ABOUT EXTENT OF ANATEXIS IN GRANITE AT EQUAL THERMODYNAMIC AFFINITIES FOR REACTIONS OF MELTING

G.T. Ostapenko *(IMag NASU),* **G.G. Pavlov, V.F. Grinchenko** *(Geological Department, KNU)*,
B.M. Mitsyuk *(IMag NASU)*
ostap@imag.kiev.ua; fax (044) 424-10-20; phone (044) 424-12-66

Key words: *anatexis, kinetics*

In addition to the study carried out previously [1], intensity of anatexis in granite was investigated into at different temperatures and water pressures under conditions of approximately equal values of thermodynamic affinity (A) for melting of granite (A=–ΔG, ΔG – Gibbs free energy for the reaction of melting). To a first approximation, the reaction can be represented by an equation based on the melt composition at cotectic minimum in the non-calcium system: $NaAlSi_3O_8$ + $KAlSi_3O_8 + SiO_2 + H_2O$, at 690-790°C and 500-3000 bar water pressure [2]. According to the obtained data, an albite (Ab): potassic feldspar (Kfs): quarts (Q) wt ratio equals 36.8: 26.4 : 36.8, and water content varies 2.9 to 8.5 wt %. Melting of 100 g granite block can be represented by the following equation (in moles):

$$0.14\,Ab + 0.09\,Kfs + 0.6\,Q + n\,H_2O = L \text{ (melt of the same composition)}, \qquad (1)$$

where n – number of water moles based on its content in the melt. Then, n = 0.16 at T = 790°C, P_{H_2O} = 0.5 kbar and 2.9 wt % H_2O; n = 0.21 at T = 740°C, P_{H_2O} = 0.8 kbar and 3.8 wt % H_2O; and n = 0,35 at T = 700°C, P_{H_2O} = 1,5 kbar and 6,0 wt % H_2O.

Taking the partial molar volumes of Ab, Kfs and Q in the melt to be essentially equal to their molar values, exceeding the molar volumes of the minerals by 10%, and, as a first approximation, the water partial molar volume ($\overline{V}_{H_2O}$) in the melt to be equal to the same in the albite glass (totaling ~11,5-12,0 cm^3/mole [3]), the following expression for thermodynamic affinity at water pressure departures (P_{H_2O}) from the equilibrium pressure ($P^*_{H_2O}$) on the cotectic line will be derived:

$$A = n[RT\ln f_{H_2O}^{P_{H_2O}} / f_{H_2O}^{P^*_{H_2O}} - \overline{V}_{H_2O}(P_{H_2O} - P^*_{H_2O})] - \Delta V_{s,пл}(P_{H_2O} - P^*_{H_2O}), \qquad (2)$$

where f – water volatility at T°K, P_{H_2O} - water pressure; $\Delta V_{s,пл}$ – change in the volume during melting of the minerals (Ab, Kfs and Q). For calculations, the following values were taken: $\overline{V}_{H_2O}$=12.0 cm^3/mole; $RT\ln f_{H_2O}^{P_{H_2O}}$ – from a table in the paper [4]; $\Delta V_{s,пл}$ = +3.8cm^3 and the above-mentioned values for the n, which equal 0.16, 0.21 and 0.35. Using the equation (2), it was found that if A = 628-669 J (150- 160 cal), then the departures of water pressure from equilibrium ($P_{H_2O} - P^*_{H_2O}$) at 790°C, 740°C and 700°C will equal, respectfully, 0.5, 0.9 and 1.5 kbar, and the pressure values themselves will total, correspondingly, 1.0, 1.7 and 3.0 kbar. To a first approximation, the obtained departure curve (broken line, Fig.1) parallels the cotectic minimum curve of Tuttle and Bowen (continuos line).

