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Review

Rock coast geomorphology: Recent advances and future research directions

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ABSTRACT

There have been considerable advances in rock coast research in the past decade, as measured in terms of the number of active researchers and in the number of research papers being produced. This review, although not exhaustive, highlights many of the improvements that have been made in our ability to identify and measure the processes shaping rock coasts, at a range of spatial and temporal scales. We review how researchers are experimenting with new techniques; grappling with quantifying the effects of multiple processes on resultant landforms; and exploring how well rock coast systems relate to wider geomorphological and earth science debates. Recent research, including those in this special issue, aptly demonstrate the scientific benefits that can be accrued by studying rock coasts at a variety of spatial and temporal scales, by considering the effect of the wide range of processes that operate on them, and by the application of new measurement techniques and approaches. Despite these advances, there is ample scope for future research, which could profit from increasing collaboration with other coastal geomorphologists and allied earth science disciplines in order to identify and quantify linkages between rock coasts and other coastal systems. It is also important that new research considers how rock coasts will respond to extreme events and to risks associated with changing climate, and to how rock coast geomorphology might contribute, beyond coastal science, to wider debates in theoretical geomorphology.

1. Introduction

There has been growing interest in rock coast geomorphology in recent years, which has been reflected in both the number of published scientific papers and the number of active researchers. This is a welcome increase to a sub-discipline that had hitherto received comparatively limited attention by coastal scientists in general, and more specifically by geomorphologists. Although there have been recent reviews on aspects of rock coasts, such as on shore platforms with notable papers by Stephenson (2000) and Trenhaile (2002), and country specific reviews of rock coasts by Stephenson and Thornton (2005) and Kennedy and Dickson (2007), there has been no general review of rock coast geomorphology since the monographs of Trenhaile (1987) and Sunamura (1992). At a time when there is increased scientific interest and wider community concern about shoreline response to climate change, a review paper and special issue on rock coasts offer an opportunity to take stock of our present state of understanding, and where and how future research might be directed.

This paper does not intend to provide an exhaustive review; instead we endeavour to provide insight into recent advances in rock coast geomorphology (extending beyond specific landforms such as shore platforms) and to contextualise this work within a more general coastal framework. In doing so, we seek to identify some of the research areas that remain under-represented, and present ways of improving the dialogue and interaction between rock coast geomorphologists and other coastal scientists.

2. Rock coast global distribution

It is not really known how much of the world's shoreline is "rocky"? While Emery and Kuhn's (1982) 80% has been frequently repeated, there has been little or no research to substantiate this figure. In fact what appears to be a simple question is rather problematic. What constitutes a rocky shore (see discussion below)? For example, many cliffed coasts are fronted by beaches so that waves only reach the cliff foot under the most energetic conditions. How should such shorelines be categorised? Similarly, the percentage of coast having a shore platform is unknown. There is a need to work with GIS specialists and global datasets to determine both the amount and type of rock coast, but this requires the generation of both suitable data sets and classification schemes. Material could be derived from recent coastal mapping and vulnerability studies such as EUrosion (European Commission, 2004), Dinas-Coast (McFadden et al., 2007) and the geomorphic mapping of the Australian coast based on the method developed by Sharples (2006).

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3. Erosional compared with depositional coastal geomorphology

While we do not advocate a return to coastal classification as a preoccupation for those interested in rock coasts there is a need to establish consistent typologies that enable distinctions to be drawn between rock and soft sediment coasts. Here we refer to rock coasts as predominately erosional landforms while soft coasts are those which are primarily depositional in nature, such as unconsolidated or poorly consolidated sediments (e.g. beaches and dunes). We feel that these terms are more appropriate than referring to rock coast landforms as 'hard' or 'resistant coasts' in contrast to 'soft', and by implication more vulnerable coasts, as is commonly done (e.g. Sherman and Gares, 2002). This is particularly important as typologies often form the basis of erosion vulnerability and sensitivity indices (e.g. Pethick and Crooks, 2000) that are increasingly used to assess risk under a changing climate (discussion below). Outputs from such indices can strongly influence perceptions on the relative importance of rock coast studies. For example, Pethick and Crooks (2000) argued that the vulnerability of coastal landforms can be characterised by relaxation times and return intervals for threshold events. Salt marshes and sand dunes are likely to respond almost instantaneously to direct wave attack caused by storm surges and would be defined as highly vulnerable environments, while the same storm may have no impact on a hard rock coast. On the other hand, while sand dunes and salt marshes may quickly recover from storms, changes to rock coasts are long lasting to permanent.

An obvious problem lies in the distinction between coasts carved in rocks and those formed in less consolidated materials, such as cohesive clays, consolidated gravels and diamicts, that share some of the same morphological elements, including cliffs and shore platforms. In California, coastal workers study composite cliffs that are variable in hardness along their vertical profile, being harder at the base and softer at the top (Hampton et al., 2004). Additional problems occur with composite coasts such as beaches with shore platform foundations and cliffs that are fronted by beaches (which may or may not lie over a platform – are these rock coasts or soft coasts? Perhaps it would be better to think of coastal landforms as being part of a continuum ranging from depositional to erosional, rather than attempting to define where rock coast studies end and soft coast studies begin?

