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Weakening mechanisms and the role of easy slip horizons in thrust belt development: a microstructural approach

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The Late Silurian Moine Thrust Zone (MTZ) of the NW Highlands of Scotland has long been fundamental to the understanding of the nature and processes that occur during thrust tectonics in the upper continental crust. This complex imbrication zone formed during final Scandian stages of the Caledonian orogeny when collision of Baltica and Laurentia led to WNW-ESE tectonic foreshortening of >100km. The MTZ juxtaposed greenschist to amphibolite facies Neoproterozoic metamorphic rocks of the Moine Supergroup over sequences of little metamorphosed Cambro-Ordovician and Neoproterozoic sedimentary rocks and their Neoarchean to Paleoproterozoic gneissic basement in a zone ranging from <1km to >20km wide.

The mechanical problems represented by thrust wedges being transported over such great distances without losing their internal cohesion has highlighted the role played by detachment structures and the need for mechanisms that create significant weakening along basal detachments that allow overthrusts to accommodate major horizontal displacements in the shallow crust. Field studies and use of section balancing techniques have highlighted that a substantial proportion of the displacement seems to be accommodated along detachments that follow specific stratigraphic levels.

Other than the Moine Thrust Mylonites and the mylonitised parts of the Cambrian Quartzites, relatively little is known about the grain scale deformation and potential weakening processes that have occurred in other parts of the MTZ. New lithological descriptions of the fault rocks and sedimentary protoliths observed in the Assynt, Durness and Eriboll areas are presented here and provide detailed microstructural evidence for the long-term weakening mechanisms that were operating at the time. These mechanisms are consistently related to the onset of grain size reduction, triggered by both chemical enhanced and geometric processes. These include feldspar alteration to fine phyllosilicates associated with cataclasis and dynamic recrystallization of quartz.

Pressure solution, evidenced by changes in the shape of minerals along cleavage surfaces and the presence of dissolution seams and caps, is widespread throughout the studied rock sequences. The profuse occurrence of this grain-scale mechanism makes it very likely that syn-deformational fluid-influx lead to the destruction of load bearing microstructural frameworks and the development of interconnected weak layers due to alteration, explaining the occurrence of detachments within impure layers of the predominantly quartzose Pipe Rock and Salterella Grit

members. The progressive development of these interconnecting fine-grained weak layers resulting from incongruent diffusive mass transfer is enhanced in the more mineralogically heterogeneous units of the Cambro-Ordovician sedimentary sequence (in particular, Fucoid Beds dolomitic siltstones and Durness limestones) explaining the consistently observed slip localization in these horizons.