RARE-METAL PEGMATITES IN THE SVECONORWEGIAN OROGEN (0.9-1.1 Ga) OF SOUTHERN NORWAY

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ABSTRACT

The Sveconorwegian orogen of the Fennoscandian shield is characterised by abundant NYF type granitic pegmatites which developed somewhat diachronously throughout the orogen in the period 1.13-0.92 Ga. They comprise two major types which include anatectic AB-HREE pegmatites formed shortly after medium- to high-grade peak metamorphism and REL-REE to REL-Li pegmatites spatially associated with granitic plutons. The latter may represent a potential source of the pegmatite magmas, although the granitoids rarely appear to be highly differentiated or specialised.

INTRODUCTION

Increasing demand for high-purity quartz in Norwegian industry has encouraged research on the chemistry of pegmatitic quartz coupled with petrogenetic studies of the granitic pegmatites in the Sveconorwegian (Grenvillian) orogen of South Norway. The latter is the topic of the present contribution which gives an overview of the polyphase development of NYF type pegmatites with enhanced contents of Be, Y, REE, Nb, Ta, U, Th, Li, Sn and F.

GEOLOGICAL SETTING

The Meso- and Palaeoproterozoic crust in the southwestern part of the Fennoscandian Shield was reworked during the Sveconorwegian (Grenvillian) orogeny when a number of terranes or crustal blocks were amalgamated and intruded by numerous late- to post-orogenic granites (Fig. 1; Bingen et al. 2008a). The terranes expose rocks of variable palaeo-crustal levels with somewhat diachronous development of medium- to low-pressure amphibolite and granulite facies metamorphism (1.14-0.92 Ga, Bingen et al. 2008b) and emplacement of polyphase granitic pegmatites. The variably sized (≤ 1 km^2) and spaced pegmatites define a number of districts comprising several belt-like pegmatite fields with general orientation parallel to the structural trend of the respective host terranes.

THE PEGMATITES

Many of the pegmatites are well known among mineralogists for their contents of rare-metal minerals identified in conjunction with exploitation of feldspar, quartz and muscovite initiated at the end of the 18th century. The pegmatite districts are dominated by simple, small-grained (<20 cm) pegmatites composed of microcline perthite, quartz and oligoclase, as well as highly variable proportions of biotite and muscovite. Spessartine-dominated garnet and apatite are common accessories, whereas tourmaline (schorl) occurs as an important constituent among small clusters of pegmatites. The pegmatite bodies and dykes cutting the tectonic structures of their host rocks represent locally feeders for bodies of porphyritic pegmatite granite with 5-80 cm alkali-feldspar phenocrysts. The zoned pegmatites quarried in the past are less abundant, but are the main host for the rare-metal minerals. These are mainly confined to the blocky feldspar zone with associated sub-zones of coarsely crystalline biotite or muscovite, as well as to the inner part of the adjacent intermediate zone, composed of more small-grained pegmatite. Some of the pegmatite fields also include rare-metal mineralisation associated with late stage cleavelandite masses and veins commonly occurring in the central parts of the pegmatites. Rare-metal pegmatites are present in all of the districts as single bodies or small clusters of several bodies. Large clusters or pegmatite fields containing high proportions of rare-metal pegmatites include the Hidra, Evje-Iveland, Tørdal and Råde pegmatite fields (Fig. 1; Brøgger 1906, Bjørlykke 1935, Adamson 1942, Oftedal 1942). In these fields the diversity of rare-metal minerals varies considerably from pegmatite to pegmatite. Some carry only beryl or beryl+gadolinite whereas others carry in addition a large spectrum of different Y-, Nb-, Ta-, REE-, U-, Th- and/or Sc-bearing minerals which can be used in the classification of paragenetic sub-types (Bjørlykke 1935). The most widespread of the primary magmatic rare-metal minerals are beryl, euxenite, polycrase, samarskite, aeschynite, yttrotitanite, gadolinite, columbite, pyrochlore, thorite, uraninite, xenotime, fergusonite, allanite, and monazite which are typical of NYF type pegmatites. Some pegmatite fields are also characterised by Sc-rich minerals such as thortveitite and bazzite, which occur in the Evje-Iveland and Tørdal fields, respectively (Bjørlykke 1935, Bergstøl & Juve 1988). These two fields are also recognised by abundant development of superimposed cleavelandite-quartz-topaz-muscovite pegmatites with associated amazonite-rich zones (Oftedal 1942, Frigstad 1999). In the Tørdal field the cleavelandite masses are characterised by enrichment of microlite, yttrotantalite, scandian ixiolite, bazzite, yellowish beryl, gadolinite, bertrandite, lithian muscovite, zinnwaldite, lepidolite and/or cassiterite (Oftedal 1942, Bergstøl & Juve 1988).