There has been limited research on rocky coasts with beaches and other depositional elements, and rock coast geomorphologists have seldom studied coasts in softer rocks such as cohesive clays (i.e. tending towards soft, unconsolidated coasts). Notable exceptions include Davidson-Arnott (1986), Davidson-Arnott and Ollerhead (1995) and Davidson-Arnott and Langham (2000) who measured downwearing rates on submerged, nearshore glacial till in the Great Lakes; the erosion rate study Charman et al. (2007) and; Trenhaile's (2009) clay coast erosional model. Research is needed on these more complex morphologies to help to refine our typologies and to improve the sensitivity of vulnerability indexes. There also needs to be greater collaboration between those who predominately study depositional landforms (e.g. soft coasts such as beaches and dunes) and those who primarily focus on erosional landforms (i.e. rock coasts).

There has been much less research conducted on rock coasts that on softer sedimentary coasts, in part because many sedimentary features, such as beaches, are perceived to have a high social and economic value (e.g. Finkl and Walker, 2002; Horn, 1997). Sherman and Bauer (1993, pg 242) in a review of coastal geomorphology (where only 4 of 139 references were on rock coasts) suggested that beaches will "retain topical dominance in coastal geomorphology over the next 20 years." A literature search was carried out in 5-year intervals since this statement was made. It is obvious from Fig. 1 that there still remains a topical dominance on beach research, and that rock coast research, although a growing area, is still less well-examined than other coastal landforms such as beaches and coastal

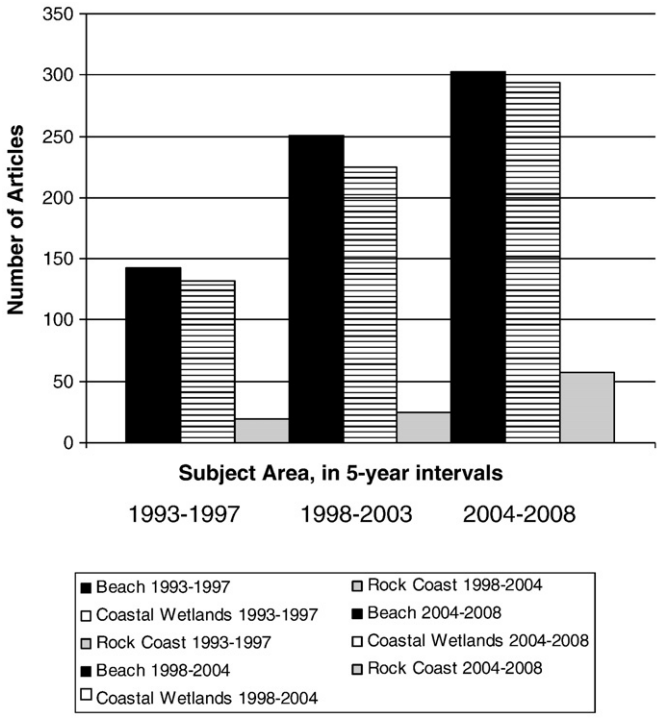

Fig. 1. Literature search illustrating the numbers of papers with beach, rock coast (shore platform or rock cliff) and coastal wetlands (including mangroves and salt marshes) in their title, in 5-year intervals since 1993 (i.e. after Sherman and Bauer, 1993). Searches conducted using Web of Science on 23rd December 2008, where subject areas were refined after the initial searches to restrict the output to geomorphology-related topics.

wetlands. Conclusions such as these perpetuate the research emphasis on those landforms. Rock coast research was conducted by a fairly small number of scientists in the 20th century and there was limited interest in rock coast processes and erosion by practitioners in allied disciplines such as coastal engineering. Research was typically carried out by small teams of geographically dispersed researchers, and limestone coasts and coral reefs were typically treated separately from other types of rock coast.

The emphasis on particular types of landform has been skewed towards depositional coasts in most coastal textbooks. We analysed the tables of contents of 19 textbooks on coastal geomorphology to assess the amount of attention given to rock coasts, excluding corals due to their biogenic origin and their subtidal location (Table 1). Although this method of analysis is quite coarse and may under-represent coverage of rock coasts by ignoring pages in other chapters that refer to rock coasts, or exaggerate their under-representation by including chapters on waves and tides, it provides a general illustration of their relative emphasis on depositional and erosional (i.e. rock) coasts. Depositional coast landforms are typically covered by several chapters on different types of landform, including beaches, dunes, and salt marshes, whereas rock coasts are typically treated in a single chapter. With the exceptions of Zenkovich (1969) and Trenhaile (1997), all general coastal texts devote one or fewer chapters to rock coasts and on average, 8.5% of the books (as a measure of the number of pages relative to book length) refer specifically to rock coasts; only six of the 19 books have more than 10% of their content devoted to rock coasts. Clearly, the attention placed on rock coasts in such texts is far below Emery and Kuhn's (1982) estimate of their global extent, relative to other types of coast.

Brunsden (2002) has actively promoted the utility of geomorphology in engineering studies, and in doing so has increased the awareness and consideration of geomorphological science in slope stability investigations. His research in Lyme Regis (Brunsden and