoe	Vein; Pb. Zn, Ag, Sn	Pb-galena, jamesonite Zn-sphalerite Ag-galena, sulphosalts
50	Eldorado	Greisen; Sn, W, Bi	Sn-cassiterite
51	Maiminovskoe	Vein; Zn, Pb, Ag	Zn-sphalerite Pb-galena Ag-galena, sulphosalts
52	Zarechnoe	Porphyry Cu; Cu	Cu- chalcopyrite, bornite, cuprite
53	Dorozhnoe	Vein; Sn, Pb	Sn-cassiterite Pb-galena

Medium Pb = 6.78% Zn = 9.80% Ag - 349 g/t Sb = 0.95% Sn=0.16-1.2%	Active mining	8
Small Sn = 0.01% Bi = 0.51% WO_3=0.01-0.53%	Undeveloped	8
Medium Zn=1.12-1.14% Pb=2.68-3.63% Ag = 59 g/t	Being mined while prospected	9
Small Cu=0.02-0.2% Au = 0.05 g/t	Undeveloped	8
Small Sn=0.01-1.92% Pb up to 9.14%	Undeveloped	8

on the Map	Deposit Name	Type, Major Metals	Major Minerals
54	Smirnovskoe	Vein; Pb, Zn, Ag, Sn	Pb-galena Zn-sphalerite Sn-cassiterite Ag-sulphosalts, galena
55	Slantsevoe	Vein; Sn	Sn-cassiterite
56	Zayavochnoe	Vein (veinlet, volcanogenic); Zn, Pb, Cu	Zn-sphalerite Pb-galena Cu-chalcopyrite
57	Nikolaevskoe	Skarn; Zn, Pb, Ag	Zn-sphalerite Pb-galena Ag-galena
58	Krasnogorskoe	Vein; Zn, Pb, Ag, Sn	Zn-sphalerite Pb-galena Ag-galena, sulphosalts

Table 1 - continued

	Size and Grade	Stage of Development	Metallogenic belt
	Medium Pb = 2.69% Zn = 3.54% Sn = 0.41% Ag = 69 g/t	Active mining	8
	Small Sn=0.04-4.88%	Undeveloped	8
	Small Zn=0.01-2.29% Pb=0.19-0.79% Sn=0.08-0.4%	In development	9
	Large Zn=1.36-10.5% Pb=1.5-8.7% Ag = 62 g/t	Active mining	9
	Medium Zn=6.77% Pb=5.01% Ag=62 g/t Sn = 0.26%	Undeveloped	9

59	Verkhneye	Skarn; Zn, Pb, Ag	Zn-sphalerite Pb-galena Ag-galena
60	Partizanskoe	Skarn; Zn, Pb, Ag	Zn-sphalerite Pb-galena Ag-galena
61	Dalnegorskoe	Skarn; boron	Â-datolite, axinite
62	Koksharovskoe	Magmatic; Ti, P	Ti-titanomagnetite, Đ-apatite
63	Ivanovskoe	Vein; Sn, Pb, Zn	Sn-cassiterite, Pb-galena, Zn-sphalerite

Medium Zn=1.75-18.75% b=0.70-11.43% Ag=32-77 g/t	Active mining	9
Medium Zn=0.6-4.0% Pb=1.5-3.0% Ag=67.6 g/t	Active mining	9
Large, world class $\hat{A}_2\hat{I}_3$ = 12.38%	Active mining	9
Medium TiO_2=3.3-4.5% P_2O_5=1.0-10.0%	Undeveloped	7
Small Sn = 0.48% Pb = 2.0-4.0% Zn - 2.0% Cu = 0.75%	Mined out	8

# on the Map	Deposit Name	Type, Major Metals	Major Minerals
64	Arsenyevskoe	Vein; Sn, Pb, Zn, Ag	Sn-cassiterite, stannite Zn-sphalerite Pb-galena, sulphosalts
65	Verkhneye	Vein; Sn	Sn-cassiterite
66	Temnogorskoe	Vein; Sn, Pb, Zn	Sn-cassiterite, stannite
67	Sadovoe	Skarn; Zn, Pb, Ag	Zn-sphalerite Pb-galena Ag-galena
68	Lidovskoe	Vein; Zn, Pb	Zn-sphalerite Pb-galena

Table 1 - cotninued

Size and Grade	Stage of Development	Metallogenic belt
Medium Sn=0.4-1.5% Pb = 3-5% Zn = 3-5% Ag=100-1000 g/t	Active mining	8
Medium Sn = 0.7%	Active mining	8
Small Sn=0.1-1.43% Pb=0.1-3.4% Zn=0.1-8.28%	Undeveloped	8
Small Pb = 3.0-7.0% Zn =5.0-9.0% Ag = 30-430 g/t	Active mining	7
Medium Zn = 6.4% Pb = 7.8%	Active mining	9

69	Silinskoe	Vein, Sn, Pb, Zn	Sn-cassiterite Pb-galena Zn-sphalerite
70	Vysokogorskoe	Vein, Sn	Sn-cassiterite
71	Levitskoe	Vein; Sn, Pb, Zn	Sn-cassiterite Pb-galena Zn-sphalerite
72	Khrustalnoe	Vein; Sn, Pb, Zn	Sn-cassiterite Pb-galena Zn-sphalerite
73	Kisinskoe	Vein; Pb, Zn, Ag, Sn	Pb-galena Zn-sphalerite Ag-native, pyrargyrite Sn-cassiterite

Medium Sn = 1.28% Pb=3.74-7.3% Zn=5.45-32.3%	Active mining	8
Medium Sn = 1.0%	Active mining	8
Small Sn=0.4-0.5% Pb = 1.20% Zn = 2.88%	Undeveloped	8
Medium Sn = 0.22% Pb=0.8-1.7% Zn up to 11.7%	Mined out, some prospectors still work	8
Small Pb=0.02-9.05% Zn=0.02-16.0% Sn=0.01-1.14% Ag= 600 g/t	Undeveloped	9

# on the Map	Deposit Name	Type, Major Metals	Major Minerals
74	Chernyshevskoe	Stratiform; Zn	Zn-sphalerite, Pb-galena
75	Blagodatnoe	Skarn; Sn	Sn-cassiterite
76	Novogorskoe	Vein; Sn,	Sn-cassiterite
77	Perevalnoe	Vein; Sn	Sn-cassiterite
78	Dubrovskoe	Vein; Sn	Sn-cassiterite
79	Monastyrskoe	Vein; Sn, Pb, Zn, Ag	Sn-cassiterite Pb-galena Zn-sphalerite

Table 1 - continued

Size and Grade	Stage of Development	Metallogenic belt
Small Pb=1.5-6.3% Zn=0.7-2.5%	Undeveloped	1
Small Sn=0.3-1.48%	Undeveloped	5
Small Sn=0.1-0.2%	Undeveloped	8
Small Sn=0.3-1.42%	Undeveloped	8
Large Sn = 1.5%	Active mining	8
Small Sn = 0.57% Pb=3.4-9.27% Zn=0.36-4.6% Ag=22-510 g/t	Active mining	9

on the Map	Deposit Name	Type, Major Metals	Major Minerals
74	Chernyshevskoe	Stratiform; Zn	Zn-sphalerite, Pb-galena
75	Blagodatnoe	Skarn; Sn	Sn-cassiterite
76	Novogorskoe	Vein; Sn,	Sn-cassiterite
77	Perevalnoe	Vein; Sn	Sn-cassiterite
78	Dubrovskoe	Vein; Sn	Sn-cassiterite
79	Monastyrskoe	Vein; Sn, Pb, Zn, Ag	Sn-cassiterite Pb-galena Zn-sphalerite

