Ostapenko G.T. , Pavlov G.G., Grinchenko V.F. Some kinetic regularities in the formation of the intergranular melt during the anatexis of granitic rocks

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key words: partial melting, anatexis, kinetics of anatexis

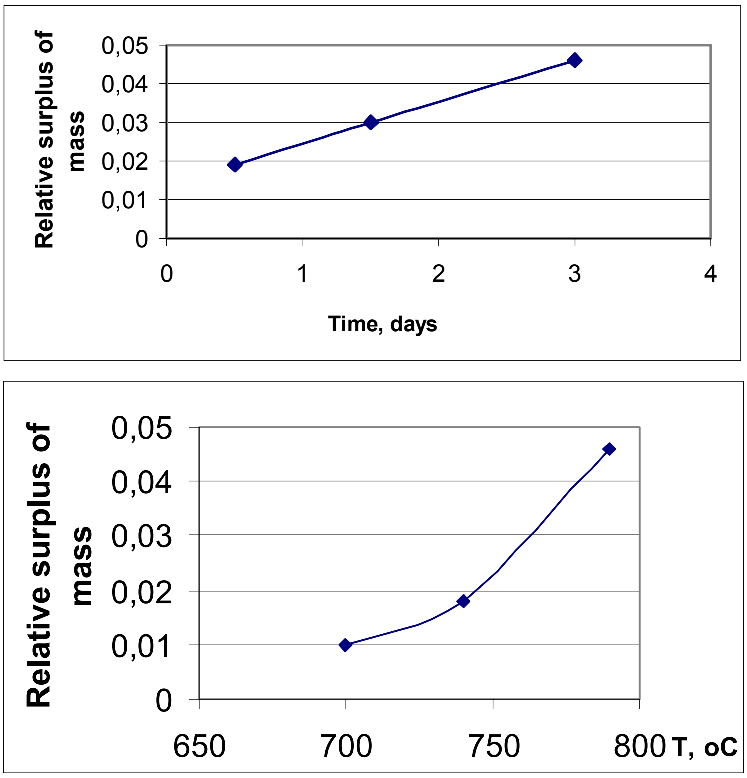
Processes of partial melting, or anatexis, of diverse rocks, including acid rocks, are a subject for the experimental study for a long time. Nevertheless, according to D. Rubie and J. Brearly [8], the kinetics of this process proceeding rapidly in non-equilibrium conditions is still not investigated properly. According to these authors, such conditions could be created in the Earth's crust and mantle, when aqueous fluid penetrates (along fractures and cracks) a "dry" metamorphic rock (which is stable under given conditions). Depending on temperature (below or above solidus), either metamorphic reactions or anatexis would effectively occur in the rock [8, 10].

Apparently, an experimental modeling of such processes is more effective using rock slabs [3-5, 8]. Such method is applied in our study. A series of experiments on the rock melting in slabs of biotite-amphibole gneiss and granite were conducted. Experiments were performed using the hydrothermal apparatus (designed in the Institute of Experimental Mineralogy, Russian Academy of Science) and the gas bomb. Cylindrical (5 mm in diameter and 8-10 mm in height) were placed into platinum capsules with some water or oxalic acid. In some hydrothermal runs, capsules were not used, and granite and quartz pieces were placed into the reactor in order to avoid dissolution of the sample. The samples were kept during 5 days at 740-900^{O}C and 1-3 kbar of water pressure. The following features were observed in the samples after the runs.

1. Melt films form at the quartz (Q) - K-feldspar and quartz (Q)-plagioclase (Pl) boundaries. Their thickness increases with temperature, water pressure and near the cylinder boundary. These results are in agreement with [3]. The minimal thickness of the films is about 0.001 mm (740^{O}C and 1 kbar), the maximal thickness is above 1 mm (at 900^{O}C).

2. The film thickness abruptly decreases in presence of the aqueous-carbonic fluid (X_{H2O}=0.5), resulting, apparently, from strong decrease of water partial pressure.

3. Surface of Pl at the contact with the melt is cogged. It can be explained by the presence of lamellae of different composition in plagioclase. Similar cogged contact of plagioclase with the melt has been observed in [4] in the experiments with biotite-hornblende-plagioclase gneiss at close PT-parameters (810^{O}C, 3 kbar, 4 days).



a)

b)

Fig.1. Dependence of the anatexis degree ($\Delta m/m_0$) on time (a, T = 790^{O}C, water pressure 3 kbar) and water pressure (b, T = 790^{O}C, time 3 days).

