Abstract

Latitudinal Controls on Modern Shoreline Geometries

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Paralic and shallow marine deposits comprise important yet potentially complex and heterolithic reservoirs in numerous fields around the World. The key control on reservoir architecture and consequently performance is the relative role of wave, tide or fluvial processes at the shoreline (Galloway 1975; Ainsworth et al. 2011). Shorelines dominated by wave processes tend to comprise good quality, clean reservoirs in sand bodies that are laterally extensive in a shore parallel direction (Howell et al. 2008). Fluvial dominated deltaic systems produce more lobate, sand bodies with a higher degree of heterogeneity related to dipping clinoforms and the compensational stacking of delta mouthbars. Tidal shoreline constitute the most heterolithic reservoirs with tidal channels, flats and subtidal bars arranged in complex lateral assemblages. Ainsworth et al. (2011) highlighted that in addition to the three end-members, a series of intermediate cases also exist which reflect different degrees of process impact on the shoreline.

Modern systems are commonly used as analogues for understanding the plan-view distribution of reservoir elements within a variety of depositional systems. The advent of free, global remote sensing data has significantly increased the availability of modern analogues and the frequency of their study. This is especially significant in shallow marine systems because many of the shallow marine reservoirs occur in major Tertiary delta systems (e.g. Niger, Baram, Nile, etc) which are still active today. In such cases the analogue comes directly from the same (or similar) depositional system as the reservoir. Whilst there have been numerous studies of modern systems, to date there has been no effort to systematically map the coastline of the entire World.

The goal of the present study has been to use GIS data to classify the coastline of the entire World with a view to improving understanding of the distribution of the key processes (WTF) and what controls their distribution and relative importance. The results of this study can be used to explore the impact of latitude upon the relative importance of the processes.

The first stage of classification was to determine whether the coastline was in net erosion or net deposition on geological timescales. This was achieved by looking at the gradient on the landward side of the shoreline. A very low gradient over an area larger than 250 sq km and areas with previously mapped Quaternary sediments (Glin 2012) typically equates to a delta or coastal plain and suggests that the associated shoreline is in long term progradation. A high relief adjacent to the shoreline suggests that the coastline is in net erosion. Of the global coastline of 350,000 km, 74,000 (21%) is in net deposition and 276,000 (79%) in in net erosion.

The second stage of the classification was to use three separate GIS layers to classify the shoreline with respect to the relative importance of the different processes (WTF). The first was mean global wave height from the World wave global database (Mørk et al. 2010). The second was mean tidal range from the global finite element solution model (Lyard 2006). Input on fluvial processes at shorelines was more difficult to obtain. No fluvial discharge models

for all of the rivers on the planet was available, so a classification based on automated mapping of the area of all of World's drainage basins was used to provide a proxy for discharge at the river mouths (Lehner et al 2008).

These three parameters were then normalised and combined using a series of algorithms that account for the relative energy of the different processes, coupled with factors to account for climate and coastal morphology. The results allowed classification of the dominant process in 5 km stretches along the entire global coastline. Classification was done to the second order level ("influenced") of Ainsworth et al (2011). The data were then presented on a global map using an RGB color scheme (Fig 1). In addition to quantifying the dominant and subordinate processes around the coast, the "total energy" of the basinal processes (wave and tide) was also calculated to give a non-dimensional number that serves to distinguish shorelines that might be dominated by the same process but have very different energy levels.

