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The Cookie Cutter: A Method for Obtaining a Quantitative 3D Description of Glacial Bedforms

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Introduction

Glacier bedforms, in particular drumlins, are visually distinctive landforms that have had a long history of study, with a particular early focus upon their location and distribution (Close, 1867; Charlesworth, 1924). Processes responsible for their genesis remain enigmatic, and there is no single, overarching theory of formation. Considerable work has focused upon drumlin parameterization (Smalley and Unwin, 1968) and internal composition in an attempt to describe and classify them. Research on drumlin morphology has also examined the role of glacier/bed interactions and bed preservation (Rose and Letzer, 1975) with a view to understanding and deciphering the landform record of multiple ice flows (Rose and Letzer, 1977; Boulton and Clark, 1990).

During this period, technological advancements in the derivation of surface morphology and data storage and analysis have enabled the gathering of larger datasets over shorter time scales and in greater detail (Clark, 1997). Despite these improvements, the three-dimensional (3D) quantification of glacial bedforms has received little attention, although this property is important for determining the relief and volume of bedforms. These are fundamental properties required for quantifying the amount of sediment moved by glaciers beneath an active ice sheet. In this poster (fig. 1) we show a newly developed methodology for characterizing the relief and volume of drumlins, apply the method to a test area, and discuss potential sources of error. The work is reported in full by Smith and others (2009).

Methodology

We propose a three stage procedure for the calculation of landform volume: Stage 1 involves initial mapping to identify and outline landforms; Stage 2 defines landform relief; and Stage 3 calculates individual landform volumes. Stage 1 requires scientific judgment, whilst Stages 2 and 3 are automated. All processing is performed within a geographic information system (GIS).