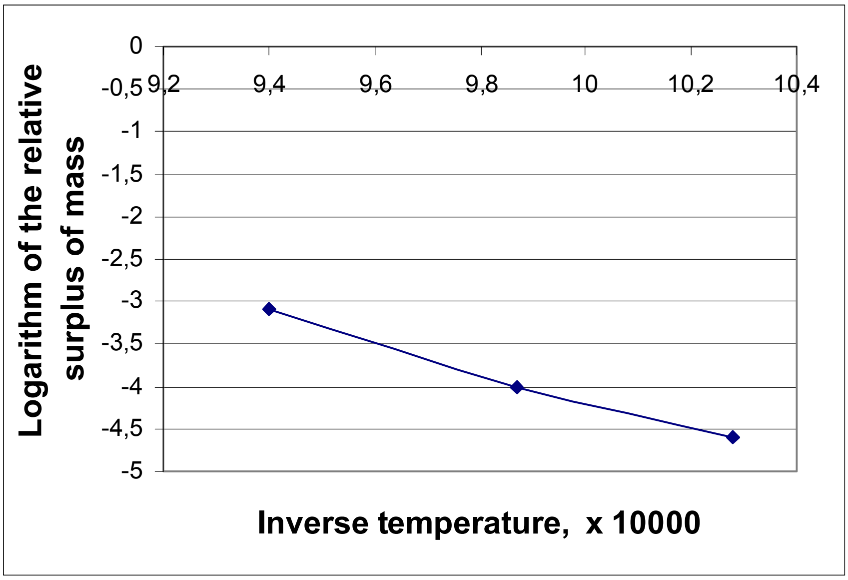


Fig.2. Dependence of ln(Δm/m_0) on inverse temperature (water pressure 3 kbar, time 3 days).

4. Melting of biotite with formation of tiny magnetite and unknown mineral (presumably, pyroxene and/or amphibole [4]) at the initial stage occurs at 820^{O}C (P_{H2O}=3 kbar). Melting of biotite is incongruent, similar to muscovite [8]. Melting of biotite ceases at 850 and 950^{O}C (P_{H2O} = 2 kbar). They turn to diffusive brownish "patches". This is an interesting results, since melting of biotite was observed in biotite-sillimanite and biotite-cordierite gneisses, where biotite grains were replaced by glass and metal oxides [11].

A series of experiments was undertaken in order to obtain generalized quantitative data on a degree of the anatexis in the rock slab in dependence on time, temperature and water pressure. Granite cylinders of homogeneous structure and texture of 4 mm in diameter and 7-8 in height were placed in Pt capsules of 5mm in diameter and 20 mm in length. 30-50 mg of water and ~3mg of quartz powder were placed into the capsule. This procedure prevents from dissolution of granite cylinders. In this case, surplus of mass (accuracy of 0.3 mg) and size (accuracy of 0.05 mm) of the sample corresponds to an amount of water (Δm), introduced into the sample to form the intergranular melt. Thus, respective surplus of the sample mass (i.e. Δm/m_0, where m_0 – an initial mass of the sample) characterizes an effectiveness of the anatexis Run conditions and results are shown in Figs. 1 and 2. Figure demonstrate the following results.

1. Starting from some moment, a portion of the anatectic melt linearly increases with time; however, initially the increase is more rapid. That could be explained by decompaction of the rock by heating and penetration of the fluid into the slab [12]. This is in accordance with the formation of melt films in the cylindrical samples (of diameter 4 mm) observed in the runs with the run time just 1 hour (at 760^{O}C and 2 kbar of water pressure) [3]. A special experiment showed that heating during 12 hours at 800^{O}C under argon pressure did not result in significant increase of the sample volume.

2. A portion of the anatectic melt almost linearly (with some acceleration at the initial stage) increases with water pressure. That is related to thermodynamic (deviation from the equilibrium curve) and kinetic (flux of H_2O in the melt film) features.

3. A portion of the anatictic melt exponentially increases with temperature. The mean activation energy of the anatexis for the interval 700-800^{O}C is 34 kcal/mol.

The above kinetic parameters can be used for estimation of the anatexis rate reflected in the film thickening in dependence on TP-conditions and distances.

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