# Geochemistry of greenstones in the Tasiusarsuaq terrane, southern West Greenland

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Tonalite-trondhjemite–granodiorite (TTG) gneisses and melanocratic to ultramafic greenstones dominate the Archaean basement of southern West Greenland. The greenstones are likely to represent different original environments, which is important as the mineral deposits they may host depend on this. For example, massive sulphide deposits associated with gold and base metals are commonly volcanogenic, while chrome, nickel and platinum group elements are more commonly associated with layered intrusions (Robb 2005). Current investigations by the Geological Survey of Denmark and Greenland (GEUS) in southern West Greenland are therefore focused on the origin of greenstones and their relationship to associated TTG gneisses.

Here, we report on work in progress on greenstones within the Tasiusarsuaq terrane (Fig. 1; Friend *et al.* 1996). They differ from many other greenstone belts in southern West Greenland in their spatial association with the TTG gneisses. Unlike the Isua, Ivisârtoq and Storø greenstone belts in the central and northern Nuuk region, the Tasiusarsuaq greenstones are not proximal to terrane boundaries but form dismembered blocks and slivers within the terrane (Fig. 1). Contact relationships to the gneisses are almost exclusively tectonic, and primary textures are, with rare exceptions, obliterated by amphibolite to granulite facies metamorphism.

## Field relationships

Stendal & Scherstén (2007) documented one of the rare examples of well-preserved field relationships for a volcanic pile of pillow basalts, rhyolites (*sensu lato*) and melanocratic-ultramafic tuffs and flows on 'Nunatak 1390' (Fig. 1). The rhyolite was extruded at 2.876 ± 0.005 Ga (Næraa & Scherstén 2008 – this volume), which is the minimum age for the basalts and within the known age range for the Tasiusarsuaq terrane.

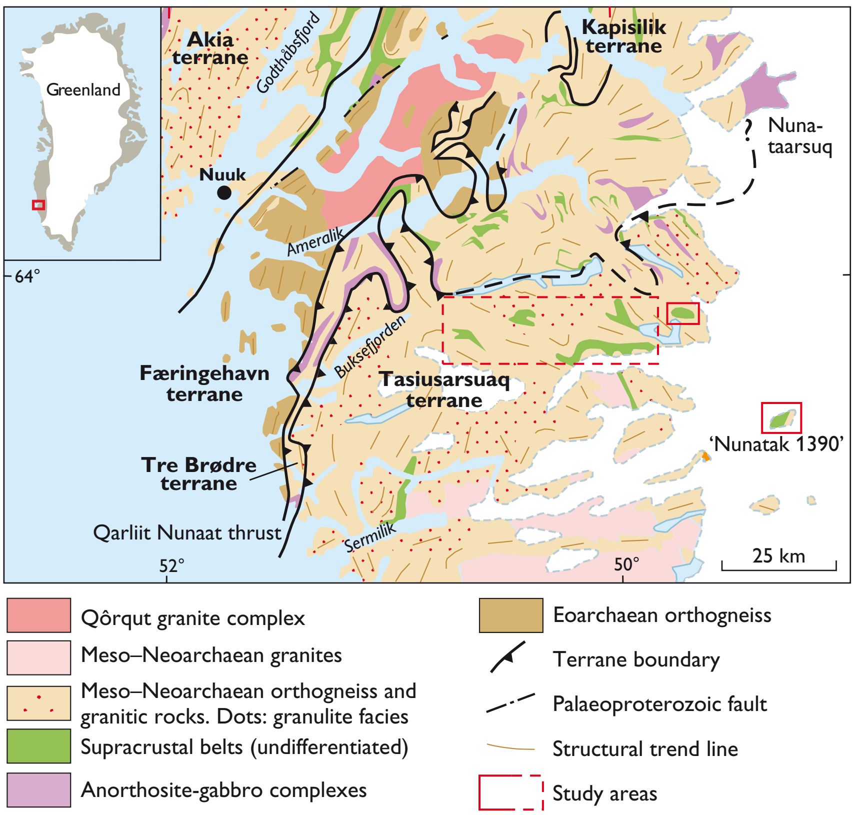



Fig. 1. Generalised map of the northern part of the Tasiusarsuaq terrane. The northern boundary as suggested by Friend *et al.* (1996) is outlined with solid and stippled lines for more or less well-determined demarcations of the terrane. It is likely that the border extends farther to the north in the eastern part (cf. Næraa & Scherstén 2008 – this volume; B. Windley and A.A. Garde, personal communication 2008). Sampling areas are highlighted by red boxes, and the two main sampling areas are indicated by solid lines.