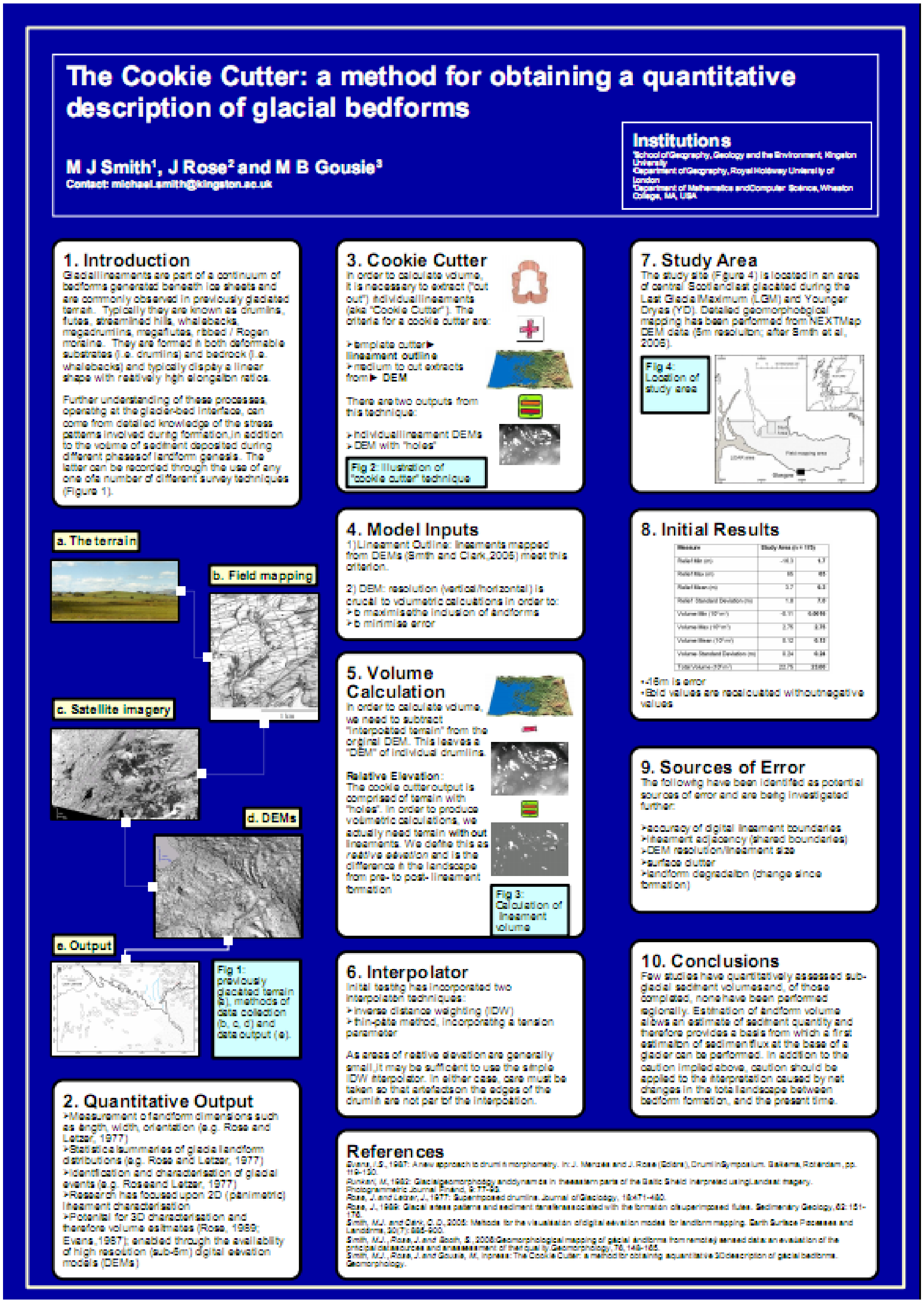

Figure 1. Extraction of 3D properties of glacial bedforms using interpreter mapping as input to an automated computer script ("Cookie Cutter") (presented as a poster; see full-resolution image at *http://ngmdb.usgs.gov/Info/dmt/docs/DMT09_Smith2.pdf*).

An input digital elevation model (DEM) is used to facilitate visualization of the terrain before the outlines of the drumlins are manually digitized (Smith and Clark, 2005). The area within the outline is then removed (the "cookie cutting" process) to produce a new DEM with "holes" or voids. A planar surface is then interpolated across each of the voids, using a thin plate spline, to leave a new "infilled" DEM. This is then subtracted from the original DEM, leaving a DEM of drumlin relief. Volume is calculated using drumlin area and height.

For this study, the NEXTMap Britain™ DEM (see *http://www.intermap.com/nextmap-britain*) is used as the data source for geomorphological mapping and subsequent calculations of drumlin relief and volume (Smith and others, 2006). NEXTMap is a single-pass interferometric synthetic aperture radar (IfSAR) product, with a spatial resolution of 5 m and a vertical accuracy of 0.5–1 m (Intermap, 2005).

Results and Conclusions

This poster presents a technique for the calculation of material volumes of drumlins from sites in western central Scotland. The method can be applied to other glacial bedforms and indeed to any landform. Digitized drumlin outlines are used to extract ("cookie cut") landforms from an underlying DEM, leaving empty voids. The voids are "infilled" through the application of a tensioned spline interpolator thereby estimating the basal surface. Drumlin relief is then calculated by subtracting the basal surface from the original DEM and then converting it to volume by multiplying by the planform area. In order for the interpolator to operate using "edge" pixels surrounding each void, it is necessary for drumlins to be processed individually.

Using the above methodology, a protocol is established for the calculation of material volumes for similarly wholly concave or wholly convex landforms. The results presented in the poster provide a first-order approximation that facilitates the rapid calculation of drumlin volume. It is important to note that volume calculations are subject to error from the source DEM, digitization procedure, and presence of surface clutter, in addition to geomorphological problems inherent in the sample studied. This technique can potentially be used wherever landform volume estimates are required, for example, calculations of sand dune volumes or sediment input to depositional environments.

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