Table 1 - continued

Size and Grade	Stage of Development	Metallogenic belt
Small Pb=1.5-6.3% Zn=0.7-2.5%	Undeveloped	1
Small Sn=0.3-1.48%	Undeveloped	5
Small Sn=0.1-0.2%	Undeveloped	8
Small Sn=0.3-1.42%	Undeveloped	8
Large Sn = 1.5%	Active mining	8
Small Sn = 0.57% Pb=3.4-9.27% Zn=0.36-4.6% Ag=22-510 g/t	Active mining	9

80	Sofiva-Alekseevskoe	Metamorphic; Au	Au-native
81	Kedrovoe	Vein; Sn	Sn-cassiterite
82	Pervomaiskoe	Greisen; Sn	Sn-cassiterite
83	Iskra	Vein; Sn	Sn-cassiterite
84	Listvennoe	Vein; Sn, Pb	Sn-cassiterite Pb-galena
85	Pogranichnoe	Greisen; CaF_2	CaF_2-fluorite
86	Voznesenka	Stratiform, sedimentary-diagenetic; Zn	Zn-sphalerite without processing

Small Au = 1.0-3.0 g/t Ag = 5.0 g/t	Undeveloped	4
Medium Sn = 0.25%	Undeveloped	8
Small Sn = 0.3%	Undeveloped	5
Medium Sn=0.5-1.0%	Being mined while prospected	8
Small Sn = 0.15% Pb = 2.2%	Undeveloped	8
Large, world class CaF_2=35.0-40.0%	In development	5
Medium Zn - 7.0%	Ore is stockpiled	1

on the Map	Deposit Name	Type, Major Metals	Major Minerals
87	Voznesenka	Greisen; CaF_2	CaF_2-fluorite
88	Yaroslavka	Vein; Sn	Sn-cassiterite
89	Sobolinoe	Vein; Sn, Pb, Zn, Sb, Ag	Sn-cassiterite, sulphostannates
90	Kim	Skarn; Sn, Pb, Zn	Sn-cassiterite Pb-galena Zn-sphalerite
91	Chapaevskoe	Greisen; Sn, W, Be	Sn-cassiterite W-wolframite Be-beryl

Table 1 - continued

Size and Grade	Stage of Development	Metallogenic belt
Large, world class CaF_2=33-35%	Active mining	5
Medium Sn = 0.52%	Active mining	5
Small Sn = 0.4% Pb = 0.41% Zn = 0.58% Sb=0.2-4.2% Ag=34-51.02 g/t	Undeveloped	7
Small Sn = 0.15% Sn = 0.37% Pb=0.23-29% Zn = up to 1.0%	Undeveloped	8
Small Sn = 0.52% WO_3 = 0.67% Be = 0.14%	Undeveloped	5

92	Lazurnoe	Porphyry Cu-Mo; Cu, Mo	Cu-chalcopyrite, bornite Mo-molybdenite
93	Osinovskoe	Vein; Sn	Sn-cassiterite
94	Kholuvaiskoe	Skarn; Pb, Zn, Sn	Pb-galena Zn-sphalerite
95	Brusnichnoe	Greisen; Sn	Sn-cassiterite
96	Sudno	Greisen; Sn	Sn-cassiterite

Small Cu-0.3-0.6% Mo=0.008-0.2% Au - up to 3 g/t	Undeveloped	8
Small Sn=0.01-0.134%	Undeveloped	5
Small Pb=2.7-17.24% Zn = 10.0%	Undeveloped	9
Small Sn=0.4-0.6%	Undeveloped	9
Sn-few hundreds of a percent	Undeveloped	9

' on the Map	Deposit Name	Type, Major Metals	Major Minerals
97	Furmanovskoe	Vein; Sn, Pb, Zn	Sn-cassiterite, stannite Pb-galena Zn-sphalerite
98	Borodinskoe	Skarn; Pb, Zn	Pb-galena Zn-sphalerite
99	Belogorskoe	Skarn; Fe, Sn	Fe-magnetite Sn-cassiterite, garnet
100	Rudnoe	Vein; W, Sn	W-wolframite, scheelite Sn-cassiterite
101	Luchistoe	Vein; Sn	Sn-cassiterite

Table 1 - continued

Size and Grade	Stage of Development	Metallogenic belt
Small Sn=0.24-0.71% Pb = 0.60% Zn = 1.0%	Undeveloped	8
Small Pb=11.03-17.26% Zn=8.6-16.38%	Undeveloped	9
Small Fe=31.82-36.54% Sn = 0.12%	Active mining	9
Small W=0.001-1.0% Sn=0.003-0.06%	Undeveloped	8
Small Sn= 0.02% to 20.2%	Undeveloped	8

102	Magistralnoe	Vein; Sn, Pb, Zn, Ag	Sn-stannite, cassiterite Pb-galena Zn-sphalerite
103	Nizhneye	Vein; Sn, Pb, Zn	Sn-cassiterite Pb-galena Zn-sphalerite
104	Skalistoe (Poperechnoe)	Porphyry Mo; Mo, W, Sn	Mo-molybdenite W-wolframite
105	Shcherbakovskoe	Vein; Pb, Zn, Sn	Pb-galena Zn-sphalerite Sn-cassiterite
106	Fasolnoe	Vein; Pb, Zn, Sn	Pb-galena Zn-sphalerite Sn-cassiterite

Small Sn=0.23-0.49% Pb = 1.0-3.0% Zn = 1.0-3.0% Ag=50-100 g/t	Undeveloped	8
Small Sn=0.33-1.53% Pb=0.002-0.02% Zn = 2.0%	Undeveloped	8
Small Mo=0.02-0.2% WO_3=0.15-2.8%	Undeveloped	6
Small Pb =2.0-9.0% Zn =3.0-5.0% Sn = up to 4.0% Ag = 258 g/t	In development	9
Small Pb=0.1-30% Zn = 0.1% Sn=0.01-0.3%	In development	9

# on the Map	Deposit Name	Type, Major Metals	Major Minerals
107	Listvennoe	Vein; Sn, Pb	Sn-cassiterite Pb-galena
108	Soyuz	Epithermal vein; Au, Ag	Au-native Ag-argentite
109	Yubileinoe	Vein; Sn, W, Pb, Zn, Ag	Sn-cassiterite, stannite W-wolframite Zn-sphalerite Pb-galena Ag-galena, sulphosalts
110	Kanyon	Vein; Sn, Pb, Zn, Ag	

Table 1 - continued

Size and Grade	Stage of Development	Metallogenic belt
Ag=66 to 225.2 g/t		
Small Sn-0.01-3.0% Pb=0.4-0.5%	Undeveloped	9
Au = 1.27 g/t	Undeveloped	8
Ag = 127.9 g/t	Undeveloped	9
Small Sn = 0.54% WO_3=0.04-6.5% Pb=0.04-0.7% Zn=0.7-5.8% Ag = 300 g/t Au = 0.5 g/t		
Small Sn - up to 3.30% Pb = 4.36% Zn = 2.65% Ag- up to 161 g/t	Undeveloped	9

111	Pasechnoe	Vein; Au	Au-native	Small Au=13.67-17.85g/t	Undeveloped	7
112	Benevskoe	Skarn; W	W-scheelite	Small WO_3=0.44-3.13%	Undeveloped	6
113	Porozhistoe	Vein; Au	Au-native	Small Au=5.39 g/t	Undeveloped	7
114	Krinichnoe	Vein; Au	Au-native	Small Au - 2.8 to171 g/t	Undeveloped	7
115	Progress	Vein; Au	Au-native	Medium Au = 5.80 g/t	Mined out by prospectors	7
116	Askold	Vein; Au	Au-native	Medium Au=5.9-7.6 g/t	Partly mined	7

Note: Metallogenic belts: 1 - Khanka, 2 - Kabarga, 3 - Laoelin-Grodekov, 4 - Prigranichny, 5 - Voznesenka, 6 - Samarka, 7 - Sergeevka, 8 - Luzhki, 9 - Taukha, 10 - Kema, 11 - Daubikhe, 12 - Ariadny.

