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Drumlins: A Classic Example of Pattern Formation.

Jeremy C. Ely (1), Chris D. Clark (1), Matteo Spagnolo (2), Ute Hahn (3), and Anna L.C. Hughes (4)

(1) Department of Geography, University of Sheffield, Sheffield, UK (gga08je@shef.ac.uk; c.clark@shef.ac.uk), (2) School of Geosciences, University of Aberdeen, Aberdeen, UK (m.spagnolo@abdn.ac.uk), (3) Department of Mathematics, Aarhus University, Aarhus, Denmark (ute@imf.au.dk), (4) Department of Earth Science, University of Bergen, Bergen, Norway (anna.hughes@geo.uib.no)

Drumlins are elongate streamlined hills, typically 250-1000 m long and 120-300 m wide, formed beneath ice sheets. They occur in fields or swarms, covering vast swathes of previously glaciated terrain, and are the most common variant of a continuum of subglacial bedforms. The processes of drumlin formation are currently elusive and contentious, hindering our understanding of the ice-bed interface. Yet, insight into drumlin formation can be gained through studying their spatial distribution and morphometric properties. When viewed from above, drumlins display striking regularity and self-similarity, suggesting that they form through a self-organising pattern forming process. However, the difficulty of observing drumlins forming in situ (i.e. beneath an ice sheet), and a focus upon individual drumlin forms, has hindered both the recognition and understanding of drumlin pattern formation. Hence, the nature of drumlin patterning is poorly understood, especially in comparison to bedforms generated by other geomorphic agents (e.g. dunes and ripples). To address these issues, here we analyse the morphometric properties of a large database of drumlins mapped from palaeo-ice sheet beds at a variety of geological and glaciological settings. Spatial statistical point pattern tests suggest that drumlins are regularly spaced across drumlin fields. However, defects to this regularity occur due to differences in preservation and initial formation conditions. Furthermore, drumlin morphometric parameters frequently conform to a log-normal distribution, common for phenomena which experience incremental growth or fragmentation. Hence, drumlin morphometrics can provide us with insight into how drumlin patterns have evolved. Between separate drumlin fields, variations in patterning and morphometrics vary, highlighting the response of drumlin patterning to local glaciological and geological factors. Hence, we suggest that many of the patterning principles which have been applied to other geomorphic phenomena can be equally attributed to drumlins and other subglacial bedforms, providing a conceptual framework for understanding their formation. Equally, we suggest that drumlins represent a classic example of pattern formation within the geosciences, and hence provide exciting opportunities for studying the dynamics of pattern formation.