Kiglapait mineralogy V: Feldspars in a hot, dry magma

S.A. Morse

1Department of Geosciences, University of Massachusetts, 611 North Pleasant Street, Amherst, Massachusetts, 01003-9297, U.S.A.

ABSTRACT

The lithology of the 1.305 Ga Kiglapait intrusion is dominated by a Lower Zone of troctolite, succeeded by an Upper Zone of olivine gabbro, ferrodiorite, and syenite with olivine composition of pure fayalite. The feldspar composition of the intrusion varies from An$_{99}$ to An$_{8}$ over a thickness of 8.4 km from the base to a sandwich horizon under an Upper Border Zone. The anhydrous nature of the Kiglapait syenites is shown by their high temperature, by the loss of minor biotite up-stratigraphy in the intrusion, and the absence of amphibole. The end-stage feldspar of the Kiglapait syenites is that of a solidus embedded in a solvus in a 3 kbar eutectic at 1000 °C. The end-member assemblage at temperature and pressure is invariant. The final bulk composition is relatively An-rich—An $\sim$11%—with a composition of $X_{An} = 1/3$ when projected to the Ab-Or sideline. The experimental feldspar solvus when corrected for the effects of An and Ba and referred to 3 kbar penetrates the solvus and fits the experimental tie lines. These conditions precede a stage of local coarsening under subsolidus conditions that is found in colloform symplectites invading mesoperthite. The oligoclase-orthoclase symplectites are iso-compositional with their host mesoperthites. The coarsening is assumed to be related to a plausibly $F$-rich vapor phase that is locally consumed with time. The observed phase compositions indicate the end of exsolution at $\sim$800 °C at 3 kbar on the binodal solvus.

Keywords: Feldspar compositions, Kiglapait Intrusion, chemistry, textures, exsolution, symplectite, coarsening, solvus, syenites, cooling history

INTRODUCTION

N.L. Bowen (1945) noticed that pure albite would never occur in the presence of calcium, in what became known as the “plagioclase effect.” By that time he must have realized that his (1915) bending of the plagioclase–diopside field boundary to pure Ab was a mistake, and if he had lived long enough to learn about linear partitioning he would have discovered that the plagioclase in equilibrium with the multicomponent liquid lying on the Di-Ab sideline was of composition An$_{9}$ (Morse 1997). This principle of the role of calcium, along with the presence of fayalite, has a profound effect on the endpoint of ternary feldspar crystallization at anhydrous pressure.

The classic story of H$_2$O-saturated or $O$-bearing ternary feldspars begins with Tuttle and Bowen (1958, submitted 1954) and flows through Yoder et al. (1957), Stewart and Roseboom (1962; in part via J.B. Thompson), Morse (1969b, 1970), Fuhrman and Lindsley (1988), to the masterful study of Nekvasil and Lindsley (1990), and a generation of work by Ian Parsons and his colleagues (e.g., 2015), in particular with the late W.L. Brown.

This work shows that in the Kiglapait intrusion the endpoint of extreme fractional crystallization of a troctolitic parent magma is composed of a ferrosyenite making an azeotrope with bulk composition An$_{111}$, $X_{An} = 1/3$ embedded in a solvus with paired limits at Or$_{31}$ and Or$_{32}$ as projected from An onto the Ab-Or sideline. The locally arrested symplectite intergrowths on mesoperthite were exsolved in the subsolidus to $\sim$800 °C.

The low-pressure solvus determined for a Ca-bearing Kiglapait mesoperthite (Morse 1969b) has the same form as in the solvus at 5 kbar in the system Ab-Or-H$_2$O of Morse (1970) and that of Waldbaurn and Thompson (1969). When adjusted for Ba content, An content and pressure from published literature studies it matches closely the 3 kbar Kiglapait endpoint determined from experimental studies. The effect of fayalite on plagioclase compositions (Morse and Brady 2017b) is striking in its ability to lower the temperatures of crystallization, in effect doing the work of water on crystallization temperatures without affecting the role of calcic pyroxene in maintaining relatively high An contents of the liquids compared with the very low An-contents of hydrous ternary feldspar liquids.

Previous work

The first and fundamental report on the Kiglapait feldspars was the crystallographic study of Speer and Ribbe (1973). This paper is important for several reasons. It was based mainly on new sampling in the Kiglapait intrusion by Speer, especially in the southern to middle part of the intrusion. It showed that the oligoclase component of mesoperthite was metastably monoclinic, coexisting with a monoclinic orthoclase component, and therefore showing that the original mesoperthite crystal was a sodium-rich monoclinic sanidine. It also located a bulk composition of mesoperthite near or at the Na limit, furnishing a practical boundary for the existence of mesoperthite. This was also the first study on Kiglapait feldspars to show a ternary crystallization path. Additional reports were made on potassium and rubidium by Morse (1981a), strontium (Morse 1981b), and the experimental partitioning of Sr and Ba (Morse and Allaz 2013).