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MESO-CENOZOIC GEODYNAMIC SETTINGS AND GOLD MINERALIZATION OF THE RUSSIAN FAR EAST

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Paleogeodynamic reconstructions and recent studies of plate tectonics are used to represent Meso-Cenozoic geodynamic evolution of the Far East as alternating subduction and transform (Californian type) settings. The formation of the bulk volume of the Okhotsk-Chukchi and Eastern Sikhote-Alin' volcanoplutonic belts is associated with subduction settings. Shear translations with intrusion of asthenospheric plumes beneath continental margin and/or island arc as a result of submergence of spreading centers into the mantle and the slab of submerged lithosphere, correspond to transform settings. "Slab windows" favored the development of magmatic complexes of different formations in the upper crustal horizons. In the Meso-Cenozoic period, along with tectonogenesis and other large-scale processes, multistage concentration of gold occurred within the area under study. This paper considers spatial and temporal distribution of diverse types of gold mineralization with respect to heterogeneous major tectonic units. Belt-and-swarm occurrence of gold deposits in heterogeneous geological settings corresponds to multifactor deep activity of fluid-pervious megazones of tectonic rearrangement. Diversity of gold mineralization is explained by geological systems of different origin and complicated mutual dependence of mantle and crustal processes.

Paleogeodynamics, transform and subduction settings, metallogeny, age of ore deposits, gold mineralization, Far East

INTRODUCTION

According to concepts of modern plate-tectonics, the first period of the Meso-Cenozoic geodynamic history of eastern Russia involves the successive accretion of tectonostratigraphic terranes to the North Asian Craton (NAC). The main cause of this process in the northern Paleopacific was that since the Jurassic the subduction of oceanic lithosphere had been increased and remote continental and island-arc structures had been gradually accreted to the margin of the North Asian Craton. The large structures to be accreted were fragmented into terranes. The margin of the craton and the terranes were joined by belts of granitoid batholiths and were overlapped by volcanoplutonic belts (VPB). In the Late Cenozoic, taphrogenic troughs of the seas of Japan and Okhotsk formed, and the accretion of the Asian continent gave way to its destruction.

Its subduction, collisional, and taphrogenic Meso-Cenozoic paleogeodynamics have recently received much study [1–5]. In addition, geodynamic models were constructed on the basis of thrust tectonics [6]. In this connection, of interest are relevant works on pre-, syn-, and postaccretion metallogeny of this territory of Russia. At the same time, some new data on various geosciences require corrections to be introduced into geodynamic constructions and more precise identification of geodynamic settings under which deposits formed (Fig. 1–3).

GENERAL GEOTECTONIC FEATURES OF THE REGION AND GEODYNAMIC COMPLEXES OF SUBDUCTION SETTINGS

The central part of the territory is occupied by the North Asian Craton [5], represented by the eastern parts of the Siberian Platform and Aldan-Stanovoy Shield and the upper-Yana passive continental margin of Late Paleozoic-Early Mesozoic age (see Fig. 1).

The upper Yana-Kolyma collage of cratonic terranes (Omolon, Okhotsk) and terranes of the Early Paleozoic continental margin (Kolyma, Omulevka, etc.) lie northeast of the craton. As a result of rifting, they were separated from the North Asian Craton in the Devonian-Carboniferous. They adjoin Jurassic island-arc terranes on the nonoceanic basement and terranes of accretionary prisms and turbidite basins as blocks of Mesozoic epioceanic structures. This collage of terranes formed in the process of the Early Cretaceous movement of the Chukchi terrane of the Paleozoic-Early Mesozoic passive continental margin toward the NAC. The Koryak collage of Jurassic-Cretaceous epioceanic terranes of island arcs and accretionary prisms formed in the Early Cretaceous as well as during the northward subduction of the Paleopacific lithosphere plates [1, 7, 8].

The Okhotsk-Mongolian collage of Mesozoic epioceanic terranes, the pre-Mesozoic collage of different terranes of the Amur superterrane, and the Sikhote-Alin' collage of Early Cretaceous epioceanic terranes occur south and southeast of the NAC [3].

East of the Late Cretaceous continent-ocean boundary, there is a vast area of Cenozoic collage of terranes buried beneath the waters of the ocean and marginal seas. The terranes of Kamchatka, Sakhalin, and the Kuriles are fragments of structural elements of the Late Cretaceous-Early Paleogene continent-ocean boundary and Late Cretaceous and Paleogene island arcs. Most of them were accreted in the Middle-Late Eocene and only the terranes of the Kronotsky Peninsula and Cape Kamchatsky, in the Neogene.

The postaccretion zones of subduction (see Fig. 3) include: the Middle Jurassic Uda VPB southeast of the NAC, the Okhotsk-Chukchi and East-Sikhote-Alin' VPB of Late Cretaceous active continental margin, a system of Oligocene-Miocene volcanic belts which extend from the Chukchi Peninsula through Western Kamchatka and Central Kamchatka to the Kurile Islands, and the modern volcanic belt of Kamchatka and the Kuriles.

GEODYNAMIC SETTINGS OF TRANSFORM CONTINENTAL MARGINS OF CALIFORNIAN TYPE

There are increasingly more data indicating that, during the Meso-Cenozoic evolution of the region, geodynamic settings associated with the transform boundaries of lithosphere plates were widely developed [9]. Partially, this model coincides with the concept of a crucial role of the Cretaceous-Cenozoic thrust regime at the Asian continent-Pacific ocean boundary [6]. These settings have much in common with the Late Cenozoic Californian-type transform boundary between plates. The main feature of such a boundary is the formation of a "slab window" beneath the continental margin, as a result of detachment of a slab (downgoing plate) and its submersion into the mantle. Magmatic complexes formed above the "slab window". Paleotransform boundaries of plates are marked by terranes of continent-marginal turbidite basins and magmatic complexes on the continental margin.

