Geodynamic Development of Eurasian Active Margin at Pre-collision Subduction and at Post-collision Closing of Tethys Ocean

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Abstract: Geodynamic development of Eurasian Active Margin is related to Phanerozoic collision and closure of Tethys Ocean coincided with northvergent movement and stressing of Afro-Arabian continent at the Eurasian margin. The collision coincided with subduction oceanic Slab under margin of continent at pre-collision stage revealed in formation of island arc, inter-arc backarc and minor ocean settings at pre-collision stage. After closure of ocean the subduction is terminated and pre-collision stage transferred in post-collision and orogenesis, caused by stressing Afro-Arabian continent at the Eurasian. Character of subduction determined the settings of pre-collision stage. The island arc setting is related with steady state subduction, interarc-backarc and minor ocean settings are controlled by steepening of subducting slab which caused invasion of mantle diapir extension and spreading the crust revealed in rifting in interarc-backarc and intensive spreading in minor ocean setting, whereas at island arc setting the mantle invasion and spreading did not occur. So, scale of mantle material participation in various settings determined character of volcanism and tectonics. The island arcs are characterized by calc-alkaline rhyo-dacite-andesite-basalt volcanism blocking tectonics, revealed in island uplifting and gold-base metal mineralization. The interarc-backarc settings revealed in tholeiite-olivine basaltic volcanism, rifting and Zn-Cu mineralization the minor ocean setting controlled by ophiolite volcanism ultimatic dunite-peridotite-magmatism and the most intensive spreading of lithosphere and copper-pyrite mineralization confirmed by volcano-petrogenic, metallogenic and tectonic indications and geochemical cryteria. Therefore, type of volcanism, magmatism and mineralization at precollision development are controlled by scale and influence of crustal-mantle participation. The post-collision stage of geodynamic development also is characterized by various scales of crustal mantle influence. Our studied region consists of pre- and post-collision stages, located in Iran, Caucasus, Turkey and Balcan-Carpathian is part of the Eurasian active margin. At post-collision, as at pre-collision stages the volcanic-magmatic activity, tectonics and mineralization are depended on the crustial-mantle scale of influence and are controlled by volcano-petrogenic, metallogenic, as well as, tectonical and geochemical indicators.

Key words: Geodynamic, pre-collision, post-collision, indicators.

1. Introduction

Studied region occurs in the Western segment of Eurasian active margin in Iran, Caucasus, Turkey and Carpath-Balkans. In the late proteozoic collision of Tethys Ocean was beginning and Oceanic slab was subducting under Eurasian Active Margin which coincided with northvergent movement of Afro-Arabian continent, associated with movement terranes teared away from passive margin [1].

The geological and geodynamic development in studied region of Active Margin at pre-collision stage was determined by subduction of oceanic slab, represented by steady state subduction and steepening of subducted slab and invasion of mantle diapir into lithosphere of active margin. Steady state subduction is related with the island arc setting, whereas the steepening subducting slab (roll back, break off, detachment and delamination) and invasion of mantle material is characterized to interarc-backarc and minor ocean settings. All of them are characterized by volcano-petrogenic, metallogenic, tectonical indicators
and geochemical criteria depending on the scale of crustal-mantle influence confirmed by data in our studied region. The data are exemplified in the Journal of Environmental Science and Engineering [1-3] and in the book published by Lambert Academic Publishing Germany [4]. The post-collision development after termination of subduction, at orogenic stage of Eurasian Active Margin, also depends on the scale of crustal-mantle participation revealed by geological and geochemical indicators. The first stage of post-collision geodynamic activity is characterized by hot flows penetrated in thick orogenic crust from mantle, smelting grono-dioritic magma and leaching trace metals (Sb, W, Mo, Hg) which we supposed as geochemical criteria of the initial stage of post-collision development, so as metallogenic indicators here are gold, antimonate, wolframite and mercury mineralization.

In this paper we are trying to show the distinct examples of volcanogenic, petrogenic, metallogenic and tectonic indicators of our studied region and temporal and spacial development of pre- and post-collision activity, as engineering revealed in study search-prospecting of deposits in pre- and post-collision settings.

2. Material

2.1 Pre-collision Stage of Geodynamic Development

Pre-collision development of the studied region began in Paleozoic and continued till terminated subduction in Oligo-Miocene. From Pleistocene, post-collision development began continuing in Quaternary.

Volcanic arc setting is exemplified in Bolnisi ore district (Georgia). Here are located Cretaceous Au, Pb, Zn, Cu porphyry, vein and lode deposits: Madneuli, Tsiteli Sopeli, Kvemo Bolnisi, Catarkaia and David Gareji in Turonian-Senonian Mashavera suite and Sakdrisi, Imedi, Darbazi, Bektakari and Bneli Khevi in the Campanian Gasardami Suite (Fig. 1) [1].

