Relationship between diffusivity of major (SiO$_2$, Al$_2$O$_3$, Na$_2$O, CaO, MgO, FeO, TiO$_2$) and volatile (H$_2$O) components and melts viscosity of the system obsidian–dacite–andesite–basalt–H$_2$O (experimental-theoretical study)

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Only limited data are currently available on multicomponent interdiffusion especially in andesitic and basaltic melts [*Watson and Baker,* 1991; *Watson,* 1994; *Yoder,* 1973; *Baker,* 1991]**.**

These results are offered of experimental study of the chemical interdiffusion of major components (SiO$_2$, Al$_2$O$_3$, Na$_2$O, CaO, MgO, FeO, TiO$_2$) in melts on the haploandesite–haplobasalt–water join as well as on the system haploandesite – natural high-Al basalt- water which have been investigated at water pressures 25–160 MPa and Ar pressures up to 160 MPa, and the T = 1300°C using the diffusion couple method.

Three type of couples have been used in experiments: a) dry haploandesitic melt (Ab$_{75}$Di$_{25}$, mol. %) was coupled with dry haplobasaltic melt (Ab$_{50}$Di$_{50}$, mol. %) and then melted at 160 MPa Ar pressures in the sealed Pt capsule; b) water bearing couples (haploandesite + haplobasalt) with 1.0, 2.1, 4.3 and 5.6 wt. % dissolved water in both melts was melted at 160 MPa Ar pressure in the sealed Pt capsule; c) water bearing couple (with 1.0 wt. % of water) on the system haploandesite – natural high-Al basalt- water was melted at 25 MPa Ar pressures in the sealed Pt capsule. An internal heated pressure vessel (IHPV) with a unique internal device was used to carry out diffusion experiments for 480 – 1500 s. Water contents in the starting quenched melts as well as along of the diffusion profiles of the water bearing couples were determined by FTIR spectroscopy. The distribution of all major components along the diffusion profiles (fig. 1) were analyzed by electron microprobe.

As a first approximation the chemical interdiffusion coefficients of all major components (SiO$_2$, Al$_2$O$_3$, Na$_2$O, CaO, MgO, FeO, TiO$_2$) in all melts studied were determined by numerical calculating program using an error-function solution of the Fick's second law.

Dependence of the interdiffusion of major components (SiO$_2$, Al$_2$O$_3$, Na$_2$O, CaO, MgO) in haplo-basalt-haploandesite melts on water content are presented at the fig. 2 in comparing with the such de-pendence for SiO$_2$ interdiffusion for the couple dacitic + rhyolitic melts [*Watson and Baker,* 1991; *Baker,* 1991].

The result for SiO$_2$ interdiffusion in haplobasalt-haploandesite melts is consist with the published data [*Watson and Baker,* 1991; *Baker,* 1991] (fig. 2) and the differences in the absolute values of SiO$_2$ diffusivities may easy explain by the difference in melts viscosity (polimerized melts with relative high viscosities, dacite + rhyolite inter-diffusion [*Watson and Baker,* 1991; *Baker,* 1991] and depolymerized melts with relative low viscosities, basalt + andesite interdiffusion, this study).

