Sedimentary Geology 284–285 (2013) 1–25

Contents lists available at SciVerse ScienceDirect

Sedimentary Geology

journal homepage: www.elsevier.com/locate/sedgeo

Invited review

World's highest tides: Hypertidal coastal systems in North America, South America and Europe

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ARTICLE INFO

Article history:
Received 4 May 2012
Received in revised form 17 October 2012
Accepted 7 December 2012
Available online 21 December 2012

Editor: G.J. Weltje

Keywords:
Macrotidal
Hypertidal
Lamina
Rhythmites
Neap–spring cycles
Annual cycles

ABSTRACT

Hypertidal systems can be defined as areas where spring tides have ranges greater than 6 m. These very high tidal ranges results in unique patterns of sedimentation within hypertidal estuaries. Such systems are not common but they do occur on a number of continents. This report will discuss six areas that have the highest tides in the world. North America hypertidal systems occur within Cook Inlet in Alaska, USA, Leaf Basin in Ungava Bay, Quebec Province, Canada, and the Bay of Fundy, Nova Scotia and New Brunswick, Canada. In South America, the Straits of Magellan and associated Atlantic coastal settings exhibit hypertidal conditions. European hypertidal systems include Bristol Channel and Severn estuary in southwest England and the Gulf of St. Malo in Normandy, France. These six areas have the highest tides in the world and spring tidal ranges that regularly exceed 10 m. All the six areas can be divided into intertidal sedimentological zones. Zone 1 is the outermost zone and contains longitudinal bars. Zone 2 exhibits laterally extensive sand flats. Zone 3 includes the innermost extent of tides and estuarine point bars. Annual and neap–spring cycles have been documented in Zone 3 and are probably the most indicative features of hypertidal systems. The North American systems occur in high-latitude cold climates where winter ice can have a minor or major impact on the development of sedimentary facies. Conversely, the European and Patagonia systems have climates minimal ice formation.

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1. Introduction

1.1. Study areas

This report will compare tidal dynamics within the intertidal zone of six areas that have the highest recognized tidal ranges on Earth (Fig. 1). Other areas, of course, also have very high tidal ranges. For example, the summary of Archer and Hubbard (2003) discusses additional areas, particularly in Asia, with hypertidal ranges. Since that earlier review, all the areas discussed in this report have been visited and at least preliminary observations have been made.

North America sites include: (1) Turnagain Arm within Cook Inlet in south-central Alaska, USA, (2) Leaf Lake in Ungava Bay, northern Quebec Province of Canada and (3) Salmon River estuary in the Bay of Fundy, Nova Scotia Province of Canada. In South America, hypertidal settings include: (4) several estuaries in the Patagonia region (southeastern Atlantic coast of Argentina). Areas in Europe include: (5) Bristol Bay and the Severn River estuary, southwestern UK and (6) and Mont-Saint-Michel Bay in Normandy, France.

1.2. Frequency distribution of global tidal ranges

Based upon maximum spring-tidal range, the subdivision of tidal systems by Davies (1964) has proved to be popular and has become widely utilized. His system defined microtidal as having a tidal range of 0 to 2 m, mesotidal as having a tidal range of 2 to 4 m, and macrotidal as having a tidal ranges greater than 4 m. No upper limit for macrotidal was originally defined. The frequency distribution of global tidal heights indicates that most coastal areas are dominated by micro- and mesotidal ranges (Fig. 2). Although macro- and hypertidal settings are rare by comparison, the dynamics of sediment erosion, transport, and deposition cause these high tidal-range areas to have extreme, short-term variability.

As applied herein, hypertidal settings are defined as having tidal ranges that exceed 6 m. This places an upper limit of 6 m for the macrotidal category originally defined by Davies (1964). There are very high energies and dynamic intertidal sedimentation in hypertidal systems. In order to make simple comparisons between these very high tidal-range areas, the hypertidal range can be subdivided into 2-m intervals (Fig. 2): hypertidal-A (6 to 8 m), hypertidal-B (8 to 10 m), hypertidal-C (10 to 12 m), hypertidal-D (12 to 14 m), and finally hypertidal-E (14 to 16 m).