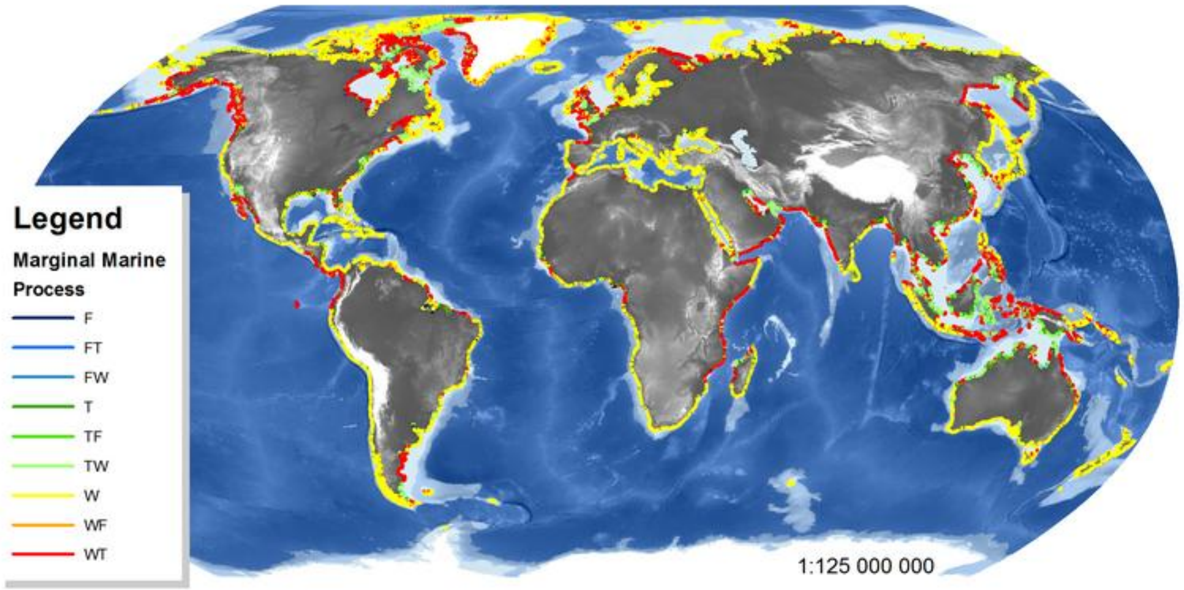

Figure 1. Global classification of shorelines in 5km increments. W- wave dominated; Wf - wave dominated, fluvial influenced; Wt - wave dominated, tidally influenced; T – tidal dominated, Tw – tidally dominated, wave influenced; Tf – tidally dominated, fluvial influenced; F – fluvial dominated; Fw – fluvial dominated, wave influenced; Ft – Fluvial dominated, tide influenced (classification after Ainsworth et al 2011).

Analysis of the data for the entire globe are presented in Figure 2. These demonstrate that globally wave processes are the most important, while tidal processes are of secondary importance and fluvial processes are only significant adjacent to river mouths. Analysis of the data by latitude (Fig 3) demonstrates that the highest energy shorelines exist in the southern ocean and there is a decrease northward to the equator and into the northern tropics (Fig 3). Energy then increases towards the northern high-latitude regions. This trend broadly corresponds with increase in the percentage area of land vs ocean at the different latitudes, with areas with a lower percentage of land receiving the greatest wave energy.

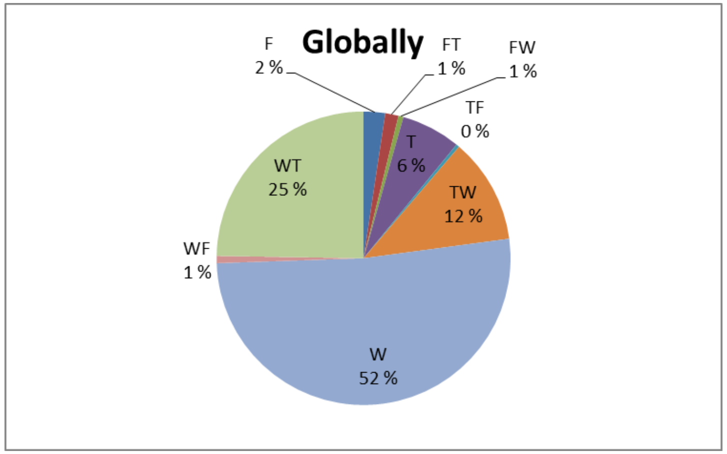

Figure 2. Global proportions of coastal processes.

The relative proportion of processes (Fig 3) by latitude shows an increase in both tidal and fluvial processes towards the equator, tropics and mid latitudes, which decrease towards the poles. There is also a decrease in tidally dominated or influenced shorelines towards the poles which is associated with a decrease in the size of the tidal bulge away from the equator.

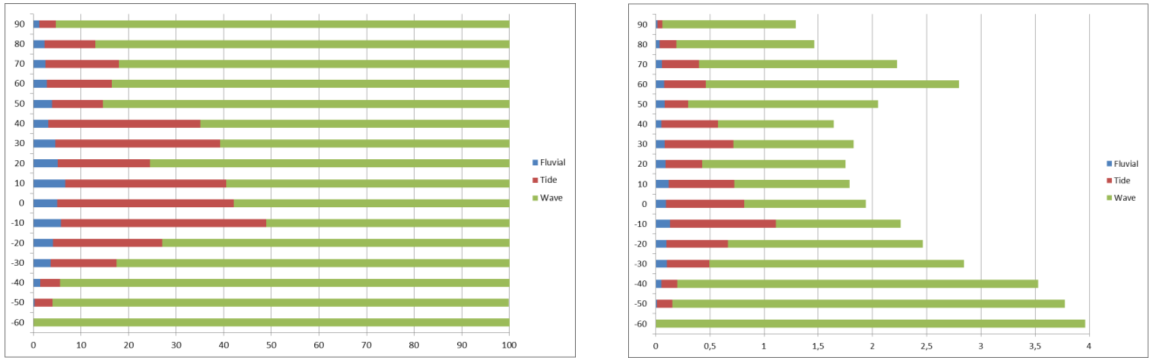

Figure 3. Left - Relative importance of Fluvial, Wave and Tidal Processes by latitude. Right – Key processes by latitude superimposed on total basinal energy.

The results of this study have a number of implications for exploration and production in shallow marine systems. Firstly, the global classification of shoreline type can be used to find suitable analogues for any shallow marine reservoir. These can be filtered by process, latitude, basin type, and climate, to ensure the optimal analogue is found.

From an exploration perspective in high latitudes, the increase in high energy wave dominated shoreline towards the poles is very positive. Such systems are commonly associated with high permeability, sand dominated shorelines which are laterally extensive along strike and lack significant internal heterogeneity. The mapping can be used to identify more detailed areas that warrant further investigation.

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