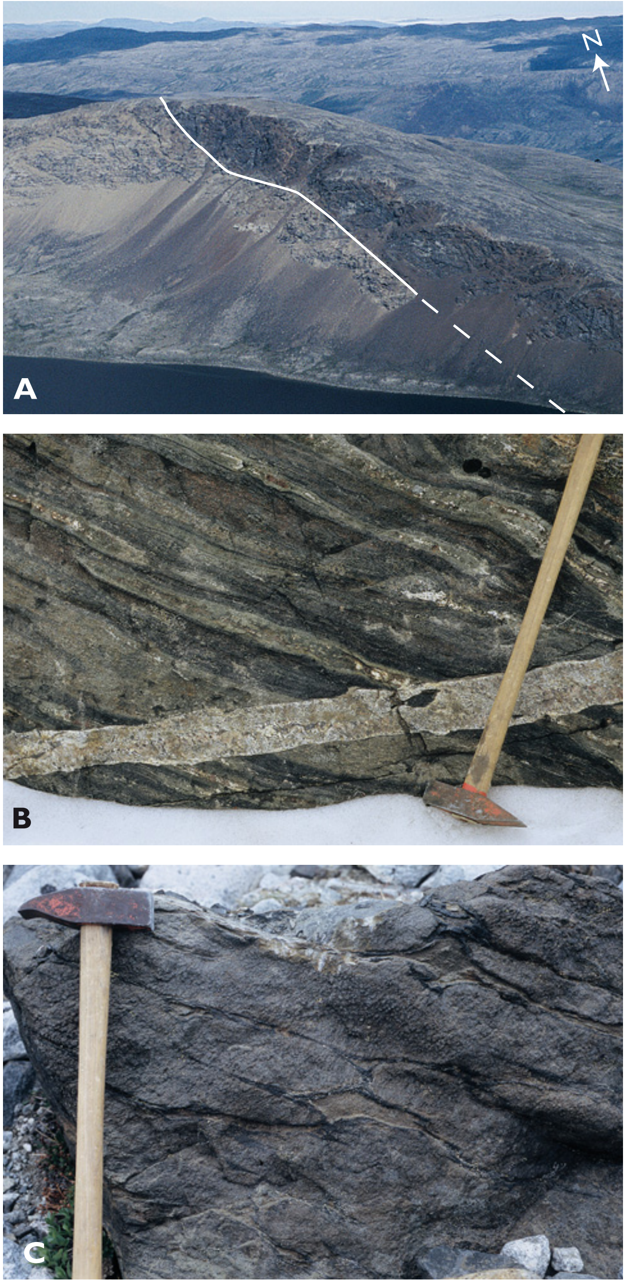



Fig. 2. **A**: Tasiusarsuaq greenstones displaying a tectonic contact with the Tasiusarsuaq grey TTG gneises; the greenstones seem to have been thrust northwards. **B**: Variably deformed pillows, sometimes with elongate calc-silicate aggregates, demonstrating a supracrustal origin for the greenstones. Such rocks are found throughout the area (cf. Stendal & Scherstén 2007, fig. 4). The flattened pillows are cross-cut by a granite dyke of unknown age. **C**: Pillow-like structures among ultramafic rocks.

Here, we make the assumption that the rhyolite date establishes the age for the majority of the greenstones within the Tasiusarsuaq terrane.

To the north-west of 'Nunatak 1390', a melanocratic to ultramafic complex forms a tectonic lens, with internal top-to-the-north thrust planes that reflect tectonic emplacement against the gneisses (Figs 1, 2A). The rocks range from ultramafic olivine-pyroxene-rich cumulates to basaltic amphibolites, sometimes with flattened pillow lavas and calc-silicates (Fig. 2B). Ultramafic rocks with pillow-like structures were also observed, and the complex is interpreted to be dominated by basaltic to komatiitic flows and shallow sills (Fig. 2C).

Similar dismembered bodies are scattered within the Tasiusarsuaq terrane but are commonly more deformed and do not preserve primary textures. The ultramafic rocks have been divided into two groups on the basis of their field appearance, with the first group containing ultramafic rocks of cumulate or undetermined origin and the second comprising ultramafic rocks with eruptive features such as pillow structures. Only the eruptive ultramafic rocks will be considered here.

