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Discussion

Preface to marine geology special issue: *Geological Records of Extreme Wave Events*

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1. Introduction

Extreme wave events, including tsunamis and storm surges, present major hazards to coastal communities around the world. In excess of 10% of the global population lives in coastal areas at elevations below 10 m, including 21% of the urban population of the Least Developed Countries (LDC) group, 50 nations with the most vulnerable economic statuses (McGranahan et al., 2007; Neumann et al., 2015). Geological investigations significantly enhance our understanding of tsunamis and storm surges, with field studies and modelling approaches contributing to improved knowledge of their long-term frequency-magnitude patterns. These long-term perspectives are required to adequately assess and model the hazards posed by future extreme wave events. The demand for geologically-supported coastal hazard assessments is continuously rising as anthropogenic sea-level rise accentuates the impact of extreme wave events (Kemp and Horton, 2013; Kron, 2013; Brown et al., 2014). As detailed geological examination of the deposits left by tsunamis and storm surges constitutes a relatively recent scientific endeavour (see Tappin, 2017 for an overview of the development of tsunami geology research), recent years have seen a rapid expansion in the range of approaches employed (Nott, 2004; Shiki et al., 2008; Goff et al., 2012; Muller et al., 2017). Responding to the need for increased dialogue, collaboration and the exchange of ideas, a thematic session held at the European Geosciences Union (EGU) annual meeting in April 2016 and again in April 2017 brought together scientists from disparate strands of extreme wave event research. In total, 194 scientists have contributed 53 presentations to the first two gatherings of the *Geological Records of Extreme Wave Events* session. These contributions included case studies from recent, historic and prehistoric tsunami and storm surge events, covered coarse-clast and fine sediment records, ranged from low to high latitude regions and described both coastal and offshore records. Presentations have detailed the latest advances in identifying, characterising, dating and modelling evidence for extreme wave events. Based on these contributions, this special issue brings together 16 papers highlighting the latest developments in the field. Collectively, this issue includes a world-wide distribution of research (Fig. 1), with papers covering three broad themes: modern analogues, long-term records and modelling of extreme wave events.

1.1. Modern analogues of extreme wave events

Contemporary extreme wave events provide opportunities to characterise the sedimentary and geomorphic signatures of events of known source, magnitude and impact. These investigations may provide new understanding of event characteristics (e.g. Goto et al., 2011; Soria et al., 2016), highlight previously unstudied archives (e.g. Goni et al., 2007; Sakuna et al., 2012; Sawai et al., 2012) and both inspire and facilitate the development of novel methodologies (e.g. Wassmer et al., 2010; Chagué-Goff et al., 2012). Post-event surveys provide valuable field observations and datasets against which numerical models may be tested and refined (see Section 1.3). Repeat surveys provide insights into the preservation potential of extreme wave event deposits and their incorporation into the geological record (Szczuciński, 2012; Spiske et al., 2013). In turn, studies of contemporary events act as modern analogues, enhancing the interpretation of older geological records of tsunamis and storm surges (see Section 1.2).

Seven research papers in this special issue focus on sedimentary evidence for recent storms. Hong et al. (2017) report the findings of a rapid survey made three months after Tropical Cyclone Pam made landfall in Vanuatu in March 2015. The authors document flow heights of up to 5.29 m at an inundation distance of 106 m from the shoreline. Sedimentary evidence extends up to 320 m inland, with pumice layers found at greater distances from the shoreline than finer-grained sand sheets. Stemming from the same field survey, Kosciuch et al. (2017) focus on Tropical Cyclone Pam's microfossil signature. Investigating foraminiferal assemblages in the onshore sand sheets, the authors highlight the intertidal and shallow subtidal zones as the primary sediment sources.

Bregy et al. (2017) investigate sediment transport associated with hurricanes Camille and Katrina, which struck the Gulf of Mexico in 1969 and 2005 respectively. The authors use these modern analogues to identify storm surge deposits preserved in coastal marsh sediments in