COAL DEPOSITS IN PRIMORSKY KRAI

Appendix 2

Number on the map	Deposit	Age	Rank	Size	Mining Method	Stage of Development
			Lignite			
1	Alchansky	Pε-N	1B-2B	M	U, O	Undeveloped
2	Bikinskoe	" - "	1B-2B	L	O	Active mining
3	Sredne-Bikinskoe	- " -	1B-3B	M	U, O	Undeveloped
4	Verkhne-Bikinskoe	Pε	3B	M	U, O	" - "
5	Gogolevskoe	Pε-N	2B	S	U	" - "
6	Marevskoe	" - "	2B	M	U	" - "
7	Maksimovskoe	Pε	2B	S	U	" - "
8	Belogorskoe	Pε-N	2B	S	U,O	" - "
9	Orekhovskoe	" - "	2B	S	O	In development
10	Malinovskoe	" - "	2B	S	U	Undeveloped
11	Krylovskoe	" - "	2B	S	U	" - "
12	Turiirogskoe	" - "	1B-2B	S	U,O	" - "
13	Il'inskoe	" - "	1B-2B	S	U	" - "
14	Zharikovskoe	Pε	1B-2B	S	U	" - "
15	Pogranichnoe	Pε-N	1A-2B	S	U	" - "
16	Rettikhovskoe	" - "	1B	S	O	Mined out

Table 2 - continued

Number on the map	Deposit	Age	Rank	Size	Mining Method	Stage of Development
17	Chernyshevskoe	" - "	2B	S	O	Undeveloped
18	Zerkalnoe	Pε	2B	S	U	" - "
19	Pavlovskoe	Pε-N	1B	M	O	Active mining
20	Vozdvizhenskoe	Pε	1B-2B	M	U	Undeveloped
21	Rakovskoe	Pε	1B-2B	S	O	Developed
22	Danilovskoe	Pε-N	1B-2B	S	U	Undeveloped
23	Pushkinskoe	N	1B-2B	M	U, O	" - "
24	Nezhinskoe	N	2B	S	O	Developed
25	Glukhovskoe	Pε	2B	M	U	Undeveloped
26	Bonivurovskoe	Pε	2B	M	U, O	" - "
27	Smolnenskoe	Pε	2B	S	U	" - "
28	Partizanskoe	Pε	2B	S	U	" - "
29	Ambinskoe	N	2B	S	U, O	" - "
	The Uglovsky lignite basin					
30	Tavrichanskoe	Pε	3B	M	U	Active mining
31	Artemovskoe	Pε	3B	M	U	" - "
32	Shkotovskoe	Pε-N	2B-3B	M	U, O	" - "
33	Sineutyosovskoe	Pε	2B	M	A	Undeveloped
34	Hasanskoe	Pε	2B	S	U	Active mining
			Hard coal			
	The Razdolnensky hard coal basin					
1	Fadeevsky	LK	D	S	U	Undeveloped

Table 2 - continued

Number on the map	Deposit	Age	Rank	Size	Mining Method	Stage of Development
1	Fadeevsky	LK	D	S	U	Undeveloped
2	Il'ichevsky	LK	D	S	U	Active mining
3	Lipovtsy	LK	D	S	U, O	" - "
4	Konstantinovsky	LK	D	S	U	Undeveloped
5	Putsilovsky	LK	D	M	U	" - "
6	Zanadvorovsky	LK	D	S	U	" - "
7	Mongugaisky	UT	J,K,T, A	S	A	" - "
8	Perevoznensky	UT	-	S	A	" - "
9	Adamsovsky	UT	T,A	M	A	" - "
10	Surazhevsky	LK	T	S	U	" - "
11	Podgorodnensky	LK	T	S	U	Active mining
	The Partizansky basin (coal-bearing districts)					
12	Dostoevsky-Varfolomeevsky	UK	T	S	U	Undeveloped
13	Arsen'evsky	UK	T	S	U	" - "
14	Verkhne-Partizansky	LK	-	S	U	" - "
15	Bezymyanny	LK	J, K	S	U	" - "
16	West-Partizansky	LK	G,K,J, C	S	U	" - "

Table 2 - continued

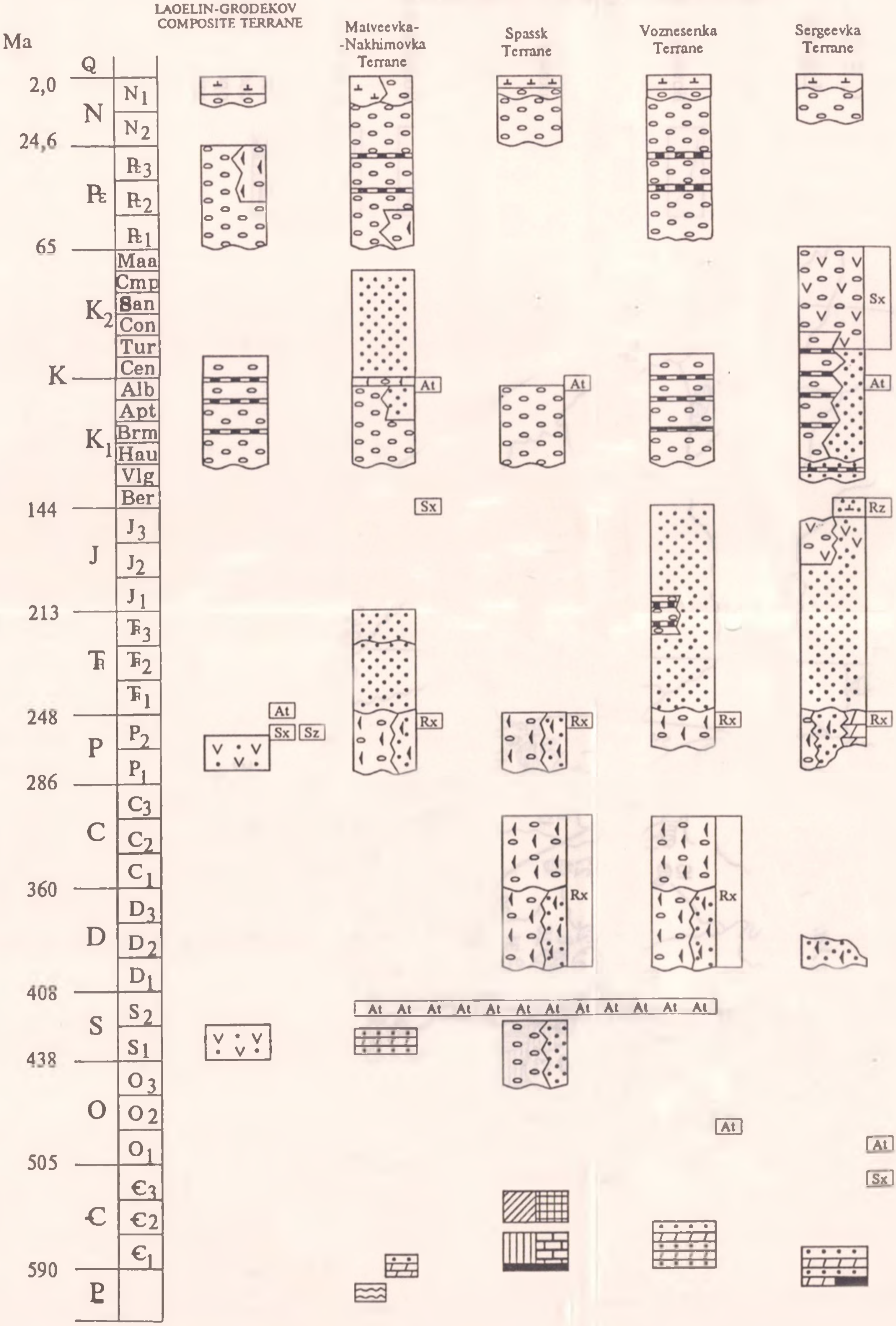
Number on the map	Deposit	Age	Rank	Size	Mining Method	Stage of Development
17	Molchanovsky	LK	L,G,J, CC	S	U	" - "
18	Sergeevsky	LK	T, J,CC	S	U	" - "
19	Belopadinsky	LK	J,G,T, OC	S	U	" - "
20	Melnikovsky	LK	G,J,D, T,CC	S	U	" - "
21	Korkinsky	LK	J,G	S	U	" - "
22	Tigrovsky	LK	J,T	S	U	Active mining
23	Staro-partizansky	LK	J,K,T	S	U	" - "
24	Smolyaninovsky	LK	T	S	U	Undeveloped.
25	Petrovsky	LK	T	S	U	" - "
26	Litovsky	LK	T	S	U	" - "

