



Liquid immiscibility significance in ore elements concentrating in magmatic processes

Значение на ликвацията за концентрацията на рудните елементи при магматичния процес

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At the present time study of process of selective concentrating of ore matter in fluid-magmatic systems continues to be relevant. According a number of experimental data magmas are concentrators of ore metals comparative equilibrium water fluids of different compositions. Data of study of maximum ore components (REE, Y, Nb, Ti, and others) solubility in silicate melt evidence about their low content which generally does not exceed first percents (depending on melt composition). Such contents are insufficient for formation of rich deposits by direct crystallization from the melt.

Liquid immiscibility allows explaining mechanism of ore matter concentrating in magmatic process from initial low content to economic concentration. In layering silicate-salt systems selective concentration of different ore elements depending on salt type has been shown. High efficiency of phosphate extraction of REE, Sr, Ti, Nb, Ta, W, and Sn, chloride extraction of W, sulphate and carbonate extraction of Sr and Ba has been experimentally evidenced (Freestone, Hamilton, 1980; Kjarsgaard, Hamilton, 1988; Veksler et al., 1998; Suk, 1997, 2001, 2003, and others).

Consideration of layering intrusions in respect of their ore-bearing leads to conclusion that poor in silica (urtite and others) horizons are most productive in respect to different types of mineral deposits – for example, in respect to apatite in Khibine alkaline massif and in respect to loparite (Ni-Nb) ores in Lovozerskiy alkaline massif.

Fluid-magmatic systems in which high concentrating salt melt separating from aluminosilicate melt can form own nonsilicate rocks (for example, carbonatites or apatite ores) exist. So, it has been investigated systems with melt separation into silicate phase and phase depleted in silica with rich content of ore elements: silicate-phosphate, silicate-carbonate and alkaline fluid

aluminosilicate systems contained Ti, REE (La, Ce), Y, Sr, and Nb.

Silicate-phosphate systems

Experiments in silicate-phosphate systems was produced at $T=1250\text{ }^{\circ}\text{C}$, $P=2\text{ kbar}$ in “dry” conditions and in presence of 10–12 wt% H_2O . Liquid immiscibility between silicate and phosphate melts has been obtained. Experiments produced in “dry” and water-bearing systems demonstrate density inversion: fluid solution in phosphate melt lead to decrease of its specific weight as compared with silicate melt, and floating-up of salt melt has been observed as a result. In “dry” systems silicate melt is more lightweight than phosphate one conversely and take place in upper part of ampoule.

Analyses of compositions of rocks and ores from Khibine massif show that apatite ores can at any rate form in two stages. Formation of apatite-bearing urtites relates to first stage. Its melts were instable and at the next stage separated into two phases. One of them was enriched in nepheline and another – in apatite. First stage has been experimental modeled in silicate-phosphate system under water pressure and second stage – in nepheline-apatite system under pressure of fluid contained water, hydrogen, carbon-bearing gases and fluorine.

Aluminosilicate systems containing ore elements

To reveal the fluid effect on the magmatic systems the experiments have been carried out at $T=1200$ and $1250\text{ }^{\circ}\text{C}$, $P=2\text{ kbar}$ without volatile components (in dry conditions) and under water or alkaline fluid pressure in the aluminosilicate systems containing Ti, REE

(La, Ce, Y), Sr and Nb. In dry systems crystallization of loparite in silicate matrix were observed. In the same systems under water (or alkaline) fluid pressure it has been obtained the immiscible splitting into two liquids: aluminosilicate one, which formed matrix, and droplets, enriched in Ti, REE (La, Ce, Y), Sr and Nb mixed with silicate component.

Due to arising of this titanate-silicate liquid immiscibility magmatic melt essential has enriched of ore elements which can has determinative significance for formation of rich REE-Nb (loparite) deposits at magmatic stage. So, experimental results obtained have grate significant for explanation of genesis of REE-Nb (loparite) deposits.

Silicate-carbonate systems

Experimental study of the silicate-carbonate systems was produced at T=900, 1100 and 1250 °C and P=2 kbar. Liquid immiscibility between silicate and carbonate melts has been obtained. Our experimental study reveals the dependence of the character of rare earth elements partitioning on the temperature. At T=1250 °C and P=2 kbar REE concentrate in silicate melt. At T=1100 °C and P=2 kbar the character of their distribution depends on the initial composition of the system.

Dependence of partition coefficients of REE ($K = C_{\text{carb}}^{\text{REE}} / C_{\text{sil}}^{\text{REE}}$) on compositions of silicate melt coexisting with carbonate melt and correlating with initial composition of the system has been revealed. At 1100 °C it has been observed the magnification of K_{REE} ($K = C_{\text{carb}}^{\text{REE}} / C_{\text{sil}}^{\text{REE}}$) with increase of (Al+Si)/(Na+K+Ca) and decrease of Ca/(Na+K) and Ca/(Si+Al) relations in silicate melt. K_{REE} of light rare earth elements becomes more than 1 at Ca/(Na+K) < 0.5 and Ca/(Si+Al) < 0.25.

The heterogeneities of obtained carbonate liquids showed in the separation of carbonate phase into alka-

line (mainly, sodic) and calc-alkaline (mainly, calcic) fractions is observed. Thereby it is observed REE predominant concentration in the calcium-rich fractions of carbonate phases as compared with Na ones which do not content REE.

So, silicate-carbonate liquid immiscibility and alkaline-calcareous splitting of carbonate melts contribute to REE concentration in carbonatite melt and formation of carbonatite deposits of REE in connection with alkalic (agpaitic) magmatism.

Conclusion

Experimental results obtained in different fluid-magmatic systems evidence about important role of liquid immiscibility in ore matter concentrating at magmatic stage as a result of which ore deposits and mineralization of different types can form. These data allow considering liquid immiscibility as effective mechanism of concentrating of ore elements in magmatic systems.

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