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An overview of the impacts of the 2010-2011 Canterbury earthquakes

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ABSTRACT

A magnitude 7.1 earthquake struck the Canterbury Region of New Zealand at 4:35 am on 4 September 2010. It was centred 11 km beneath the rural town of Darfield, on the Greendale fault, which was previously unidentified. Christchurch City lies 40 km east of Darfield, and was home to a population of approximately 370,000 at the time of the earthquake. There was extensive damage as a result of the MM9 shaking, particularly to buildings and infrastructure, but fortunately there were no deaths. The residents began the recovery process, plagued by frequent aftershocks. Then, more than five months after the mainshock, on 22 February 2011, a M6.3 aftershock occurred 5 km south-east of Christchurch at a depth of only 5 km. This earthquake struck at lunchtime on a working day, causing catastrophic damage to the city, and resulting in 185 deaths. Most of these casualties occurred as a result of the collapse of two large office buildings, with further deaths resulting from falling bricks and masonry, and rockfalls in city suburbs. The M7.1 earthquake and associated aftershocks have caused extensive impacts on the local built, economic, social, and natural environments. The on-going aftershocks have also caused a disrupted environment in which to recover. This paper will outline the nature of the Canterbury earthquakes and provide an introduction to the ongoing effects the earthquakes have had on these local environments to help frame the growing body of research coming out of the Canterbury earthquakes.

1. Introduction

On 4 September 2010 a moment magnitude (M_w) 7.1 earthquake occurred near the small town of Darfield in the Canterbury Plains of the South Island of New Zealand ([21]; Fig. 1). While many older brick and masonry buildings were damaged and approximately 100 people were injured in this earthquake, there were no associated deaths. This is largely due to the earthquake taking place in the early hours of the morning when residents were in bed, and due to the distance of the earthquake from major urban areas. An aftershock sequence was initiated, which included a catastrophic M_w 6.3 earthquake on 22 February 2011 beneath the city of Christchurch, killing 185 people.

The Canterbury earthquake sequence caused severe and ongoing impacts on the social, built, economic, and natural environments in the region. The purpose of this paper is to provide the context for this special issue on the Canterbury earthquake sequence using the initial findings from the Canterbury Earthquake Recovery Authority (CERA) Wellbeing Survey reports and other relevant literature that has come out since the sequence. It begins with a description of the earthquakes and the social setting of the Canterbury Region. It then reviews some of the initial and ongoing impacts on the aforementioned local environments related to these events. By providing this broad overview of the local environment impacts this article will provide a means by which researchers can understand the related contextual issues linked with the recovery process as well as an overall context for understanding and the literature being written about these events and the local recovery.

1.1. Geological setting and historical earthquakes

The South Island of New Zealand lies on a zone of continental convergence, with the Pacific tectonic plate in the east subducting beneath the Australian plate in the west under the northern South Island, and the reverse happening in the southern South Island, with the Australian plate subducting beneath the Pacific plate. The right lateral strike-slip Alpine Fault is the interface of the convergence, stretching for 650 km through the Southern Alps. It has a recurrence interval of approximately 200–300 yr for major earthquakes ($M > 7.5$), and most recently ruptured in 1717 (e.g., [53,46]).

Other nearby faults have ruptured during historical times,

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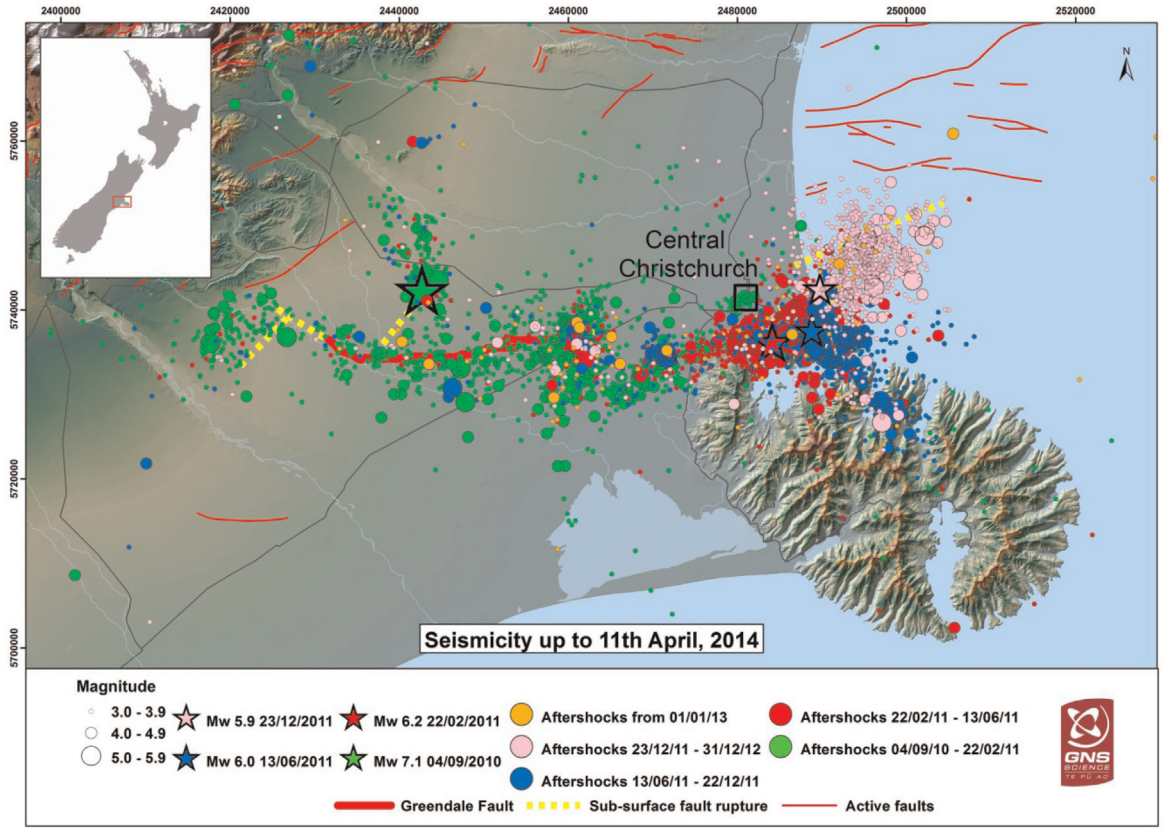