The results obtained indicate that the D of the all major components increase by approximately an order of magnitude with increasing C(H$_2$O) in such melts from 0 to 2.0–3.0 wt. % and then increase much more smaller with further increasing of water content in the melts up to 6 wt. %.
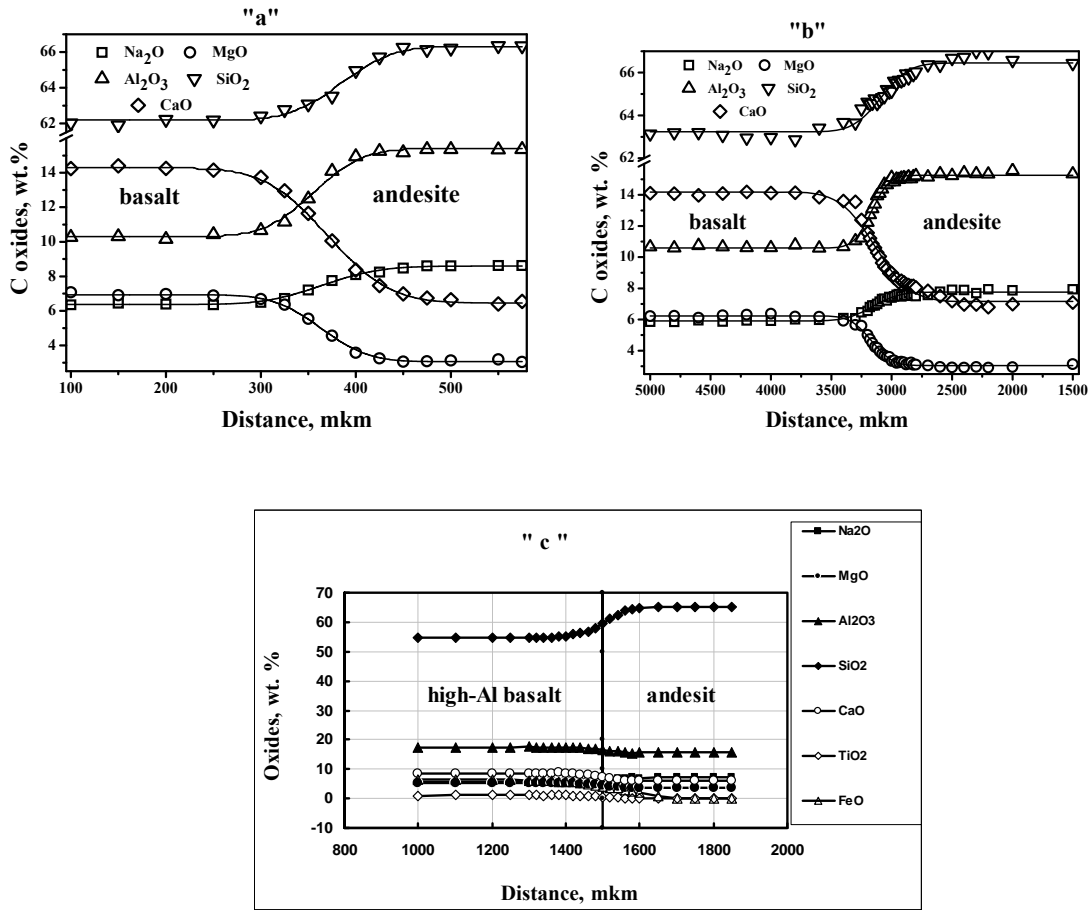
Fig.1. Measured concentration profiles of major components in the system basalt–andesite–water at the T = 1300°C and at the Ar pressures up to 100 MPa (the curves at the all diagrams are error function fits).

a – water free melts, run 1641/1, run duration was 480 sec; b – water bearing melts, run 1664/1, run duration was 1320 sec, 4.3 wt. % water content; c – water bearing melts in the system Ab$_{75}$Di$_{25}$ + natural basalt, run 1665/1, run duration was 1320 sec, 1.0 wt. % water content; vertical line is the interface between two melts or Matano interface)
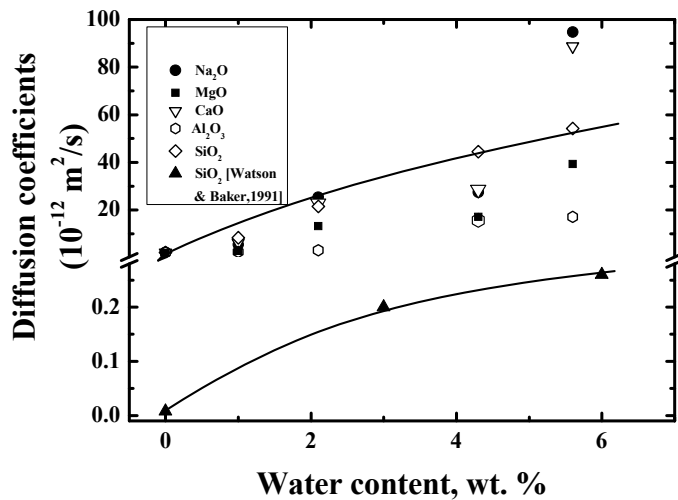
Fig.2. The dependence of chemical interdiffusion of major components (SiO$_2$, Al$_2$O$_3$, Na$_2$O, CaO, MgO) in haplobasalt-haploandesite melts on water content at the total pressure up to 160 MPa and T = 1300 ^{o}C (Data for SiO$_2$ diffusivities during interdiffusion of dacitic and rhyolitic melts at 1 GPa total pressure, up to 200 MPa water pressures and at the T = 1300 ^{o}C is from [*Watson and Baker,* 1991; *Baker,* 1991])

The results indicate too that the rates of chemical interdiffusion of major components (SiO_2, Al_2O_3, Na_2O, CaO, MgO) in dry melts are identical and they are higher than the rates of tracer diffusion of Si and Al by approximately on the two orders of magnitude. In contrast, the rates for the major components are lower than the rates of tracer diffusion of Na, Ca, and Mg cations, but approximately on the one order of magnitude. Such behavior may consider as chemical diffusion of the molecules of Ab and Di in opposing directions with the same rates. But the diffusion mechanism is dramatically change for a water bearing melts and the interdiffusivities of major components (SiO_2, Al_2O_3, Na_2O, CaO, MgO) become a quite different (fig. 2).

