Appendix: sources

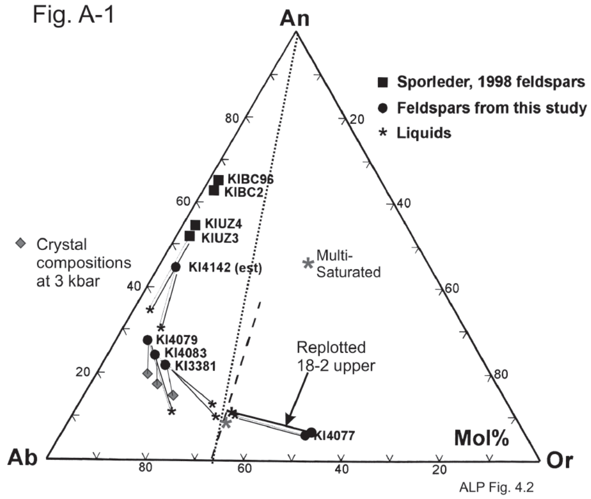
Recent experimental sources go back to the MS thesis of Brad Sporleder (1998) who began our search for a liquid line of descent for the Lower Zone of the Kiglapait intrusion. This was done at the Five-College Experimental Petrology Laboratory housed at Smith College under the directorship of John B. Brady. Experiments were made at 5 kbar in graphite capsules. Compositions were made by mixing well-described Kiglapait mineral samples to approximate the bulk compositions of expected liquids, then adjusting the compositions to bracket the evolving experimental cotectic. In this process olivine and plagioclase were the sought and found crystals of successful experiments, after which the more evolved components of augite, Fe-Ti oxides, apatite, fayalite, albite, and ilmenite were systematically added. The results were incorporated into a major publication by Morse, Brady, and Sporleder (2004). The experimental run times eventually converged on 8 h after testing results from 3 h to as long as 168 h. Experimental results were characterized optically and by electron microprobe at the University of Massachusetts.

A continuation of that study was made by Abigail Peterson to find the line of descent for the Upper Zone (Peterson 1999). In view of the complexity of the Upper Zone rock compositions, it was decided to make this series of experiments using six well-described rocks from 92.8 PCS to the end of crystallization at the nominal end point, 99.985 PCS. These crushed rock samples were heated at 5 kbar to find their coexisting minerals plus liquid, or at least to bracket that condition, and then to find the liquidus. Experiments were run from 3 h for exploration to a normal time of 24 h for equilibrium, again at 5 kbar. Parts of the Peterson results with respect to element partitioning for plagioclase and olivine were incorporated in the study by Morse et al. (2004) cited above.

Several of the Peterson experiments were useful in determining the FSP-CPX and CPX-OL field boundaries near the triple point, and others agreed reasonably well with the FSP-CPX-OL triple point itself as found by Sporleder. The purposes of the present feldspar study were especially well served by Peterson's determination of a series of five tie-lines in the plagioclase field and one fundamentally important tieline from sample KI 4077 (99.985 PCS) in the orthoclase field, with three liquid compositions bracketing a relatively An-rich (11% AN) liquid composition centered at $X_{Or} = 1/3$ when projected from An. An annotated copy of Peterson's Figure 4.2 showing the experimental data for ternary feldspars in both MS studies is now shown here as Appendix[1] Fig. A-1.

Peterson actually reports 10 experiments with sample KI 4077 plus liquid, listed here as Appendix[1] Table A-1. There is only one reported composition of feldspar 4077, made from Run KU 18-2, which contained 10% feldspar and 90% glass. The glass of that experiment was found in two positions, one

Fig. A-1



From Peterson (1999). "Experimentally-produced feldspars from this study plotted with their associated liquids. *Dashed* line shows the location of the consolute point over a range of temperatures and pressures (based on Fuhrman and Lindsley, 1988)"

designated as "lower" and the other as "upper". The "lower" glass has composition Or_{28}; the "upper" has composition Or_{31}, more in line with the other nearby melt compositions shown in Appendix[1] Fig. A-1. There is also another glass composition "Multiply saturated" (KU 17-2, Appendix[1]Table A-1) that was analyzed and listed at p. 71 of the thesis, and that has a composition close to the liquidus samples; I have plotted it as an asterisk in grayscale in Appendix[1] Fig. A-1.

It should not be forgotten that almost all this experimental work was done at 5 kbar. But the intrusion ended its crystallization at <3 kbar, and that makes an important difference in the plotted results because of the significant effect of pressure on the An content of plagioclase. By themselves, Peterson's last three plagioclase compositions lie well above (more An-rich than) the evolved curve of the natural plagioclase feldspars. However, when these 5-kbar crystal compositions are corrected for the pressure effect they fall into the trend of the natural feldspars. This pressure correction is discussed in the main text.

