Taranaki Seismic and Ground Deformation Monitoring: July 2015 to June 2016

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EXECUTIVE SUMMARY

During the period July 2015 to June 2016, 241 earthquakes were located in the Taranaki region by GeoNet. This is similar to the annual numbers since 1994, and accounts for about 1% of the total number of earthquakes located in New Zealand in that period. Similar to the long-term trend, shallow earthquakes (less than 50 km deep) occurred either in a north-east – south-west trending swath west and north of Mt Taranaki, or in a cluster north-east of Stratford; the earthquakes to the south-east, near Hawera, are substantially deeper (greater than 100 km).

Although a few earthquakes were located beneath or near Mt Taranaki, we conclude that during the period July 2015 to June 2016 seismic activity on the Taranaki Peninsula was not volcanologically significant.

During the year, no changes were made to the seismograph network in Taranaki, and no substantial technical problems occurred.

Three GNSS[1] monitoring sites are operated near Mt Taranaki. These sites have recorded stable conditions, that is, no deformation of the volcano has been observed since they were installed.

[1] GNSS = Global Navigation Satellite System. This includes GPS (the US Global Positioning System). These are used for precisely measuring the position of a site, and also for navigation.

1.0 INTRODUCTION

This report summarises earthquake occurrence and ground deformation in Taranaki for the period 1 July 2015 to 30 June 2016. It compares the location and rate of earthquake occurrence in the last year with recent historical activity and also examines the ground deformation data. These are assessed for volcanic significance.

Ground deformation measurements started in 2014.

2.0 EVOLUTION OF THE SEISMOGRAPH NETWORK

The Taranaki Volcano-Seismic Network was commissioned by Department of Scientific and Industrial Research in late-1993, with the first usable data being recorded in January 1994. Since that time data have been recorded almost continuously.

In 2001, the GeoNet project began improving the existing network for monitoring earthquakes in New Zealand. In 2005, work commenced to upgrade seismographs in Taranaki to a standard equivalent to that in other parts of New Zealand. The upgraded network in Taranaki substantially improved the monitoring capabilities.

The network upgrade in Taranaki was completed in 2010. In October 2012, a new instrument (NBEZ, Figure 2.1) was installed in a borehole replacing a nearby noisy site. No changes to the seismograph network have been undertaken since then.

There are currently nine seismographs in the Taranaki area continuously sending data to GeoNet data centres for analysis. Data are sent via hubs located at the Taranaki Emergency Management Office in New Plymouth; at Kahui Road west of Mt Taranaki; and at Eltham (Figure 2.1).

Several seismographs outside Taranaki record earthquakes that occur in Taranaki, aiding in locating these earthquakes.