Note: Ranks of lignite (moisture holding capacity percent): 1B - more than 40%, 2B - 30-40%, and 3B - less than 30%. Ranks of hard coal: D - long flame, G - gas, GJ - gas fat, J - fat, KJ - coking fat, K - coking, K2 - coking 2, CC - poorly baking, OC - lean baking, T - lean, and A - anthracite. Mining operation: U - underground, O- opencut, and A - adit. Reserves, mln t: large (L): coking - over 150, hard coal - over 500, and lignite - over 1000; medium (M): coking - 75-150, hard coal - 100-500, and lignite - 200-1000; and small (S): coking - less than 75, hard coal - 200, and lignite - 200.

TECTONOSTRATIGRAPHIC

Compiled by A.I.Khanchuk

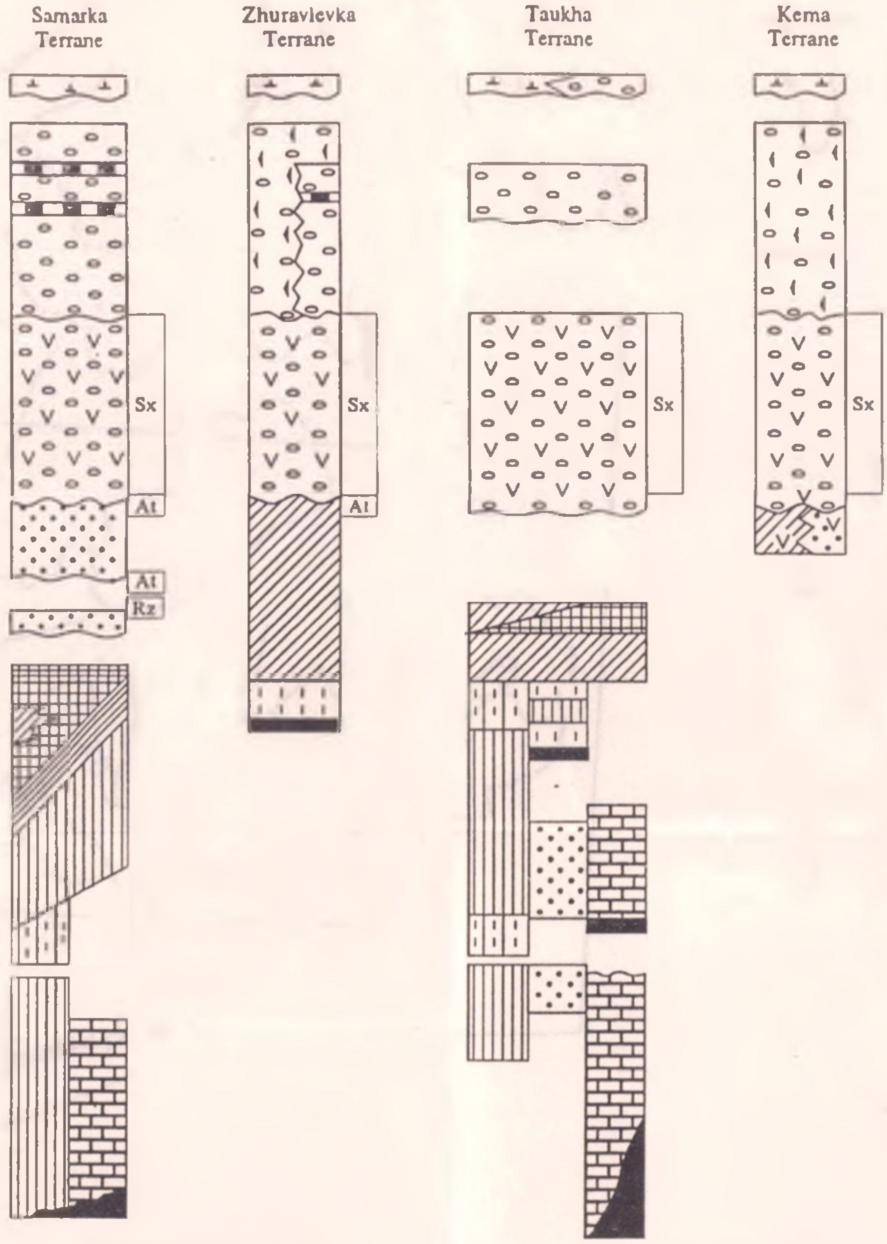
KHANKA SUPERTERRANE



TERRANES OF PRIMORYE

and V.V.Golozoubov

SIKHOTE ALIN SUPERTERRANE



Sedimentary rocks

- Continental
- Shallow-marine
- Coal-bearing
- Ribbon cherts
- Siliceous mudstone
- Carbonate rocks of guyots and seamounts
- Carbonate rocks of shelf
- Turbidites of continental slope and fan
- Subductionary melange
- Schist, gneisses, and amphibolite

