Petrogenesis of Sveconorwegian magmatism in southwest Norway; constraints from zircon U-Pb-Hf-O and whole-rock geochemistry

Nick M W Roberts[1,2], Trond Slagstad[3], Randall R Parrish[1,2], Michael J Norry[2], Mogens Marker[3], Matthew S A Horstwood[1], and Torkil Røhr[3]

[1] NERC Isotope Geosciences Laboratory, BGS, Nottingham, UK
[2] University of Leicester, Leicester, UK
[3] Geological Survey of Norway, Trondheim, Norway

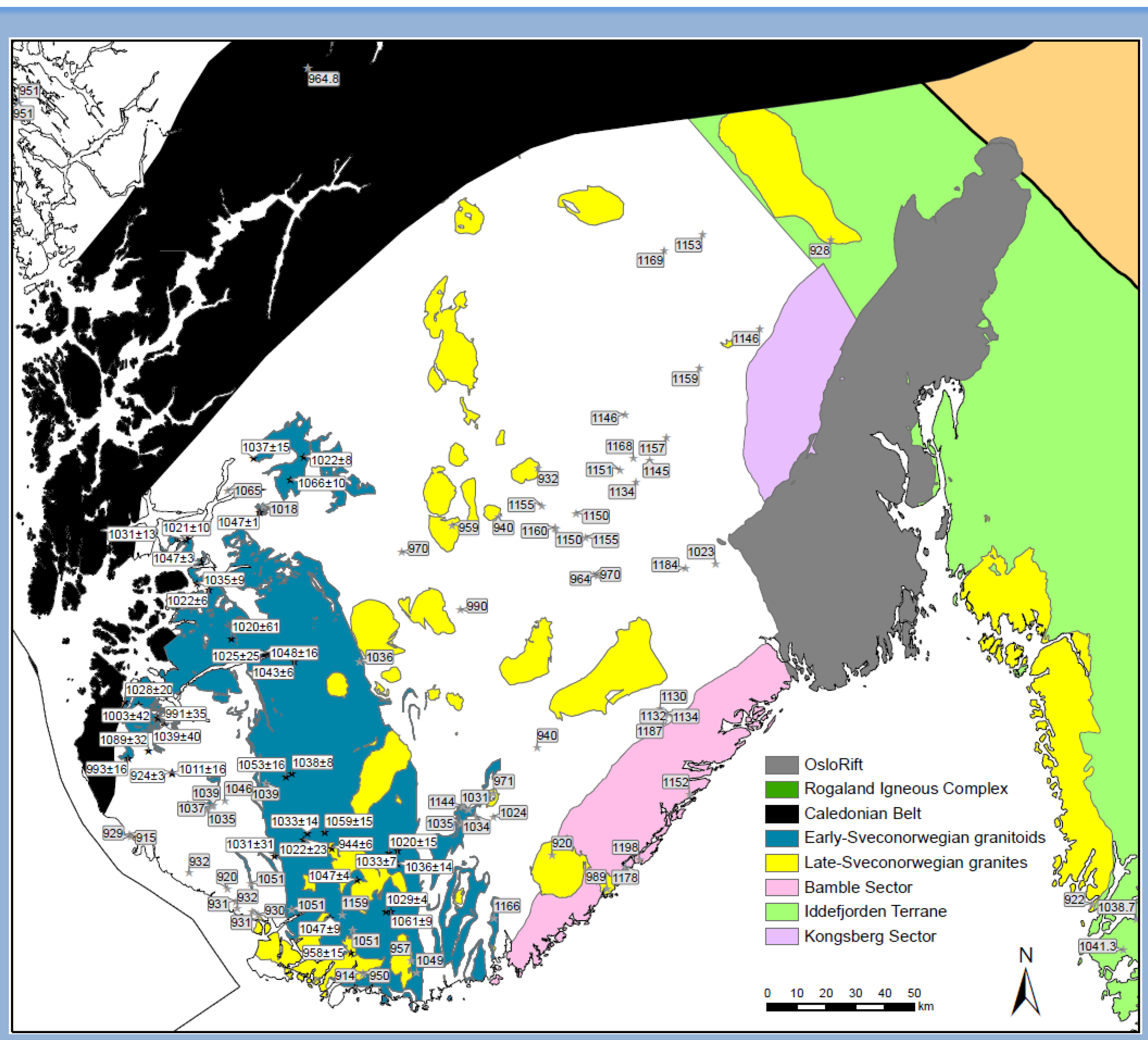
nirob@bgs.ac.uk

Introduction

The Sveconorwegian orogen is traditionally interpreted as a Himalayan-scale continental collision, and the eastward continuation of the Grenville Province of Laurentia; however, it has recently been proposed that it represents an accretionary orogen without full-scale continental collision (Slagstad et al. 2013).

