Marine Geology 247 (2008) 46–60

MARINE GEOLOGY
INTERNATIONAL JOURNAL OF MARINE GEOLOGY, GEOCHEMISTRY AND GEOPHYSICS

www.elsevier.com/locate/margeo

Scale invariant characteristics of the Storegga Slide and implications for large-scale submarine mass movements

Aaron Micallef [*,1], Christian Berndt, Douglas G. Masson, Dorrik A.V. Stow

National Oceanography Centre, University of Southampton, European Way, Southampton, SO14 3ZH, UK

Received 19 April 2007; received in revised form 9 August 2007; accepted 23 August 2007

Abstract

This study documents the fractal characteristics of submarine mass movement statistics and morphology within the Storegga Slide. Geomorphometric mapping is used to identify one hundred and fifteen mass movements from within the Storegga Slide scar and to extract morphological information about their headwalls. Analyses of this morphological information reveal the occurrence of spatial scale invariance within the Storegga Slide. Non-cumulative frequency-area distribution of mass movements within the Storegga Slide satisfies an inverse power law with an exponent of 1.52. The headwalls exhibit geometric similarity at a wide range of scales and the lengths of headwalls scale with mass movement areas. Composite headwalls are self-similar.

One of the explanations of the observed spatial scale invariance is that the Storegga Slide is a geomorphological system that may exhibit self-organized criticality. In such a system, the input of sediment is in the form of hemipelagic sedimentation and glacial sediment deposition, and the output is represented by mass movements that are spatially scale invariant. In comparison to subaerial mass movements, the aggregate behavior of the Storegga Slide mass movements is more comparable to that of the theoretical 'sandpile' model. The origin of spatial scale invariance may also be linked to the retrogressive nature of the Storegga Slide. The geometric similarity in headwall morphology implies that the slope failure processes are active on a range of scales, and that modeling of slope failures and geohazard assessment can extrapolate the properties of small landslides to those of larger landslides, within the limits of power law behavior. The results also have implications for the morphological classification of submarine mass movements, because headwall shape can be used as a proxy for the type of mass movement, which can otherwise only be detected with very high resolution acoustic data that are not commonly available.
© 2007 Elsevier B.V. All rights reserved.

Keywords: Storegga Slide; scale invariance; power law; self-organized criticality; 'sandpile' model; retrogressive cascade

1. Introduction

Submarine landslides are common phenomena on continental margins. Large landslides are the dominant geomorphic agents that transfer sediment across the continental slope (Masson et al., 2006), and they play a major role in the evolution of submarine landscapes. The Storegga Slide, located 120 km offshore Norway, is the largest known submarine landslide (Fig. 1). Dated at 8100±250 cal yrs BP (Haflidason et al., 2005), the Storegga Slide is the last in a series of slope failures that have characterized the mid-Norwegian Margin during the past 2.6 Ma (Solheim et al., 2005). The Storegga

* Corresponding author. Tel.: +44 23 80 596563; fax: +44 2380 596554.

E-mail address: amicall@noc.soton.ac.uk (A. Micallef).

[1] Present address: 16, Triq l-Ghakkies, Naxxar, NXR 05, Malta.

0025-3227/$ - see front matter © 2007 Elsevier B.V. All rights reserved.
doi:10.1016/j.margeo.2007.08.003

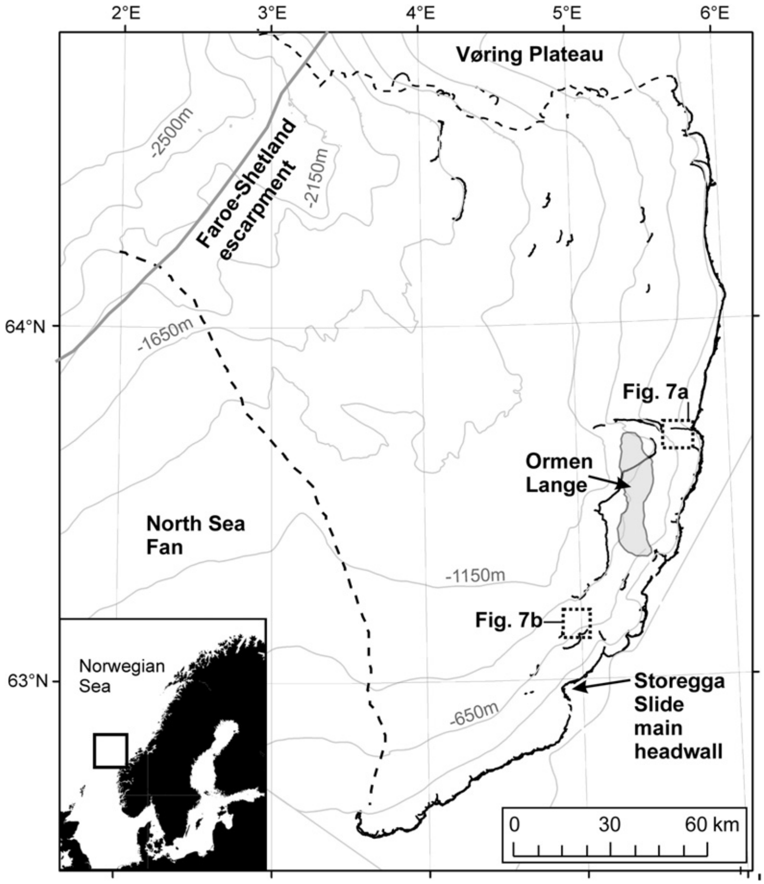

Fig. 1. Bathymetric map of the Storegga Slide. Bathymetric contours at 250 m intervals are shown as grey lines, whereas the extracted headwalls are represented by solid black lines. The dashed black line indicates the boundaries of the Storegga Slide. The location of the slide is shown in the inset.

Slide consisted of sixty-three quasi-simultaneous mass movements, which span an area of 95 000 km^2 and have evacuated 2400–3200 km^3 of sediment (Haflidason et al., 2004). These mass movements formed an amphitheatrical depression that contains numerous headwalls and scarps, the largest of which being the 320 km long main headwall located at the shelf break. The scar also encloses morphological features recognized as spreads, debris flows, turbidity flow channels and compressional ridges, which occur across a depth range of ~2700 m. The sedimentological framework of the Storegga Slide area is characterized by the alternation of glacial diamictons and ice-proximal sediments, deposited during glacial maxima, and fine-grained glacimarine, hemipelagic and contouritic sediments, deposited during interglacials (Berg et al., 2005). Because of its complexity and size, we consider the Storegga Slide as a macro-scale geomorphological system (10^2–10^6 km^2 in area, according to Summerfield (1991)).

Concepts associated with non-linear dynamic systems, such as fractals, chaos and self-organization, have gained considerable attention in many aspects of the geosciences. The fractal model, for instance, captures aspects of topography that other morphometric measures do not (Klinkenberg, 1992), and it provides a powerful approach to the representation of geoscientific data. The growing use of digital elevation models and the increasing resolution of topographic data sets have enabled geomorphologists to identify fractal structures and scale invariance in numerous subaerial environments (e.g. Pelletier, 1999; Southgate and Möller, 2000). The statistical characteristics of large populations of landslides, for example, have become a recent focus of study in geology and geomorphology (e.g. Guzzetti et al., 2002; Hergarten, 2003; Turcotte et al., 2006). Submarine mass movements, however, are still generally studied as isolated slope failure events using an engineering approach (e.g. Kvalstad et al., 2005; Sultan

Download English Version:

https://daneshyari.com/en/article/4719433

Download Persian Version:

https://daneshyari.com/article/4719433

Daneshyari.com