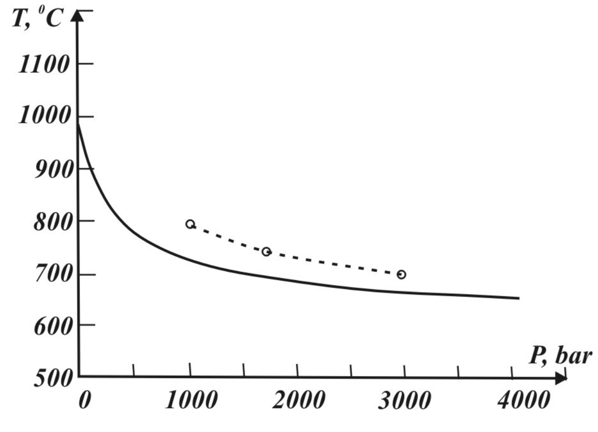
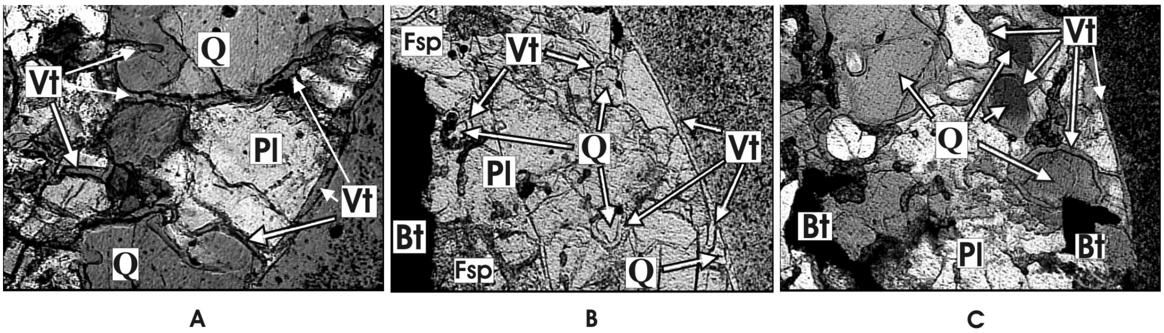


Fig. 1

Experiments with granite cylinders of 4 mm diameter and 7 - 8 mm lengths, used in paper [1], were carried out at the above temperatures and pressures. The same method, allowing to make fairly precise quantitative estimations of the anatexis intensity, was applied. Extent of anatexis development, determined via relative increment of the cylinder mass (Δm/m$_o$), appeared to equal 0.005 (at 790°C and 1.0 kbar), 0.007 (at 740°C and 1.7 kbar) and 0.010 (at 700°C and 3.0 kbar), being minor under conditions of low and almost constant reaction affinity, especially within small temperature interval of ~50°C. That was supported by thickness both of interstitial melt films close to the cylinder surface and outer melt layer (Fig. 2). In details, the results are considered in [1]. The above melt thickness equaled 10 ± 3 μm (790°C and 1.0 kbar), 13 ± 5 μm (740°C and 1.7 kbar) and 20 ± 7 μm (700°C and 3.0 kbar).

Calculations using equation (2) showed, that at 790°C, thermodynamic affinities (A) approximate 150, 201, 226 and 222 cal at pressures of 1, 1.65, 2 and 3 kbar respectfully. In this way, A values rise significantly in case of departure from the cotectic curve, increasing linearly with water pressure build up at the first phase of departure from the cotectic minimum line. Subsequently, increase in the affinity terminates due to more intense growth of the members with $\overline{V}_{H_2O}$ and $\Delta V_{s,пл}$ in the equation (2).



A B C

Fig. 2. Extent of anatexis in granite at: A) T= 700^{0}C, P_{H_2O}= 3 kbar ; B) T = 740^{0}C, P_{H_2O}= 1.7 kbar; C) T= 790^{0}C, P_{H_2O}= 1 kbar (image length – 1 mm, parallel nicols)

Other results are obtained based on the partial pressures, determined in the special paper [5]. The authors got the following data: values for $\overline{V}_{H_2O}$ equal 19.3 and 17.2 cm^3 (18.25 cm^3 on average) at 700°C, P_{H_2O} 1.5 and 3.0 kbar; 21.5 and 19.7 cm^3 (20.6 cm^3 on average) at 740°C, P_{H_2O} 0.8 and 1,7 kbar; 22.8 and 22.0 cm^3 (22.5 cm^3 on average) at 790°C, P_{H_2O} 0.5 and 1.0 kbar. Inserting average values for partial volumes of water in the equation (2), the following melting reaction affinities can be obtained: 130 cal at 790°C and 1 kbar; 100 cal at 740°C and 1.7 kbar; 57 cal at 700°C and 3 kbar. From the above results it follows that, correlation between the melting reaction affinity and anatexis extent is absent at the aforesaid pressure departures (under high pressures and low temperatures). Nevertheless, the positive values for the affinity in case of departure from the equilibrium curve point to possibility of using the A value to study the kinetics of melting, although the extra speeding up of the partial melting is obviously connected with water pressure values.

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Electronic Scientific Information Journal “Herald of the Department of Earth Sciences RAS” № 1(21)'2003
Informational Bulletin of the Annual Seminar of Experimental Mineralogy, Petrology and Geochemistry – 2003
URL: http://www.scgis.ru/russian/cp1251/h_dgggms/1-2003/informbul-1_2003/magm-35e.pdf
Published on July 15, 2003