



Experimental study of local dehydration and partial melting of biotite-amphibole gneiss with participation of the H₂O-CO₂-(K, Na)Cl fluids at the middle-crustal conditions

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Activity of aqueous chloride-rich brines coexisting with CO₂-rich fluids is identified in many amphibolite and granulite terrains suggesting that this type of fluid is an important agent of high-grade metamorphism in the lower to middle crust (see reviews in Touret, 2009; Newton, Manning, 2010). Although thermodynamic and transport properties of these fluids is well constrained both theoretically and experimentally, their affect on complex natural assemblages is poorly understood and demands systematic experimental study. We report here results of the experiments on interaction of the biotite-amphibole gneiss from the Sand River formation (Limpopo Complex, South Africa) with the fluids H₂O-CO₂-(K, Na)Cl at 5.5 kbar, 750 and 800 C, the chloride/(H₂O+CO₂) varying from 0.1, and molar CO₂/(CO₂+H₂O) = 0.5.

No any reaction textures were identified in the sample interacted with the chloride-free CO₂-H₂O fluid at 750 C. At this temperature, addition of KCl into the fluid resulted in formation of spectacular reaction textures around biotite (Bt), amphibole (Amp), plagioclase (Pl) and quartz (Qtz) in the starting gneiss. These textures are intergrowths of low-Al clinopyroxene (Cpx) and K-feldspar (Kfs) (sporadically accompanied by ilmenite, sphene and Ti-bearing low-Al mica) corresponding to a progress of the following reactions: $\text{Phl} + 3\text{An} + 18\text{Qtz} + 3(\text{K}_2\text{O in fluid}) = 3\text{Di} + 7\text{Kfs} + (\text{H}_2\text{O in fluid})$ and $\text{Prg} + \text{Ed} + 7(\text{K}_2\text{O in fluid}) + 37\text{Qtz} + 5\text{An} = 9\text{Di} + 14\text{Kfs} + (2\text{H}_2\text{O} + \text{Na}_2\text{O in fluid})$. Local partial melting of the gneiss interacted with KCl-bearing fluids at 750°C was observed only in the run at $\text{KCl}/(\text{CO}_2 + \text{H}_2\text{O}) = 1/30$ and could be caused by local variation of water activity in the sample. Nevertheless, at 800 °C, granitic (>70 wt. % of SiO₂) K₂O-rich and Cl-bearing melt appears along the grain boundaries in all run samples. This melt produces K-feldspar and clinopyroxene, which are found as euhedral crystals in the glass. Melt films are usually accompanied by K-feldspar microveins and Cpx similar to those in the runs at 750 C. At $\text{KCl}/(\text{CO}_2 + \text{H}_2\text{O}) = 1/10$, strongly “K-feldspartized” portions of the samples along cracks contain minute kalsilite, Ca-garnet, and calcite.

In contrast, all NaCl-bearing (including mixed KCl-NaCl-bearing) runs both at 750 and 800 C show evidence for melting, whose intensity clearly increases with increasing NaCl/(CO₂+H₂O) ratio in the fluid. Na-granitic (> 70 wt. % of SiO₂) melt forms at relatively low degrees of melting. Depending on NaCl concentration in the fluid, this melt coexists with Cpx, Opx and Na-rich (richteritic) Amp. Formation of Na-amphibole proceeds via peritectic reactions of biotite and pargasite-edенite amphibole with plagioclase and sodium-rich fluid, for example $5/3\text{Phl} + \text{An} + 12\text{Qtz} + 2\text{Na}_2\text{O} = \text{Richteritic Amp} + [5/3\text{Kfs} + 2\text{Ab}] + 2/3\text{H}_2\text{O}$ and $5/4\text{Prg} + 23/4\text{Qtz} + 1/4\text{Na}_2\text{O} = \text{Richteritic Amp} + 1/4\text{H}_2\text{O} + 3/2\text{An} + [1/4\text{Ab}]$, where Kfs and Ab are the basis of the silicate melt. Euhedral albite was observed crystallizing from the melt in the runs, where NaCl was the only chloride species in the fluid. Euhedral plagioclase crystals were found in glass in the runs with the mixed KCl-NaCl-bearing fluid, while melt films and pockets in the samples are accompanied by K-feldspar microveins. Na-rich “phonolitic” (55-56 wt. % of SiO₂) melt containing up to 1.8 wt. % of Cl forms at almost complete melting of the gneiss in presence of NaCl-rich fluids. This melt coexists with pargasite-richterite amphibole and clinopyroxene, as well as with residual accessory phases. It should be noted that solubility of chlorine in the melts forming in equilibrium with the NaCl-rich fluids is by 0.3-0.5 wt. % higher than in the melts equilibrated with the KCl-rich fluids.

Thus, the results of the experiments demonstrate that interaction of biotite-amphibole gneiss with H₂O-CO₂-(K, Na)Cl fluids is able to produce a wide spectrum of mineral assemblages and melts depending on temperature, bulk chloride concentration, and K/Na ratio in the fluid. These assemblages vary from syenitic Cpx+Kfs in presence of KCl-rich fluids to alkali (sodic) amphibole-bearing in presence of NaCl-rich fluids, while melt compositions vary from granitic to Na-rich phonolitic. Experiments show different effect of NaCl and KCl on partial melting. Addition of NaCl significantly intensifies melting, while in presence of KCl melting is suppressed both at 750 and 800°C. The NaCl-rich fluid seems to interact more actively with biotite and pargasite-edенite amphibole in contrast to the KCl-rich fluid. Because of local dehydration, such interaction produces more additional water in

the fluid increasing its activity and assisting to melting. Moreover, KCl has larger suppressing effect on water activity than NaCl does (Aranovich, Newton, 1997). In addition, higher solubility of chlorine in Na-rich melts would assist to melting, as well.

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References

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