There are two stages in the evolution of the transform continental margin of Sikhote-Alin'. The first stage (pre-Late Hauterivian) was dominated by the pull-apart setting. As a rule, clays accumulated on the continental slope and at its bottom, and ultramafic-mafic alkaline magmatic complexes formed. At the second stage (Hauterivian-Cenomanian), zones of compression and pull-apart alternated in time and space. Movements along the continent-marginal sinistral strike-slip faults became more active, and sandy and flyschoid deposits began to accumulate on the continental slope. The Central Sikhote-Alin' Fault and its continuation in Japan (Tanakura and Median Faults) inherited the boundary of lithospheric plates and resembled the modern San Andreas Fault in California. Terranes of the Jurassic-Early Cretaceous island arc that existed east of the Central Fault moved from south to north for about 1000 m and collided with the continental margin in the Albian. West of the Central Fault, the Jurassic accretionary prism was translated for about 700 km along the boundary with the Amur continent. The strike-slip faults also cut the margin of the Amur continent and transported some of its blocks northward, providing a specific festoon shape to the eastern boundary of the Amur continent. The Hauterivian-Cenomanian translations along sinistral strike-slip faults formed a giant S-shaped structure of the Sikhote-Alin' and led to thickening and formation of continental crust. The Hauterivian-Cenomanian stage of the development of the Sikhote-Alin' transform continental margin is associated with the formation of synshift granitoid plutons and volcanoplutonic complexes of bimodal type with predominance of rhyolites (Khingan-Okhotsk and other belts). The granitoid plutons have diverse geochemical characteristics. Ilmenite and magnetite series of granites formed in epioceanic terranes of accretionary prisms and turbidite basin, whereas only magnetite series formed on the margin of the Amur continent. Plutons of Li-F-granites with basaltoid signs are associated with large strike-slip faults. Granodiorite tonalite-plagiogranite plutons of I-type magnetite series are auriferous. The auriferous plutons are typically riched in Ba and Sr, have no Eu anomaly, are depleted in HREE, and have the primary Sr isotope ratio of bout 0.705.

By analogy with the Early Cretaceous setting on the Sikhote-Alin', paleogeodynamic analysis of the interaction of lithosphere boundaries suggests the Jurassic-Early Cretaceous setting for transform continental margin on the south and northeast of the NAC, the Paleocene-Eocene setting along the Okhotsk-Chukchi volcanoplutonic belt (OChVPB), and the Paleogene-Miocene one along the East Sikhote-Alin' volcanoplutonic belt (ESAVPB) of the continent-ocean paleoboundary. The transform plate boundary existed also along the Kurile-Kamchatkan volcanic arc in the Late Neogene-Early Quaternary time.

The Jurassic and Early Cretaceous transform continental margins in northeastern Russia (see Fig. 2) extend along the southern boundary of the Chukchi terrane and along the Kolyma structural loop (KSL). The latter contains terranes of the Jurassic turbidite basins (Kular-Nera, In'yali-Debin, Poluosnensky) at the transform boundaries of the North Asian Craton and the Okhotsk, Omolon, and Kolyma craton terranes. Farther, toward the center of the loop, the Momo-Selennyakh tectonic zone is recognized, which contains terranes of a Jurassic accretionary prism with fragments of the Paleozoic-Early Mesozoic ophiolite-containing oceanic crust, as well as terranes of the Early-Middle Paleozoic passive margin of the craton (Omulevsky, Tas-Khayakhtakh, Selennyakh, Ulakhan-Tas, etc.), which are not usually considered to be elements of the Jurassic zone of subduction. It is remarkable, however, that terranes of continental margin (Khorsky, Sergeev, and Southern Kitakami), which lie on or within an accretionary prism and are deformed together with it, are also associated with the Jurassic accretionary prisms of the Sikhote-Alin' and Japan. By analogy, it can be supposed that the Momo-Selennyakh tectonic zone is part of the zone of subduction of the Jurassic Alazei island arc and continental terranes of the Selennyakh zone are the fragments of a plate hanging over the zone of subduction that were cut off along later strike-slip faults.

The KSL structure as a whole [7] can be imagined as a system of giant folds with vertical hinges and fault boundaries on the wings, sinistral on the west and dextral on the north and east. Faulting zones of the KSL framing (often with granitoid plutons) are shear fractures (kind of megacleavage) relative to the giant folds.

Of special interest are the following steps of the Kolyma loop history [7, 10, 12]. In the Late Jurassic, the Momo-Selennyakh-Alazei island system moved closer to the transform margin of the North-Asian Craton and craton terranes, thus leading to the formation of a slab, intrusion of asthenospheric diapirs, and formation of the Late Jurassic Oloi and Uyandina-Yasachny volcanic belts along the transpressional structure of the zone of collision. In the Early Cretaceous, many intrusions of synshift granitoids with hybride crustal-mantle characteristics formed in collision setting. Further evolution of the "slab window" in the Middle-Late Cretaceous resulted in alkaline volcanic rocks of the Dzhakhtardakh-Oloi volcanic belt. In the Early-Late Cretaceous, the same evolution was experienced by the southern margin of the Chukchi terrane after the lithosphere of the South-Anyui oceanic basin had been submerged beneath it.

The Jurassic continent-marginal turbidites of the Un'ya-Bom and Ul'ban terranes mark the transform boundary of the Siberian continent that had been existing before the closure of the Mongolo-Okhotsk oceanic basin. The Early Cretaceous collision of the Amur superterrane with the NAC proceeded under the conditions of sinistral shift [3]. Geochemical features of the Early Cretaceous volcanic rocks are typically taphrogenic. Zonal alkaline dunite-clinopyroxenite massifs (Konder etc.) are known to exist on the margin of the craton.