Magmatism is one of the key constraints that can help differentiate between different types of orogens; thus, detailed investigation of the timing and petrogenesis of the magmatic record is a requirement for better understanding of the Sveconorwegian orogen as a whole.

Here, we present new U-Pb geochronology, zircon Hf-O isotope, and whole-rock geochemical data to constrain the petrogenesis of the early –Sveconorwegian Sirdal Magmatic Belt (SMB).



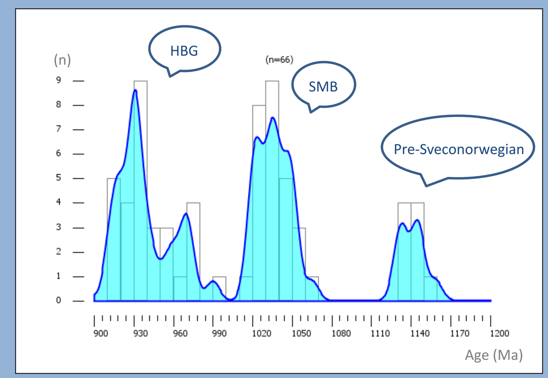
The Sirdal Magmatic Belt (SMB)

The SMB is a voluminous granitoid batholith that intrudes the Rogaland-Hardangervidda Block in southwest Norway between 1070 and 1020 Ma, pre-dating high-grade metamorphism by >30 Ma.

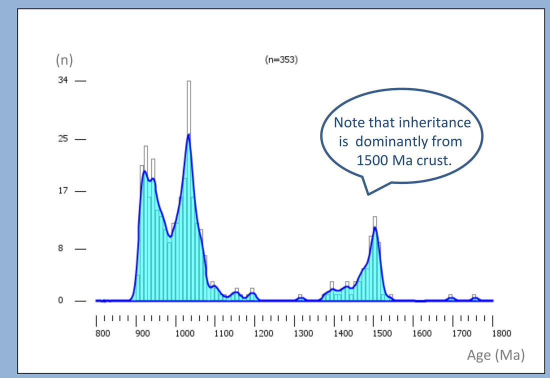
The geochemistry of the SMB is similar to that of Cordilleran batholiths in western US, e.g. Sierra Nevada, Peninsular Ranges.

The SMB is typically non- to weakly-deformed, but includes units that are ductilely deformed into augen gneiss.

The SMB contains inclusions ranging from mafic microgranular enclaves (MME) to rafts of country rock that are m's to 10 km's in size (these are amphibolite- to granulite-facies ortho and paragneiss).



Compilation of ages from S Norway granitoids (Hardangervidda-Rogaland & Telemark Blocks)



Compilation of all individual zircon ages from Sveconorwegian granitoids in S Norway

