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Estimating long-term cliff recession rates from shore platform widths

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Abstract

Coastal cliff erosion is a problem in many coastal areas. However, often only very limited data are available to quantify the rates of recession for the development of coastal management strategies. In the soft flysch deposits of the Waitemata Group, Auckland, New Zealand, coastal cliffs are associated with shore platforms. Two models exist for the profile evolution of shore platforms and associated cliffs: the first suggests that an equilibrium profile develops in response to erosive processes, and this profile subsequently migrates landward; the second model suggests that the seaward margin of the shore platform is relatively static, and the profile extends landward through a combination of cliff recession and platform lowering. Physical simulations and field measurements for mudstone and limestone lithologies indicate that the second model is more likely for soft flysch deposits. A eustatic sea-level curve for the Weiti Estuary, Auckland, suggests that up to 7120 ± 70 years have been available for shore platform development since sea level reached the present seaward margins of shore platforms. Shore platform widths were measured using GPS at two sites in Waitemata Group rocks: the North Shore of Auckland; and the southern side of the Tawharanui Peninsula, North Auckland. The long-term cliff recession rates estimated from shore platform widths (1.4 ± 0.1 to 14.3 ± 0.1 mm y^{-1}) are consistent with the lower end of the average range of cliff top and face recession rates published for Waitemata Group rocks using different methods (11–75 mm y^{-1}), and in agreement with cliff base recession estimates (~3.5 mm y^{-1}). Shore platform widths were qualitatively related to the rock mass characteristics of the associated cliffs, and therefore platform widths could provide a method of identifying regions of potential hazard.

Keywords: Coastal erosion; Cliff erosion; Mass wasting; Rock mass characteristics; GPS; Slope stability

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1. Introduction

Coastal cliffs are a major component of ~80% of the world's shorelines (Emery and Kuhn, 1982), and they are a major feature of the coast within the Auckland metropolitan area, New Zealand (Moon and Healy, 1994). Along the Auckland coast these include 10–30 m high cliffs developed in sedimentary rocks (e.g. Waitemata Group) and volcanic rocks (basalt lava flows), and lower 0–5 m high banks developed in cohesive sediments and soils. In many parts of Auck-

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land, development has occurred up to the cliff and bank edges, so that erosion poses a risk.

In order to determine the magnitude of cliff erosion hazard it is necessary to predict the landward extent of cliff edge translation over a specified planning period. This prediction is complicated for coastal cliffs because cliff erosion is a combination of relatively steady small incremental losses, and episodic rapid larger losses (Hall, 2002). Further, cliff erosion may exhibit large spatial variability so that an assessment of erosion at one location may have limited application beyond that site (Runyan and Griggs, 2003).

The rate of cliff erosion may be determined by dividing the historical extent of cliff recession by the time period over which erosion occurred. Episodic large failures can distort this assessment (Hall, 2002; Runyan and Griggs, 2003), so that most methodologies attempt to separate the long-term trend from the extent of episodic events (viz. Glassey et al., 2003). This requires a sufficiently long period of observations in order to be able to separate the two, and to ensure that the magnitude of episodic events has been reliably captured.

Previous studies have attempted to characterize erosion rates for Waitemata Group rocks around Auckland (Brodnax, 1991; Gordon, 1993; Moon and Healy, 1994). These studies demonstrate that for the Auckland region, the available historical record is too short to be able to reliably estimate the long-term cliff erosion rate. In this paper, the widths of shore platforms associated with Waitemata Group sedimentary rocks are assessed as a potential measure of long-term erosion rates.

2. Background

2.1. Shore platform development

There are two main theories for the profile evolution of shore platforms (Fig. 1): an equilibrium approach where the entire shore platform migrates land ward at a rate controlled by the recession of the associated coastal cliffs (Challinor, 1949; Trenhaile, 1974); and alternatively a static model that sees the seaward margin of the shore platform remaining relatively fixed, so that the platform width increases over time (Sunamura, 1983; Trenhaile, 2000, 2001). The equilibrium model is largely driven by wave-induced erosion, which acts at much the same rate everywhere on the platform. In contrast, wave erosion plays a minor role in the static model, with subaerial processes acting on the cliff dominating platform development.

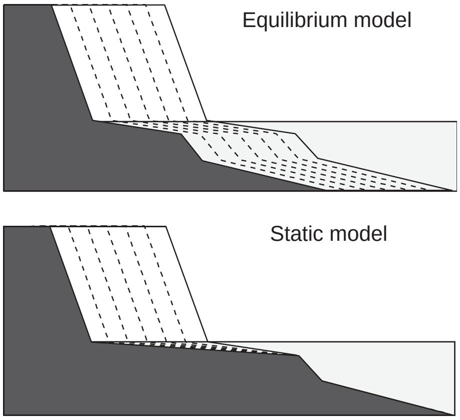

Fig. 1. Schematic diagram of the equilibrium and static models for the evolution of shore platforms.

Investigations into coastal cliff recession rates in a range of materials have found little correlation with available wave energy, but strong correlations with the strength of the cliffs (viz. Benumof and Griggs, 1999; Benumof et al., 2000; Budetta et al., 2000; Jones et al., 1993) or climatic factors such as rainfall (viz. Emery and Kuhn, 1982; Griggs and Brown, 1998; Lahousse and Pierre, 2003). There are many rating systems used to classify the strength of rock masses (Bieniawski, 1989; Romana, 1993), which consider the contributions from factors such as the intact strength of the rock, the characteristics of discontinuities in the rock mass, and water content. Selby (1993) considers the relative contribution of these factors to slope stability (Table 1).

Table 1
Summary of the rock mass characteristics affecting slope stability, and their relative contribution as reported by Selby (1993)

Factor	Contribution
Intact rock strength	20%
Discontinuity characteristics	
Spacing	30%
Orientation	20%
Width	7%
Continuity & infill	7%
Water	6%
Weathering	10%