Geophysical Research Abstracts
Vol. 18, EGU2016-13626, 2016
EGU General Assembly 2016

On the issue of equifinality in glacial geomorphology

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A contemporary trend in glacial geomorphology is the quest for some form of unifying theory for drumlin and/or ribbed moraine formation: there MUST be ONE explanation. The result of this is attempts to apply 'instability theory' to the formation of all drumlinoid and ribbed moraine formation or, as an alternative to this, the 'erodent layer hypothesis' for single processes driven formation. However, based on field geology evidence on internal composition and architecture and the internals relation to the exterior, i.e. the shape of drumlins or ribbed moraine, many glacial sedimentologists would argue that it is instead different processes in their own or in combination that lead to similar form, i.e. look-alike geomorphologic expression or equifinality in spite of different process background for their formation. As expressed by Cleland (2013) from a philosophical point of view of a 'common cause explanation', as exemplified with mass extinctions through geologic time, there is probably a 'common cause explanation' for the K/T boundary extinction (massive meteorite impact on Earth), but this is not a common explanation for every other mass extinction. The parallel to our Quaternary enigma is that there can of course be a single common cause for explaining a specific drumlinoid flow set (a particular case), but that does not have to be the explanation of another flow set showing other sedimentological/structural attributes, in turn suggesting that the particular case cause cannot be used for explaining the general case, i.e. all drumlins over glaciated terrain on the globe.

We argue in the case of streamlined terrain, which often have considerable morphologic difference between features at local landscape scale whilst still remaining part of the drumlinoid continuum on regional scale, is a product of different processes or process combinations (erosion/deformation/accumulation) in the subglacial system, tending towards the most efficient obstacle shape and thus bedform for sliding to take place on. The logic for this in the first order is that obstacles enhance sliding speed by increasing melting and plastic flow. However, if an obstacle is too 'rough' the increase in basal drag counteracts this. Therefore the subglacial system finds an efficiency equilibrium whereby an obstacle is shaped so that it enhances flow with a minimum of drag, i.e. the typical streamlined form is the result of a positive feedback cycle that tends towards efficiency. From Swedish geomorphologic data sets we find the dominating rock-cored drumlins to be formed by accumulation around rock obstacles, in some areas with deep drift the streamlined surface expression is due to combinations of excavational and constructive deformation without any 'seed cores', and in some areas with pre-LGM deglacial sediment successions there is erosional carving into drumlinoid forms. In the case of ribbed moraine it is evident from field geology that such are not single-process bedforms but form in a number of ways (i.e. equifinality); examples from the Swedish Quaternary landscape are ribbed moraine formed (i) from melt-out of stagnant ice, (ii) from re-moulding of pre-existing landforms and (iii) from subglacial stacking/folding of sediment and lee-side cavity infill.