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Models of deformation processes within subglacial tills – the application of microsedimentology

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Introduction

Subglacial sediments are subject to cycles of erosion, comminution, transportation, and deposition (emplacement) in very active, if ephemeral and often spatially localized environments, where basal ice conditions are dynamic and ever changing. It is critically relevant to observe and detect how these mobilized sediments, change to immobile sediments as a time-transgressive process. Within subglacial bed environments, it has been shown that rheological processes occur at the microscale as distinctive sedimentological signatures. These signatures deserve further attention as they provide valuable information on subglacial sediment processes and ultimately contribute to our understanding of till formation. A pair of models of subglacial interface interaction are presented that demonstrate the likely interactions between basal ice, bedrock (or hard bed), and soft subglacial sediments, classified as (a) Model I: limited passive interactive (Hard Bed) sliding in which the moving ice is detached from its substrate; and (b) Model II: dynamic active interactive (Soft Bed) sliding in which the ice mass is integrated with the substrate and shear fronts lie within the substrate. In Model I's case movement at the subglacial interface occurs along a shear plane between the ice and bedrock and/or sediment, the latter likely highly consolidated (hard or is frozen). In all cases it thought that there is limited erosion and any interaction between the bed and the ice is restricted. In contrast, in Model II there is active interaction between the ice and its bed with multiple transient shear fronts lying within the underlying substrate leading to (a) to erosion and subsequent deposition at the bed interface across bedrock or 'scavenging' across underlying substrate sediments and likewise sediment deformation or bedrock sculpting into either negative (striae, scours, groves, p-forms) or positive (drumlins, flutes, MSGLs) 'bedforms'; or (b) deformation processes within the substrate sediment leading to localized erosion and accretion at the various sub-interfaces in some cases all pervasive, in others non-pervasive deformation. The deformation may well be confined to a stratum (or lithofacies unit) or be transient across a wide range of lithofacies leading to various glaciotectonic effects and subsequent structures.

Case Studies

Case studies specifically of Model II, for this paper, are presented from Quaternary subglacial sediments from Lichtenegg, Germany (Menzies & Ellwanger, 2011) ; Moneydie, Strathmore, Scotland (Menzies and van der Meer, 1998); Weissbach (Menzies and Reitner, 2018) and Ainet (Reitner and Menzies, in press) , Austria; Wayne County, New York State, USA; and north Oakville (Eyles et al., 2011), and the Attawapiskat area, James Bay Lowlands (Gao et al., 2012), Ontario and Pine Point Mine (Rice et al. 2019), NWT, Canada where examples demonstrate the effects of soft sediment deformation at the subglacial interface where microstructures, deformation bands and deformation fronts, derived from fluctuations in shear stress, can be detected.

