Kunts A.F. Hydrothermal and metasomatic ore formation in carbonate rocks (experimental models)

Geological Institute of Komi Scientific Center, Ural Branch of RAS

Hydrothermal and metasomatic mineral formation plays a significant role in formation of many industrially important ore deposits (fluorite, barite, galenite, sphalerite etc.), forming by means of replacement of some rocks by ore minerals as a result of interaction with ore-bearing hydrothermal solutions or other fluids, magmatic melts, etc. Most of such deposits is attached to stratified sequences of carbonate rocks, which are characterized by distinctly different anisotropic physico-chemical properties and contrast composition. These features explain appearance and localization of the ore-bearing formations, fluid-generating formations, lithologic and structural collectors, screening horizons, geochemical barriers of diverse types. Every complex has one or several typical formations, which determine their specifics, including a metalogenic specification. Among ore-bearing sedimentary complexes, three major groups are distinguished by lithologic composition: terrigenous, terrigenous-carbonate, and chert-carbonate-terigenous. The industrial concentrations of ore elements are localized in horizons dominated by carbonate constituent, while clays and other sedimentary lithologies serve as screens on the ways of migration of hydrothermal solutions. Carbonate ore-bearing rocks include limestones, dolomites and their transition varieties, rarely rocks of mixed composition.

Data on mineral composition of ore bodies, alteration of host rocks and study of fluid inclusions in minerals allow determination of values of major physico-chemical parameters of the formation of the main ore formations of stratified ore-deposits in carbonate rocks. Most of T and P determinations are within the intervals 200-400^{O}C (56 %) and 500-1500 atm (55 %).

According to the geological data, two major mechanisms of ore formation in carbonate rocks are distinguished: by way of formation – ores of filling and replacement; by way of mass transfer (way of transportation of the material by hydrothermal fluids) – convective (infiltration) and diffusional. In formation of industrial ore deposits, ores of replacement, forming by diffusional mass-transfer of ore components, play the major role.

Basing on the geological data, the regularities of the formation of the above ore deposits by the influence of hydrothermal solutions on carbonate rocks were experimentally studied.

In the course of the experimental modeling, the conditions of the formation of major types of the fluorite-barite-sphalerite-galenite ore deposits, related to variations of external factors (temperature, composition of hydrothermal solutions and their acidity) were identified. The regularities in changing of mineral composition in the zones of the hydrothermal and metasomatic transformation were established. The character of migration of major mineral-forming components was determined (Fig. 1).

The preferential conditions of the formation of some mineral assemblages were found: fluorite – by interaction of moderately acid fluoride solutions within the interval 150-250^{O}C; barite – acid chloride solutions with barium sulfate at 200-300^{O}C; sphalerite – acid solutions with zinc sulfide at temperatures above 200^{O}C; galenite – acid solution with lead sulfide within 200-300^{O}C, neutral – above 300^{O}C; fluorite-barite – by interaction of moderately acid fluoride solutions with barium sulfate at temperatures below 200^{O}C; fluorite-sphalerite – does not practically form; fluorite-galenite – by interaction of fluoride and especially silica-fluoride solution with lead sulfide at temperatures below 200^{O}C; sphalerite-galeniet – acid solutions with zinc and lead sulfides at temperatures above 200^{O}C, neutral – below 200^{O}C; fluorite-sphalerite-galenite – fluoride solutions with zinc and lead sulfides at temperatures >200^{O}C (maximum at 250^{O}C), by interaction of silica-fluoride solution sphalerite does not form; barite-sphalerite-galenite – acid solution with barium sulfate and zinc and lead sulfides at temperatures above 300^{O}C; fluorite-barite-sphalerite-galenite – silica-fluoride solutions with barium sulfate and zinc and lead sulfides, i.e. in assemblage with quartz, at temperatures above 200^{O}C.

Ratios of ore-forming and rock-forming components notably vary with the increase of temperature. The Pb/Zn ratio decreases from 1.14 to 0.60 with the increase of temperature from 150 to 350^{O}C. The Fe/Zn ratio decreases from 2.11 to 0.67, Fe/Pb from 1.85 to 0.72-1.13. The ratio Zn/Ba increases from 1.34 to 3.02. According to these data, there is a definite temperature zoning in fluorite-barite-sulfide hydrothermal ore deposits in carbonate rocks.

Comparison of the results of the experimental study, performed at different conditions, shows a distinct dependence of the structure of the metasomatic zoning on composition and acidity of hydrothermal fluids, temperature and a number of other factors.

The general regularity of interaction of the hydrothermal solutions with carbonate rocks is the formation of the metasomatic zoning, reflected in formation of distinct zones of different mineral and chemical composition. Internal, frontal zones are enriched in components of carbonate rocks, while outer zones are enriched in components of the solution. Changes of mineral composition occur at boundaries of the zones. These changes are expressed in the disappearance of some minerals and the formation of other phases. Some minerals are common for several zones. In all columns, one-mineral or two-mineral zones are predominant. Three-mineral and four-mineral zones are rare. A number of general regularities in formation of the experimental metasomatic columns were recognized: simultaneous formation of the zoning, definite sequence of the formation of the zones in time, deceleration of the rate of front displacement, etc. Due to different rates of diffusion, the micro-rhythmical structure of the zones, especially monomineral, is often observed.

