Conclusions

There are two intraplate magmatic stages being determined in northern Vietnam, including Paleozoic -Mesozoic (mainly Permian – Triassic) and Cenozoic (mostly Paleogene). The magmas are distinguishable in terms of coexisting mineral assemblages, chemical compositions, geodynamic settings and mineralization processes.

The early stage may be related to Emeishan super-plume, to which the Permian – Triassic magmatic activities in northern Viet Nam may be viewed as southwestern and southeastern margins of the Emeishan large igneous province, having been extruded southeasterly along the Ailao Shan – Red River shear zone in the Cenozoic. This period is characterized by wide occurrence of mafic – ultramafic and felsic magmas including the wide presence of picritic magma (high-Ti komatiite and picrite in the Song Da rift zone and low-Ti picrite in the Song Hien belt). Geochemical and isotopic characteristics of the Permian – Triassic mafic and ultramafic magmas suggest their parental melts were generated from a highly heterogeneous lithospheric mantle. And that the low-Ti, high-Mg magma associations in the Song Da rift zone were derived from a depleted sub-oceanic-like lithospheric mantle, while the high-Ti magma series were generated in a sub-continental-like lithospheric mantle above a subduction- associated mantle wedge.

The redetermination of formation age of Permian – Triassic for felsic volcano – intrusive magmas in the Tu Le basin and Phan Si Pang uplift block suggests that the magma occurrence was related to geodynamic activities of the Song Da rifting, on the one hand, and the continental nature of the rifting activities, on the other. Therefore, the geological history of northwest Viet Nam in particular and northern Viet Nam in general has been rewritten to become closer to what happened. It may suggest that the previously determined separate structures such as Song Da rift and Tu Le basin were basically belonged to an actual continental rift system developed in marginal zones of the Yangtze craton. The presence of picrites in the Song Hien structure similar to those in the Shizong – Mile belt in southeastern margin of the craton indicates that Permian – Triassic magmatism in the Song Hien belt occurred synchronously with a rifting activity in cratonic marginal areas.

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The above-subduction mantle geochemical characteristics observed in Song Hien volcano-plutonic magma associations are not in conflict with intraplate nature of the magmatism; in contrast, they suggest the nature of above-subduction lithospheric mantle under southern margin of the Yangtze craton in late Paleozoic – early Mesozoic. The Song Hien volcano-plutonic magmatic melts reflect mantle – crust interaction, showing the difference between these and other Emeishan mantle plume-related magmas in other geological structures in northern Viet Nam, on the one hand, and provide new evidence, more reliable in explaining the nature of tectonic settings with regard to Permian – Triassic mafic – ultramafic and felsic magmas in nearby Phu Ngu – Lo Gam structure.

The Cenozoic magmatic activities were associated with India – Eurasian collision. Detailed studies show that Eocene – Oligocene volcano-plutonic mafic and felsic magmatism in northern Vietnam were produced as a result of mantle upwelling melting under the impact of geodynamic activities of the Indochina and Vietnam – China blocks following India – Eurasian collision. Meanwhile potassic and ultra-potassic alkaline mafic and felsic magmas along the border between Song Da rift and Phan Si Pang uplift are viewed as products related to intraplate extension occurred prior to the extrusion of Indochina block along the Red River shear zone. This is a regional tectonic event that occurred in entire collision-effected zone and extended further to the east of Asian continent. The mantle-derived magmas also include syn-extrusion mafic and ultramafic intrusions in the Red River zone, showing features different from those of deep mantle origin, which are explained by the fact that they were produced in a high-pressure and temperature metamorphic belt.

Review of mineralization activities during the Permian – Triassic and Cenozoic stages in northern Vietnam shows the following results:

1. The Permian – Triassic ore formations are classified and their temporally forming order was established. These serve as basics for division of regional mineralized ore types for Permian – Triassic period, where the Song Da – Song Hien mineralized belt is most detailedly reported. Besides, the Au-sulfur and Sn-sulfur ore sites have been systematized with regard to the magma – ore systems
2. For the first time, comparison of magma – ore formation age has been conducted; also the wide development of various Au-mineralization types was determined, including the determination of highly potential ore types (Au-As, Au-Sb-Hg, Au-Cu) related to magma – ore systems which appear to be highly ore-productive in the Permian – Triassic period.
3. Confirmation has been made on highly potential Cu-Ni-PGM and Ti-V mineralization in Permian – Triassic mafic and ultramafic magmas in the Song Da, Song Hien and Lo Gam – Phu Ngu ore belts along with newly determined Au-mineralized ore, especially the non-conventional such as Au-Sb-Hg type that is related to Permian – Triassic magmatism. Given such criteria northern Viet Nam may be considered as a new ore province having high potential of this mineralization type in southeast Asia.

4. The fact that Permian – Triassic magmatism in rifting structures northern Viet Nam was influenced by a mantle plume there is a high possibility that Ni-Co-As and Cu-(Mo)-Au ore mineralization may occur, especially in Ta Khoa and Suoi Cun- type intrusive magmas.
5. Magma generation modeling for gabbro – peridotite intrusions in the Phu Ngu – Lo Gam belt has provided evidence on contemporaneous Cu-Ni-PGM ores in the differentiated magmas and Ti-Fe-V mineralized products in pegmatoidic series in the magmatic intrusions. Besides the modeling also provides reasonable fact for expanding investigation of Ti-V ore mineralization in satellite gabbroic bodies of Nui Chua-type magmas.
6. The prospect of Cu-(Mo)-Au and Cu-Au ore mineralization along with new porphyry- type ore may be expected to discover in Permian – Triassic felsic volcanic (rhyolite) and sub-volcanic silicic (granite porphyry) magmas in the Song Hien structure and trachy-rhyolite – granosyenite in the Tu Le zone, and in trachyte and syenite porphyry as well as in Paleogene alkaline mafic magmas in the border between Song Da and Phan Si Pang structures.

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