The Paleogene turbidites of the Ukelayat terrane in the north of Kamchatka mark the transform boundary of plates. Earlier, the Campanian-Maastrichtian zone of spreading, whose fragments are described in the Yanranai terrane [8], had been submerged beneath the continental margin. The (Maastrichtian?)-Paleocene-Early Eocene volcanic rocks associated with the OChVPB occur on this transform margin. Fragments of the Late Cretaceous zone of spreading are recognized in the axial part of Sakhalin. The subduction zones were directed westward, beneath the continent, and eastward, beneath the East Sakhalin island arc. The approachment of the arc to the continent and the detachment of slabs began in the Paleocene, whereas the collision and intrusion of granitoids on Sakhalin began in the Eocene (42 Ma BP). A "slab window" formed beneath the continental margin, which specified the Paleogene-Neogene magmatism of the ESAVPB and the Neogene magmatism on Sakhalin under the conditions of development of dextral strike-slip faults.

It is supposed [13] that a change of the subduction boundary by the transform one preceded the Eocene sinistral collision of the Late Cretaceous Olyutorsko-Kamchatkan (Achaivayam-Valaga) island arc on its western margin. The slab detachment followed by the intrusion of asthenospheric diapirs led to the formation of Maastrichtian-Paleocene zonal dunite-clinopyroxenite-gabbro intrusions in the zone where the arc coincides

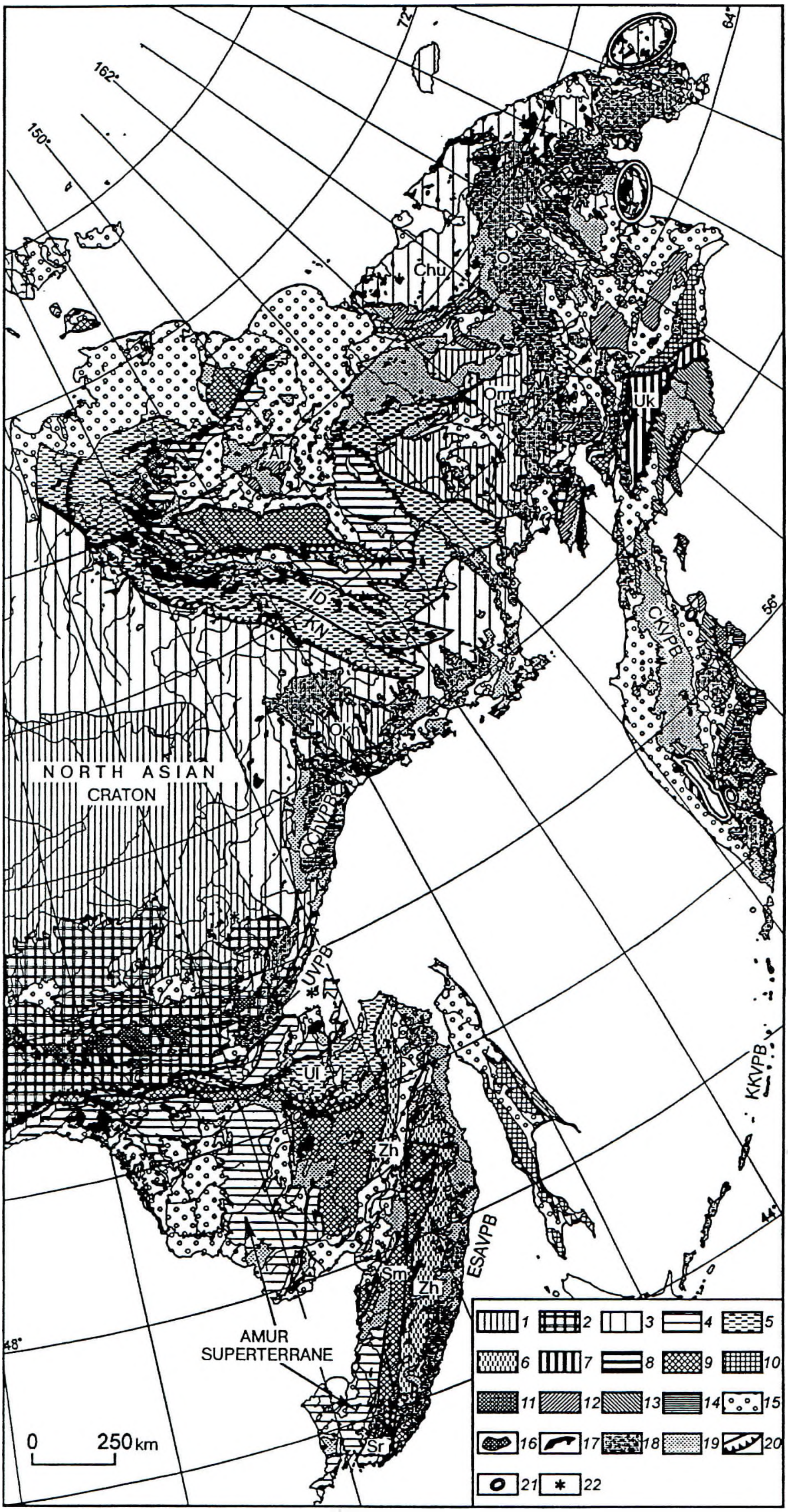
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Fig. 1. The main Meso-Cenozoic tectonic units of the Russian Far East territory. *1* — platform part of the North Asian craton, Okhotsk and Omolon craton terranes; *2* — Archean and Proterozoic granite-metamorphic complexes of the craton and craton terranes; *3* — Late Paleozoic-Early Mesozoic passive continental margins of the North Asian trough and Chukchi terrane; *4* — pre-Mesozoic continental terranes; *5–8* — turbidite and shale terranes of sedimentary basins of the transform boundaries of continental lithospheric plates: *5* — Jurassic, *6* — Early Cretaceous, *7* — Paleocene-Eocene, *8* — Neogene; *9–11* — terranes of accretionary prisms of subduction boundaries of continental lithospheric plates: *9* — Jurassic and Early Cretaceous, *10* — Late Cretaceous, *11* — Oligocene-Miocene; *12–14* — island-arc terranes (accretionary prisms and volcanic arcs, undifferentiated): *12* — Jurassic and Cretaceous, *13* — Late Cretaceous, *14* — Paleogene; *15* — Meso-Cenozoic sedimentary depressions; *16, 17* — synshift granitoids of transform boundaries of lithospheric plates and microplates: *16* — Jurassic, *17* — Early Cretaceous (partially including the beginning of the Late Cretaceous); *18* — Meso-Cenozoic subduction volcanoplutonic belts; *19* — Meso-Cenozoic volcanoplutonic belts of transform continental margins (of Californian type); *20* — faults; *21* — complexes of metamorphic cores (of Cordilleran type); *22* — dunite-clinopyroxene zonal massifs. Terranes: Al — Alazei, Zh — Zhuravlevsky; ID — In'yali-Debin, KN — Kular-Nera, Om — Omolon, Okh — Okhotsk, Sm — Samarkin, Sr — Sergeevsky; Uk — Ukelayat, Ul — Ul'ban, Chu — Chukchi. Volcanoplutonic belts (VPB): ESA — East Sikhote-Alin', KK — Kurile-Kamchatkan, OCh — Okhotsk-Chukchi, U — Uda, CK — Central Kamchatkan.

