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Where is the seaward edge? A review and definition of shore platform morphology

David M. Kennedy *

School of Geography, The University of Melbourne, Parkville, Vic 3010, Australia

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ABSTRACT

Shore platforms are erosional coastal landforms that have attracted scientific attention since the mid 19th century. The defining element of a platform is width that is used in many calculations such as determining a platform's evolutionary state or inferring how wave energy is distributed along the shore. Although a critical variable, there are no uniform criteria for defining the seaward edge. Quantification of platform width has been driven by site-specific variables, with the seaward edge defined on the basis of tides, morphology, biology, processes and sediment coverage. The lack of a uniform definition has meant that comparative studies are difficult and results are possibly spurious, as widths derived from very different criteria can vary by an order of magnitude just on the basis of which criteria is used to determine its edge. In this review a combination of morphologic and process elements is used to define the seaward edge of a shore platform. The development of strict criteria is especially needed in an environment of rising sea levels if measurements of landscape change are to be made. In addition, the advent of seamless datasets that cross the land–sea boundary means that the delineation of platform morphology is no longer limited by physical access. This review concludes that the seaward edge of a shore platform will occur at or landward of wave base and should be defined as: the point where active erosion of the bedrock ceases, characterised by erosional features such as notches and block-plucking scars or the deposition of sediment of such a thickness that the underlying bedrock is not exposed during storm events.

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1. Introduction

Shore platforms are erosional landforms found on rocky shorelines (Dana, 1849). They occur where the underlying geological structure has been truncated by exogenous erosive processes (Stephenson et al., 2013). A degree of truncation of the local geological structure, either bedding or joint planes, is necessary to differentiate a platform from coastal bedrock exposures where erosion has merely removed weathered alluvium to expose a pre-existing bedrock surface, such as commonly found in igneous terrains (e.g., Migon, 2006; Knight and Burningham, 2011). A shore platform will form when the assailing forces of hydraulic action exceed the resistance force of the rock (Sunamura, 1991); the resisting force being determined by inherent rock strength, the degree of subaerial weathering (Sunamura et al., 2014) and the intensity of biological activity (Naylor et al., 2012; Stephenson et al., 2013). The point at which assailing and resisting forces are equal is termed the critical erosion depth (Z_c) and this is where the shore platform forms (Sunamura, 1991).

* Tel.: +61 383449168.
E-mail address: davidmk@unimelb.edu.au.

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"It is width which defines the presence of platforms, as well as best expressing their state of development" (Trenhaile, 1983) (p. 147). For example, when modelling the long-term (millennial scale) evolution of shore platforms the width is assumed to either remain relatively constant through time (dynamic equilibrium) or to progressively widen (static/steady-state equilibrium) (Trenhaile and Layzell, 1981; Trenhaile, 1983; Sunamura, 1991; Dickson et al., 2013; Stephenson et al., 2013). Platform width also determines how much wave energy is delivered to coastal cliffs (Limber and Murray, 2014; Limber et al., 2014), it is used as a proxy for hazard planning (de Lange and Moon, 2005; Stephenson, 2008), and is used to infer process dominance through the assumption that the widest platforms occur where wave processes are dominant (Bird and Dent, 1966; Abrahams and Oak, 1975).

It is surprising therefore, that given its importance, width is inconsistently defined or often not defined at all. For example, in Bird and Dent (1966) there is no mention of precisely how width is determined. Abrahams and Oak (1975) on the other hand state "both the seaward and the landward edges of the shore platform should be readily definable" (p. 191) yet no further indication is given on how they delineate the seaward edge. In Dickson et al.'s (2013) commentary they use Trenhaile (1987) to delineate the seaward edge as an "abrupt slope at their outer edge" (p. 1046), but neither 'abrupt' nor 'outer' is defined. The question therefore arises as to where does a platform begin and end. The purpose of this review is to explore rocky coast morphology across the globe in order to define the position of the seaward edge of a shore platform. The need for such a definition is particularly pressing due to the advent of seamless terrestrial and marine topographic datasets which require strict delineation criteria because mapping is no longer limited by physical access (Kennedy et al., 2014).

2. Platform morphology

Shore platforms can be subdivided into two broad types, those which slope seaward as a uniform ramp and those with a distinctive seaward edge characterised by a cliff (Stephenson et al., 2013). Sunamura (1992) termed these two end members Type-A and Type-B respectively (Fig. 1). In general the slope of a platform increases with increasing tidal range (Trenhaile and Layzell, 1981) with platforms in meso to macrotidal ranges having slopes typically ranging from 1.5° to more than 4° (Trenhaile, 1987; Stephenson et al., 2013). In microtidal regions semi-horizontal, or type B, platforms dominate (Trenhaile, 1987; Sunamura, 1992). Erosion of shore platforms therefore appears to be tidally modulated (Stephenson et al., 2013) and while Z_c may equate to platform elevation in microtidal settings (Sunamura, 1991, 1992) it cannot be considered to be spatially static in macrotidal regions as it moves vertically many metres daily.

