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The Bed Ribbing Instability Explanation (BRIE) - Testing a Numerical Model of Ribbed Moraine Formation Arising from Coupled Flow of Ice and Subglacial Sediment.

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Ribbed moraines are prominent landforms that cover expansive areas of the beds of palaeo ice sheets. Since the late 1800's a wide range of interpretations have been offered that place their formation in variety of glaciodynamic settings ranging from ice marginal or near marginal positions, to formation under stagnant ice. However, it is now widely accepted that they formed subglacially, which has important implications for our understanding of ice sheet stability because the processes that generate ribbed moraines must logically influence ice sheet motion. Consequently, an understanding of their genesis is critical to our knowledge of ice sheet dynamics.

Numerous hypotheses exist that seek to explain how ribbed moraine are formed: by shearing and stacking of subglacial sediments (e.g. Aylsworth and Shilts, 1989; Bouchard, 1989); as a consequence of subglacial megafloods (Fisher and Shaw, 1992); by fracturing and extension of frozen till sheets (Hättestrand, 1997) by sediment deformation (Boulton, 1987; Hindmarsh, 1998a,b, 1999) or formation by separate stages of development (Lundqvist, 1989, 1997; Möller, 2005; Sarala, 2006). The theory by Hindmarsh (1998a,b, 1999) differs markedly from all the others in that it is the only quantitative explanation of ribbed moraine genesis that has been developed into the first numerical process-model of subglacial bedform creation.

The model is a numerical development of the theory of landform generation by de-

formable bed mechanisms (Boulton, 1987) and quantitatively models the behaviour of an ice sheet sliding over a deforming bed. The theory, referred to as the Bed Ribbing Instability Explanation (BRIE), takes a linearised approach and predicts under which conditions sediment amplification can be initiated in a deforming subglacial till. In the model, when ice deforms internally and slides across the till surface, and when the till deforms internally and slides on the underlying bedrock small perturbations in the till surface grow to become waves that migrate downstream. BRIE demonstrates that transverse subglacial ridges (i.e. ribbed moraine) spontaneously grow under certain conditions and it predicts their wavelength (spacing between ridges). The theory is a significant development because it is the first real quantitative theory of subglacial bedform generation that makes predictions which can be quantitatively tested.

Since its inception formal testing of BRIE has been delayed due to the paucity of data on ribbed moraine characteristics. However, this shortfall has been recently addressed and there now exists a representative database of ribbed moraine characteristics (Dunlop and Clark, 2006) that can be used to try and falsify the BRIE. This paper introduces the concepts that underpin BRIE and describes the model in detail. It discusses the types of model tests that are currently possible and presents results from the first formal tests. An assessment of BRIE's validity is made on how well it is able to reproduce the primary features of ribbed moraine.