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Inefficiency of magma mixing and source heterogeneity in the genesis of granitoids : the example of the Farsund intrusion (southern Norway)

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The Farsund intrusion (≈930 Ma, ≈150 km^2) is an apparently homogeneous igneous body belonging to the Sveconorwegian (Grenvillian) postcollisional magmatic suites of southern Norway and comprising mostly opx-bearing lithologies (qtz mangerites to charnockites). However, a detailed geochemical and petrological study has revealed that it results from a large scale mingling process between two distinct magmas. The first magma crystallized as a light grey facies lacking orthopyroxene and containing abundant hornblende (926±4 Ma : U-Pb on zircon) and the second magma, as a slightly darker facies containing both orthopyroxene and hornblende (931±2 Ma : U-Pb on zircon). In major and trace elements variation diagrams, the two facies display similar trends from 60% up to 72 % SiO_2, but there are significant differences. Mainly FeO_t/MgO, MnO, Na_2O are higher whereas Rb and Pb are lower in the opx-bearing facies. Also, the amphibole from the opx-bearing facies has a higher Fe# (0.60-0.82) than that of the other facies (0.59-0.65) reflecting the higher FeO_t content of the magma. Most importantly, the isotopic composition of Sr and Nd unequivocally identifies the two magmas. In an ε_{Ndt} versus Sr_i diagram (@930Ma), the two facies define two perfectly distinct groups: Sr_i= 0.7097 to 0.7114 and ε_{Ndt} = +1.1 to -0.4 for the opx-bearing facies and Sr_i= 0.7054 to 0.7078 and ε_{Ndt} = -1.0 to -2.0 for the other facies. The mineralogical, geochemical and isotopic characteristics of these two magmas perfectly mimics those of the two postcollisional magmatic suites which have been identified in the Sveconorwegian (Grenvillian) orogeny of southern Norway, namely the Anorthosite-Mangerite-Charnockite (AMC) and Hornblende Biotite

Granitoids (HBG) suites (Vander Auwera et al., 2003). The former, characterized by opx-bearing lithologies (the Rogaland anorthosite Complex), is located on the western side of southern Norway whereas the latter intruded the eastern part of the orogeny. Note that the Farsund body was emplaced just at the boundary between these two domains. The rheologies of the two magmas which mingled in Farsund were probably similar. Indeed, melts calculated densities and viscosities are identical or close : ρ=2.45 for both facies (at 1000˚C, P=400 MPa and fO_2 at FMQ for the opx-bearing facies and at NNO+1.2 for the other facies : Lange, 1994 ; Kress and Carmichael, 1991), η=2262 Pa.s for the opx-bearing facies and 519 Pa.s for the other facies considering 5.5 %H_2O in both melts (Shaw, 1972). Temperature, pressure of emplacement and H_2O contents have been estimated with the apatite saturation geothermometer (Harrison and Watson, 1984), the Al-in hornblende geobarometer (Johnson and Rutherford, 1989) and experimental data acquired on similar compositions (Bogaerts et al., submitted ; Dall'Agnol et al., 1999). Consequently, the persistence of the distinct mineralogical, geochemical and isotopic characteristics of the two magmas in the same intrusion implies that the ascent and emplacement processes were fast enough to preclude their mixing and even self diffusion of Sr and Nd isotopes between isotopically contrasted magmas. Ascent and emplacement mechanisms of one intrusion of the HBG suite, the Lyngdal body located just on the east of Farsund, have been discussed by Bogaerts et al. (2003). These authors showed that dyking (Clemens and Mawer, 1992 ; Petford et al., 2000) was the main ascent mechanism and that the final emplacement of the magma was controlled by the crustal anisotropy defined by the brittle-ductile transition of the upper crust (≈3kb). Similar processes may have taken place for Farsund. Another consequence is that as isotopes were not disturbed during ascent and emplacement of both magmas in Farsund, their contrasted isotopic compositions probably record the contrasted isotopic compositions of their respective sources, most probably in the lower crust.

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