A note on feldspar samples KI 4077 and 4078 and related samples

These two samples occupy the Kiglapait sandwich horizon. The two drill holes, with 3 cm diameter cores about 18–20 cm long, were collared just outside the western edge of the Upper Border Zone as shown on the map of the Caplin-Patsy traverse in Supplementary Maps SM 2 and SM 5 here. Field notes show that Sample 4078 was collared 5 m East of Sample 4077. Both samples are fresh, fine-grained ferrosyenites with pale green hedenbergite and pale yellow fayalite as seen in thin section.

Because these two feldspars themselves have not been analyzed in bulk, and we wish to know the equivalents to such analyses, four nearby samples that have been analyzed both in whole rocks and in feldspar separates were used as proxies to determine any systematic variation between the separate mineral analyses and those given by the oxygen norm. The results were then applied to the two samples under discussion here, with the corrected values for the average shown in the lower right part of Appendix[1] Table A-2. The two feldspar compositions are essentially identical. The combined average was then plotted in Figure 7 for comparison with the other seven samples that define the end of crystallization.

In that figure, sample KI 4075 is shown to lie at essentially the same composition as the average of KI 4077 and 4078. The sample location is shown on the map cited above as nearly touching the UZ-UBZ contact, a meter or so from 4078. Therefore the final ferrosyenite zone is something like six or seven meters thick at essentially constant composition.

In text Figure 7, it is seen that five samples lie well to the right of the black cross marking the composition X_{Or} = 1/3 projected from the An apex. All these samples lie in the orthoclase field of primary crystallization. Thin sections of samples 4075, 4076, 4110, and five other samples near the UZ-UBZ boundary also show primary orthoclase as the dominant feldspar. Samples 4077–4078 define that sense of tie line, and thereby they map the end of crystallization as an azeotrope. Any of these eight samples would yield Or-rich tie lines similar to that obtained by Peterson (1999).

The three samples that project through the black cross from the An apex are combinations of mesoperthites, orthoclase, and symplectites with abundant mafic minerals. Sample 4106 has more mesoperthite than orthoclase. Sample 4104 is essentially all symplectite and therefore represents a coarsened mesoperthite. Sample 4081 is mostly mesoperthite, accompanied by mottled orthoclase with patches of oligoclase. These samples define the apical line.

Sample 3001 of experimental fame lies just to the right of the apical line and mostly contains megacrysts of orthoclase with subordinate ragged patches of mesoperthite. It therefore lies just barely in the orthoclase liquidus field. This is the sample that was used to determine the solvus for mesoperthite at 0.5 kbar water pressure by Morse (1969b).

TABLE A-1. Review of Peterson (1999) ALL data on sample KI 4077 with melt present

Run	Sample	Th'couple T	*t* (hr)	Description	Est. actual *T*
KU:					
6-2	KI 4077	1090	3	gl99fsp1	
8-2	-do-	1080	4	gl90fsp10	
10-2!	-do-	1085	4	gl97fsp3*	<1085
12-2	-do-	1095 > 1085	9	gl95fsp5 1 hour 1095	
13-2	-do-	1085	8	gl95fsp5*	<1085
14-1,2	-do-	1100	2	gl100	"glass standard"
17-2	-do-	1085	24.25	gl30fsp50ol tr aug20 ox tr *	<<1085 multiphase
18-2	-do-	1095	24	gl90fsp10	
35-3	-do-	1100	24	gl99fsp1*	<1085
38-1	-do-	1080	24	gl99fsp1	<1080
40-3	-do-	1110	24	gl100	
41-3	-do-	1080	24	gl97fsp3*	"*T* compromised" <1080

Notes: Solidus determined at 5 kbar 1010 °C (Morse and Brady 2017) so there is a likely range between solidus and liquidus, but the temperatures here are uncalibrated for TC-spl positions. Clearly runs 13 and 17 disagree greatly from each other and from our solidus determination. Run 17 approaches our solidus, so ~1015–1020? KU10-1 is KI 3381; KU 10-2 is KI 4077: both at the same *T*; KI 3381 gets glass92, fsp8. All Peterson experiments up to KU 28 contained only two samples, beyond which there were three samples per experiment. With only two samples, identities are easily confused until the phases are probed. Abbreviations: gl = glass; fsp = feldspar; ol = olivine; aug = augite; ox = oxide mineral; tr = trace. Estimated values given in volume percent. * = used Figure 16.

TABLE A-2. Upper Kiglapait Syenite Compositions

OXNORM	KI	KI		
KI Whole rocks	**4077**	**4078**		
AP	0.96	0.88		
MT	2.72	2.96		
IL	2.89	2.58		
OR	20.35	21.21		
AB	35.77	34.9		
AN	4.51	4.29		
DI	21.74	24.11		
HY	1.04	4.02		
OL	10.02	6.05		
Sum	100	100	AVG	**Normalized**
FSP	60.63	59.4		
X AN	7.4	7.2	7.3	**9.5**
X AB	59.0	58.8	58.9	**57.4**
X OR	33.6	34.0	33.8	**33.1**
OLHY	10.7	6.5		
OLRAT	0.306	0.177		
Sum fsp	100	100		100