The processes of hydrothermal and metasomatic ore formation in carbonate rocks is selective. It is conditioned by the composition of the rocks, and, consequently, differences in physical and mechanical properties of the rocks. Lime-rich varieties of carbonate rocks are more susceptible to replacement by ore minerals rather then dolomites. Intensity of ore formation is lower in the latter rocks. The

phenomenon of the multiple increase of the intensity of metasomatic transformation of carbonate rocks during their interaction with the carbon-bearing hydrotheramal solution is found.

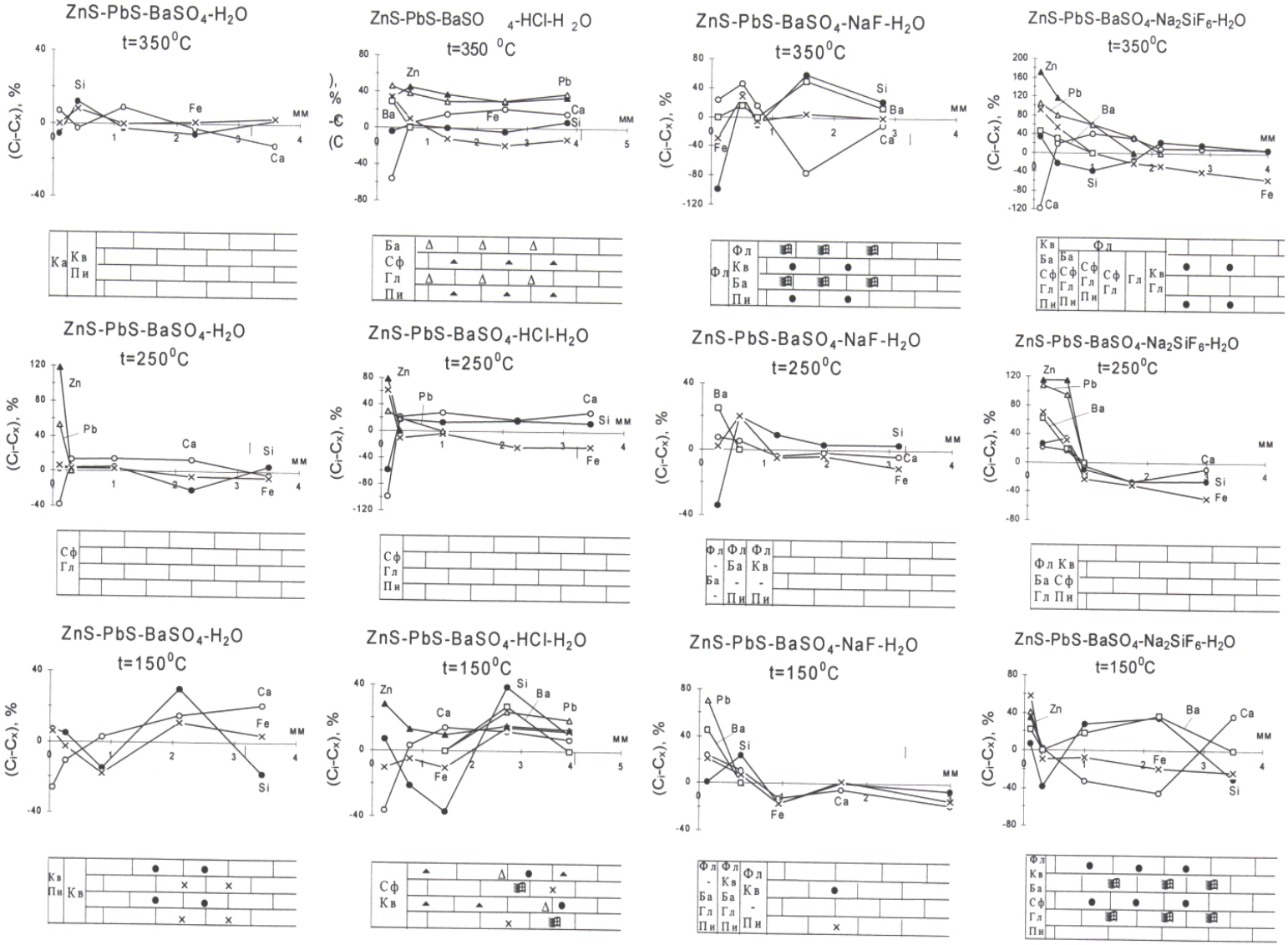

Fig. 1. Metasomatic transformations of lime-stones by influence of Zn^{2+}- Pb^{2+} -Ba^{2+}-S^{2-}—$SO4^{2-}$—bearing hydrothermal solutions.