Editorial

Editorial for the Special Issue: Experimental and Thermodynamic Modeling of Ore-Forming Processes in Magmatic and Hydrothermal Systems

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A number of excellent books and articles on the ore-forming processes, magmatic and hydrothermal systems, physicochemical conditions of the ore-forming fluids, and thermodynamic modeling in the geosciences have been published over the past 50 years [1–13]. Fundamental knowledge about ore-forming processes has practical applications for mineral exploration.

Experimental investigations and thermodynamic modeling have been successfully used to solve many problems, in which ore-forming processes play an important role. The experimental study of simple systems with precisely controlled parameters provides the data necessary for obtaining reliable thermodynamic characteristics of minerals, aqueous species (ions, complex ions, and molecules), gas mixtures, and solid solutions. The main obstacles to the experiments are the multicomponent, multiphase and multiaggregate features of natural systems and the inevitability of their simplification. Thermodynamic modeling can be an alternative to complex model experiments. To construct quantitative genetic models of ore-forming processes, computer thermodynamic modeling on the basis of modern program complexes is used [14–18]. The reconstruction of the sources of ore components and fluids, physicochemical parameters, and the mechanisms of accumulation and separation of elements during the formation of ore deposits is an important task in addressing the fundamental problems of ore-forming processes. Some of the papers in this issue deal with experimental and thermodynamic modeling [19–25], while the others are devoted to the analytical geochemistry, geochronology, and genesis of some ore occurrences [26–28].

In the article by Zotov and coauthors [19], the solubility of gold was measured in HCl/NaCl fluids (NaCl concentration varied from 0.1 to 3 m) at 450 °C and pressures from 500 to 1500 bar. The obtained data for the stability constant of the $AuCl_2^-$ complex, together with values from the literature for temperatures from 25 to 1000 °C, were fitted to the simple equation of $\log Ks°$. Fluid chlorinity, together with acidity and redox state, controls the concentration of many ore metals, which can migrate in the fluid phase in the form of chloride complexes. The speciation of gold in natural chloride-bearing fluids is discussed. The results of the study are important to the understanding of the formation process of hydrothermal gold deposits.

Tauson and coauthors [20] investigated the partitioning of precious metals (Au, Pt, and Pd) in the system of a "mineral–hydrothermal solution", where the minerals were pyrite, As–pyrite, magnetite, Mn–magnetite, and hematite and the fluids were ammonium chloride-based hydrothermal solutions at 450 and 500 °C and 100 MPa pressure. These authors study the cocrystallization (exchange) coefficients (D_e) of rare earth elements (Ce, Eu, Er, and Yb) and Fe in magnetite and hematite at 450 °C and 100 MPa. Trace element partitioning in the "mineral–hydrothermal solution" system was

studied by the method of thermogradient crystal growth coupled with the internal sampling of a fluid phase. The analytical procedure used enables the evaluation of structurally bound and superficially bound modes of trace elements in crystals and the determination of corresponding dual partition coefficients. The obtained experimental results assume that the distribution of precious metals and rare earth elements is largely dependent on the composition of the superficial nonautonomous phases, which affects geochemical regularities.

Bataleva and coauthors [21] report the results of the experimental modelling of interactions of Mg, Fe, and Ni–olivine with anhydrite and Mg–sulfate, which are possible sources of oxidized S-rich fluid under lithospheric mantle P–T parameters. An experimental study was performed in the olivine–$CaSO_4$($MgSO_4$)–C systems at 6.3 GPa and temperatures of 1050 and 1450 °C using a multianvil high-pressure apparatus. Calcium and magnesium sulfates, being the most abundant sulfur-bearing minerals in the Earth's crust, are expected to play a principal role in the recycling of oxidized forms of sulfur into the deep mantle under subduction settings. It was experimentally shown that olivine–sulfate interaction can result in mantle sulfide formation and the generation of potential mantle metasomatic agents: S- and CO_2-dominated fluids and silicate–oxide or carbonate–silicate melts.

Murzin and coauthors [22] present a physicochemical model for the formation of magnetite–chlorite–carbonate rocks with copper–gold in the Karabash ultramafic massif (Southern Urals, Russia). This massif is located within a belt of ultramafic massifs stretching along the Main Ural fault zone in the Southern Urals. It was constructed based on the geotectonics of the Karabash ultramafic massif; features of the spatial distribution of metasomatically altered rocks, their geochemical characteristics, and mineral composition; data on the P–T parameters; and composition of the ore-forming fluids. This model included a four-reservoir calculation scheme. Thermodynamic modeling was performed using the Selektor-C software that employs the Gibbs energy minimization method, including minerals, aqueous solution components, and gases in the Na–K–Mg–Ca–Al–Si–Ti–Mn–Fe–Cu–Ag–Au–Hg–S–P–Cl–C–H–O system. The thermodynamic properties of various compounds were calculated using the Selektor-C database. The rocks (serpentinites, gabbro, harzburgite and limestones); deep magmatogenic fluids, mixed with metamorphogenic fluids released during the dehydration and deserpentinization of rocks in the lower crust; and meteoric waters were considered as the possible sources of the petrogenic and ore components in the model. It supports the involvement of sodium chloride–carbon dioxide fluids extracting ore components (Au, Ag, and Cu) from deep-seated rocks and is characterized by the ratio of ore elements corresponding to Clarke values in ultramafic rocks. The model calculations show that copper–gold can also be deposited during the serpentinization of deep-seated olivine-rich rocks and ore fluids risen by the tectonic flow to a higher hypsometric level. These results predict the copper–gold-rich ore occurrences in other ultramafic massifs.

