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Introduction

Megathrust earthquakes and sea-level change: a tribute to George Plafker

For numerous scientific disciplines that contribute to the understanding of megathrust earthquakes, 2014 was an anniversary year of two great, >M_w9, earthquakes; fifty years since the March 27 1964 earthquake in Alaska and ten years since the December 26 2004 Aceh-Andaman earthquake and attendant tsunami. 2014 was also the final year of International Geoscience Programme (IGCP) Project 588 "Preparing for Coastal Change", which was the latest in the 25 year history of IGCP coastal change research.

Given the growth of research on megathrust earthquakes, and their associated tsunamis, we felt that the coincidence of the end of IGCP 588 and the 50th anniversary of the 1964 earthquake provided an excellent opportunity to attract a diverse community of researchers to Alaska for a field conference to explore both recent research and the interlinking of disciplines that traditionally study processes over quite different time and spatial scales. With exemplary logistical support from the Seismological Society of Society of America (SSA) and financial support from IGCP to support early career scientists, and USGS to support attendance of an invited speaker, a field meeting took place in coastal south-central Alaska in May 2014, immediately after the SSA annual meeting in Anchorage. The field guide and abstracts from the meeting are available online from the Alaska Division of Geological & Geophysical Surveys (Barlow and Koehler, 2015).

This Special Issue marks the outcome of papers submitted following the meeting. Our aim, for both the meeting and the Special Issue, was to attract contributions on topics that interlink over different timescales and spatial scales, yet typically would appear in different journals. We are, therefore, thankful to the Editor in Chief of QSR for supporting our proposal to produce a special issue that ranges from the tectonics of mountain building to seismic hazard assessment.

One other key driver for us was to mark the contribution of George Plafker to several science disciplines focused on megathrust earthquakes. As detailed in the first paper by Fuis et al. (2015) it is difficult today for the younger generation of Earth scientists to picture the 1964 Alaska earthquake outside a framework in which Pacific Ocean floor subducts beneath North America. Yet this picture was far from clear until George Plafker painted it, starting with his mapping of land uplift and subsidence caused by the Alaska event (Plafker, 1965, 1969). We were delighted that George was our invited speaker and could discuss his work and thoughts in the field, inspiring another generation of Earth scientists as he has inspired the four of us.

The research papers in this special issue relate to earthquake hazard analysis, the history of earthquakes over a variety of spatial and temporal scales, and tectonic processes and rates. A cross-cutting theme relevant to all time frames is that diverse approaches are needed to characterize earthquake deformation. Haeussler et al. (2015) show evidence from Alaska with thermochronology and geophysical data for focused exhumation along megathrust splay faults that ruptured during the 1964 earthquake. They demonstrate that the large uplift which occurred in 1964 has been a continuous process for at least two million years. Enkelmann et al. (2015) also utilize thermochronology data from Alaska for characterizing Quaternary earthquake hazards. They show a good agreement between the pattern of long-term exhumation and the 1899 coseismic uplift pattern along the Esker Creek and Chaix Hills Fault, and is the first paper to explore how thermochronology data can be incorporated into seismic hazard analysis. Mueller et al. (2015) outline their strategy for a new effort to update the probabilistic seismic hazard maps (PSHM) for Alaska. Seismic hazard maps are crucial in developing hazard mitigation strategies, and the USGS last updated the hazard maps for Alaska in 2007. PSHM are prepared by calculating the probability that a given site will experience ground motion intensity exceeding a certain value within a target period.

Interpretation of paleoseismic records of megathrust earthquakes requires a robust knowledge of long term sea-level change and the rates of change. Many of the papers in this special issue circle around this topic, but some address it head on. Engelhart et al. (2015) develop a new sea-level database for the last 16 kya for the Pacific coast of central North America and address the interplay between the contributions from eustatic, isostatic (glacio and hydro), tectonic and local factors, all of which have different response timescales. Garrett et al. (2015a) address these same factors at a single site near Cordova, Alaska, that was affected by the Little Ice Age isostatic subsidence and the 1964 earthquake together with compaction associated with delta loading. In a completely different depositional environment, Bardají Azcarate et al. (2015) address coseismic and climatic factors in interpreting the elevation of sea-level highstands from MIS7 and 5e from southeastern Spain. They find differential uplift of marine terraces linked to underlying blind thrusts.

