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Fast ice flow at the southern fringe of the Scandinavian Ice Sheet facilitated by specific subglacial meltwater drainage conditions

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Mechanisms of fast ice flow and ice streaming in land-based ice sheets are closely related to bed rheology and coupling between the ice and its bed. The highest flow velocity is expected on soft beds as the result of some combination of pervasive sediment deformation and enhanced basal sliding, both processes being caused by highly pressurised subglacial water. Soft sediment deformation is triggered by high pressure of interstitial porewater reducing the material strength whereas basal sliding is facilitated by a water layer at the ice/bed interface that may cause basal de-coupling if sufficiently pressurised. Both mechanisms operate when the water pressure is in the vicinity of the glacier flotation point, i.e. around 90% of ice thickness. Occurrence of such highly pressurised water can be expected when water recharge at the interface is very high and/or when the ice is underlain by strata of low permeability preventing meltwater evacuation from the glacier sole.

The southern, soft-bedded periphery of the last Scandinavian Ice Sheet (SIS) is characterised by numerous well defined glacial lobes that project up to several tens of kilometres outside the main ice margin. These lobes typically host geomorphic features suggesting fast and highly dynamic ice flow (e.g. attenuated drumlins, Mega-Scale Glacial Lineations, glaciotectonic squeezing and thrusting phenomena at the outermost ice margin, deep ductile deformation structures in the underlying sediments), but the causes of such behaviour are uncertain.

Using well constrained geological and hydrogeological data two SIS lobes in northern Poland have been examined to evaluate the potential role of basal meltwater on the flow mechanisms. Odra lobe is one major lobe in the central European Lowland hosting drumlins, eskers and tunnel channels, all spreading radially towards the ice margin. Cross-cutting relationships suggest that channelised drainage was the last subglacial process under the ice lobe by which large volumes of meltwater were evacuated, possibly stabilising the ice sheet and terminating fast ice flow. Numerical modelling of subglacial groundwater flow suggest that due to a relatively low hydraulic conductivity of the underlying sediments only a small portion of basal meltwater drained through the bed. Parseta lobe is a small, smooth-floored lobe barren of distinct subglacial landforms. Also here the palaeohydrogeological simulation indicates a deficit in bed drainage capacity in relation to the meltwater recharge. Based on the groundwater flow simulation coupled with the geomorphic record we argue that fast ice flow in these lobes (and possibly other lobes along the southern SIS margin) was facilitated (if not triggered) by the meltwater surplus at the ice/bed interface caused by specific geological conditions.