Chemical signature of quartz and feldspar in polygeneration pegmatites in Froland, Norway

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ABSTRACT

Element concentrations in quartz and feldspar of Sveconorwegian (1.13-0.9 Ga) pegmatites in Froland, Norway, were analysed by LA-ICP-MS and XRF, respectively, to reveal chemical variations of different pegmatite types and within pegmatite bodies. Quartz of undeformed syn-orogenic pegmatites has a consistent trace element signature. Al, Li, Fe, and Ti in quartz of late- and post-orogenic and deformed syn-orogenic pegmatites vary with pegmatite type but are consistent within the pegmatites. Feldspar chemistry depends largely on the differentiation degree of the pegmatites and varies within them.

Keywords: *pegmatite, quartz, feldspar, Froland, LA-ICP-MS.*

INTRODUCTION

The Sveconorwegian pegmatite field of Froland in southern Norway comprises different types of granitic pegmatites of the abyssal class, some transitional to AB-HREE pegmatites (Černý & Ercit 2005). The field extends ca. 20 km in NE-SW direction, is 5 km wide and includes about 105 known major pegmatite occurrences (Ihlen et al. 2002). The pegmatites have been mined for quartz and feldspar since the end of the 18th century.

The general aim of the study is to reveal relationships between the quartz and feldpar chemistry of the different pegmatite types and to establish chemical zonation patterns of both the minerals within the individual pegmatites.

CLASSIFICATION OF THE FROLAND PEGMATITES

The Froland pegmatites formed during the Sveconorwegian orogeny, i.e. syn-orogenic (1.13-1.06 Ga), late-orogenic (0.93 Ga, syn-genetic in respect to the emplacement of the Herefoss pluton) and post-orogenic (<0.93 Ga). The largest volume of pegmatites formed during the syn-orogenic stage (Henderson and Ihlen, 2004). The Froland pegmatites can be subdivided structurally and chemically into a number of sub-groups including pegmatitic granites, granite pegmatites, plagioclase-dominant granitic pegmatites, zoned granitic pegmatites, K-feldspar-dominant granitic pegmatites, and muscovite pegmatites (Ihlen et al. 2002). The syn- and late-orogenic pegmatites represent relatively primitive melts in respect to granite differentiation and contain Fe-phlogopite and Mg-siderophyllite. The muscovite pegmatites related to both the final phase of the syn-orogenic stage and the post-orogenic stage, have much more evolved chemistry reflected by the appearance of zinnwaldite.

QUARTZ AND FELDSPAR CHEMISTRY

Quartz

Lattice-bound trace elements in pegmatitic quartz were analysed by LA-ICP-MS. Quartz from undeformed syn-orogenic pegmatites has relative consistent chemistry independent of pegmatite type (Table 1). The quartz can be classified as medium purity in terms of raw material quality (Harben 2002, Müller et al. 2005). However, the strongly recrystallised and contact metamorphosed (Herefoss pluton emplacement) zoned pegmatites at Vaselona and Fossheia West have higher Ti, K and Ge and lower Li. Al and Li in quartz decrease, whereas Ti increases with increasing degree of recrystallisation and contact metamorphism (Table 1; Fossheia West). Quartz of the late-orogenic pegmatites related to the emplacement of the Herefoss pluton is high in Ti (average 20.4 µgg^{-1}) caused by higher crystallisation temperatures (Wark & Watson 2006). Quartz of the post-orogenic muscovite pegmatites is strongly enriched in Al and K, and is high in Ti and low in Li.

Sampling traverses across the individual syn-orogenic pegmatite bodies reveal insignificant variations in the trace element contents of quartz (Figure 1).

TABLE 1. Average concentrations of trace elements in quartz of the different pegmatite types. Analyses shown in grey represent medium purity and those in white low quality of quartz due to Ti >20 µgg^{-1} and/or Al >120 µgg^{-1} (Harben 2002, Müller et al. 2005). PGr- pegmatitic granites, GP - granite pegmatites, NaP - plagioclase-dominant granitic pegmatites, ZoP- zoned granitic pegmatites, KP - K-feldspar-dominant granitic pegmatites, PD - muscovite pegmatites, HP – zoned pegmatites related to Herefoss pluton emplacement, n – number of analyses, recryst. - recrystallised.