with the continental margin. In the Eocene, complexes of Cordilleran-type metamorphic cores formed in the Central Kamchatkan and Ganal terranes. A Neogene-Quaternary "slab window" formed beneath Kamchatka after the subduction boundary had changed by the transform one, marked by the Neogene turbidites of the Tyushev trough.

Earlier, the volcanic complexes of the recognized Meso-Cenozoic transform continental margins of the Far East were already proposed to be qualified taphrogenic (synshift) or within-plate rather than subduction features. The previously amagmatic areas are characterized by basalts with within-plate parameters. When the development of transform margins was preceded by subduction (Late Cretaceous Okhotsk-Chukchi and East Sikhote-Alin' active margins), the composition of basalts varied in time from calc-alkalic (high-alumina) to within-plate (Cenozoic basalts of the OChVPB and ESAVPB). The absence of Nb minimum on their spidergrams distinguishes them drastically from the suprasubductional basalts. The rocks typomorphous for transform margins are high-alumina basalts, which are characterized by high contents of alkalies, especially potassium, and of the majority of incompatible elements (Rb, Sr, Ba, Zr, Th, and U) as well as by high K/Na, Ni/Co, LREE/HREE, and LILE/HFSE but low K/Rb ratios. The high-Mg composition of low-Ca pyroxenes is evidence of higher crystallization temperatures, whereas high Ti/V, Ba/La, Nb/La, and $^{87}Sr/^{86}Sr$ at a relatively low $^{143}Nd/^{144}Nd$ suggest a different composition of a magmatic source as compared with typically subductional basalts. The within-plate basalts of the Meso-Cenozoic transform boundaries of the Far-East plates are enriched in the so-called subductional components and are characterized by relatively high contents of alumina and large-ion lithophile elements (Rb, Ba, and Sr) and, in some cases, are depleted in HFSE (Ta and Nb). In addition, they are connected, through numerous transitions, with high-alumina magmas of the initial stage of volcanism on the transform margin [14, 15].

In general, the Meso-Cenozoic transform continental margins of the Far East are characterized by antidromous volcanism. Large-volume deposits of rhyolites often make up the basement of the structures of pull-apart and are usually associated with blocks of the pre-Mesozoic continental crust. Subordinate amounts of acid volcanic rocks are present in bimodal series. Both large-volume acid volcanic rocks and acid volcanic rocks of basalt-containing units of the transform margins under consideration show signs of basic (plume) origin.

GOLD MINERALIZATION: TYPES AND GEODYNAMIC SETTING

Because under various geodynamic settings the rock complexes were disturbed in different ways and to a varying degree, the geological structural conditions of gold deposition are quite diverse. The direction and steps of origin, interaction, and destruction of geotectonic units of varying hierarchy, determined the polychronous character of the Meso-Cenozoic gold ore genesis. The observed resulting linear-nodal motif of spatial arrangement of more than two hundred gold deposits shown in Figs. 2 and 3, in general, seems to correspond to the location of tectonic megazones permeable for fluid flows, with subsequent magmatism,