Developing records of earthquake histories is neither quick nor simple as it involves an understanding of coastal geomorphology together with detailed litho-, bio- and chronostratigraphic analysis. This volume has a series of papers that address earthquake histories utilizing different techniques in a range of environments. Dura et al. (2015) and Garrett et al. (2015b) both present records of megathrust earthquakes and tsunamis from central Chile, near the rupture area of the M_w9.5 1960 Great Chile earthquake – the world's largest recorded. The Dura et al. (2015) record extends back to the mid Holocene, whereas Garrett et al. (2015b) concentrates on the last Millennium. Both studies utilize the paleogeodetic

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technique of analyzing diatom species to evaluate the amount of uplift or subsidence in these ancient earthquakes and also suggest that the preservation of such sequences is related to the nature of the relative sea-level rise. Hoffmann et al. (2015) provide evidence for an extreme flooding event within the Arabian Sea. Stratigraphic evidence suggests a tsunami inundated archeological sites in coastal Oman around 4450 yr BP. Bender et al. (2015) review the use of a geochemical sea-level indicators ($\delta^{13}C$, N and C/N) and apply them to reconstruct coseismic subsidence at a site affected by the 1964 earthquake in Alaska.

Beach ridges are a common feature of coastal landscapes, which can often be quickly identified on satellite imagery. The relationship of beach ridges to sea-level change and earthquakes is uncertain. Kelsey et al. (2015) examine beach ridges and associated wetlands on the southeast coast of the Kenai Peninsula that provide evidence of two great earthquakes in the last Millennium in addition to 1964. They conclude that a portion of the megathrust that presently is mostly creeping ruptured independently of an adjacent segment that is presently locked. Monecke et al. (2015) interpret beach ridges along the Acehnese coast of Indonesia as being diagnostic features for reconstructing coastal subsidence during large megathrust earthquakes. Similar to the Alaskan studies, examining the coastal geomorphology after the recent giant megathrust earthquake, in this case the 2004 Aceh-Andaman earthquake was crucial to interpretation of the evolution of the features.

It is a goal of these paleoseismic and paleotsunami studies to understand the earthquake deformation cycle; the accumulation and release of tectonic strain. GPS instrumentation at subduction zones coupled with increasingly sophisticated modeling are identifying previously unresolved patterns of plate-boundary deformation, but because GPS measurements span only a fraction of most earthquake cycles, key aspects of ongoing plate-deformation lack a unique interpretation. Reconstructing the history of individual great earthquakes, as recorded by coastal land-level changes and the accompanying tsunamis is the only means of testing megathrust segmentation over many earthquake cycles. Several of the papers in this volume touch on this question [Haeussler et al. (2015), Kelsey et al. (2015), Garrett et al. (2015b), Mueller et al. (2015), Dura et al. (2015) and Jara-Munoz et al. (2015)]. Jara-Munoz et al. (2015) address the issue of segmentation through analysis of uplifted marine terraces and suggest that some regions represent segment boundaries for most, but not all ruptures.

The unexpected magnitudes of the Andaman-Aceh (2004; M_w 9.2), Maule, Chile (2010; M_w 8.8), and Tohoku-oki (2011; M_w 9.1) earthquakes and accompanying tsunamis underscore the danger of relying only on historical records of earthquakes and modern geodetic measurements when assessing seismic hazards at subduction zones. This Special Issue has drawn together scientists working on earthquakes and tsunamis with the aim of assisting coastal communities to develop an understanding of risk and plan for sustainable coastal development.

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