The ore-bearing rocks of these suites consist of calc-alkaline rhyo-dacite and andesite volcanics (Muavera suite) and trachy-ryhodacite subalkaly (Casadami suite). Both of them are characterized by ignimbrite explosions and caldrone subsidence. The origins of the island arc setting of the Bolnisi Mining district were related with invasion of the granodiorite intrusives uplifting the island, which later transformed in volcanic chambers, exploring ignimbrites caused caldrone subsidence. The uplifting islands by intrusive envision and caldera ore block-tectonic indication in island arc settings [1, 2]. The calc-alkaline volcanism is volcanogenic indicator and Au, Ag, Pb, Zn, Cu pyrite mineralization is metallogenic indicator. It is known that the Au-Ag and Pb formed by Precambrian crust concentrated in sialic crust, Zn and Cu in basaltic, whereas in mantle zest only Cu. The island arc settings are related to steady state subduction. The slab here was deepening in a mantle, so here in formation participate all above mentioned metals Au, Pb, Zn an Cu of the island arc settings, confirmed by geochemical criteria of the island arc volcanism of Bolnisi which are $^{87}\text{Sr}/^{86}\text{Sr} = 0.705-0.715$ and $^{208}\text{Pb}/^{204}\text{Pb} = 39$, $^{149}\text{Nd}/^{144}\text{Nd} = 0.5119$.

Interarc-backarc settings exemplified by rifting and olivine-basalt-tholeite volcanism and Cu, Zn mineralization occur in Hudes group deposit (Hudes, Urup, Daud) of Forrange of North Caucasus [5]. Their genesis may be explained by envision of mantle diapir that caused rifting from zone of volcanism and mineralization and represents the backarc setting. The metallogenic indicators here are Cu and Zn mineralization leaching from basaltic crust and mantle, with a lack of Au and Pb. Tectonic indicator here is extension and rifting. The source of Zn in basaltic crust, the source of Cu mantle diapir caused the extention and rifting. The geochemical criteria of the setting here $^{87}\text{Sr}/^{86}\text{Sr} = 0.7036$.

The minor ocean setting in the studied region is paleozoic Küre Complex (Turkey), which consists of ophiolite volcanics and dunite-peridotite intrusions, gabbro, pillowlava cut by diabase dikes. Their oceanic
Fig. 1 Lithostratigraphic column of the Bolnisi ore district.

nature is confirmed by geochemistry of immobile elements and copper-pyrite mineralization, and a lack of Zn and Pb mineralization in associated deposite Ashikoy and Pakibaba [6]. The intensive spreading spread out of zone of volcanism and mineralization as sialic, so basaltic crusts sourced of Au, Pb, Zn and mineralization consist of only Cu, whose source here is only mantle. So, metallogenic, volcanogenic and petrogenic indicators here are ophiolites, serpentization and dunite peridotite intrusive bodies. The tectonic indication is extension and spreading, metallogenic is only Cu, sialic and basaltic crust here are spreaded out from zone of volcanism and mineralization. The geochemical criteria of minor ocean of Küre Complex is $^{87}\text{Sr}/^{84}\text{Sr} = 0.7024$.

Pre-collision development is controlled by subduction process temporally and spatially.

Temporally geodynamic settings alternated in the Caucasus from Paleozoic to Eocene (Fig. 2). In the Caucasus (Ajara-Trialety zone) with the known ascending succession alteration the calc-alkaline islands are Cretaceous setting upstream transferred in Middle Eocene interarc tholeites overlain by Upper Eocene andesite and subalkaly sienite-diorite setting [1].

The alteration depends on envision of the mantle diapir and spatially volcanic arc setting synchronously altered in interarc setting or by minor ocean. Somewhere along dippening of subduction the Paleozoic island arc alter by Mezozoic back-arc setting (Fig. 3).

Somewhere laterally the subduction is not characterized by temporal alteration. It is exemplified in Adjara-Trialety zone (Georgia), here Eocene tholeites of interarc setting to west transere in Eocene minor ocean of Black Sea and to East in Eocene island arc andesite (Fig. 3). So, Bulgarian Cretaceous Burgas interarc rift transferred in Cretaceous Black Sea minor ocean [7] as well as in Eocene Talish back arc rift of in Azerbaijan transferred in Caspian sea minor ocean [8].

The pre-collision temporal alternation of geodynamic development of the studied region is presented on the idealized scheme (Fig. 4).