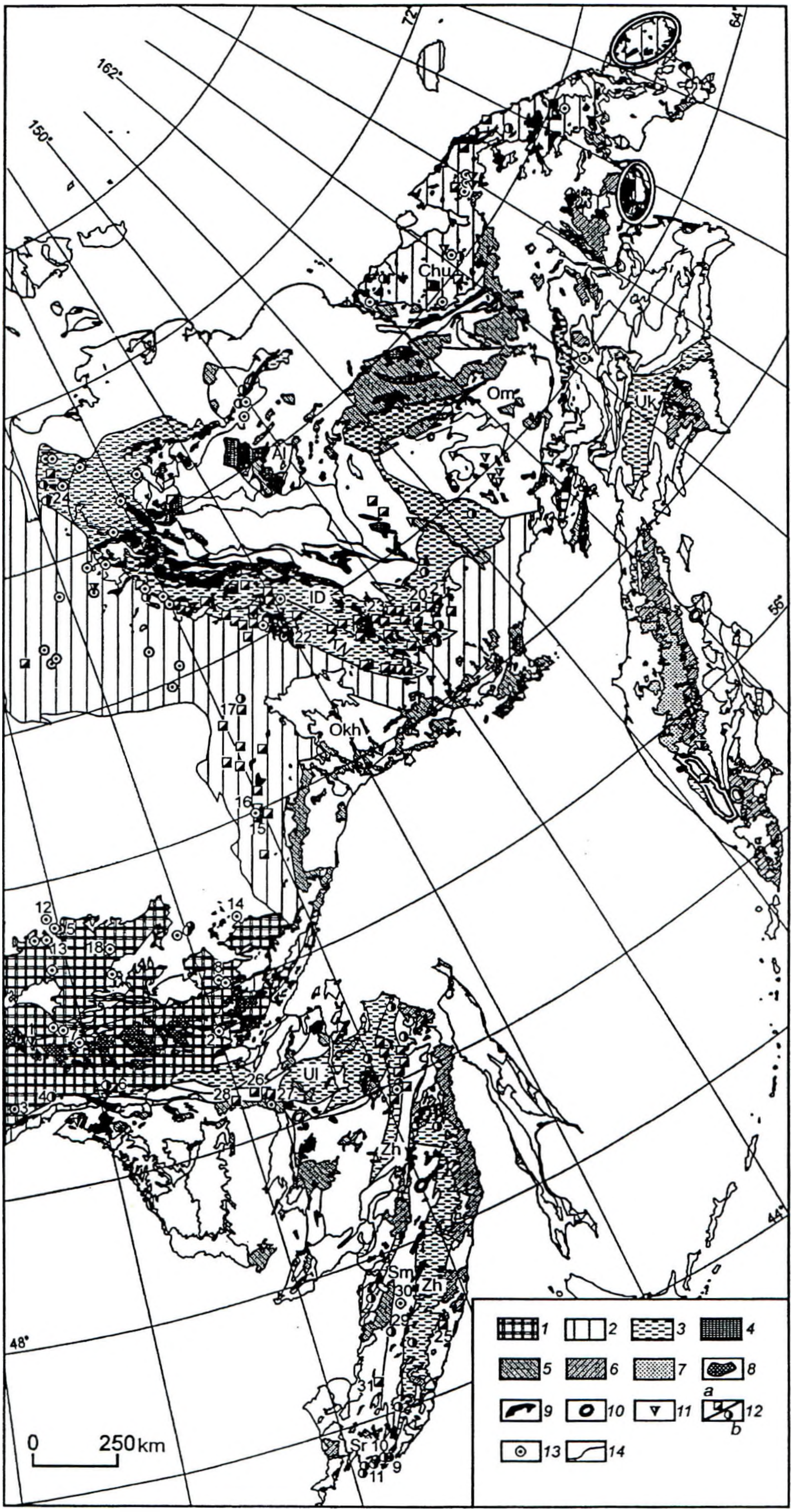
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Fig. 2. Geodynamic complexes of transform boundaries of lithospheric plates and Meso-Cenozoic gold-ore deposits. ***1*** **— Archean and Proterozoic granite-metamorphic complexes of the North-Asian craton and cratonic terranes;** ***2*** **— Late Paleozoic-Early Mesozoic passive continental margins of the North-Asian craton and Chukchi terrane;** ***3*** **— turbidite and shale terranes of sedimentary basins of transform boundaries of continental lithospheric plates;** ***4–7*** **— synshift volcanoplutonic series:** ***4*** **— Jurassic,** ***5*** **— Early-Late Cretaceous,** ***6*** **— Paleogene-Neogene,** ***7*** **— Pliocene-Early Quaternary;** ***8, 9*** **— synshift granitoids of transform boundaries of lithospheric plates and microplates:** ***8*** **— Jurassic,** ***9*** **— Early Cretaceous (partially including the beginning of the Late Cretaceous);** ***10*** **— complexes of metamorphic cores (of Cordilleran type);** ***11–14*** **— gold-ore deposits mentioned in the text:** ***11*** **— gold-silver,** ***12*** **— gold-(sulfide)-quartz (*****a*****) and granitoid-associating gold-(rare metal)-quartz (*****b*****),** ***13*** **— the rest;** ***14*** **— boundaries of terranes. Deposits: 1 — Bamskoe, 2 — Kolchedannyi Utes, 3 — Berezitovoe, 4 — Kirovskoe, 5 — Lunnoe, 6 — Zolotaya Gora, 7 — Uspenskoe, 8 — Kholodnikan, 9 — Porozhistoe, 10 — Smutnoe, 11 — Progress, 12 — Kuranakh, 13 — Lebedinoe, 14 — Konder, 15 — Duet, 16 — Yur, 17 — Nezhdaninskoe, 18 — Maiskoe, 19 — Dorozhnoe, 20 — Utinskoe, 21 — Srednekanskoe, 22 — Ergelyakh, 23 — Busugun'ya, 24 — Kyuchus, 25 — Glukhoe, 26 — Tokur, 27 — Kharga, 28 — Malomyr, 29 — Nezametnenskoe, 30 — Kornevoe, 31 — Otkosnaya Ploshchad'.**

metamorphism, etc. caused by different agencies. Accumulation of gold on this heterogeneous territory accompanied a wide range of geologic processes; for this reason, the diversity of genetic models for Meso-Cenozoic auriferous systems is so evident. They correspond to several types of mineralization. The leading formational groups of deposits are gold-(sulfide, rare-metal)-quartz and gold-sulfide (including "black-shale"), which are typical of the Early-Middle Cretaceous, and gold-silver, specific for the Late Cretaceous-Quaternary.

