Preface

The study of intraplate magmatism with the aim to reconstruct geodynamic settings and estimate related endogenic mineralization has significant scientific and practical meanings. These allow to consider the role of deep mantle and mantle – lithosphere interaction processes in the formation of large-scaled intraplate rift systems, collision and shear zones, and their associated magma – ore formations having high potentials of gold, gold-copper, precious platinum group metal (PGM), rare earth and radioactive metals (REE–U–Th), and gemstones (ruby, sapphire, etc.).

The clearest expression of intraplate magmatism is mantle plume-induced large igneous provinces (LIP) in Asia during the Permian–Triassic (Dobresov 1997; Nikishin et al. 2002). The mantle plume-related magmatic activities were widely developed in the Asian continent in rift and trap environments forming the Siberian craton and Emeishan LIP, which have been well studied. However, intraplate magmatic activities during the period of Permian–Triassic in Viet Nam have not been detailedly studied with focus on their identification and role in southeastern Asian geodynamic evolution as a whole, as well as their associated mineralization.

This monograph is a combined report of petrological and metallogenic studies of late Paleozoic–early Mesozoic and Cenozoic magmatism in northern Viet Nam in the past several decades by the authors through collaboration between the Institute of Geological Sciences, Vietnam Academy of Science and Technology, and the Institute of Geology and Mineralogy, Siberian Branch of the Russian Academy of Sciences, on magma–metallogeny. Two intraplate magmatic–metallogenic stages in northern Vietnam are being introduced in this monograph; these were associated with two important tectonic events in the evolution of the southeastern Asian continent including Emeishan-type mantle plume during ca. 260–250 Ma and India-Eurasian collision ca. 60–55 Ma.

The Emeishan mantle plume-related impact produced magmas which occurred in wide areas in western and southern margins of the Yangtze craton (China) forming a series of mafic–ultramafic and felsic along with alkaline felsic associations in the craton's peripheral terrains (e.g., Cathaysian multi-cycle folded belt) including the northeastern terrain of Vietnam. Depending on particular structurally geological

positions within the then-northern Viet Nam regional structure – tectonic framework and the geochemistry according to the lithospheric mantle source – the mantle dynamics and nature of mantle–lithosphere interaction of the Permian–Triassic magmatism formed a number of chemically diversified magmatic–metallogenic associations in northern Viet Nam. Among the ore minerals, clearly high potential associations include Cu–Ni–PGM, Ti–Fe–V, Cu–Au, Sn–Pb–Zn–Ag, Sb–Hg–(Au), and others that occurred in industry-rated ore fields that are being exploited to serve the nation's needs. Among the Permian–Triassic magmatic formations, this monograph will focus only on volcano-plutonic mafic–ultramafic and felsic magmas in the Song Da–Song Hien rift zone and Song Chay anticlinoria. With the new understanding of mantle plume and its role in generating mantle and lithospheric mantle magmatic melts, the Permian–Triassic volcano-plutonic mafic–ultramafic–felsic and alkaline mafic–felsic associations and accompanying metallogeny in northern Viet Nam may be explained by the impact of the Emeishan mantle plume on the lithospheric mantle under different lithospheric structures in southwestern and southern margins of the Yangtze craton. This is the first time that genetic relation between the magmatism and mineralization has been proven using geochemical and isotopic data.

The India-Eurasian collision in the Cenozoic is considered as the major force that changed the form in the southeast Asian tectonic map, forming intercontinental shear zones such as the Ailao Shan–Red River. Along both sides of the shear zone, there are a series of intraplate extended belts containing typical Mediterranean-type mafic and felsic magmatic associations and their accompanying ore mineralization of Cu–Au, Cu–Mo–Au porphyry, REE–Th–U, and others, starting from Tibet to Vietnam. This is also the first time that the formation of Cenozoic magma–metallogenic associations is associated with the evolution of the shear zone.

The monograph contains nine chapters included in three parts: Part I introduces general regional geological structures in northern Viet Nam; Part II is about Permian–Triassic magmatic–metallogenic associations; and Part III dedicates to Cenozoic (Paleogene) magmatic ore mineralization formations, corresponding to the abovementioned geological events. Each chapter describes geological features, principles of dividing magmatic associations in different structures, and compositional characteristics, including geochemical, mineralogical, isotopic, and chronologic compositions analyzed using the latest analyzing methods in world well-known laboratories. In explaining formation conditions of magmatic ore associations and related geodynamic settings, the authors have employed with selection the concept of plate tectonics and plume-related kinematics from the world's most recent geological literature. Many of the research results being introduced in this monograph have been reported in international and domestic reputed journals, as well as appeared in a number of master's and doctorate theses. Besides, the monograph also contains newly achieved results that have not been reported elsewhere.

Materials being introduced in this monograph may be useful for both domestic and international geologists in exploring the history of geological and metallogenic evolution in Vietnam as an important marginal region of the Asian continent. One of the most practical contributions offered by the monograph is providing new criteria on prediction and potential evaluation of magmatic metallogenesis,

directly helping in exploring and finding new and valuable mineral resources for national use. The introduced monograph is useful for science and technology projects and may be used as university teaching materials in the field of petrology and metallogeny.

After the first monograph entitled *Permian–Triassic mafic and ultramafic magmatic formations in Northern Vietnam* published in 1996 in the occasion of the 20th Anniversary of the Institute of Geological Sciences, Vietnam Academy of Science and Technology (1976–1996), this monograph is the second being introduced as a result of a 25-year Vietnam–Russia research collaboration (1984–2009).

During the preparation of the monograph, the authors have constantly received support from the leaders of Vietnam Academy of Science and Technology (VAST), Institute of Geological Sciences (IGS), and Science and Technology Publishing House. Discussions with and suggestions by colleagues helped improve the contents of the monograph. Contributors from the Magma Department (IGS), direct or indirect, include Drs. Hoang Huu Thanh, Vu Van Van, Bui An Nien, Tran Quoc Hung, Phan Luu Anh, and other researchers including Tran Viet Anh, Hoang Viet Hang, and Tran Hong Lam; international colleagues from the Russian Institute of Geology and Mineralogy (Siberian Branch, Russian Academy of Science) include Petrov V.G., Petrova T.I., Ponomarchuc V.A., Gaskov I.V., Shelepaev R., Telesev A.E., and many others. Many of the geochemical and isotopic data being introduced here were analyzed at the National Taiwan University and Institute of Earth Sciences, Academia Sinica (Taiwan) thank to Drs. Chung S-L., Lo C-H., and Lan C.Y.

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Last, regardless of our best effort, there must be shortcomings in the monograph's preparation and edition, the authors kindly appeal to readers for suggestions in order to improve the quality of the monograph.

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