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Pressure-solution creep leads to strain hardening in mylonitic amphibolites: examples from the Ben Hope Sill, Moine Supergroup, NW Scotland

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Amphibolites are typically produced during regional metamorphism of mafic-ultramafic rocks in the hydrated middle and lower crust. Despite their abundance, their rheology is somewhat enigmatic, especially when compared to better-known quartzo-feldspathic and phyllosilicate-rich rocks.
We investigated the ductile deformation of amphibolites associated with the Ben Hope Sill in Port Vasgo (NW Scotland) combining field and microstructural observations with Electron Backscattered Diffraction analysis. The Ben Hope Sill is a metamorphosed mafic body embedded within the Moine metasediments that experienced tight to isoclinal sheath folding and ductile Caledonian thrusting (local D2 event) under lower amphibolite-upper greenschist facies conditions. Pervasive ESE mineral lineations and widespread shear criteria (S-C fabrics, asymmetric pressure shadows) consistenly indicate top-to-the-WNW transport during D2 mylonitization. At the outcrop scale, the sill constitutes a series of spatially associated 0-10 m thick layers displaying progressive strain localization, from pockets of almost undeformed lenses to pervasively mylonitized horizons. The undeformed lenses are characterized by massive, coarse-grained amphibolites (hbl+qtz+plg+grt) in which static growth of poikiloblastic hornblende and almandine garnet, hosts a fabric of an earlier (D1) event.
Within amphibolite mylonites formed during D2 shearing we infer progressive pressure-solution of quartz, plagioclase and amphibole demonstrated by: i) the decrease in modal abundance of plg and qtz and increase/recrystallization of hbl; ii) the precipitation of hbl in pressure shadows and iii) the growth of Ca-rich rims of porphyroblastic garnet. Moreover, pockets of (locally sourced) overpressured fluids are represented by 1-30 cm veins of quartz (±Plg±Cal) that cross cut the shear bands and are locally highly strained into sheath folds. Thin horizons, typically observed at the edge of the deformed sill, show enrichment in biotite at the expense of the amphiboles and progressive brittle fragmentation of garnets.
Collectively, these observations suggest that initial D2 strain softening and localization within the amphibolites is guided by pressure solution. However, strain softening is limited by the sluggish kinetics of horneblende pressure-solution. Therefore, enrichment of amphiboles above a critical volumetric threshold leads to a substantial hardening of the mylonites causing, together with local fluid overpressure, brittle failure and ingress of metasomatic fluids. We emphasize the importance of fluids in supplying and removing chemical species during deformation, leading to complex brittle-viscous deformation cycles in amphibolitic rocks under middle crustal conditions.