FRACTAL STATISTICS OF THE STOREGGA SLIDE

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Abstract

The statistics of submarine mass movement inventories are poorly characterised in comparison to those of subaerial mass movements. In this study we investigate the aggregate behaviour of the Storegga Slide by carrying out a statistical analysis of its constituent mass movements. By using area as a proxy for mass movement magnitude, we demonstrate that the non-cumulative frequency-magnitude distribution of mass movements within the Storegga Slide is a power law with an exponent of 1.52. The Storegga Slide has the characteristics of a dissipative system in a critical state, where the input of sediment is continuous in the form of hemipelagic sedimentation and glacial deposition, and the output is represented by mass movements that are spatially scale invariant. We conclude that the Storegga Slide may be modelled as a large-scale geomorphic system that exhibits self-organised critical (SOC) behaviour. In comparison to subaerial mass movements, the aggregate behaviour of submarine mass movements is more comparable to that of the theoretical ‘sandpile’ model. The origin of SOC may be linked to the retrogressive nature of the Storegga Slide. Since SOC is an emergent feature, the large-scale behaviour of the Storegga Slide should be autonomous of the smaller-scale elements. A power law distribution also implies that incomplete submarine mass movement inventories may be extrapolated within the limits of power law behaviour, which is important in terms of hazard management.

1. Introduction

Concepts of non-linear dynamic systems, such as scale invariance and the fractal model, provide a powerful approach to the representation of a wide range of geoscientific data (e.g. fluvial systems (e.g. Pelletier 1999), coastal profiles (Southgate and Möller 2000). Scale invariant properties of data inventories are identified by demonstrating a single power law exponent in a frequency-magnitude distribution (Mandelbrot 1983). A power law distribution implies that when we compare the number of events of size $A$ or greater, with the number of events of size $\eta A$ or greater ($\eta$ is an arbitrary factor), the number always differs by the same factor $\eta^{-\beta}$, regardless of the absolute size of the events (Hergarten 2003). A power law distribution can be replaced with other measures of the size of the event (e.g. area, volume and thickness of mass movements are strongly correlated with each other, and a distribution can be converted between variables (Hovius et al. 1997)); thus a power law distribution is free of a characteristic scale and can be described as fractal (Mandelbrot 1983).

The Storegga Slide, located 120 km offshore Norway, is a mega-scale geomorphic system (Figure 1). Like most other submarine slides, the Storegga Slide has been investigated using an engineering approach. In subaerial geomorphology, the statistical characteristics of landslide inventories have become a recent focus of study (e.g.

Guzzetti et al. 2002). In comparison, the statistics of submarine mass movement data are still poorly characterised. The extensive coverage and the excellent quality of the acoustic imagery from the Storegga Slide allow us to investigate the aggregate behaviour of the Storegga Slide and carry out a statistical analysis of its constituent mass movements. The objectives of this study are to assess whether the size statistics of the Storegga Slide mass movements exhibit scale invariance, and to explain the origin and implications of such behaviour.

Figure 1. Bathymetric contour map of the Storegga Slide (contour interval of 250 m). The headwalls that were extracted from the bathymetric data set are represented by solid black lines. The arrow indicates the direction of sediment mobilisation. The location of the Storegga Slide is shown in the inset.

2. Method

The study is based on a high resolution multibeam bathymetry data set covering the slide scar from the main headwall down to a water depth of ca. 2700 m (Figure 1). Most of the data have a horizontal resolution of 25 m or better. A mass movement is defined as a single episode of slope failure where sediment moves downslope under the influence of gravity. The area of the mass movement is delineated by a steep scarp at the upslope limit (headwall) and the distal point of the depositional section at the downslope limit. We use mass movement area as a proxy for magnitude. The estimation