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The sedimentary signature of ice-contact sedimentation and deformation at macro- and micro-scale: a case study from NW Scotland

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Studies on the genesis of subaerial debris flows and associated deposits are relatively rare in the literature, especially in an ice-marginal context of moraine formation. The present contribution reports results from both the macro- and micro-scales of a subaerial depositional setting in order to contribute to closing this gap. At the macroscale, alternating loose, stratified, clast- and matrix-supported diamicts and finely-laminated sand units indicate deposition of debris flows and fluvial units in a subaerial, ice-marginal setting that were stacked up to form a terrestrial ice-contact fan. Macro-scale and micromorphological analyses show that this fan displays evidence of a three-phased formation: (a) overriding and glaciotectonisation of pre-existing sediments followed by retreat and burial of this core by (b) ice-contact fan deposition dominated by water-rich fluvial deposition with relatively little debris flow activity and (c) a switch to a gravitational sedimentation style with dominantly debris flow deposition and fewer and thinner fluvial units. Thin-sections of both the diamict and laminated sand units show evidence of deposition of a mud and fine sand rich slurry being expelled from the tops of advancing mass flows. Water-rich fine-grained slurries appear to have been progressively overridden and deformed in response to ductile shear occurring at the base of individual flows. Liquefaction and remobilisation of sand within laminated deposits occurred during such basal shear events, resulting in the injection of liquefied sediments into variably deformed laminated sands and clays. Deformation is more likely to have taken place through internal movement of the sediment due to changing porewater conditions and loading upon emplacement. Our approach confirms previous results that highlight the possibilities of increasing the accuracy of sedimentological investigations through combined sedimentological analyses at varying scales.