To calculate the width of a shore platform both its landward and seaward limits must be quantified. The landward edge of a shore platform may be marked by a cliff, be buried by beaches or by hillslope talus. A distinct change in angle away from the mean slope of the hinterland

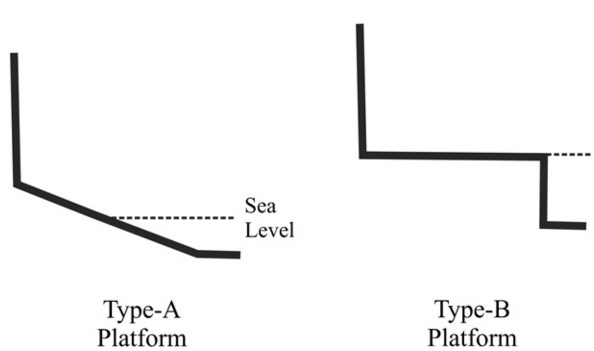

Fig. 1. Classic Type-A and Type-B shore platforms as described by Sunamura (1992).

geology should delineate the landward edge in situations with little or no sediment accumulation. In macrotidal areas, such as the Bay of Fundy, platforms slope at an angle of up to 7.5° (Porter and Trenhaile, 2007), while on granitic mesotidal Irish platforms the gradient is up to 10° (Knight and Burningham, 2011). In microtidal environments platform slopes are often near-horizontal (Stephenson et al., 2013) but abrasion ramps at the landward edge may reach 11.4° (Kennedy and Milkins, 2015). The landward edge could therefore be considered to occur when the slope exceeds 12–15°. Critically, the slope of the platform should be less than that of the underlying geological structure. In cases where the rear of the platform is buried by sediment, the depth at which the entire sediment column is no longer mobilised during decadal storm events can be considered the landward edge. Walkden and Dickson (2008) proposed that a beach would protect the platform at $0.23H_b$ (H_b = breaking wave height) and this measure could serve as a proxy for delineating the landward edge of a platform when it is buried by sediment that is able to be mobilised by waves.

Delineating the seaward edge is however the most difficult task and is the focus of this review. Five broad criteria are identified which all researchers use to some extent to mark the seaward edge of the platform, namely: (1) tidal elevation, (2) morphology, (3) sedimentology, (4) biology and (5) wave processes.

2.1. Tidal elevation as a defining category

The position of the tide is one of the most commonly used methods to delineate the seaward edge of a shore platform as it is easily identified in the field. Sunamura (1992) (p. 142) classified the seaward edge as occurring at the mean sea level (MSL) for type-A platforms, while mean low water spring (MLWS) mark was used in mathematical modelling of Trenhaile (2000, 2001, 2004, 2005, 2008). A tidal level is used in studies of the macrotidal (range 9–12 m) Vale of Glamorgan, Wales. Here the platforms slope seawards at 2–3° and range in width from 100 to over 300 m (Naylor, 2001; Naylor and Stephenson, 2010). Steps of decimetre scale are present along shore-normal profiles, relating to block plucking of specific limestone layers (Naylor, 2001; Naylor and Stephenson, 2010), with the platforms descending below low tide level with little break in slope (Trenhaile, 1972) (Fig. 2). Both Trenhaile and Naylor define the platform edge to occur at mean low water (MLW) mark at Glamorgan (Trenhaile, 1999; Naylor, 2001; Naylor and Stephenson, 2010). This same position is used to define the seaward edge on the mesotidal sloping platforms of North Yorkshire, U.K. (Robinson, 1977a) and the chalk platforms of SE England (Dornbusch and Robinson, 2011). In contrast Davies et al. (2006) in their investigations of the Glamorgan coast use low spring tide (LST) to calculate platform width.

In microtidal settings, such as on the shore platforms of Kaikoura, New Zealand, a tidal elevation is also used to delineate the seaward edge. Here the shore platforms are just under 100 m wide, with the rocky substrate extending over 500 m further seaward to at least 25 m water depth (Stephenson and Kirk, 2000a,b). Above MSL, the platforms slope between 0.5° and 1.5° with a small seaward cliff occurring on the lowest gradient surfaces (Stephenson and Kirk, 2000a) (Fig. 3). Stephenson and Kirk (2000a,b) identified both type-A and type-B platforms on Kaikoura and define the seaward edge to occur at the lowest low tide (LLT) mark. Davies et al. (2006) in their investigations of the microtidal Japanese platforms on the Kii and Izu Peninsulas use a slightly higher tidal elevation of LST to delineate the seaward edge.

The use of tidal elevation, such as LLT, MLWS, and MLW, is a convenient way to analyse platforms as it relies on a tidal benchmark for delineating the platform edge. The problem arises when comparing studies that use different tidal levels. For example on a theoretical platform in a mesotidal area (tidal range 5 m) with a moderate slope of 3° the horizontal distance between MSL and MLWS will be 47.7 m. In the field, the width of platforms in England (North Yorkshire) and Wales