Volcanic rocks

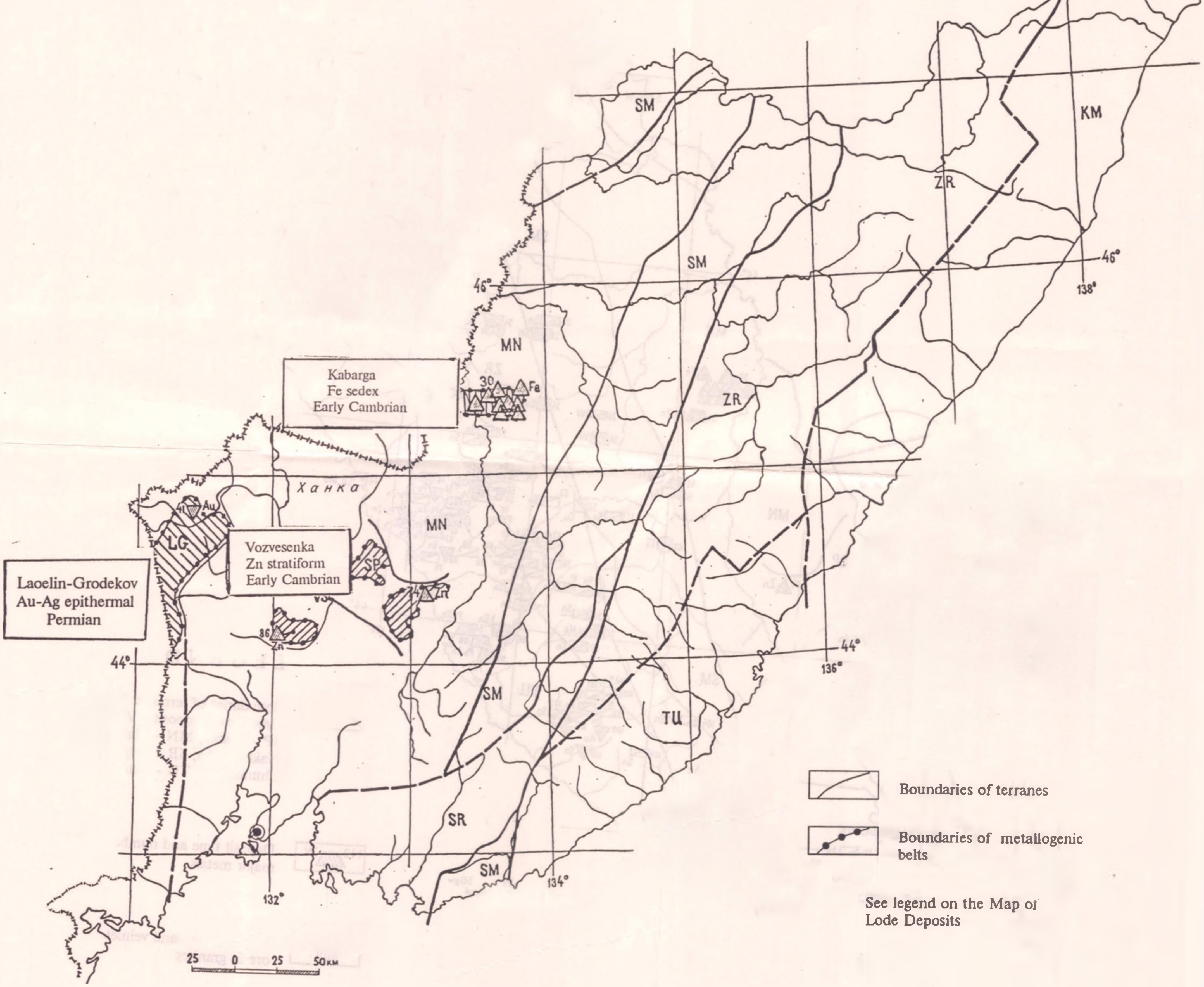
- Basalts of within-plate "non-mixed" series
- Bimodal volcanic rocks of within-plate "mixed" series
- Differentiated rocks of volcanic arcs over subduction zones
- Basalts of oceanic crust

Plutonic rocks

- Rz Alkalic gabbroic and ultramafic rocks of within-plate "non-mixed" series
- Rx Syenite and alkalic granitoids of within-plate "mixed" series
- Sx Diorite and granitic rocks related to subduction zones
- Sz Gabbro and ultramafic rocks of subduction zone
- At Anatectic (collision) granites

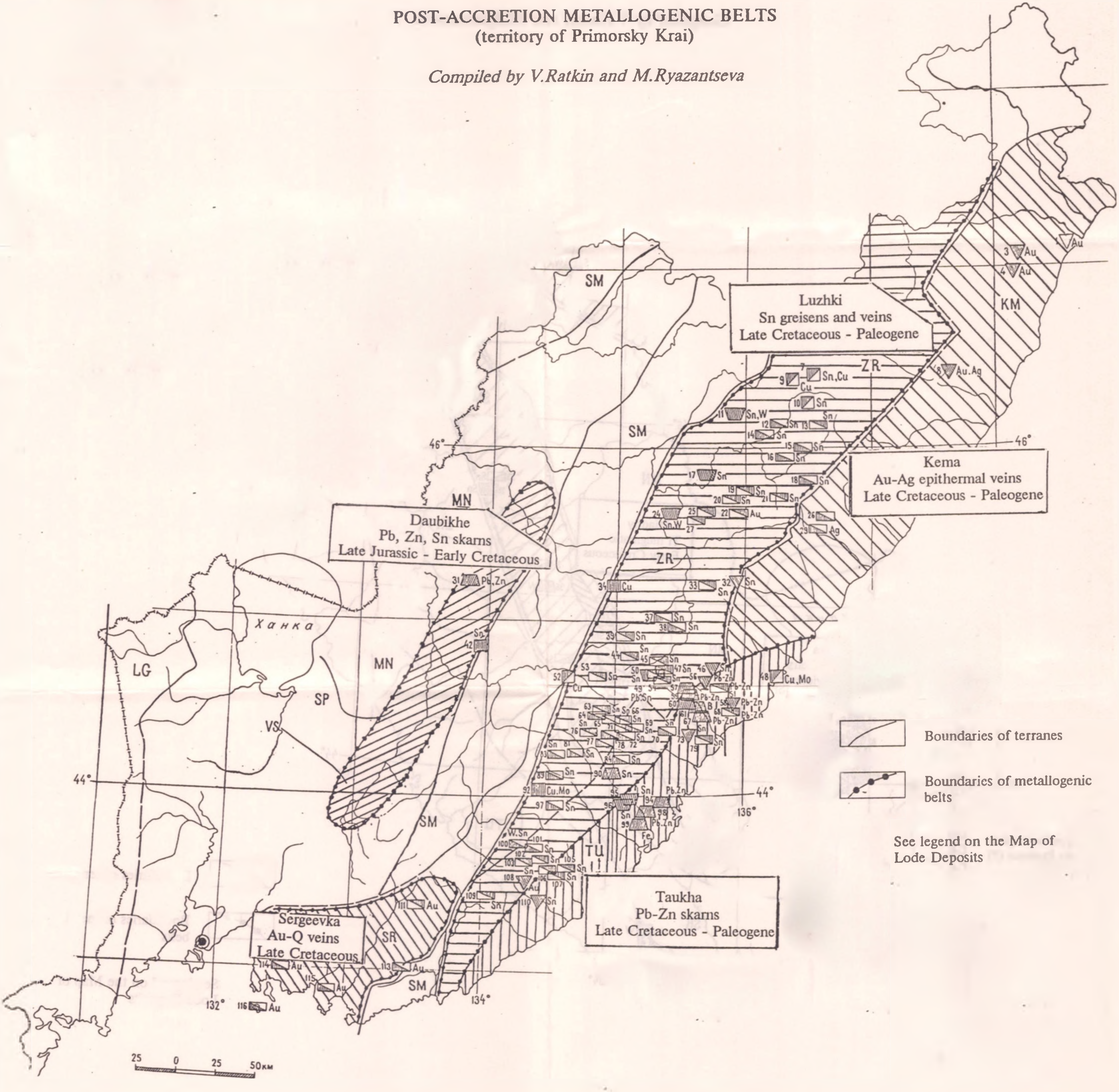
PRE-ACCRETION METALLOGENIC BELTS
(territory of Primorsky Krai)