## Whole-rock geochemistry

The rocks considered here are dominated by tholeiitic metavolcanic amphibolites and meta-ultramafic rocks of komatiitic composition. The ultramafic rocks are signified by MgO >16 wt%, $Al_2O_3$ <5.5 wt%, high Ni and Cr (>500 and >1500 ppm, respectively), and $Al_2O_3/TiO_2$ ratios <10, while the amphibolites have MgO <10 wt%, $Al_2O_3$ >10 wt%, Ni and Cr (<250 and <500 ppm, respectively) and $Al_2O_3/TiO_2$ ratios of 7–37, of which most ratios are >10 (Fig. 3). The ultramafic rocks are aluminium depleted and show strong positive correlation between Ni and MgO (Fig. 3), which is presumably controlled by olivine and pyroxene fractionation. $Al_2O_3/TiO_2$ ratios of 10–40 for the amphibolites and <10 for the ultramafic eruptives imply a deeper melt origin (>5 GPa, i.e. >150 km) for the ultramafic rocks (Walter 1998). On 'Nunatak 1390' at least some of the ultramafic rocks seem to be intercalated with basaltic pillow lavas, which might suggest that they formed sills that are younger than the basalts (Stendal & Scherstén 2007). This could imply that the depth of melting increased with time (presuming that the ultramafic rocks are indeed slightly younger than the pillow lavas), or that shallow melting was induced by the deeper melts if they were contemporaneous.

The ultramafic rocks have smooth trace element patterns, but with Nb/Th ratios that are lower than the primitive mantle (PM; Fig. 4). This implies some degree of enrichment in the mantle source, or that the Nb/Th ratios have decreased due to shallow continental crustal contamination. The light rare-earth element (REE) signatures are horizontal, whereas the mid- to heavy REE signature slopes towards lower abundances, indicating a garnet residue during mantle melting, which is consistent with their deep origin as discussed above (Fig. 4). The REE signatures of the amphibolites are similar to those of the ultramafic rocks, but with slightly higher con-