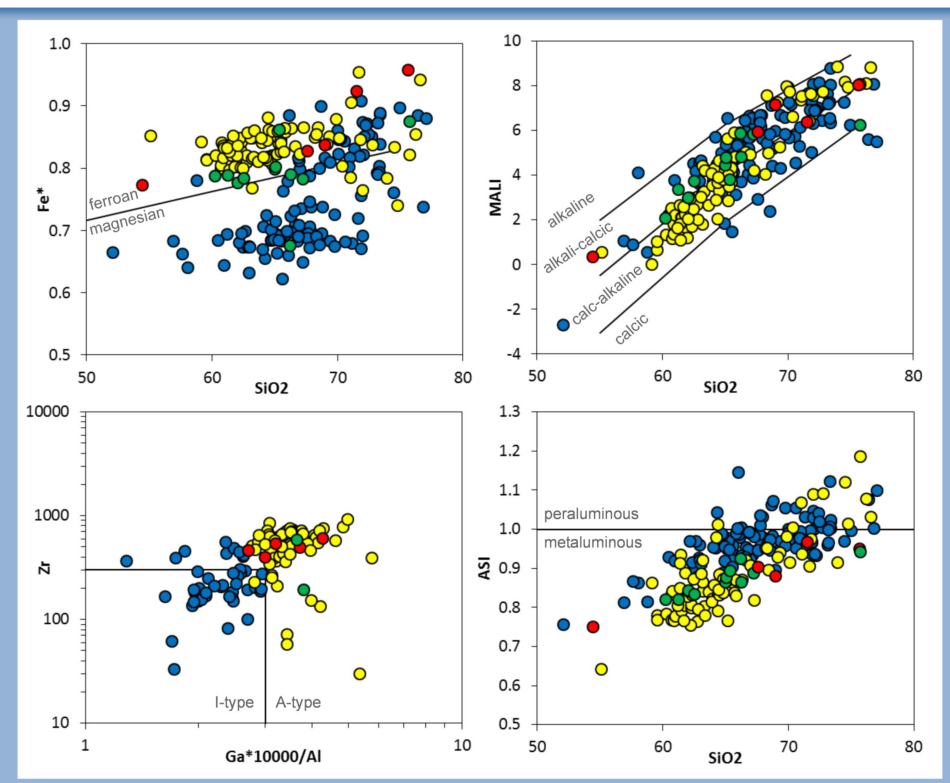
Geochemistry *(1)*

The SMB exhibits geochemical signatures typical of supra-subduction zone arc magmatism:

i.e. magnesian (I-type), calc-alkaline to alkaline, metaluminous to weakly peraluminous, LILE/HFSE enrichment, LREE/HREE enrichment, low Ga/Al

Negative Nb, Ta, Ti, Sr, & P anomalies.

A linear liquid line of ascent between 60 and 75% SiO2.



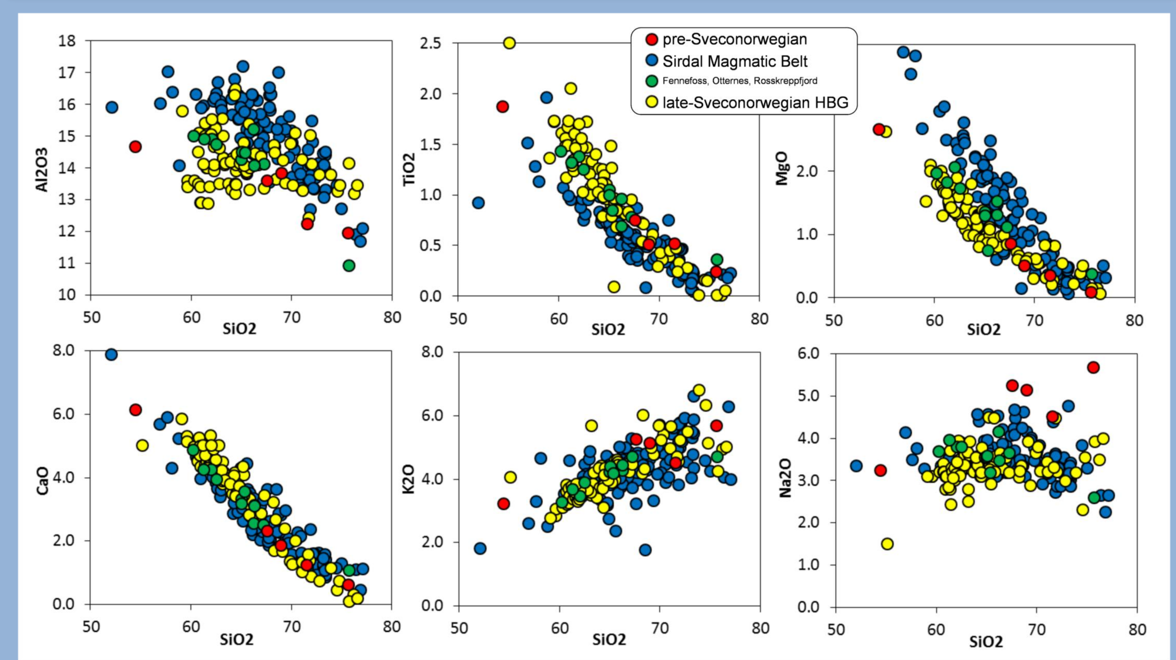
Geochemistry *(2)*

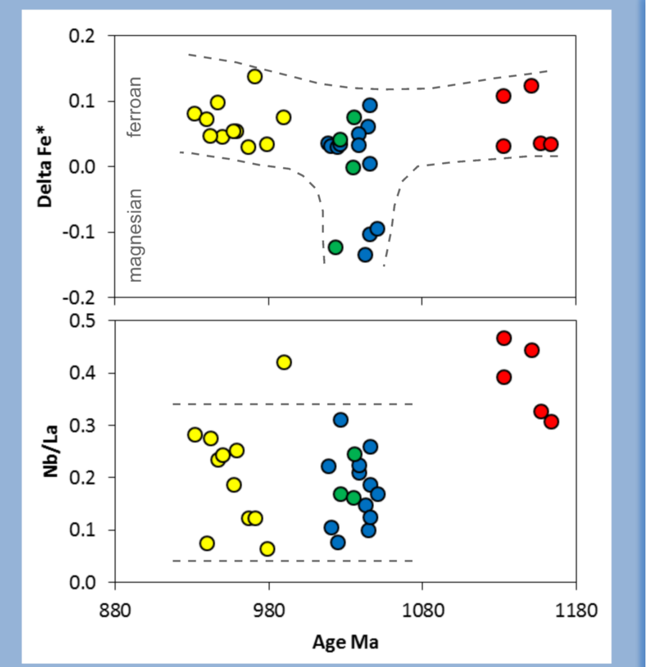
The SMB has a geochemical signature broadly similar to that of the late Sveconorwegian HBG, with some key similarities and differences:

LILE contents and the size of the Nb anomaly are broadly equivalent.

Fe, and the incompatible elements (e.g. REE and HFSE), are higher in the HBG.

Al and Mg are lower in the HBG.





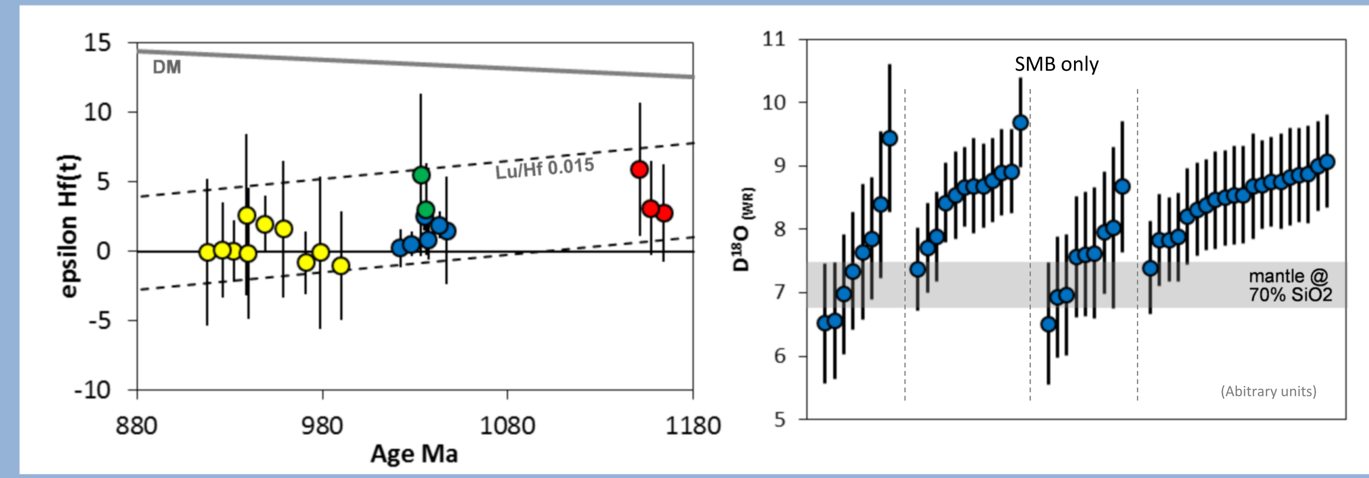
Petrogenesis

The subduction zone signature of the SMB may have been derived from its protolith, since a similar signature is seen in earlier and later granites (e.g. HBG), that are likely derived from crustal melting.

However, the SMB marks a clear transition to more magnesian (I-type) compositions, from earlier and later granites that are ferroan (A-type).