Compiled by V.Ratkin and M.Ryazantseva



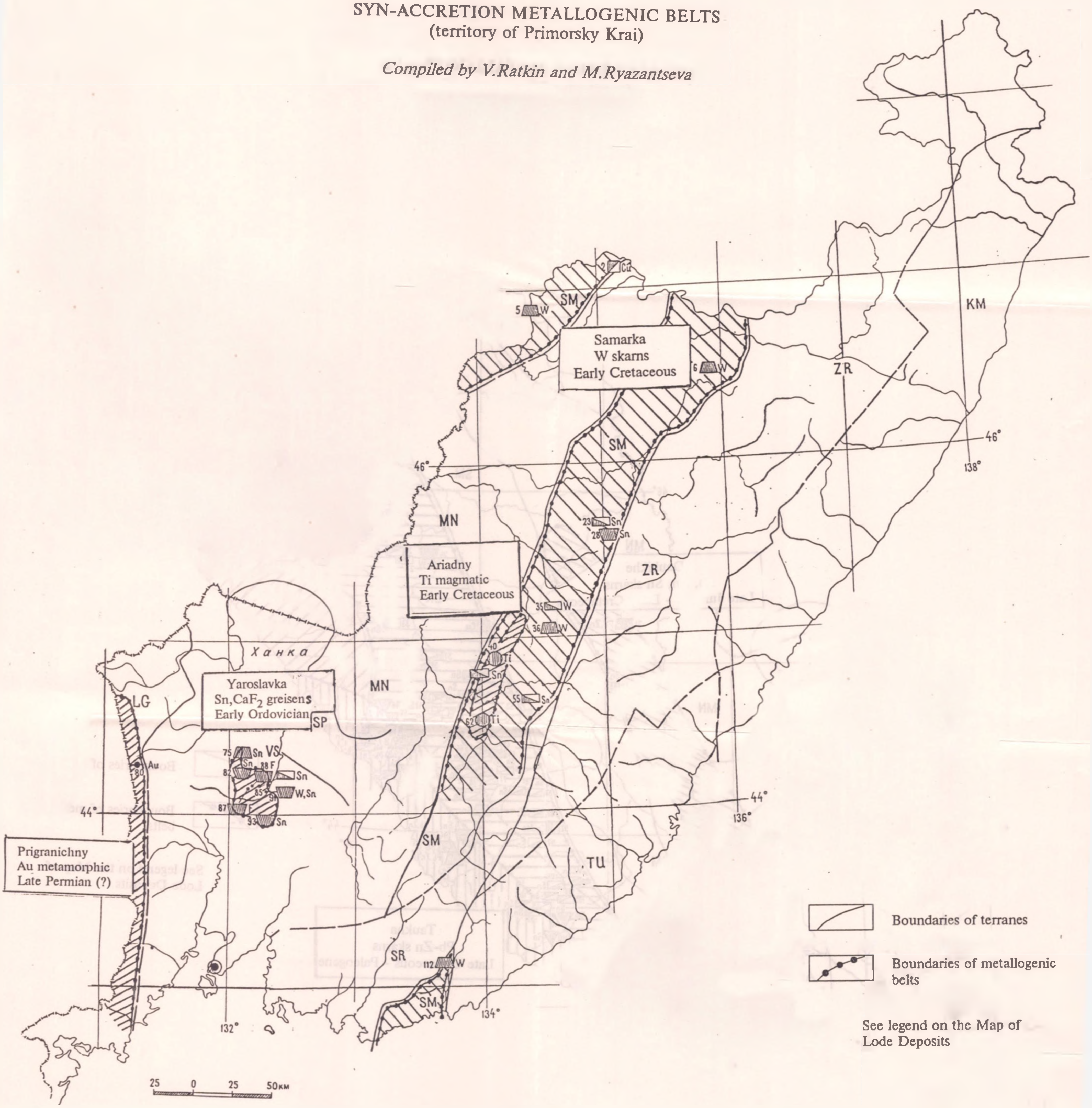
POST-ACCRETION METALLOGENIC BELTS
(territory of Primorsky Krai)

Compiled by V.Ratkin and M.Ryazantseva



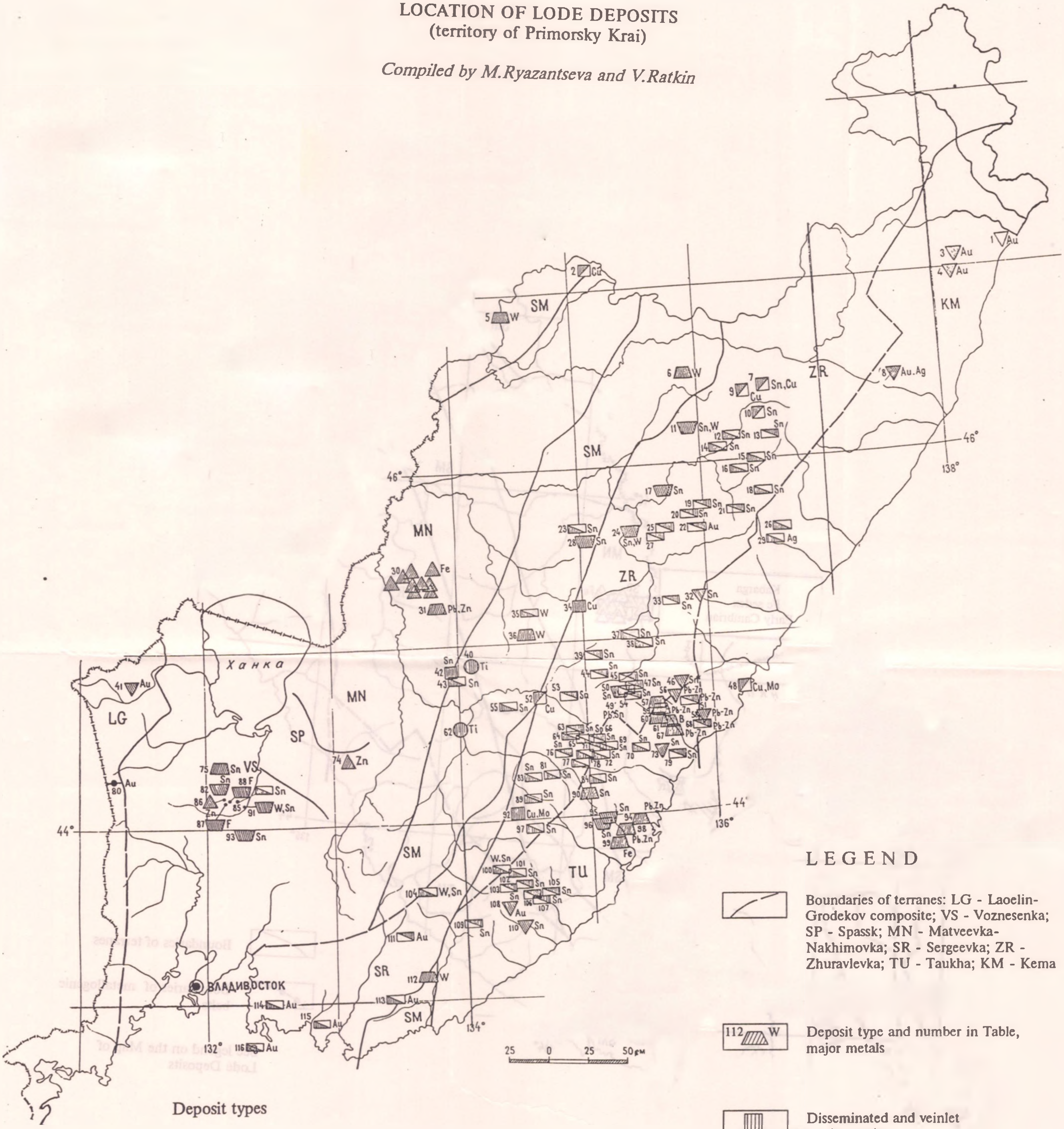
SYN-ACCRETION METALLOGENIC BELTS
(territory of Primorsky Krai)