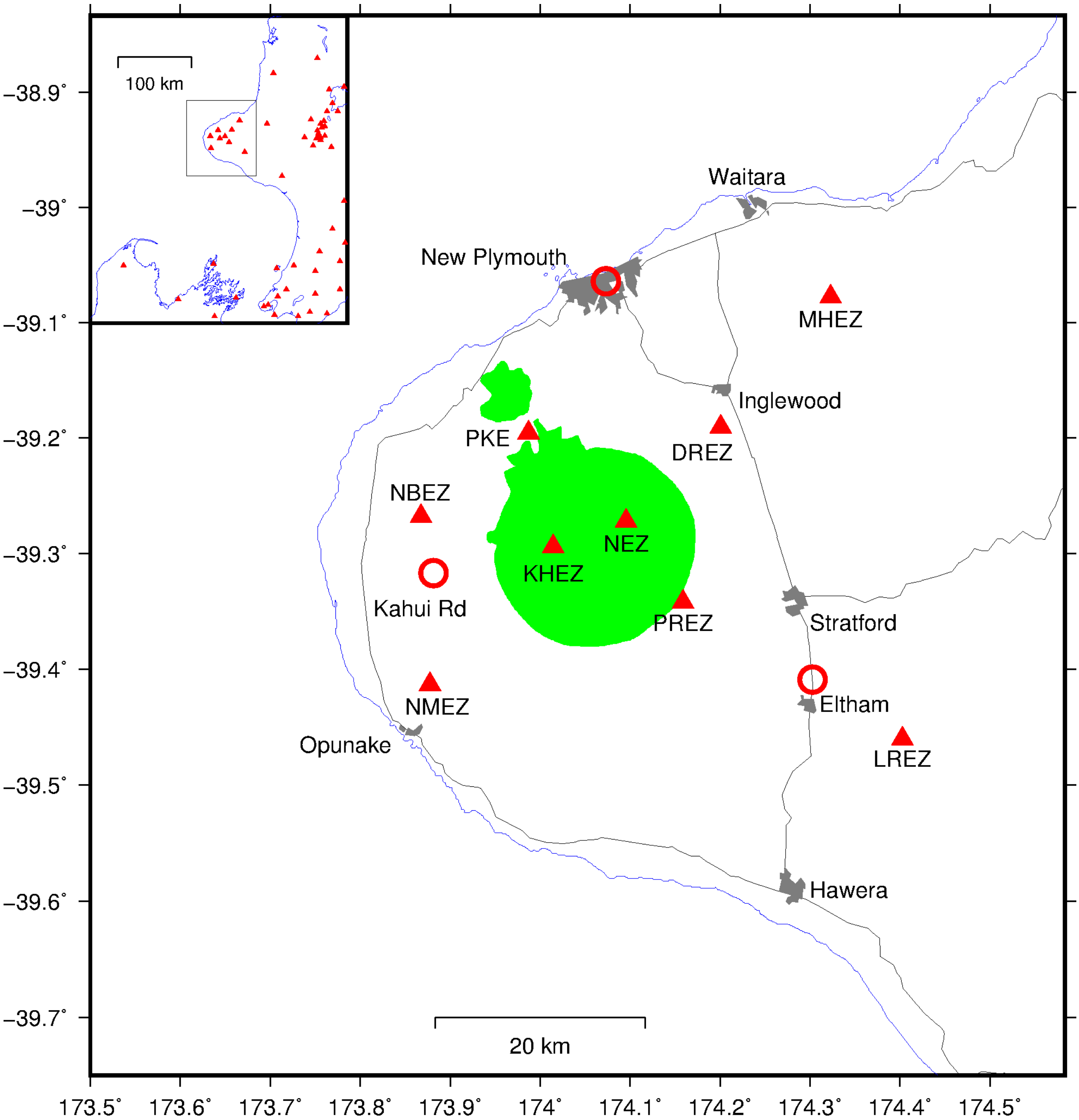

Figure 2.1 A map of the seismographs located in Taranaki. Seismograph sites are indicated by triangles and labelled by their three or four-letter site codes. The network shown (red triangles) is that at the end of the 2016 reporting period. NEZ is North Egmont, NBEZ is Newall Road Borehole, PKE is Pukeiti, DREZ is Durham Road, MHEZ is Mangahewa, NMEZ is Namu Road, KHEZ is Kahui Hut, PREZ is Palmer Road, and LREZ is Lake Rotokare. Data collection (hub) sites are shown by red circles. Population centres are shown in grey and named. The Egmont National Park is shown as a green area. Major roads are shown as black lines. The coastline is marked in blue. The inset shows Taranaki and additional nearby GeoNet seismographs (red triangles) that are sometimes used in locating earthquakes in Taranaki.

3.0 EARTHQUAKE DATA ANALYSIS

The Taranaki Research Group at Auckland University was responsible for analysis of data recorded by the network from January 1994 until June 1997. These data were regularly reported to Taranaki Regional Council (TRC), and data from the period January 1994 to March 1995 were summarised in Cavill *et al*. (1997). In July 1997, GNS Science took over responsibility for data analysis and annual reporting under contract to TRC.

Seismic data from Taranaki are continuously transmitted to GeoNet data centres. In near real-time, an automatic earthquake analysis program (SeisComP3[2]) is used to search for signals that may be caused by earthquakes. When the signal from an earthquake is detected, the program estimates the arrival time of the earthquake waves at each of the seismographs (in Taranaki and elsewhere) and attempts to automatically locate the earthquake.