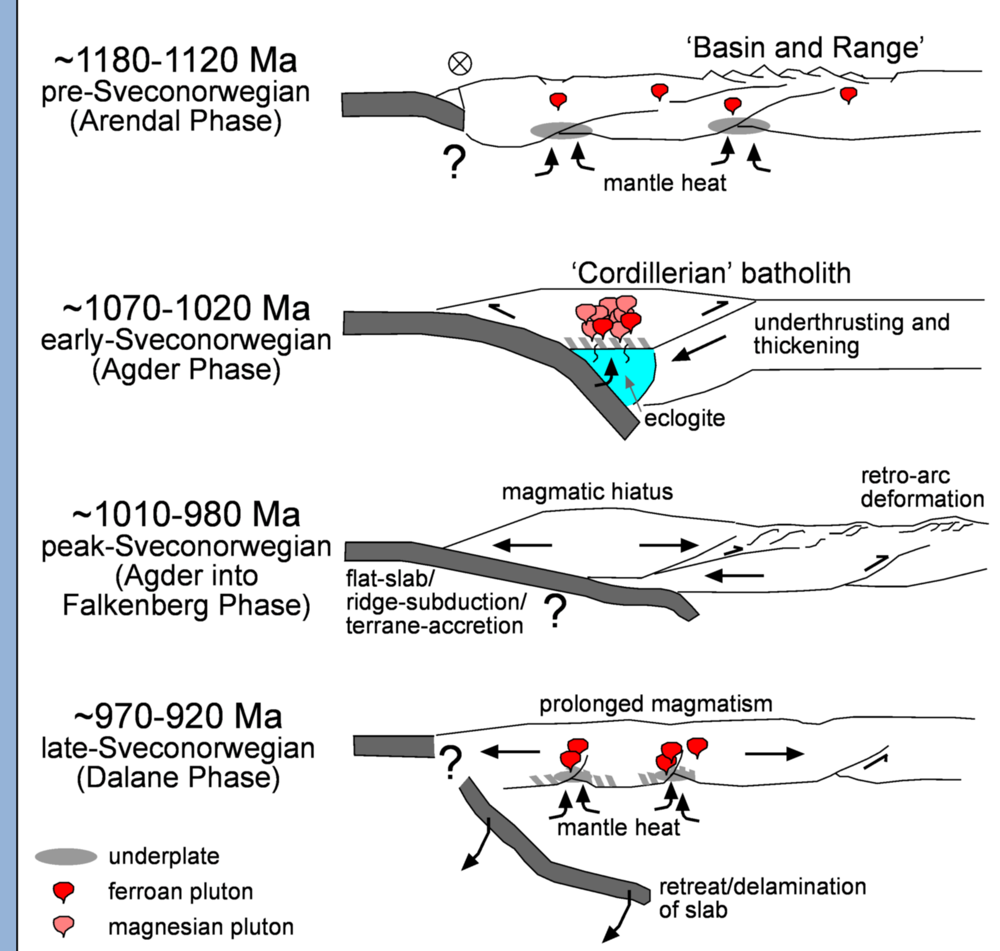
This change in composition is unlikely related to source, since the Hf isotope signatures are broadly equivalent across all of the granite suites (and suggest a dominant input from pre-existing crust, i.e. 1200-1500 Ma).

We suggest this change relates to an increase for the SMB in fO_2 and/or H_2O wt% in the source region during melting, which will decrease the proportion of residual plagioclase during melting, and decrease Fe-Ti oxide as a peritectic phase.



Elevated $\delta^{18}O_{(zircon)}$ signatures in the SMB could be intepreted as evidence for a supracrustal input to magmatism – however, this signature is probably inherited from the pre-existing 1.5 Ga crust that also exhibits high $\delta^{18}O_{(zircon)}$ (and that itself had a supracrustal input; Roberts et al., 2013).

Integrating the magmatic record into the Sveconorwegian Orogeny



A model

Pre-Sveconorwegian granites are scattered throughout the region, and likely intruded in an extensional or transtensional regime, the margin may have been strike-slip, or subduction may have been occurring far outboard.

The SMB indicates a phase of magmatism that is interpreted to be supra-subduction, and compatible with a Cordilleran 'flare-up' model (e.g. DeCelles et al.2009).

The end of the SMB magmatism overlaps with high-grade metamorphism in the region. Magmatism then ceases, and metamorphism occurs in the inboard easterly parts of the orogen – the cause of this remains debated (see Slagstad et al., this session).

After a period of high-grade metamorphism, granites traditionally termed post-collisional (HBG) intrude the region – this magmatism is prolonged, and thus unlikely related to a single delamination/slab-drop-off event. An extensional/transtensional setting is inferred by most models.

Finally, subduction either ceased or jumped outboard.

Conclusions

1) The SMB has a clearly contrasting geochemical signature from earlier and later granite suites (i.e. magnesian rather than ferroan).
2) The subduction zone signature in the SMB (and HBG to an extent) may have been inherited from its protolith.
3) Melting of the lower crust (comprising 1.5 to 1.2 Ga arc basement) produced the SMB and HBG, and requires mantle heat for both.
4) The composition of the SMB requires greater fO_2 and H_2O% during melting, we infer this to be a consequence of a supra-subduction environment with volatile input from the hydrated mantle-wedge.

References:
DeCelles et al. 2009. Cyclity in Cordilleran orogenic systems. Nature Geoscience, Nature Geoscience, 2, 251-257.
Roberts et al. 2013. Sedimentary recycling in arc magmas: geochemical and U-Pb-Hf-O constraints on the Mesoproterozoic Suldal Arc, SW Norway. Contributions to Mineralogy and Petrology, 165, 507-523.
Slagstad et al. 2013. A non-collisional, accretionary Sveconorwegian orogen. Terra Nova, 25, 30-37.