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Fe-Ti oxide-silicate (QUIlF-type) equilibria in feldspathoid-bearing systems

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Abstract

Silicate-oxide equilibria (abbreviated as QUIlF) have proven to be very powerful tools for reconstructing the temperature and oxygen fugacity evolution of magmatic systems containing magnetite and ilmenite with olivine, quartz, or pyroxenes. In this paper, we extend these QUIlF equilibria to include rocks where silica activity is controlled by equilibria between feldspars and feldspathoids.

We present data on the orthomagmatic assemblage of titanomagnetite + ilmenite + feldspar + nepheline + compositionally variable olivine, which we call AUNIlF:

$$\underset{\text{Albite}}{NaAlSi_3O_8} + 4\underset{\text{Ulvøspinel}}{Fe_2TiO_4} = \underset{\text{Nepheline}}{NaAlSiO_4} + 4\underset{\text{Ilmenite}}{FeTiO_3} + 2\underset{\text{Fayalite}}{Fe_2SiO_4}$$

The AUNIlF reference curve (with unit activities for albite, nepheline, and fayalite) is stable at oxygen fugacities ≥2 log units below the QUIlF surface at temperatures of about 700 to 800 °C, temperatures typical of late-magmatic stages. At temperatures > ~800 °C, the AUNIlF reference assemblage would only be stable at unrealistically low f_{O_2} conditions more than 5 log units below FMQ (where FMQ is the fayalite-magnetite-quartz buffer), which explains the rarity or absence of orthomagmatic AUNIlF assemblages. We determine the most reduced conditions indicated by displaced AUNIlF assemblage from Mont Saint-Hilaire (Quebec, Canada) to be ΔFMQ = –1.15 at ~800 °C (olivine is Fa_{67} and $a_{SiO_2} = 0.41$) and conclude that AUNIlF assemblages involving pure fayalite do not stably occur in terrestrial magmatic systems.

The stability field of naturally occurring AUNIlF assemblages is a function of albite, nepheline, and olivine compositions and is controlled by the ratio of silica activity to fayalite activity (a_{SiO_2}/a_{Fa}). At values higher than ~0.77 for a_{SiO_2}/a_{Fa}, olivine is Fa < ~70 when silica activity is buffered by the nepheline-albite equilibrium. In these situations, AUNIlF is stable at oxygen fugacities ≥ –1.15 (ΔFMQ). At values below a_{SiO_2}/a_{Fa} ~0.77, the AUNIlF equilibrium is shifted to lower oxygen fugacities and ilmenite becomes unstable relative to ulvøspinel. Analogous to the construction and application of AUNIlF, a QUIlF-type reaction curve for potassic systems (KULIlF) involving leucite and alkali feldspar is presented and applied to naturally occurring assemblages. Potassic rocks invariably crystallize forsteritic olivine in the presence of ilmenite and magnetite, reflecting higher oxygen fugacities during crystallization than their sodic counterparts. As a result of low fayalite component in olivine, the a_{SiO_2}/a_{Fa} ratio becomes ≥4 in assemblages of potassic systems consisting of alkali feldspar, magnetite, leucite, ilmenite, and olivine.

Keywords: QUIlF, nepheline, leucite, feldspar, olivine composition, silica activity, oxygen fugacity, Mont Saint-Hilaire