Recently the experimental data on water diffusivity in haploandesitic and haplobasaltic melts have been obtained using traditional high gradient methodology and the imperfections of this methodology have been discussed [*Persikov, et. all,* 2010; *Персиков, и др.,* 2010]. Now a new clean data on water diffusivity over the range of silicate melt compositions from obsidian to basalt, wide water content range (0.1–6 wt. %), temperature range from 700° to 1300°C and water pressures up to 200 MPa have been obtained using a new small gradient methodology.
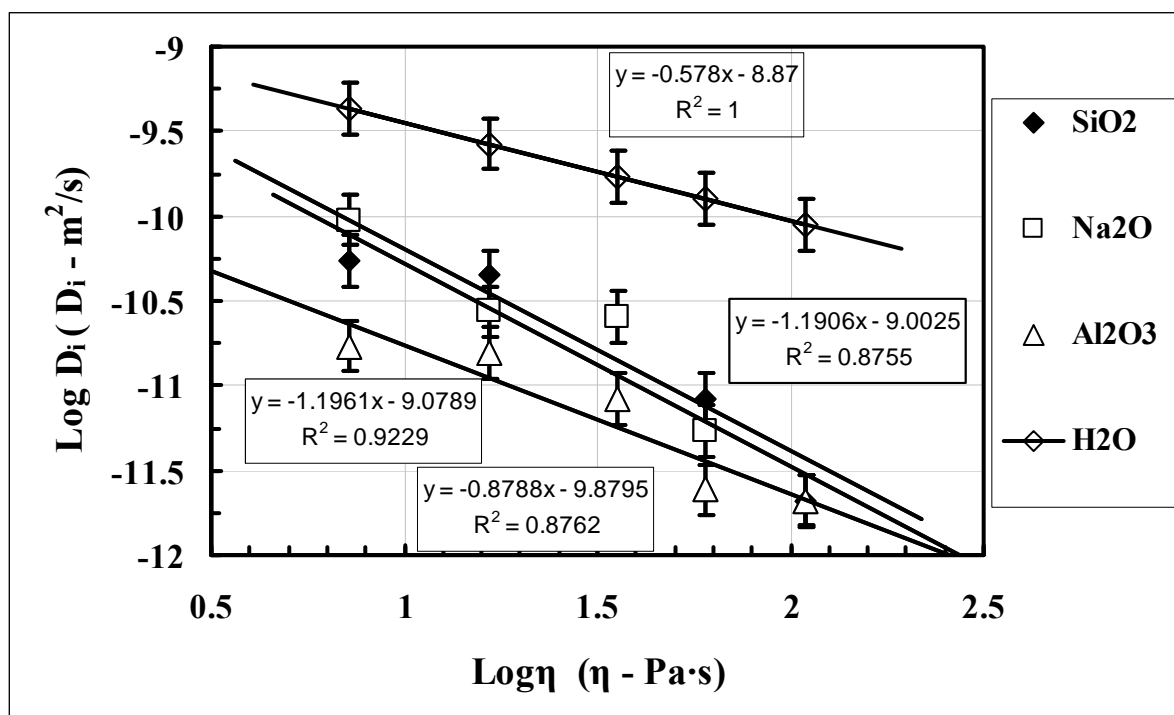
Fig. 3. Relationship between interdiffusivities of a few major components (SiO2, Al2O3, Na2O), diffusivity of water and melt viscosity over the range of silicate melt compositions from andesite to basalt (water pressures up to 160 MPa, T = 1300°C and water content into melts up to 5.6 wt. %)

The theoretical analysis of these new data on interdiffusivities of a major components (SiO_2, Al_2O_3, Na_2O, CaO, MgO, FeO, TiO_2) and on water diffusivity in relationship with melt viscosity is allowed to establish of the regular dependence between these a very important transport properties. This dependence is consist to a well known Stokes-Einstein and Eyring equations, that diffusivity of any components is inversely proportional to the viscosity of a simple molecular liquids (fig. 3).

Viscosity along of the diffusion profiles was calculated as a function of pressure, temperature and melt composition according to the structural- chemical model developed by Persikov [*Persikov,* 1998; *Persikov and Bukhtiyarov,* 2009]. Fig. 3 shows too that water diffusivity is higher on about one order of magnitude than the diffusivities of any major components including of the alkali (Na_2O) at the same T, P-parameters and melt compositions.

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