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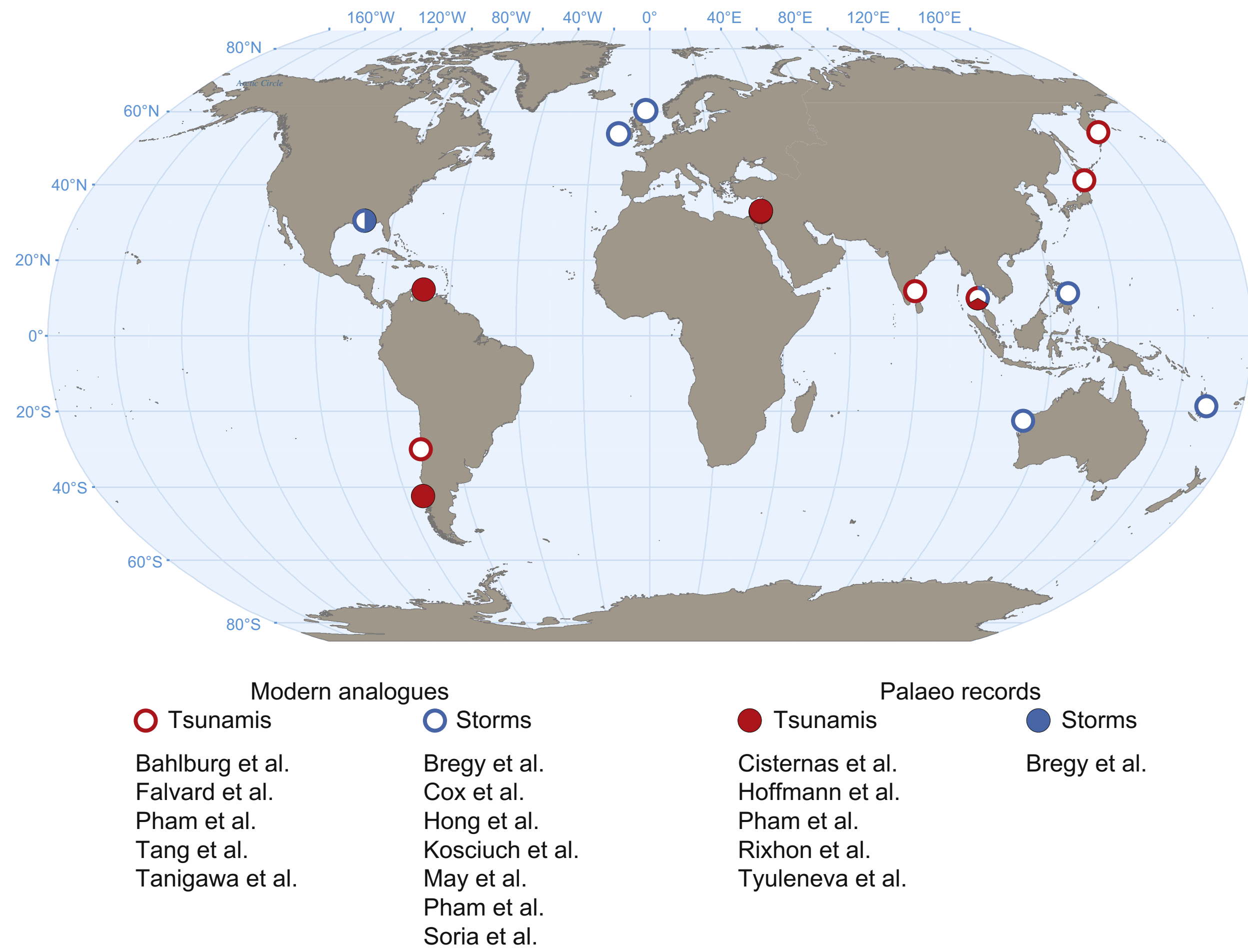

Fig. 1. Field locations of the extreme wave event studies reported in this special issue.

Mississippi, USA. The offshore origin of the prehistoric storm surge deposits and modelled flooding levels indicate similar storm surge magnitudes as during the two recent category 5 hurricanes.

Typhoon Haiyan made landfall in the Philippines in November 2013, with the interaction of wave sets and particular offshore bathymetry resulting in destructive long-period infragravity waves particularly around Hernani, eastern Samar (Roeber and Bricker, 2015). Soria et al. (2017) document both fine- and coarse-grained deposits associated with this event. A carbonate sand sheet extending > 300 m inland contains foraminifera again indicative of shallow nearshore and beach environments. Seaward of this deposit, the storm surge also transported boulders, the majority ≤ 10 t, across a reef flat. The ability of storms to move boulders is also the focus of a study by Cox et al. (2017). Investigating sites in the Shetland Islands and western Ireland, the authors demonstrate an inverse correlation between quantitative boulder roundness measurements and boulder elevation in coastal locations. Their work not only highlights the utility of the Kirkbride device (Kirkbride, 2005) for deriving robust and repeatable roundness values but also marks an important step towards a much-needed sedimentological model of coastal boulder deposit emplacement.

Coastal sand ridge sequences may provide information on extreme wave frequency and magnitude. May et al. (2017) investigate the processes responsible for chenier-type ridge formation in Giralia Bay, Australia, a region with a documented history of both tropical cyclone and tsunami inundation. Their combination of monitoring from 2013 to 2015, a period including Tropical Cyclone Olwyn, stratigraphic analysis and dating highlights the importance of episodic events (both storm surges and extreme rainfall) in driving sand accretion and ridge development.

Pham et al. (2017) contrast the sedimentological characteristics of a fine-grained 2007 storm deposit and the 2004 Indian Ocean tsunami sand layer, in addition to two older tsunami deposits, encountered at a site on Phra Thong Island, Thailand. The authors demonstrate that discrimination between storm surge and tsunami deposits – a long-standing and ongoing debate within the community – is complex, with the Phra Thong deposits largely indistinguishable in their mineral content and trace element geochemistry. Three further papers in this issue document fine-grained sedimentary evidence for recent tsunamis. Tanigawa et al. (2017) focus on diatom assemblages in the 2011 Tōhoku tsunami deposits along the Misawa coast of Aomori Prefecture, northern Japan. The mixed assemblages of marine, brackish and freshwater species imply the deposit originates from a variety of sediment sources, including the coastal forest, intertidal zone and potentially also subtidal environments. Investigating the deposits left by the 2015 Illapel tsunami close to La Serena and Coquimbo, Chile, Bahlburg et al. (2017) detail a diverse array of sedimentary structures. Grain-size distributions suggest beach sands provided source materials, while water escape structures, rarely documented in extreme wave event deposits but abundant and well-preserved here, are postulated as a mechanism for the homogenisation of some tsunami-deposited sand layers. Falvard et al. (2017) focus on a tsunami generated by a volcano, rather than a megathrust earthquake: the 1996 phreatomagmatic eruption in Karymskoye Lake on the Kamchatka Peninsula. The authors employ X-ray computed tomography to investigate heavy mineral distributions in the landward thinning and fining deposit, highlighting the significant potential of this technique.