Hypertidal systems have enormous tidal ranges coupled with a tremendous potential energy. A complete understanding of the

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0037-0738/$ – see front matter © 2012 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.sedgeo.2012.12.007

Fig. 1. Location of areas with highest tides in the world (black text). Hypertidal settings in North America include, from west to east: Cook Inlet, Alaska, USA; Ungava Bay, northern Quebec, Canada and Bay of Fundy, Nova Scotia, Canada. Settings in South America include the hypertidal estuaries of Rio Santa Cruz, Rio Coyle and Rio Gallegos. Study sites in Europe include the Severn River estuary in southeastern UK and the Mont-Saint-Michel Bay in Normandy France. Note that except for Cook Inlet all settings are part of the Atlantic Ocean margins. Other prominent areas of hypertidal ranges (green text) have been discussed by Archer and Hubbard (2003).

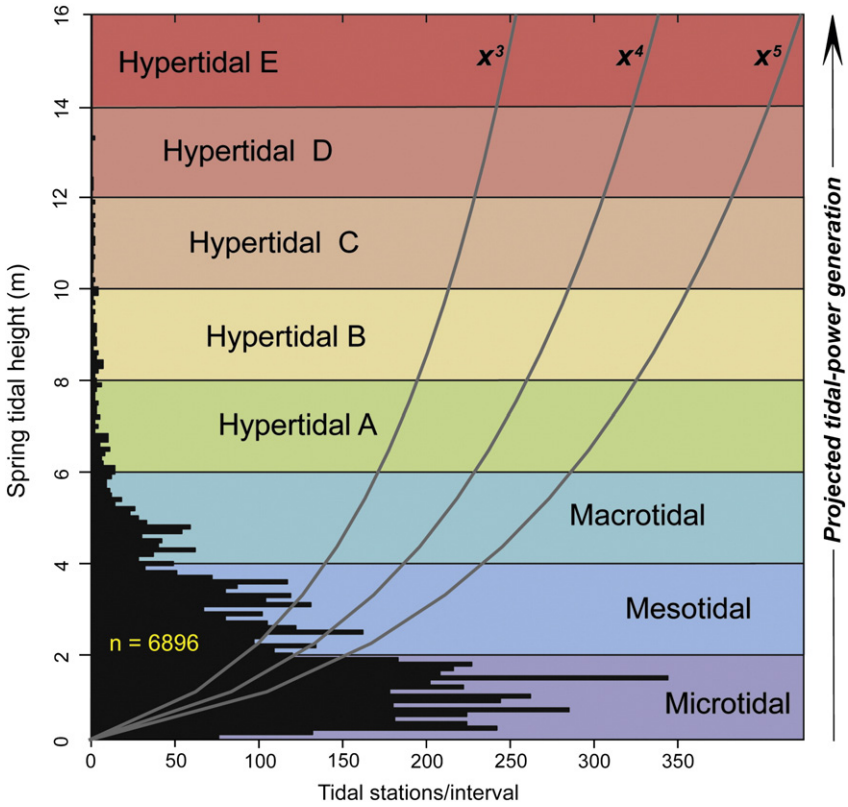

Fig. 2. Frequency distribution (histogram) of global tidal ranges extracted from NOAA (1998) tidal tables. This navigational database includes maximum-spring-tidal ranges from 6896 primary and secondary sites around the globe. Color bars delineate the widely used microtidal (0 to 2 m), mesotidal (2 to 4 m) and macrotidal (4 m and above) ranges. The macrotidal division as currently in use is open-ended and incorporates a tremendous range of tidal heights and potential tidal energies. For purposes of this comparative study, an upper limit for macrotidal is set at 6 m and all higher tides are defined as hypertidal. A tidal range of 6 to 8 will be termed Hypertidal A or abbreviated to hyper-A. Tidal ranges from 8 to 10 m will be referred to as Hypertidal B, and so on. Similar color bars will be used within subsequent tidal range diagrams in order to indicate the various hypertidal ranges. Projected tidal-power curves based upon changes in tidal heights taken to the 3rd, 4th, and 5th powers. These curves indicate that tremendous potential for tidal-power generation within hypertidal systems.

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