Compiled by V.Ratkin and M.Ryazantseva



LOCATION OF LODE DEPOSITS
(territory of Primorsky Krai)

Compiled by M.Ryazantseva and V.Ratkin



LEGEND

Boundaries of terranes: LG - Laoelin-Grodekov composite; VS - Voznesenka; SP - Spassk; MN - Matveevka-Nakhimovka; SR - Sergeevka; ZR - Zhuravlevka; TU - Taukha; KM - Kema

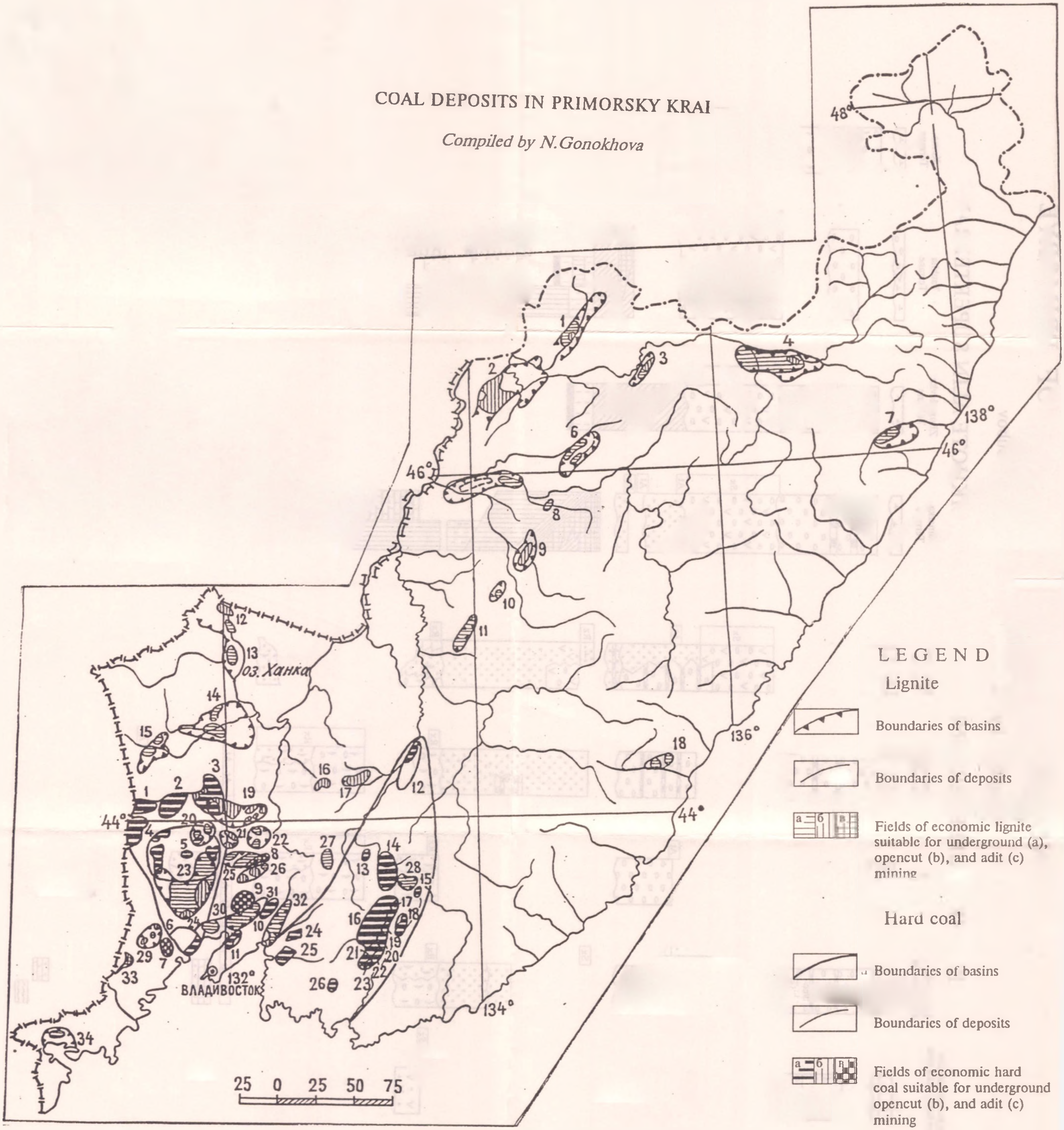
112 W — Deposit type and number in Table, major metals

Deposit types

- Stratiform in carbonate and fine-grained clastic rocks
- Skarn
- Greisen
- Veins in volcanic rocks (epithermal type)
- High-sulphide veins and zones of replacement
- Low-sulphide veins and zones of replacement
- Disseminated and veinlet ore in granites
- Disseminated and veinlet ore in volcanic rocks
- Magmatic
- Metamorphic

COAL DEPOSITS IN PRIMORSKY KRAI

Compiled by N.Gonokhova



L E G E N D

Tectonic Map
(territory of Primorye krai)

OVERLAP ASSEMBLAGES

Sedimentary rocks of intracontinental and continental margin depressions

Cenozoic (a) including coal-bearing (b)

Sedimentary rocks of continental margrin

Mesozoic (a), including coal-bearing (b)

Upper Permian

Subduction - related volcanic and plutonic rocks

Maastrichtian-Danian rhyolite, rhyodacite, dacite, their tuff and ignimbrite, more rarely andesite-basalt and basalt

Maastrichtian-Danian granite, diorite, gabbro

Albian-Cenomanian and Cenomanian-Campanian rhyolite, tuff and ignimbrite,rarely rhyodacite, dacite, andesite, basalt, and tuffite

Cenomanian-Campanian granite,rarely diorite, gabbro, and monzonite

Upper Jurassic (?)-Lower Cretaceous rhyolite and tuff

Late Jurassic (?)-Lower Cretaceous granite

Collision (anatectic) granites

Early Cretaceous

Late Silurian

Withinplate volcanic and plutonic rocks of "non-mixed" magmatic series

Pliocene basalt

Late Jurassic-Early Cretaceous alkaline ultramafic, gabbro, nepheline syenite, and carbonatite

Withinplate volcanic and plutonic rocks of "mixed" magmatic series

a) Post-collision

Upper Albian rhyolite, dacite,rarely andesite and tuff

Permian basalt, andesite, dacite, rhyolite, and tuff, tuffaceous-sedimentary and sedimentary rocks

Late-Permian granite, diorite, gabbro

Carboniferous rhyolite, dacites, tuff, and ignimbrite, volcanogene-sedimentary and sedimentary rocks