SeisComP3 is capable of automatically obtaining a reasonably accurate location for all moderate size earthquakes within 1-2 minutes of an earthquake's occurrence. In most cases, the automatic locations are sufficiently accurate for rapid notification of these events to the public and responding authorities without requiring additional manual checking and analysis. SeisComP3 has been very successful in this regard, but there have been some shortcomings as well. Because of the way GeoNet has configured SeisComP3, it is less sensitive to smaller earthquakes in Taranaki than the system that operated before January 2012. This was discussed in detail in the 2012-13 report (Sherburn and Scott, 2014) and highlighted in a presentation to the Taranaki Seismic and Volcanic Advisory Group in September 2013.

In compiling this report we have used data from the GeoNet earthquake catalogue[2], as it is the official record of seismicity in New Zealand, despite its current shortcomings in the Taranaki area. The catalogue currently comprises locations from the previous analysis system up to December 2011 and SeisComP3 locations from January 2012.

Because automatic locations from GeoNet are sufficiently accurate for rapid notification, many of the locations, particularly for events smaller than magnitude 3 are no longer manually reviewed. In displaying the locations of earthquakes in Taranaki we have distinguished between automatic and reviewed locations. In some cases automatic locations may be less reliable than reviewed ones.

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[2] http://info.geonet.org.nz/display/appdata/Earthquake+Catalogue

4.0 EARTHQUAKE LOCATION RELIABILITY

The reliability of earthquake locations determined from seismic networks depends on several factors. These include:

- The number of instruments at which an earthquake is recorded. Small earthquakes are often poorly recorded or recorded on only a few instruments. Locations for these earthquakes are not as good as those for larger events which are well recorded at many more instruments distributed over a range of distance and directions.
- How far an earthquake is from the network. There is little control on the location of earthquakes well outside a network so these are usually poorly located; in the case of Taranaki this particularly applies to offshore earthquakes.
- Technical problems with a seismic network; these degrade data quality and reduce the number of sites at which an earthquake can be recorded.

If there are insufficient data to locate an earthquake well, it is common practice to fix the depth of that earthquake at some appropriate value, while still calculating the earthquake time and position. In particular, this situation often arises with shallow earthquakes when the event is farther from the nearest seismograph than it is deep. For Taranaki this usually occurs for earthquakes offshore. Historically, ~20% of earthquakes in Taranaki have had a fixed depth, though this is far less common with the SeisComP3 analysis system.

During the reporting period there were no technical problems that caused substantial loss of data from sites used to locate earthquakes in Taranaki.

5.0 EARTHQUAKE RESULTS

Two hundred and forty-one (241) earthquakes were located in the Taranaki region by GeoNet between July 2015 and June 2016 (Figure 5.1). This accounts for about 1% of the total number of earthquakes located in New Zealand for the same period. The largest event was a M 4.8 on 21 October 2015, located about 15 km west of Mt Taranaki at 18 km depth. We received 1334 felt reports for this event.

Shallow earthquakes (for the purpose of this report, those with a depth less than 25 km) were concentrated in a north-east to south-west trending swath west of Mt Taranaki, with a cluster north-east of Stratford (Figure 5.1). Deep earthquakes (for the purpose of this report, those with a depth greater than 25 km) were mainly located in the Hawera region beneath south-east Taranaki (Figure 5.1).

The depths of earthquakes in Taranaki shallower than 50 km are shown in Figure 5.2a, and Figure 5.2b. Most earthquakes west of Mt Taranaki occurred between 5 and 20 km deep, and most east of Mt Taranaki between 15 and 30 km deep.

