Tsunamis: geology, hazards and risks – introduction

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A decade or so ago, if you had asked almost anyone in Europe or North America, they might not have recognized the word ‘tsunami’. The enormous and tragic event that swept across the shores of the Indian Ocean on 26 December 2004, followed only a few years later by the devastating tsunami caused by the March 2011 Great Tohoku earthquake off Japan, both with appalling loss of life, changed all that. Today, the words ‘tsunami warning issued’ seem to appear frequently on international ‘breaking news’, showing the extent to which we have become sensitized to the triggers that launch these deadly, but terrifyingly spectacular, natural events. Yet, great tsunamis and the tectonic events that cause them have not suddenly become more frequent. The historical records of old civilizations contain accounts of major inundations reaching back hundreds or thousands of years and sometimes even warnings to future generations – valuable, if they are heeded. What has changed, and has consequently raised the profile of tsunamis, is the exponential growth in world population over the last few 100 years, the great majority of whom live in coastal areas and are consequently exposed to hazard, along with instant global communication, which brings every large earthquake on Earth’s plate margins directly and immediately onto our screens.

The consequence of recent events and our response to the compelling images that record these catastrophes is a global recognition of the potential hazards to life and infrastructure associated with tsunamis. For planners and decision-makers at all levels, what is demanded from scientists is more information: where can this happen; how big can it be; when will the next event occur and will there be any warning? Being able to address these questions and provide clear answers is a major responsibility for geoscientists, and a real challenge. The root of our knowledge here is a mechanistic understanding of the tectonic (and other) processes that cause tsunamis, and of how tsunamis evolve, propagate and fade. This understanding helps to start answering the ‘where’, ‘how big’ and ‘how fast’ questions, but in order to address the critical ‘when’ question, and obtain more focus on ‘how big’, requires seeking forensic geological evidence of the traces left by past tsunamis.

All of this information must then be integrated in a way that identifies and quantifies the inevitable uncertainties, before scientists can begin to discuss probabilities in a useful fashion for specific regions.

Academic societies have a role to play in promoting such research efforts and the Geological Society of London has collaborated with its partner, the Geological Society of Japan, in holding two symposia: one in 2014 in Kagoshima, and another – the Arthur Holmes Meeting in 2015 – in London. Both these symposia focused on ‘Tsunami Hazards and Risks: Using the Geological Record’ and emphasized the importance of geological studies in developing a better understanding of tsunamis. The results of the first meeting were summarized in a special issue of the journal *Island Arc* (September 2016). The results of the second are presented in this Special Publication.

The papers explore the sedimentological and dynamic traces of recent and prehistoric tsunamis globally – from Europe to the Pacific – as well as looking at historical records and how the information can be used to characterize the scale of impacts and areas that are most susceptible to tsunami

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hazards. Armed with this information, scientists can begin to quantify risks – both to populations and in economic terms.

The papers are arranged into two sections: one on tsunami hazards globally, focusing on specific historical records, and another on risk modelling.

In the first section, **Tappin (2017)** presents a history of geological involvement in tsunami science, and its importance in advancing understanding of the extent, magnitude and nature of the hazard from tsunamis.

There are three chapters relating to tsunami studies in Japan: **Wallis *et al.* (2017)** investigate geological studies in tsunami research since the 2011 Tohoku earthquake; **Goda *et al.* (2017)** present tsunami simulations of a wide range of realistic slip distribution and kinematic rupture processes, reflecting the current best understanding of what might happen due to a future mega-earthquake at the Nankai–Tonankai Trough; and **Ikehara *et al.* (2017)** give an overview of spatial variability in sediment lithology and sedimentary processes along the Japan Trench, which can be used to reconstruct the recurrence history of large earthquakes and tsunamis.

Moving on from Japan, **Lindholm *et al.* (2017)** focus on tsunami hazards in Central America, where the Pacific subduction zone, coupled with the growing coastal tourist industry in this area, has the potential for creating large tsunami risk.

Focusing on Europe, **Boulton & Whitworth (2017)** investigate block and boulder accumulations on the southern coast of Crete, and interpret what these can tell us about tsunami propagation in the Mediterranean; **Mottershead *et al.* (2017)** also focus on the Mediterranean, specifically on the Maltese Islands, and on evidence for tsunami landfall, allowing for critical reassessment of the exposure of Malta to tsunami hazard. **Costa *et al.* (2017)** investigate the microtextural and heavy mineral analysis of sandy storm and tsunami deposits from Portugal, Scotland, Indonesia and the USA, considering inundation events of different chronologies and sources that affect contrasting coastal and hinterland settings with different regional oceanographic conditions.

In contrast, **Long (2017)** gives an overview of cataloguing tsunami events in the UK – located well away from any subduction zone, and so not exposed to as high a risk as the other locations in this section. Detailed examinations of the impact of three tsunamis on the UK coast are discussed as examples of events triggered by seismicity, submarine landslides and coastal landslides.

The second section focuses on risk modelling, with a comprehensive overview by **Woo (2017)** on risk-informed tsunami warnings presenting a probabilistic approach to assessing the tsunamigenicity of fault rupture, using both the geological record and historical catalogues. **Power *et al.* (2017)** present the New Zealand Probabilistic Tsunami Hazard Model (NZPTHM), for use as an effective quantitative estimate of tsunami hazard using the Monte Carlo method, and suggest detailed inundation modelling of a small set of scenarios in New Zealand. **Davies *et al.* (2017)** discuss a global-scale probabilistic tsunami hazard assessment (PTHA), extending previous global-scale assessments based largely on scenario analysis.

It can be seen from the wide range of contributions included in this volume that the field of tsunami research and understanding is diverse and highly dependent on the identification and interpretation of the geological traces left by past tsunamis. There is still some way to go in fully understanding and answering the 'where', 'how big', 'how fast' and 'when' questions. However, knowledge and techniques are developing rapidly, owing to the increased interest globally in this topical area of natural hazard research, and there is an expectation that the risks associated with tsunamis along overpopulated coastlines can, to some extent, be mitigated.

The editors would like to thank all of the contributors and reviewers for their patience and help in putting together this book, which we hope will prove a valuable resource for colleagues working in this field.

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