Devonian rhyolite, rarely basalt, volcanogene-sedimentary, and sedimentary rocks

Devonian and Carboniferous granite, gabbro, and syenite

b) Post-subduction

Paleocene-Miocene basalt, andesite-basalt, rarely rhyolite dacite, and tuff

Faults

Terrane boundaries: a - left-lateral strike-slip fault; b - thrust

Post-accretion: a - left-lateral strike-slip fault, b - thrust, c -fault

TERRANES

PRECAMBRIAN CONTINENTAL MARGIN TERRANES

MATVEEVKA-NAKHIMOVKA TERRANE. Proterozoic crystalline schist, gneiss, amphibolite, marble; Upper Proterozoic-Lower Cambrian schist and ferruginous quartzites. Late Proterozoic granite. Lower Paleozoic terrigenous and carbonaceous rocks

ACTIVE CONTINENTAL MARGIN ARC TERRANES

VOZNESENKA TERRANE. Lower Cambrian terrigenous-carbonaceous rocks, rarely acid volcanite; Early Ordovician granite

SERGEEVKA TERRANE. Proterozoic (?) amphibolite, calciphyre, schist; Late Cambrian gabbro-gneiss, diorite-gneiss and Early Ordovician granite

ACCRETIONARY WEDGE AND SUBDUCTION ZONE TERRANES

TAUKHA TERRANE. Neocomian turbidite and subductionary melange with fragments of Late Devonian-Early Jurassic paleoguyots, Permian, Triassic, and Jurassic radiolarian chert and basalt, Middle-Upper Triassic sandstone and Lower Cretaceous conglomerate and sandstone

SAMARKA TERRANE. Middle Jurassic - Berriasian turbidite and subductionary melange with inclusions of Middle Paleozoic ophiolite, Upper Paleozoic limestone, Upper Paleozoic and Lower Mesozoic radiolarian chert and basalt

SPASSK TERRANE. Lower Paleozoic turbidite and subductionary melange with inclusion of radiolarian chert, ophiolite, Lower Cambrian limestone; blocks of Early Cambrian carbonaceous rocks and Middle Cambrian sandstone

Inclusions of ophiolite in accretionary wedge

ISLAND ARC TERRANES

KEMA TERRANE. Aptian - Albian greywacke and arkose turbidite, basalt, andesite, dacite, and their tuff

LAOELIN-GRODEKOV COMPOSITE TERRANE. Lower - Upper Permian andesite, dacite, rhyolite, volcanogene - sedimentary and sedimentary rocks, Late Permian dunite - clinopyroxenite-gabbro and tonalite-granite intrusions, fragments of terranes of Early Silurian volcanogene-sedimentary and sedimentary rocks

TURBIDITE BASIN TERRANE

ZHURAVLEVKA TERRANE. Early Cretaceous terrigenous, partly flysh formations: a - Berriasian-Barremian, b - Aptian-Albian

OTHER SYMBOLS

Trends of axes and limbs of folds

granite

granodiorite and diorite

gabbro

monzonitoid and syenite

Letters in the circles designate the following faults: A - Arsenyevsky, AL - Alchansky, S - Spassky, M - Meridional, C - Central Sikhote-Alin, K - Kolumbinsky, F - Furmanovsky

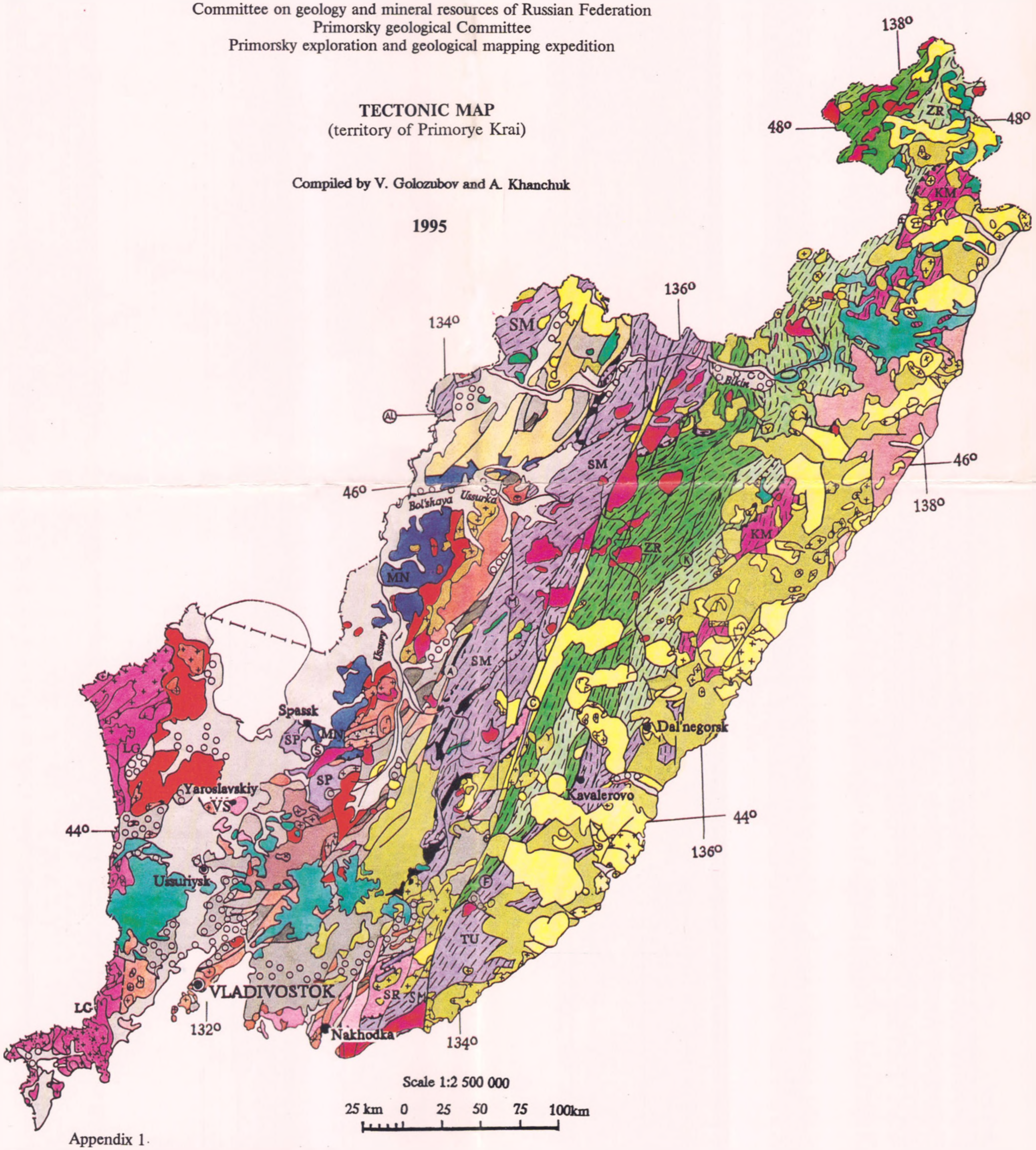
Russian Academy of Sciences
Far Eastern Branch
Far Eastern Geological Institute

Committee on geology and mineral resources of Russian Federation
Primorsky geological Committee
Primorsky exploration and geological mapping expedition

TECTONIC MAP
(territory of Primorye Krai)

Compiled by V. Golozubov and A. Khanchuk

1995



Appendix 1.

To the book by A.I.Khanchuk et all."Geology and Mineral deposits of Primorye Kray (essay)" ,1995