Most of the pegmatites can, in accordance with the classification of Černý & Ercit (2005), be termed abyssal pegmatites (AB) which are generally biotite-bearing, although some fields are comprised of muscovite-rich pegmatites (MS). The mineralogy of the rare-metal pegmatites, commonly containing subordinate amounts of LREE minerals like allanite and monazite, suggests that they range from AB-HREE pegmatites to REL-REE and REL-Li pegmatites typical of the Evje-Iveland and Tørdal fields, respectively.

GENETIC ASPECTS

Field relationships and U/Pb isotope dating show that the rare-metal pegmatites developed during two major stages of the Sveconorwegian orogeny: 1) shortly after peak granulite- to amphibolites facies metamorphism and 2) in conjunction with the crystallisation of late- to post-orogenic granite intrusions (1.0-0.9 Ga). Both stages comprise multiple episodes of pegmatite emplacement. The proportions of pegmatites related to the different stages are difficult to assess due to the restricted number of dated pegmatites. However, the stage 2 pegmatites occurring in the exo- and endocontact of the late-to post-orogenic granites generally have small dimensions in comparison with the stage 1 pegmatites.

The first stage of pegmatite emplacement, comprising synkinematic pegmatites, includes those in the Bamble terrane where U/Pb dating of rare-metal pegmatites yields ages in the range 1.06-1.12 Ga (Baadsgaard et al. 1984, Cosca et al. 1998) which is somewhat younger than the metamorphic overprint in the district (1.14-1.08 Ga; Bingen 2008b). These pegmatites show no spatial relationships with coeval granite intrusions and appear to be of anatectic origin. Rare-metal pegmatites in the exocontact of the Bohus-Iddefjord granite batholith (0.92 Ga), previously assumed to be genetically related to the granite, yield ages in the range 1.04-0.98 Ga, i.e., more than 50 Ma before the granite (Romer & Smeds 1996), but shortly after amphibolites facies metamorphism at 1.05-1.02 Ga (Bingen et al. 2008). Although several rare-metal pegmatites occur within the Bohus-Iddefjord batholith (Brøgger 1906) and in other similar granites elsewhere in southern Norway some of these may represent rafts of the first-stage pegmatites. This was shown to be the case in the Froland field where the Herefoss granite cuts the anatectic pegmatites of the Froland-Lillesand belt (Fig. 1; Müller et al. 2008).

