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Impact of subglacial groundwater flow on the formation of Stargard drumlin field, NW Poland – insights from numerical modelling

Piotr Hermanowski (1) and Jan A. Piotrowski (2)

(1) Institute of Geology, Adam Mickiewicz University, PL-61-680 Poznań, Poland, (2) Department of Geoscience, Aarhus University, DK-8000 Aarhus C, Denmark

Over the last 50 years of research, drumlins have generated more controversies than any other glacial landform. As long as their origin is poorly constrained, our understanding of ice-sheet movement dynamics over soft beds and the related processes of glacial sediment transport and deposition remains fragmentary. With over 1300 drumlins, Stargard drumlin field is one of the most prominent drumlin fields in the central European Lowland. It is located in the terminal area of a major land-based palaeo-ice stream of the Scandinavian Ice Sheet, which makes it highly relevant to the study of fast ice flow in general. Ongoing studies document a great diversity of glacial deposits in these drumlins, possibly unrelated to the drumlinizing process itself.

Here we present numerical modelling of subglacial groundwater flow during the drumlin-forming ice advance using an array of transient-flow and steady-state-flow simulations with Finite Difference and Finite Element codes. The simulations show a complete re-organization of groundwater flow dynamics to a depth of up to ∼200 m in relation to non-glacial times. A mosaic of intervening groundwater recharge and discharge areas originates whereby some areas experience multiple shifts in groundwater flow directions. A prominent time- and space-transgressive pressure pump recharges groundwater in a subglacial zone up to about 20 km within the ice margin and releases it in front of the ice sheet. The results suggest that the drumlins occur preferentially where groundwater upwells and discharges at the ice/bed interface contributing to the weakening of basal deposits and the interface itself. Consistent with field data, this study indicates that Stargard drumlins were generated primarily by some combination of direct glacial erosion and subglacial meltwater erosion by removing antecedent material from the inter-drumlin areas and streamlining the resultant bumps. Our data support erosion as a unifying process of drumlin formation.