### 2.2 Post-collision Stage of Geodynamic Development

The post-collision development settings are exemplified in Iran, Caucasus, Southern Turkey and Carpath [3, 4]. Everywhere it is related to Oligo-Miocene granodiorite stocks at the orogenic stage. Here the distinct example of post-collision setting is the Zophkito deposit in the Southern Slope of Caucasus (Georgia). Its mineralization is represented by gold-copper base metals and quartz-antimonate lode ores in Lower Jurassic schists, cut by Oligo-Miocene granodiorite stocks. Other significant deposit is Lukhumi with gold-arsenoryorite-antimonite-mineralization, controlled by shear zones disposed in Upper Liassic schists and limestones, where quartz-antimonite-realgar-orpment and quartz-sheelite stockworks occur. All deposits and orewall rocks are characterized by trace metals Sb, W, Mo and Hg association geochemical indication of post-collision setting. The similar situation occurs in other post-collision setting in the world: Australia, Canada, etc. The greatest post-collision gold deposits are located in the Altaid orogeny-Tianshan (Uzbekistan). Here are the known Paleozoic post-collision groups of deposits: Murutau, Cholboy, Zarmitan. The most significant is Murutau (175 m.oz Au). All of them associate with trace metals (Sb, W, Mo, Hg), the geochemical indicator of post-collision setting. The deposits are located in Eastern segment of Eurasian Active Margin. The post-collision setting of west segment of the Eurasian active margin its initial stage is dated by Oligo-Miocene and continued in second stage from Plioce till Quartenary. So post-collision development of Eurasian Active Margin in its Western Segment is Oligocene-Quartenary, whereas its Eastern Segment is Late Paleozoic.

The second stage of post-collisional development depended on reinforcement of stressing Afro-Arabian continent on Eurasian margin reasoned fold-thurst activity in orogenic lithosphere, the mantle material was penetrated in deep volcanic chambers, provoked shoshonite, olivine and tholeite volcanic activity [9].
Fig. 2  Pre- and post-collision development and metallogeny exemplified in the Caucasus region.

1—subducted slab, 2—basaltic crust, 3—sialic crust, 4—calc-alkaline volcanic series, 5—shoshonite series, 6—tholeite and alkali olivine basalt series, 7—VMS mineralization, 8—granodiorite porphyry, 9—fold-trust zone, 10—faults. BS—Black Sea, CS—Caspian Sea, GC—Great Caucasus, SSC—Southern Slope of Caucasus, TC—Transcaucasus, AT—Achara-Trialety, LS—Lesser Caucasus, EP—East Pontides, BSMO—Black Sea Minor Ocean, T—Talysh. Pre-collision mineralization: ◊—Au, Pb, Cu, Zn; ○—Pb, Zn; □—Zn, Cu; Post-collision mineralization: ☆—Au, Cu, Zn, Pb associated Sb, W, Mo, Hg, Mo, Cu and Au.
Fig. 3 Schematic map reflects the E-W lateral geodynamic transformation of subducted slab above IAES suture, showing the character of the Eocene volcanic series in the East Pontides and Lesser Caucasus.

Fig. 4  Idealized scheme of interrelation of volcanism and mineralization at various stages of subduction of the Tethys ocean slab.

characterized by geochemical criteria of pre-collision volcanism [10]. There was no occurrence of rifting, spreading and mineralization characterized for pre-collision interarc-backarc volcanism.

The volcanism of post-collision as well as pre-collision depends on scale of crustal-mantle influence. At the initial stage it is characterized only by activity of hot flows penetrating from mantle and on second stage with participation of mantle material in volcanic chamber.

3. Results and Discussion

The results are based not only on material presented in this paper, but in my paper published earlier in the Journal of Environmental Science and Engineering in 2018, 2019, 2020 years [1-3]. Geodynamic development of Eurasian active margin is related to collision and closure of the Tethys ocean is related to northvergent movement of Afro-Arabian continent towards Eurasian margin. The collision of the Ocean at pre-collision stage that depended on subduction of ocean coincided with termination of the subduction and transferring pre-collision development to post-collision. The process of subduction revealed in two stages: the steady state subduction and steepening of subducting slab. The steady state subduction occurs in dipping of subducting slab into mantle without steepening and encursion of mantle diapir is related to island arc setting. It is characterized by calc-alkaline volcanic activity explosion of rhyodacites, andesited and basalts. The volcanic activity at this stage presents ignimbrite explosion and caldrone subsidens on islands uplifted in sea during invasion of and collapsing caneras revealed as blocking tectonic. The intrusion of grano-diorite magma and calc-alkaline volcanic activity is petrovolcanogenic indicator of island arc setting and uplifted and collapsed blocks as tectonic indication. The volcanic arc in the Eurasian active margin revealed in Au, Pb, Zn, Cu mineralization. The precious metals and Pb sourced from sialic crust, Zn and Cu from basaltic and only Cu from mantle.