The majority of the deposits mentioned below are described by researchers of Far Eastern and Moscow geological institutions, whose material we use to generalize specific characteristics of locations of gold mineralization with regard to low-rank geodynamic settings. These are craton terranes and platform nappe, terranes of passive margins of cratons, turbidite basins, and accretionary prisms, as well as overlying volcanogenic and sedimentary complexes.

GOLD MINERALIZATION IN GEODYNAMICALLY HETEROGENEOUS COMPLEXES OF TERRANES

Gold mineralization, chronologically distant from the formation of rock complexes of cratonic structures, was related to processes of tectonomagmatic activity triggered by the development of global transform margins.

The terranes of the basement of the North Asian craton on the Aldan-Stanovoy Shield (see Fig. 2) contain deposits of numerous gold-ore-placer clusters, including platiniferous ones. The observed diversity of mineralization is due to the complicated cosubordination of processes of the Late Jurassic-Early Cretaceous transform margin, which proceeded during multiple pulses of activity of the marginal part of the craton in the form of movement of domal blocks and powerful magmatism (belt of Early Mesozoic batholiths of calc-alkalic granitoids etc.). The Mesozoic gold mineralization is localized in metamorphic and ultrametamorphic rocks (Bamskoe, Kolchedannyi Utes*), apometamorphic rocks (regional and local diaphthorites in the upper-Timton, Sutam, and other districts), pre-Paleozoic granitoids (Berezitovoe) and ultramafic rocks, near or inside the massifs of Mesozoic granitoids (Kirovskoe), as well as in younger rocks. The quartz-veined hydrothermalites are in places rich in carbonates and feldspars (Lunnoe, Zolotaya Gora). The gold content of sulfides is responsible for the productivity of some accumulations, including those among diaphthorites. Being enriched in sulfides, some deposits (Kolchedannyi Utes, Uspenskoe) belong to the gold-polymetal type with specific metasomatites (Berezitovoe). In addition, there are gold-rare metal-quartz (Kirovskoe, Kholodnikan), gold-silver sulfide-depleted (Bamskoe), Au-Cu-Mo, and other types of mineralization. Of interest are the areas with joint Au and Pt specialization and coexisting auriferous IGE deposits.

In the southern Primorsky Territory, an example of gold mineralization in old crystalline rocks is a large block of the so-called "Sergeev gabbroids". In these metamorphosed and migmatized para- and orthorocks, the Early Cretaceous gold-quartz occurrences (Porozhistoe, Smutnoe, Progress, etc.) tend to zones of synshift tectonites and hybride gneissous rocks of diorite-granodiorite-granite composition.

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* Hereafter the parenthesized names belong to deposits (see also Figs. 2 and 3).

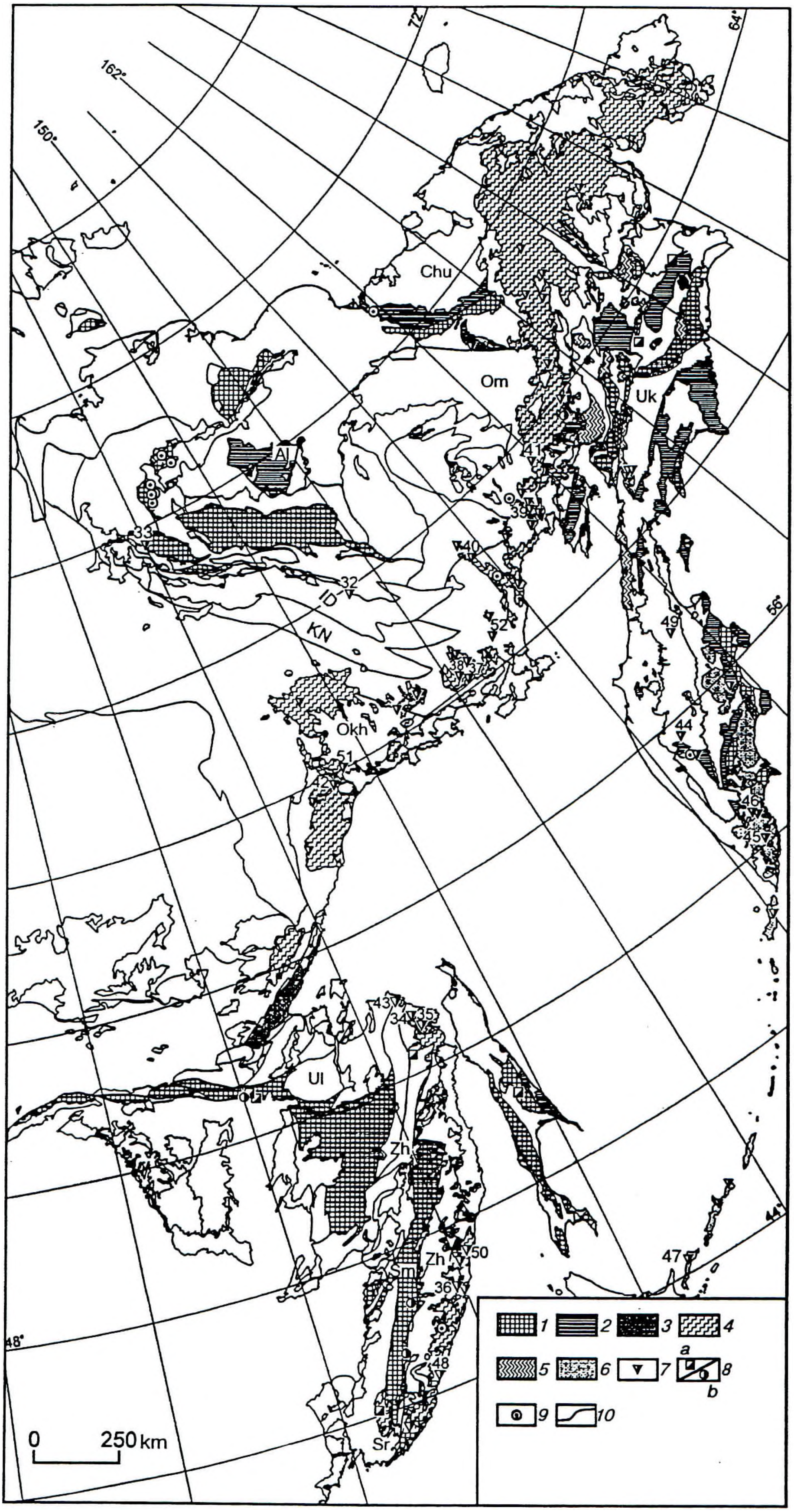
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Fig. 3. Geodynamic complexes of subduction boundaries of lithospheric plates and Meso-Cenozoic gold-ore deposits. *1* **— terranes of accretionary prisms of subduction boundaries of continental lithospheric plates and microplates;** *2* **— island-arc terranes (accretionary prisms and volcanic arcs, undifferentiated);** *3–6* **— subduction volcanoplutonic belts:** *3* **— Jurassic,** *4* **— Late Cretaceous,** *5* **— Late Eocene-Oligocene,** *6* **— Neogene-Quaternary;** *7–10 — gold-ore deposits mentioned in the text*: *7* **— gold-silver,** *8* **— gold-(sulfide)-quartz (*a*) and granitoid-associating gold-(rare metal)-quartz (*b*),** *9* **— the rest;** *10* **— terrane boundaries. Deposits: 32 — Urul'tun, 33 — Kysylga, 34 — Belaya Gora, 35 — Bukhtyanskoe, 36 — Salyut, 37 — Karamken, 38 — Utesnoe, 39 — Evenskoe, 40 — Dukat, 41 — Kegali, 42 — Yur'evskoe, 43 — Mnogovershinnoe, 44 — Aginskoe, 45 — Asachinskoe, 46 — Rodnikovoe, 47 — Prasolovskoe, 48 — Maiskoe-Dal'negorskoe, 49 — Ozernovskoe, 50 — Yagodka, 51 — Khakandzha, 52 — Nyavlenga.**