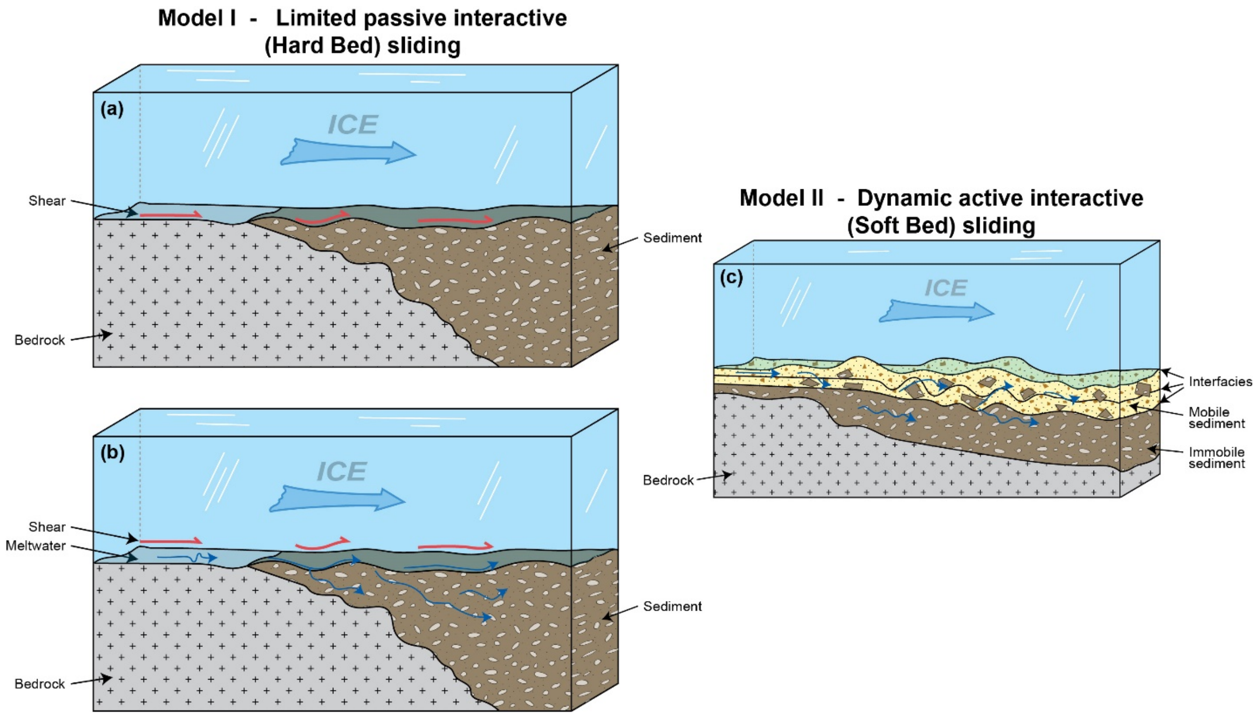

Figure 1. Models of Subglacial – Substrate Interaction. (a-b) Model I - Passive limited interactive sliding in (a) moving ice is detached from its substrate showing movement of ice across a bedrock or frozen of highly consolidated substrate, (b) in which meltwater flows between the ice and bed and, in some cases, meltwater flows into the substrate but the substrate, itself, is immobile; and (c) Model II Dynamic interactive sliding in which the ice mass is integrated with the substrate and shear fronts lie within the substrate (mobile sediment) showing active processes at a soft deforming bed in which multiple interfaces between deforming and immobile substrate occurs, where substrate scavenging occurs and where, under certain circumstances bedforms, at either the upper ice bed interface or within the substrate, evolve.

In a till sequence below outwash gravels at Lichtenegg the underlying sequence of tills show the impact of soft sediment deformation in a package of varying lithofacies units lying within a complex till sequence. In what was originally mapped as a glacial readvance sequence of the Late Devensian ice stream in Strathmore, eastern Scotland the site at Moneydie illustrates the impact of high strain on deforming subglacial tills. At sites on the edge of the Inn Ice Stream (LGM) of the European Alpine Ice Cap in northern Austria the site at Weissbach shows a sequence of till units within which a series of deformation fronts can be detected as the transient passage of stress from the overlying ice occurs. In contrast the site at Ainet in south central Austria lies along the margin of the Drau Ice Stream (LGM) as it moves southward to the margin of the European Alpine Ice Cap. The site shows a series of tills that again show the effect of the passage of deformation fronts within the till packages. Within the central section of the New York State drumlin field in Wayne County, a series of till samples from both within and between drumlins were sampled that demonstrate the remarkable similarity of the tills in terms of their microsedimentology that leads to the conclusion that such drumlin were formed from the underlying tills and so drumlins were sculpted as a function of mobile tills as the sediment flux passed along the ice-bed interface within the soft deforming sediment layers. Finally, in Canada sites in Ontario at north Oakville, southern Ontario and in the James Bay Lowlands near Attawapiskat, northern Ontario and at Pine Point to the south of Great Slave Lake in the NWT all in Late Wisconsinan tills of the Laurentide Ice Sheet were investigated that show the effects of soft sediment subglacial movement and consequent microsedimentology. In the case of Pine Point, in the NWT, the transient nature of deformation fronts was detected as evidence of till depositional mechanisms associated with Model II. In all cases examined in this paper the evidence of till microsedimentology supports the contention that subglacial models, as described, help explain the features repeatedly noted in subglacial tills and highlight development of subglacial interface kinematics providing clues to till deposition, likely subglacial bedform development both negative and positive forms, and further clues in our grasp of the underlying processes in till provenance distributions and drift exploration.

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References

Eyles, N., Eyles, C., Menzies, J., and Boyce, J. 2011. End moraine construction by incremental till deposition below the Laurentide Ice Sheet: Southern Ontario, Canada. Boreas 40(1): 92-104. doi:10.1111/j.1502-3885.2010.00171.x.

Gao, C., McAndrews, J.H., Wang, X., Menzies, J., Turton, C.L., Wood, B.D., and Pei, J., Kodors, C. 2012. Glaciation of North America in the James Bay Lowland, Canada, 3.5 Ma. Geology 40: 975-978. doi:doi:10.1130/G33092.1.

Menzies, J., and Ellwanger, D. 2011. Insights into subglacial processes inferred from the micromorphological analyses of complex diamicton stratigraphy near Illmensee-Lichtenegg, Höchsten, Germany. Boreas 40(2): 271-288. doi:10.1111/j.1502-3885.2010.00194.x.

Menzies, J., and Meer, J.J.M. van der 1998. Sedimentological and micromorphological examination of a Late Devensian multiple diamicton sequence near Moneydie, Perthshire, east-central Scotland. Scottish Journal of Geology 34: 15-21.

Menzies, J., and Reitner, J.M. 2019. Microstructures, subglacial till deposition, and shear band development revealing up-section changes in shear–A study from Weissbach, Austria. Proceedings of the Geologists' Association 130(2): 196-209. doi:10.1016/j.pgeola.2018.11.001.

Rice, J., Menzies, J., Paulen, R.C., and McClenaghan, M.B. 2019. Microsedimentological evidence of vertical fluctuations in subglacial stress from the northwest sector of the Laurentide Ice Sheet, Northwest Territories, Canada. Canadian Journal of Earth Sciences, 56: 363-379. doi: 10.1139/cjes-2018-0201.

Reitner, J. and Menzies, J. *in press* Microsedimentology of tills near Ainet, Austria – were palaeo-ice streams in the European Alps underlain by soft deforming bed zones?