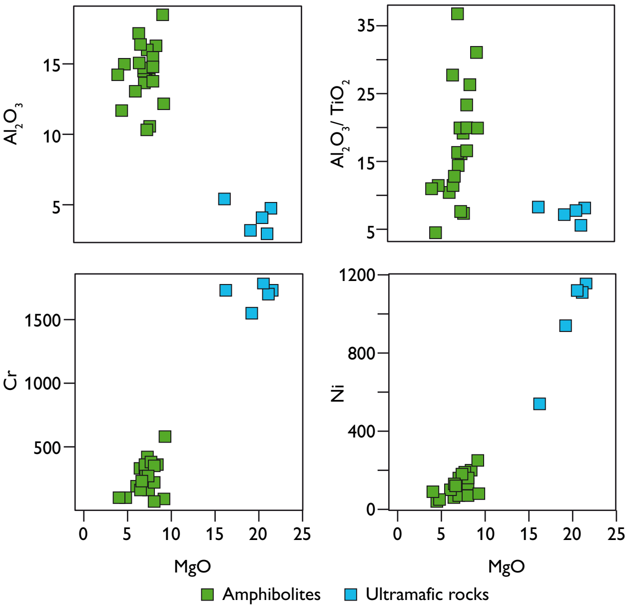


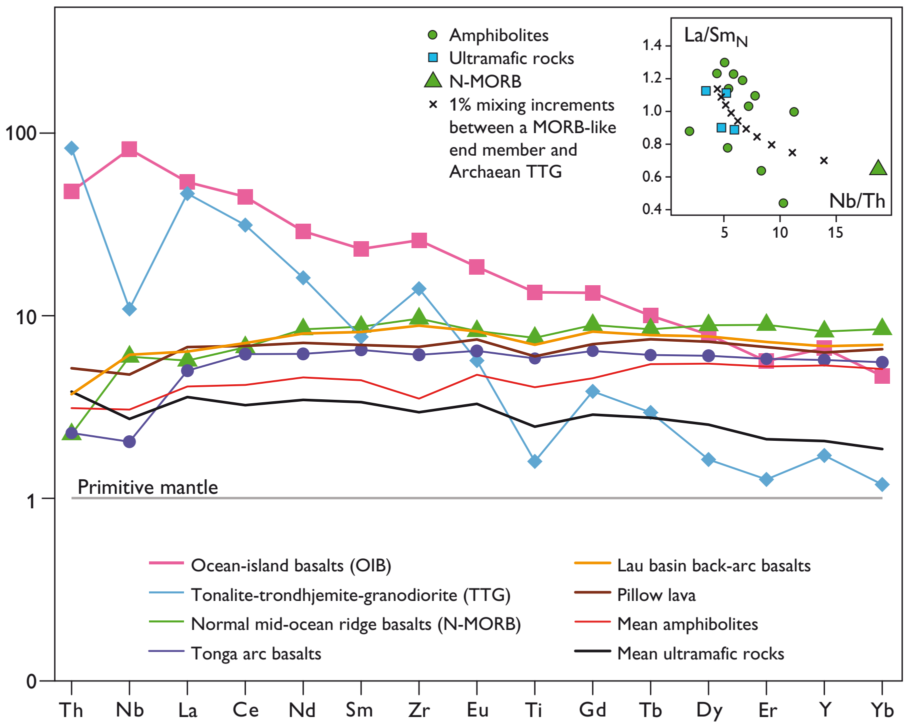

Fig. 3. MgO bivariate plots for a selected oxide, an oxide ratio and compatible trace elements. See text for further discussion.

centrations, and lacking the garnet signature noted for the ultramafic rocks (Fig. 4). Nb/Th ratios are generally PM-like. Overall, the amphibolites are generally more mid-oceanic ridge basalt (MORB)-like in their range of trace element ratios and abundances. In particular, one core of a pillow basalt from 'Nunatak 1390' consistently lacks continental crustal (or arc-like) trace element patterns.

## Crustal contamination

The general geochemical signatures and the subaqueous nature of the amphibolites and ultramafic rocks are consistent with an ocean-floor origin in its broadest sense. The MORB-like signatures of the amphibolites might be suggestive of an ocean basin, a back-arc basin or even a primitive tholeiitic arc. However, a major extensional setting such as a mid-ocean ridge is at odds with major simultaneous continental crust formation, which is indicated by e.g. massive volumes of presumably contemporaneous TTG crystallisation (Næraa & Scherstén 2008 – this volume), while a back-arc basin seems more conceivable. The trace-element arrays indicate source enrichment, i.e. variable amounts of enriched subduction components, or local contamination during emplacement (Fig. 4). Positive correlations for Nb/Th and Nb/La against the Th or La concentration reciprocals lie between mantle and continental crustal end-members, and these ratios are the most sensitive to small degrees of conta-

Fig. 4. Primitive mantle (Palme & O'Neill 2004) normalised trace element diagram for Tasiusarsuaq greenstones, one pillow lava from 'Nunatak 1390' and selected reference rocks and reservoirs. For comparison plots of N-MORB (Hofmann 1988), OIB (Sun & McDonough 1989), Archaean TTG (Martin 1995; Martin *et al.* 2005), Lau basin back-arc (Regelous *et al.* 2008 ) and median Tonga arc basalts (http://georoc.mpch-mainsz.gwdg.de /georoc) are shown. **Inset**: N-MORB, Lau basin back-arc basalts and OIB are characterised by Nb/Th ratios that are higher than PM, while median Tonga arc basalts and TTG have ratios that are lower than PM. The Tasiusarsuaq ultramafic rocks and one pillow lava have arc-like ratios lower than PM Nb/Th, while the amphibolites are variable with both sub- and supra-PM ratios. Minor TTG contamination of magmas with MORB-like ratios would rapidly decrease Nb/Th with associated increasing La/Sm, as these ratios are extreme in TTG. A plot of Nb/Th against chondrite normalised La/Sm is shown in the figure inset for the Tasiusarsuaq data, displaying a moderate fit with a mixing scenario as discussed above.



mination. Assuming a TTG crustal component as the contaminant, the array can be explained by <5% contamination for all but one sample, supposing that the most primitive ultramafic rocks are uncontaminated.

## Tectonic implications

If the basalt–komatiite magmatism in the Tasiusarsuaq terrane is indeed concurrent with TTG-formation, an arc environment for the former magmatism is favoured (cf. Stendal & Scherstén 2007; Næraa & Scherstén 2008 – this volume), and such a hypothesis is still viable in the light of the current geochemical data. The origin of komatiites remains controversial, although most authors advocate a mantle-plume related origin. The komatiite-like rocks documented here do not readily fit such an origin as they seem to be primarily associated with subduction and growth of continent crust. Alternatively, renewed models for subduction-related komatiite genesis might be considered. However, this scenario typically involves shallow melting (Grove & Parman 2004), while the REE ratios observed here favour deep melting with residual garnet.

## Outlook

Further work with detailed field studies and geochronology over the next few years will hopefully shed new light on these outstanding issues. Emphasis will be placed on searching for primary relationships between the TTG gneisses and the ultramafic rocks and amphibolites in conjunction with detailed geochronology and geochemistry.

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