In the platform cover of the southeastern margin of the Siberian Platform, gold mineralization "traces" different links of a giant chain of magmatic provinces of multistage Jurassic-Cretaceous volcanoplutonic activity. Magmatites formed under variable tectonic regime of transform continental margin. The multiformational nature of subalkalic and alkali-earth granitoids is due to the great number of chambers existing at different depths. Ore genesis was expressed in different parts of these large domal uplifts. Noble metallization shows several types specifically related to different facies of subalkalic and alkaline magmatites. The Kuranakh and Lebedinsky types of gold deposits with elements of lithological and stratified control became classical.

As the natural alloys of Au, Ag, Cu, Pd, and Pt consist of many components, the Au-Cu-PGE load of alkaline-ultrabasic complexes (Konder) is also quite peculiar.

The passive margin of the craton is characterized by gold-ore accumulations in some ore districts that occur among the Paleozoic and Mesozoic sedimentoliths. A remarkable pattern is created by multistory inter- and substratal quartz veins conformal to folds of carbon measures (Duet, Yur, etc.). This kind of gold-(sulfide)-quartz mineralization is categorized as metamorphogenic-hydrothermal and even as sedimentary-thermal. Mineralization also occurs in steep (large Nezhdaninskoe Au-Ag deposit) and fault-accompanying gentle zones of shattering. There are also gold-rare metal-quartz ores associated with granitoids.

Of the gold-ore accumulations in the rock complexes of the passive margin of the Chukchi terrane, noteworthy is the Maiskoe deposit, which serves as a standard large accumulation of large-volume gold-sulfide disseminated-veined mineralization in black-shale rocks.

The turbidite terranes of paleotransform boundaries of plates typically contain many mesothermal deposits, producing rich gold placers. Thus, diverse examples of deposits (Dorozhnoe, Utinskoe, Srednekanskoe, etc.) of the Yana-Kolyma folded zone, where large-scale granitoid magmatism was expressed in the Early Cretaceous, are well known for the Triassic-Jurassic turbidites. The general linearity of development of the Early-Middle Cretaceous deposits follows chiefly the repeated large dislocations (including strike-slip faults), which governed the arrangement of multiphase plutons and small intrusions. The mineralization is chiefly gold-(sulfide, carbonate)-quartz and, more rarely, gold-rare metal-quartz (Ergelyakh, Busugun'ya, etc.) with Bi and other admixtures. In certain places, the ores have a silver profile. Some gold-quartz deposits were reported to be platiniferous. Veined-disseminated gold-sulfide mineralization also occurs (large Kyuchus Hg-bearing deposit).

The terranes of Cretaceous turbidites contain deposits on the lower reaches of the Amur River (Bekchi-Ul, Kherpuchinsky, Takhtinsky, and other ore-placer clusters). Gold-sulfide-quartz veined mineralization exists among sand- and siltstones, at the exo- and endocontacts of Cretaceous dikes and stocks of diorite-andesite and granodiorite-dacite compositions.

Large-volume gold-sulfide mineralization with signs of platinum (Glukhoe) has been found in the Cretaceous dislocated carboniferous aposiltstones in the Central Sikhote-Alin'.

The accretionary prisms are characterized by localization of gold-ore deposits in diverse rock complexes in some districts of the region.