Krneta and coauthors [23] investigated the REE fractionation in apatites from the Olympic Dam iron oxide–copper–gold deposit (South Australia) with the aim of constraining fluid evolution. The concentrations of trace elements and their variation within hydrothermal minerals can provide valuable information on the fluid parameters and conditions of ore deposition for assemblages. The behavior of the REE in hydrothermal fluids is affected by parameters such as pH, temperature, salinity, redox conditions, and fluid composition, thus allowing the REE to be used as a geochemical tracer in hydrothermal systems.

The REE signatures of three unique types of apatite from hydrothermal assemblages crystallized under partially constrained conditions were numerically modeled, and the partitioning coefficients between the apatite and fluid were calculated. Article by Krneta et al. [23] adds important information to the current knowledge on REE fractionation in apatites.

The article by Testa and coauthors [24] tried to resolve the evolution of hydrothermal fluids responsible for complex Bi–Cu–Pb–Zn–Mo–As–Fe–Ag–Au mineralization in the San Francisco de los Andes breccia-hosted deposit (Frontal Cordillera, Argentina). The authors provide well-documented insights into the complex mineralogy and mineral microtextures of the hydrothermal precipitates and reconstruct the physiochemical conditions of the ore-forming processes (temperature, fO_2, fS_2, fTe_2,

and pH). They suggest that the mineralization formed due to the magmatic contribution of Te to the hydrothermal system. This study presents an interesting problem of genetic and (in part) practical importance related to the Bi and Te ores.

Sirqueira and coauthors [25] studied the genesis and evolution of Paleoproterozoic Sn and rare metal albitites in the Goiás Tin Province (central Brazil). Albitites are uncommon rocks with typically more than 70–80% of albite. Most of the known albitites worldwide have their origin attributed to the action of hydrothermal fluids on granites. More rarely, albitites are formed by direct crystallization from Na-rich magmas, generally related to specialized and rare-metal granites. Geological, petrological, and isotopic data from albitites and spatially associated granites were integrated to constrain the evolution history of the albitites. This study also intends to contribute to the petrogenesis and metallogenesis of evolved granitic systems rich in rare metals. These results extend the possibilities of a tin source in the Goiás Tin Province. They have implications for the province's economic potential and help understand the solubility and tin concentration in peraluminous granitic systems which are highly evolved and very rich in sodium.

Cao and coauthors [26] investigated the genesis and geochronology of the Xitian W–Sn polymetallic ore field (Hunan Province, South China). Analytical and calculated data obtained during the study of hydrothermal zircon U–Pb and muscovite $^{40}Ar/^{39}Ar$ dating allowed them to conclude: (1) there are two epochs of W–Sn mineralization formation: skarn-type at ca. 226 Ma and quartz vein/greisen-type at ca. 156 Ma; (2) the ore-forming fluids for the two metallogenic events are both characterized by enrichment in F and low oxygen fugacities; and (3) the ore components for the skarn-type and quartz vein/greisen-type W–Sn mineralization are both originated from a crust source. A good distinction is made between the skarn deposits, which are related to the earlier period of magmatic activity and the vein deposits, which are related to the second period of magmatic activity. This paper reports on some new geochemistry in the Xitian deposit with applications regarding the timing of mineralization and metal sources.

Yang and coauthors [27] studied the geochronology, petrology, and genesis of two small-sized granitic plutons (Laiziling and Jianfengling) of the Xianghualing Ore Field (South Hunan Province, South China). These granitic plutons have a close relationship with the super-large Xianghualing Sn deposit and large Dongshan W deposit, respectively, both in time and space. South Hunan, located in the central part of the Shi–Hang zone, is well known for its world-class W–Sn polymetallic deposits. The Shi–Hang zone, well known as the collision suture between the Yangtze Block and Cathaysia Block in the Neoproterozoic, is also an important granitic magmatic belt and polymetallic metallogenic belt.

New data of the zircon U–Pb dating, bulk-rock geochemical compositions, and zircon Lu–Hf isotopes of Laiziling and Jianfengling granites constrain the source and origin of the granitic magmas, discuss the tectonic setting, and clarify the relationship between these two plutons. Both of the Laiziling and Jianfengling granitic plutons are characterized by extremely similar elemental and Lu–Hf isotopic compositions. These features indicate that they both belong to highly fractionated A-type granites and were formed in an extensional setting and from the same magma chamber, which originated from the Paleoproterozoic metamorphic basement of South China with a certain amount of mantle-derived magma involving temperatures of ca. 730 °C and low oxygen fugacity.

Wei and coauthors [28] report the zircon U–Pb dating results of a porphyritic granite intrusion recently discovered in the Zhuanzhilian section and try to establish evidence of age and the relationship with the Au mineralization of the Dongping gold deposit (North Hebei, China). The gold deposits associated with alkaline rocks worldwide are widely distributed and have important economic value. The Dongping gold deposit, located in the middle northern part of the North China Craton, is the first giant gold deposit discovered among the alkaline complex-hosted in China in the 1980s. Mechanisms, possible sources, and tectonic environments of gold mineralization in the Dongping deposit are well discussed in this paper.

Conflicts of Interest: The author declares no conflicts of interest.

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