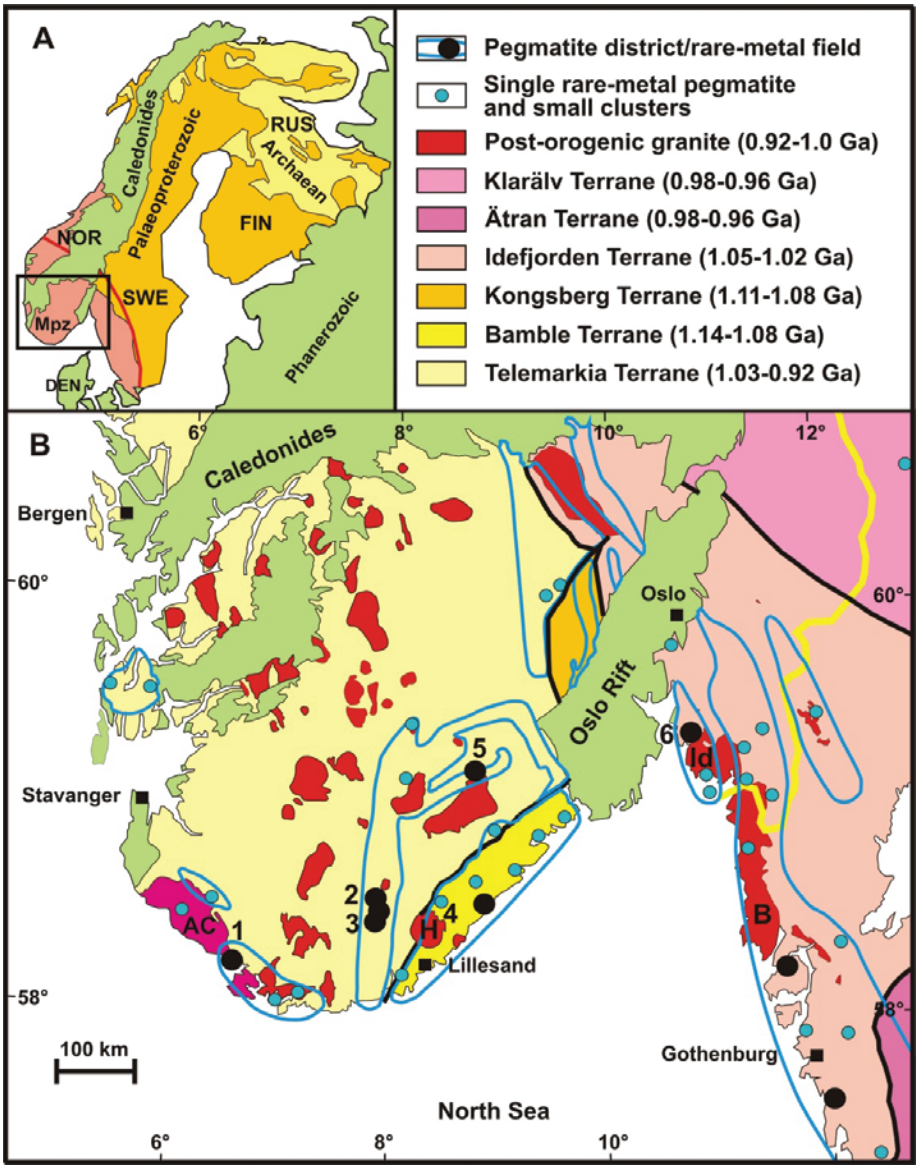

Figure 1- A) Key map show the location of the Sveconorwegian orogen (west of red line) and Mesoproterozoic crust (MPz) in the Fennoscandian Shield. B) Simplified geological map of the Sveconorwegian terranes in S Norway and part of SW Sweden (yellow line = national border) showing the distribution of pegmatite districts and rare-metal pegmatite fields. Ages given in the legend refer to extent of amphibolite and granulite facies metamorphism in the individual terranes (Bingen 2008b). AC = anorthosite complex, B = Bohus granite, H = Herefoss granite, Id = Iddefjord granite. Numbered rare-metal pegmatite fields are 1) Hidra, 2) Evje, 3) Iveland, 4) Froland, 5) Tørdal, and 6) Råde. Fields in Sweden adapted from Smeds (1990).

The late- to post-orogenic granites comprise composite plutons of quartz monzonites, granodiorites and granites. This magmatic event represents emplacement of mantle-derived magma into the source region of granitic magmas in the lower crust leading to formation of hybrid magmas containing crustal and mantle-derived components (Andersen 2002). Highly differentiated phases are uncommon in the plutons and none of these phases appears to be spatially related to rare-metal pegmatites. The relationships between pegmatite formation and granite magmatism will be discussed in the light of results from bulk chemical analyses of stage 1 and 2 pegmatites and plutons in the Froland-Herefoss field.

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