Thus, in the Mongolo-Okhotsk folded zone this is the famous Salemdzhino-Kerbinsky auriferous belt, where the gold-quartz veined mineralization gravitates toward certain levels of a section of stratified units metamorphosed to a varying degree (Tokur, Kharga, etc.) as well as toward separate features of the Chelogorskaya, Sagurskaya, Pravobureinskaya, and other domal structures and metamorphic cores. The proper gold-sulfide (arsenopyrite-pyrite) veined-disseminated type of mineralization occurs in places (Malomyr).

In the Sikhote-Alin' folded zone, the Jurassic accretionary prism contains a gold-tungsten deposit in a Cretaceous stock of granitoids (Nezametninskoe), gold-sulfide mineralization in zones of shattering (Kornevoe), and veinlet-veined poor gold-quartz mineralization in tuffaceous-terrigenous olistostrome formations (Otkosnaya Ploshchad').

EPITHERMAL GOLD-SILVER MINERALIZATION OF VOLCANOGENS

Unlike the systems considered above, the volcanogenic hydrothermal ore systems are usually characterized by a paragenetic relationship of mineralization and magmatism. The intricate mutual relations of tectonic and magmatic structure-forming agencies of varying scale account for diverse variants of volcanotectonic and volcanoplutonic hierarchically subordinate models.

The subduction continent-marginal and island-arc VPB are characterized by a wide development of classical epithermal mineralization of gold-silver formational group. Many Au-Ag accumulations of the OChVPB are in association with middle-stage rocks, magmatites of trachydacite-trachyrhyolite-alaskite formation, which belong to independent volcanic formations and their comagmates. According to Ar-Ar dating [16, 17], the formation of numerous Au-Ag deposits (Karamken, Utesnoe, Evenskoe, Dukat, Kegali, etc.) extensively proceeded throughout the belt like a Campanian pulse within a chronological range of ore events (85–70 Ma BP) extended from Santonian (Yur'evskoe) to Maastrichtian. The final Danian episode of postaccretionary mineralization (Mnogovershinnoe) is typical of somewhat younger ESAVPB. This temporal approachment of spatially separated (for thousands of kilometers) ore deposits where gold accumulation crowns the subduction stage of the formation of volcanogens is indicative of a leading role of deep-level processes in the evolution of metaliferous volcanotectonic structures.

To continue the eastward rejuvenation of margin-continental and island-arc VPB, the gold-silver mineralization followed the successive origination of volcanic belts of the Kurile-Kamchatkan region (Late Miocene Aginskoe, Pliocene-Pleistocene Asachinskoe and Rodnikovoe, and Pleistocene Prasolovskoe). It is remarkable that the Kamchatkan "young" mineralization in volcanic structures coexist with modern hydrothermal systems.

Of critical importance in localization and structuring of metaliferous hydrothermal systems in magmatogenic-tectonic buildings were disjunctions of varying nature, centers of eruptive phenomena, injective magmatic bodies, etc. The mineralization is known to be governed by dikes (Maiskoe-Dal'negorskoe, Ozernovskoe, etc.), to be localized in intrusions (Yagodka), and to occur partially in the roof of granitoid massifs (Prasolovskoe).

The gold-silver ores are characterized by a great species diversity of minerals and scarcity of their finely disseminated separations. The dominating mineral is quartz, which is responsible for the variety of structural and textural patterns of veinlet-veined formations. Occasionally, rhythmically banded veins contain monomineral layers of calcite (Rodnikovoe, Prasolovskoe, etc.). Rhodochrosite and Mn-calcite have been found at the deposits of different types (Khakandzha, Mnogovershinnoe, and Dukat). Where the carbonate-bearing ores have experienced "intrusion" of late intrusive phases of granitoids, skarnoid mineral parageneses occur (Mnogovershinnoe, Nyavlenga, and Dukat).

The main mineral types of the ores are gold-argentite, gold-sulfosalt, gold-selenide-sulfosalt, gold, gold-telluride, and telluride. The telluric branch of mineralization coincides with the gold and silver-gold types of mineralization, whereas the selenic branch coincides with the gold-silver and silver types. The former branch is associated with normal-basic, femic, magmatites and the latter, with rocks of moderately acid, sialic, nature [11].

Volcanogens of Mesozoic **transform geodynamic settings** (Fig. 3) are (gold) silver mineralization of the Uyandino-Yasachny VPB (Urul'tun) with antimony, arsenic, bismuth-telluric, and fluorine mineralization. In this belt, Au-Ag mineralization occurs among the Jurassic terrigenous sediments (Kysylga). The Au-Ag ores that formed in the Cenozoic volcanogens against the background of transform geodynamic regime are associated with their contrasting basalt-rhyolite series of the final stages of the VPB formation. For example, these are compact Au-Ag deposits of the northern (Belaya Gora and Bukhtyanskoe) and central (Salyut) parts of the ESAVPB. Their ores having a radiological age of 38.2–44.4 Ma are of simple composition and belong to gold-argentite and gold-argentite-sulfantimonite types.

CONCLUSIONS

Using new data, we have demonstrated a peculiar character of Meso-Cenozoic geodynamic settings reflecting the interaction of lithospheric plates. The formation of many volcanoplutonic belts with Au-Ag mineralization was linked with subduction, and the transform interaction of plates was responsible for a very intricate complex of phenomena of tectonomagmatic activity of continental margins and collision of terranes, which was accompanied by the development of many formational types of deposits. When such a vast territory of long-term and complicated geodynamic and metallogenic history is to be described, a discussion is inevitable, but due to space constraints, we could not comprehensively reflect the new materials on this circle of problems to make some questions less debatable.

A discussion of the geodynamics of formation of higher-rank metallotect structures is the next step in developing deterministic models for auriferous systems of corresponding rank and organization.

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