relative age	pegmatite type	n	Li	B	Al	Ge	Ti	K	Fe
syn-orogenic	PGr	4	10.2	<1.0	34.4	0.88	3.8	<1	<0.2
	GP	43	8.7	<1.4	40.3	1.37	6.1	<1	<0.2
	NaP	33	8.3	<1.0	40.5	1.80	4.9	<1	<0.2
	ZoP	43	6.9	<1.4	36.2	1.31	7.2	<1	<0.2
	KP	8	5.9	<1.6	43.7	1.70	4.3	<1	<0.2
	recryst. ZoP Vaselona	2	4.9	<1.0	40.7	2.77	16.3	6.0	0.51
	recryst. ZoP Fossheia West	2	0.3	<1.0	26.2	2.42	29.0	4.0	0.92
	PD, Hellheia, Skåremyr	5	6.2	<1.0	37.8	1.97	8.5	<1	<0.2
late-orogenic	HP	12	4.3	<1.0	45.4	1.19	20.4	<7	1.01
post-orogenic	PD, Haukemyrliene	4	3.6	<1.0	122.2	2.07	15.5	18.2	1.01

Feldspar

Major and trace elements of feldspar were analysed by XRF. The Rb/(Sr+Ba) and Rb/Sr ratios of K-feldspar and plagioclase, respectively, reflect the degree of differentiation of the magma from which the pegmatite crystallised. The most primitive ratios exhibit the syn-orogenic plagioclase-dominated pegmatites and the late-orogenic granite pegmatites related to the emplacement of the Herefoss pluton. The feldspar chemistry of the syn-orogenic pegmatite granites, granite pegmatites, zoned pegmatites and K-feldspar-dominant pegmatites reflects moderate differentiation whereas that of the muscovite pegmatites is the most differentiated. Syn-orogenic pegmatitic granites, granite pegmatites, zoned pegmatites, plagioclase-dominant pegmatites, K-feldspar-dominant pegmatites and the muscovite pegmatites have >13 wt.% K_2O, which is the requirement for glass- and ceramic-grade K-feldspar.

Sampling traverses across the individual syn-orogenic granite pegmatites and zoned pegmatites reveal large variations of the Rb/(Sr+Ba) and Rb/Sr ratios of the feldspars (Figure 1). The ratios decrease from the core towards the margin of the pegmatites. But also the feldspar megacrysts itself, which can be up to 2 m in size, are chemically zoned. The megacryst cores are more primitive in composition than their margins.

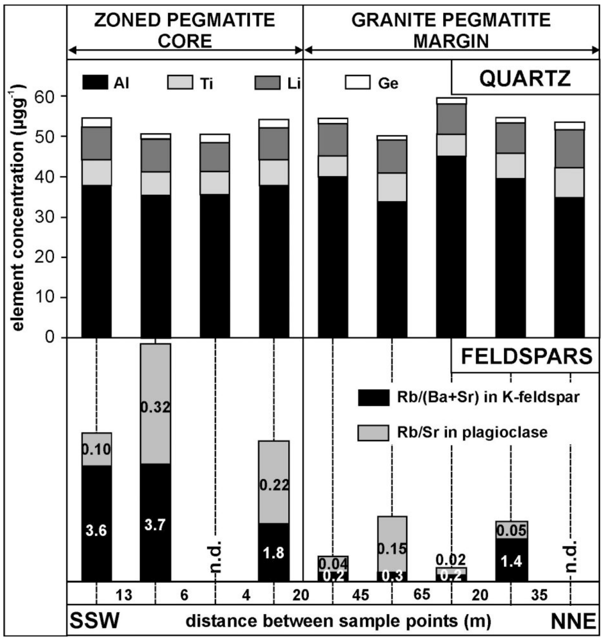

FIGURE 1. Chemistry of quartz and feldspars sampled along a 208-meter long traverse crosscutting the zoned pegmatite core and its granite pegmatite margin. Al, Ti, Li, and Ge concentrations of quartz vary insignificantly (upper diagram) whereas the Rb/(Sr+Ba) and Rb/Sr ratios in K-feldspar and plagioclase, respectively, decrease tendentiously from the core towards the margin (lower diagram). n.d. – not determined.

CONLUSIONS

The trace element abundances in quartz from the undeformed syn-orogenic pegmatites are unexpectedly consistent and independent of pegmatite type. In contrast, the feldspar chemistry largely reflects the degree of differentiation of the pegmatite-forming magma. Post-crystallisation contact metamorphism (emplacement of the Herefoss pluton) and recrystallisation of syn-orogenic pegmatites caused the diminishing of lattice-bound Al and Li in quartz, whereas the Ti content increased. However, undeformed syn-orogenic pegmatites comprising the major type in the Froland pegmatite field were derived from a common crustal source. Variations in the Al, Li, K and Fe contents in quartz of late- and post-orogenic pegmatites may indicate different melt/fluid chemistries and sources, whereas the Ti concentration depends largely on the crystallisation temperature of quartz.

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