Earthquake science at the University of Otago

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ABSTRACT

Since the establishment of University of Otago's Earthquake Science Chair in early 2016, our activities have been multidisciplinary, comprising: paleoseismology; earthquake statistics; ground motion simulations; seismic hazard modelling; and assistance with evaluating the seismic safety of University buildings. A primary goal of our group is to promote awareness in earthquake science across southern New Zealand, and in particular, the significant hazards posed by the local active faults. We also recognize an urgent need to address the considerable vulnerability of Dunedin's aging building stock. Collaboration across various University Departments (Geology, Geography, Mathematics and Statistics), School of Surveying, Centre for Sustainability, GNS Science, and Otago Regional Council have greatly facilitated our efforts. Dissemination of information has thus far been by way of technical and public lectures, media interviews, professional groups (e.g. University of Otago's Seismic Programme Advisory Group), consultancy reports, scientific papers, and an Otago-based international forum on seismic hazard in late 2018. Significant support for our efforts has come from EQC, QuakeCoRE, GNS Science, Contact Energy Ltd, Pacific Gas and Electric Company, and Geoscience Australia.

1 INTRODUCTION

The establishment of the Chair of Earthquake Science, and appointment of an Inaugural Chair in early 2016 effectively marked the commencement of significant efforts to address earthquake science and the associated hazards and risks in low seismicity southern New Zealand. Otago and Southland share a similar low seismicity tectonic setting to that of Canterbury, as all three provinces lie east of the plate boundary. The 2010-2012 Canterbury earthquake sequence showed these regions to be capable of significant activity after long periods of seismic quiescence. The establishment of an endowment through the generous donations of individuals such as Emeritus Professor Rick Sibson has made the chair position possible, and the position has also recognised the need to have earthquake science expertise permanently established in the Otago region. The following briefly describes our activities over the past four years.

2 ACTIVITIES

2.1 Earthquake recurrence modelling in Otago

We have conducted paleoseismic studies on a total of five active faults. Four of these have been in the Otago region: Akatore Fault (Taylor-Silva et al., 2019); Hyde Fault; Cardrona Fault; and Titri Fault (the latter a GNS Science-led study). The fifth study has been a joint Otago-GNS Science study of the Hundalee Fault, one of the 20+ faults that ruptured during the M7.8 2016 Kaikoura earthquake (Stirling et al., 2017; Williams et al., 2018; Litchfield et al., 2018). The Otago studies have been very important in terms of understanding the recurrence behavior of faults in low seismicity regions, and in educating the public that local faults exist, and are much more hazardous than the distant Alpine Fault. The Akatore Fault is especially the case, as it has had three large ground-rupturing earthquakes in the Holocene, with two of them occurring in the last c.1000 years (Taylor-Silva et al., 2019). The fault also shows the only contemporary microseismicity in the general area, which is consistent with it being in a phase of heightened activity (Todd et al. 2020). In a joint collaborative effort with Geoscience Australia and EQC we have been using these data to develop models of earthquake recurrence in low seismicity regions, and in doing so have been investigating the possibility that the faults behave in a strongly aperiodic manner.

2.2 Ground motion simulations for Dunedin and Mosgiel

We have been using the SCEC broadband simulation platform to develop ground motion simulations for Dunedin and Mosgiel from local active faults (Hyde, Akatore, and Titri). Initial simulations assumed rock site conditions, followed by a progression to 1D non-linear site response modelling. We are now extending the 1D simulations to 2D in order to model the site response from the sediment profiles beneath parts of Dunedin, and from the fault-controlled Taieri sedimentary basin. It is clear from these results that the occurrence of a large local earthquake on the Akatore Fault would produce shaking 5-10 times stronger than Dunedin has experienced in historical time (since 1840). This would have massive impacts on Dunedin buildings, especially heritage buildings.

2.3 Seismic hazard modelling

We are involved in a number of projects in New Zealand and beyond. Most importantly, Stirling is a core team member of the MBIE-funded national seismic hazard model (NSHM) update, which will produce a new NSHM by the end of 2021. The last update to the model was almost 10 years ago (Stirling et al. 2012), with an update of the Dunedin city area in recent years (Villamor et al., 2018). Additional activities are: leading the development of magnitude-frequency distributions for major active faults in Japan as part of SSHAC level 3 studies for the Ikata nuclear power plant; undertaking reviews of seismic hazard models for the insurance/reinsurance sector; and using the age and fragility of fragile geologic features to develop and test seismic hazard models. The latter studies have been conducted for the Clyde Dam in New Zealand (the first-ever application of fragile geologic features to design loadings), and for the Diablo Canyon power plant in California.

We hope to commence a major EQC-funded study this year, which will be in collaboration with Caroline Orchiston of the Centre for Sustainability. The multi-year project will address the seismic hazard and risk of the scientifically-neglected Southland province. The distribution of active faults and seismic hazard show anomalous gaps in Southland that are likely to be due to a lack of resourcing to that area, rather than due to real physical differences in seismotectonics and hazard.

2.4 Himalayan Frontal Thrust

We have embarked on a collaborative project with Tribhuven University in Nepal to characterize the seismic potential of the Himalayan Frontal Thrust (HFT), the present boundary of the Indian and Eurasian plates. We will constrain the dip on the fault to determine the net slip on the fault plane that accompanies the c.7m single-event throws that have been measured on the fault. Determining the amount of slip on the fault during major HFT earthquakes is important for seismic hazard, as the amount of displacement can be used to estimate the total length and width of the fault rupture. It is currently unknown as to whether the fault is capable of Mw≥9 events, but if the fault dip is shallow (e.g. 20º) a c.7m throw could easily translate to about 20m net slip, rupture length of hundreds of km, and Mw≥9.

2.5 Seismic safety of University buildings

University of Otago's Seismic Programme Advisory Group is charged with reviewing the seismic safety of University buildings, and provide solutions for addressing significant discrepancies with respect to the New Zealand Loadings standard (Standards New Zealand, 2004). Over 50 buildings show significant discrepancies, and these are a mix of 19th and 20th Century buildings. The most extreme cases are being prioritised, with plans being developed for the relocation of occupants, and in some cases, eventual demolishment of the building. It is satisfying to see our expertise related to the hazard basis for the code (Stirling et al., 2002) and in the potential impacts of large local earthquakes in the city being applied to reducing earthquake risk in the University.

3 CONCLUSIONS

The Otago Earthquake Science Group is now in its fourth year of operation, and in this time we have mainly focused on addresing issues relating to the largely under-studied and under-appreciated seismic hazard of southern New Zealand. Our current work streams effectively cover the spectrum of seismic hazard work, from field-based characterisations of active faults, through development of seismic source models, seismic hazard modelling, and ground motion simulations from local earthquake sources. A big goal of our work will also be to apply the lessons learned from these efforts to low seismicity regions elsewhere in New Zealand, and beyond.

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