The steepening of oceanic slab during subduction determined mantle incursion at interarc-backarc settings. Volcanism in this setting consists of trachybasalts, olivine basalts and tholeiites. Envisaged mantle material is the reason of alternation content of volcanic activity. Diapir incursion reasoned the extention crust, rifting and spread out from some of volcanism and mineralization sialic crust and process controlled by basaltic crust and mantle. So, here indication of volcanism is trachyandesites subalkaly basalts, alkaly olivine basalts and tholeiites. The tectonic indicator is extension and rifting. The indicator of mineralization is Zn, Cu-pyrite deposits, lack of precious metals Au, Ag and Pb. The further steepening of subducting slab at the most intensive and highest invasion of mantle diapir revealed in minor ocean formation in Eurasian active margin. This is characterized by ophiolite volcanism and dunite-peridotite intrusions as volcano-petrogenic indicators of minor ocean setting and copper-pyrite mineralization. The intensive extraction here spread out the sialic and basaltic crust from zone of minor ocean. So, only mantle is the source of Cu. The most intensive extension and spreading is the tectonic indicator of oceanic setting.

4. Conclusion

The pre-collision geodynamic development in Eurasian active margin is controlled temporally and spacially along dipping of subduction slab, so spacially to dipping. In our studied region along dipping volcanic arc setting temporally alternates with interarc-backarc setting. At the same time laterally to dipping the alternation occurred only sinchronnal, it is exemplified by alteration of Black Sea Eocene minor ocean, transferred to Eocene interarc and volcanic arc setting consist calc-alkaline volcanic suite. So, Eocene Talish backarc rift to East transferred in Caspian Sea minor ocean setting (Fig. 4) as well as Cretaceous
minor ocean of Black Sea to West transferred in Burgas interarc rift.

Temporal and spacial alternation of geodynamic settings in studied region depended on character of subduction process. The steady state subduction occurred without distructuring the slab and invasion of mantle diapir, forming volcanic arc setting, whereas steepening of subductive slab was determined by evasion of mantle diapir in interarc-backarc and minor ocean settings of Eurasian active margin. So, alternation of geodynamic settings was controlled by scale of crustal-mantle participation and influence. Mantle participation and its influence are arisen from island arc to interarc-backarc and minor ocean setting.

At the post-collision development, where subduction is terminated scale of crustal-mantle influence controlled by stressing Afro-Arabian and Eurasian continents, it caused the distracion thick orogenic lithosphere by faults and thursts. At initial stage the hot flows penetrated from mantle revealed in smelting granodiorite magma from thick sialic crust and leaching arc preecons and base and rare metals and association of trace metals (Sb, W, Mo, Hg). This association world widely spread wide in post-collision settings. Analyzing geological data of post-collision settings at Eurasian active margin, I proposed the mentioned trace metal association as the geochemical indicators of post-collision settings. The next second stage of post-collision development, when mantle material is penetrated in deep volcanic chambers and post-collision volcanism is presented by subalkaly and alkalyl basalts and tholeiites characterized by geochemical cryeria of precollision stage, never consists of above mentioned trace metal association. Here is not established any mineral deposits and spreading. Post-collision development characterized by arising of mantle influenced from second stage to initial. At initial stage mantle influence occurs only in hot flows penetrated from mantle to sialic crust, where in high pressure the flows smelting granodiorite magma and leaching pressous and base and rare metals and association of trace metals (Sb, W, Mo, Hg) spread wide in initial stage ores, as well in orewall rocks and in orebearing rocks at post-collision settings. Therefore, in post-collision setting, pre-collision geodynamic development depended on scale of crustal-mantle influence.

Geodynamic development and volcanogenic mineralization and tectonic indication of pre-collision settings of the studied region showed the perspective for search prospecting deposit of various settings. The block tectonic of island arc setting determined searching lode and porphyry deposits of gold-base metals, the interarc-backarc settings with extension of sialic crust and rifting controlled by stratiform Zn-Cu-pyrite mineralization of deposits, where the copper-pyrite deposits would search in minor ocean settings. Post-collision stage controlled the gold, gold-base metals and rare metals deposits-realgar, orpiment and mercury lode and porphyry mineralization and there were many significant gold deposits of Murtan group in Tian-Shan range. All of post-collision deposits coincide with trace metals association, which are the searching indication of post-collision mineralization.

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References