Fig. 1. Location of epicentres during the Canterbury earthquake sequence. Source: Robert Langridge, GNS Science.

causing damage in the Canterbury Region (Table 1). Nonetheless, prior to the September 2010 earthquake, there was a perception that the likelihood of a future earthquake in Canterbury was low [33]. This perception rose significantly following the Darfield earthquake. Interestingly, the perceived likelihood for an earthquake to occur in other cities also increased following the Canterbury earthquake sequence [33].

Many rivers flow eastwards from the Southern Alps towards the Pacific Ocean, depositing post-glacial alluvial gravels that have built the Canterbury Plains over time (e.g., [20]). The city of Christchurch is vulnerable to shaking and liquefaction due to the foundation of alluvial sediment. Underlying these sediments are tectonic faults, only some of which have been identified (e.g., [51,21]).

1.2. Social setting of the Canterbury Region

The population of Canterbury Region is just over 550,000 [52]. Canterbury has a strong agricultural industry built on the alluvial plains, which contributes to its economy. Additionally tourism is also an important economic contributor, with many tourists visiting Christchurch prior to the earthquakes and enjoying the scenery created by the Southern Alps. In terms of transport, road, rail, Christchurch airport, and a busy port at Lyttelton Harbour form the main links [52]. With respect to local government, the organisation Environment Canterbury (which was run by commissioners, rather than elected officials) oversaw management of the Canterbury Region prior to the earthquakes. There are ten district councils located within the region (Fig. 2) including Kaikoura, Hurunui, Waimakiriri, Selwyn, Christchurch City, Ashburton, Timaru, Mackenzie, Waimate and Waitaki.

The main city in the region is Christchurch, with approximately 370,000 people living there prior to the earthquake sequence. Christchurch City was made up of approximately 145,000 dwellings at the time of the earthquake, with approximately 10,000 of those listed as unoccupied [49]. According to the 2006 census, 7.4% of residents living in Christchurch considered themselves of Maori descent [49]. Other notable ethnic groups included Asian (7.6%) and Pacific Island (2.7%) [49]. Median figures for age, household composition and income were close to the national figures for 2006. Christchurch was location to a number of important services that the wider community relied on including a hospital, university, art gallery and sports facilities.

2. The 2010-2011 Canterbury earthquake sequence

The Darfield earthquake occurred at 4:35 am (New Zealand Standard Time, NZST) on 4 September 2010, causing no fatalities and few injuries. It was centred 9 km southeast of the town of Darfield, 40 km west of Christchurch (all locations mentioned in the text are in Fig. 2). The movement was strike-slip, however analysis of seismograph and geodetic data indicate complex subsurface fault movement (e.g., [3]). The earthquake occurred at a depth of 10.8 km on a previously unidentified fault, which has since been named the Greendale fault [21]. The Greendale fault had a surface rupture of 30 km, trending east-west across predominantly farmland (Fig. 1). It had a maximum displacement of approx. 5 m horizontally and 1.5 m vertically [21,44].

Aftershocks were strong and frequent (Fig. 3), including one on 26 December 2010 (M4.9). However, the decay rate decreased quickly, most likely due to a lack of significant 'afterslip' [45]. Five and a half months after the mainshock occurred beneath the Canterbury Plains, an aftershock with a moment magnitude (M_w) of 6.3 [45] struck approximately 6 km southeast of Christchurch city at 12:51 pm. It was centred at a depth of 5 km on a previously

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