

# Review of “Ribbed bedforms in palaeo-ice streams reveal shear margin positions, lobe shutdown and the interaction of meltwater drainage and ice velocity patterns” by Jean V´erit´e and ten others for *The Cryosphere*

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## 1 Overview

This revised paper by Jean V´erit´e and colleagues (V++) from *Le Mans Universit´e, Universit´e de Nantes*, University of Sheffield and Alberta Geological Survey addresses, as did the first submission, a centuries-old topic in glacial geomorphology, namely the mechanisms operating and conditions needed to produce certain glacial geomorphological landforms; in particular their focus is on ribs transverse and obliquely transverse to the ice flow direction. They discuss these ribs within the context of ice-streams; a key feature of the revision is provided by the sentences “*Within this general model, the meaning of ribbed bedforms remains unclear. Different types and shapes have been described, different theoretical models have been proposed for their formation, various interpretations exist for their timing and conditions of formation compared to ice and subglacial drainage dynamics, and their spatial distribution within glacial landsystems is still debated*” (1.81-84). This helps enormously; previously I had difficulty in ascertaining the function of the paper; now I see that it is aimed at the spatial distribution of sub-glacial ribs, and emphasises that they do not only occur under slower moving parts of the ice, but also in stream-marginal locations of various kinds - I mentioned in my first review that they wish to focus on some previously underconsidered aspects of geomorphology.

The lab experiments produce rib forms in what glacial geomorphologists might regard as unusual locations, and V++ wish to emphasise the spatial realism of their results.

V++ use an integrated approach, simulating the ice sheet with a pancake of flowing silica gel, which overlies sand, and pump water in underneath in order to lubricate the base. As part of the experiments, silica streams form, which V++ compare with ice streams.

The paper is organised into six main sections, containing sub-sections and sub-sub-sections; which bring out the logical flow of the paper;

- §1 *Introduction*: A one-page focus on the landsystems associated with former ice-streams
- §2 *Ribbed bedforms in ice stream landsystems*: Contains
  - §2 Introductory subsection: Includes key quote referenced above, commencing “*Within this general model, the meaning of ribbed bedforms remains unclear..*”
  - §2.1 *Types and shapes*: Emphasises that V++ use “*ribbed bedforms*” as a descriptive term with no genetic implications.
  - §2.2 *Spatial distribution in ice stream landsystems*: Indicates that not only are ribbed bedforms created under slower-moving areas of ice (a view current in 2021) but also in association with streamlined forms e.g. drumlins, a view underemphasised at the moment.
  - §2.3 *Theoretical models of formation*: A brief one paragraph review of current models of ribbed bedform genesis.
- §3 *Methods*
  - §3.1 *Analog modelling*: Describes lab setup and experiments.
  - §3.2 *Mapping and morphometric analysis on palaeo-ice stream landsystems*: Outlines V++’s work on mapping landforms in selected areas.
- §4 *Results*
  - §4.1 *Ice stream dynamics and development of ribbed bedforms in the experiment*: Discussion of two stream-types found in the lab experiments and how they relate to evolution of bedform fields.
  - §4.2 *Palaeoglaciology: ribbed bedforms beneath ice stream margins*: Focus on ribbed patterns close to stream lateral and downstream margins (this is a novel to the palaeo-glaciological community feature of V++’s work).
- §5 *Discussion*:

§5.1 *Morphometric comparisons between experimental and natural ribbed bedforms*: Compares lab results with an extensive set of field observations.

§5.2 *Processes of ribbed bedform formation at ice stream margins*: Focus on processes occurring at stream margins in the lab and in the field.

§5.3 *Ribbed bedforms in ice stream landsystems*: Emphasises that both lab and field rib formation not only occur not only in the slower-moving areas but also in special marginal areas of the fast-flowing streams.

- §6 ‘Conclusion’: Key sentence “*Despite the ubiquitous and extensive nature of subglacially-produced ribbed bedforms beneath former ice sheets (variously called Rogen moraine, ribbed moraine, ribbed bedforms, mega-scale transverse ridges), their significance in ice stream landsystems and their formation processes remain poorly understood*”; this is a major point arising from V++’s work.

My summary of the contents indicates that V++ have made a serious effort to revise the paper in accordance with the referees’ requests, and that the logical flow is much more straightforward; the first submission gave the impression of trying to solve *all* the problems of glacial sedimentary geology. In my first review I said that “V++ presents novel exciting experimental work which will inspire a very large portion of the glaciological community, and should certainly be published” - I believe it to be publishable now, and recognise that any differences between me and the authors are essentially ‘matters of opinion’, and that research over the coming decade(s) will clarify most of the issues.

The paper contains two key points; (i) rib formation is not confined to slower moving areas of ice; and (ii) there are distinct analogies between the slow viscous flows of ice-sheets over clastic sediments, and the slow viscous flow of silica over sand.

I am happy for the paper to be published; I don’t have any ‘Major Points’ to be dealt with and encourage the authors to act on the minor points below.

## 2 Minor/Editorial Points

The English is mostly excellent, but ...

1. 1.118-119. Sentence “*Ribbed bedforms are thus believed to be ubiquitous from the inner, cold-based, regions of ice sheets*”. This sentence seems to saying that bedforms are created under frozen bed conditions - is this what V++ intend? Perhaps change to “inner, slower-moving, regions of ice-sheets”?
2. 1.155. “3.1 *Analog modelling*” change to “3.1 *Analogue modelling*”; ‘analog’ is US-based spelling, *The Cryosphere* is a European-based journal.

3. 1.264 “4.1. *Ice stream dynamics and development of ribbed bedforms in the experiment*”. Is the focus in this section on ice-stream dynamics or silica-stream dynamics? Perhaps change to “4.1. *Stream dynamics and development of ribbed bedforms in the experiment*”.
4. Nearly everywhere: change “*silicon*” to “*silica*”; ‘silicon’ is an element, ‘silica’ is a silicon-based substance used in the experiments.