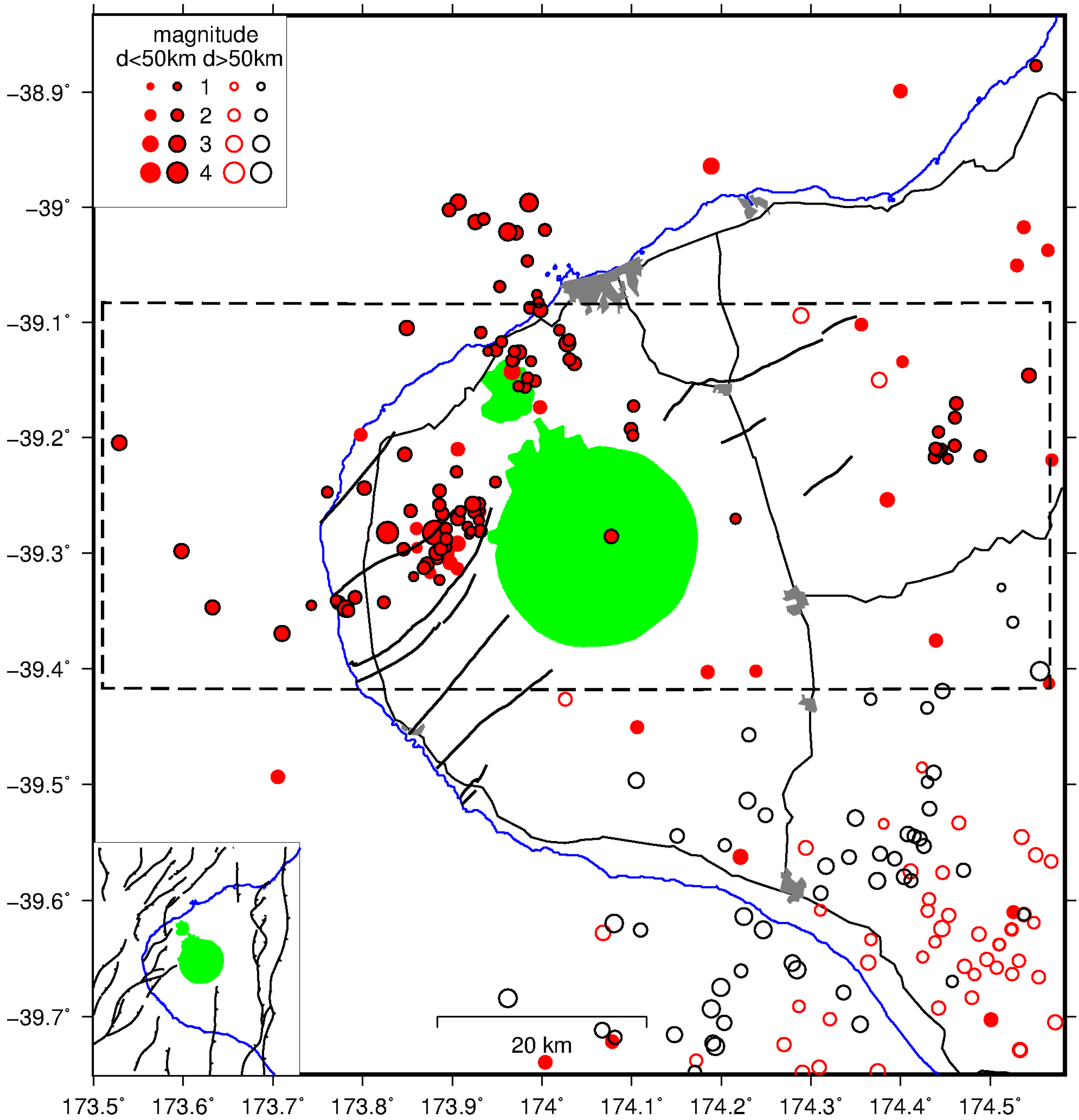

Figure 5.1 A map of all earthquakes located in Taranaki by GeoNet between July 2015 and June 2016. Closed circles indicate earthquakes less than 50 km deep and open circles those more than 50 km deep. Earthquakes that have been manually reviewed have a symbol that is surrounded by a black ring, those without the black ring are automatic locations. The size of the symbol is proportional to the magnitude of the earthquake, and representative symbols are shown in the top left corner of the diagram. Population centres are shown in grey and Egmont National Park is in green. Major roads are also shown (thin black lines). Active faults (thick black lines) are from the New Zealand Active Faults Database (Langridge *et al*., 2016). The dashed box marks the location of the cross-section in Figure 5.2a. The lower left inset shows mapped faults that offset the basement rocks, but are not considered active. Small ticks on these faults show the fault throw.

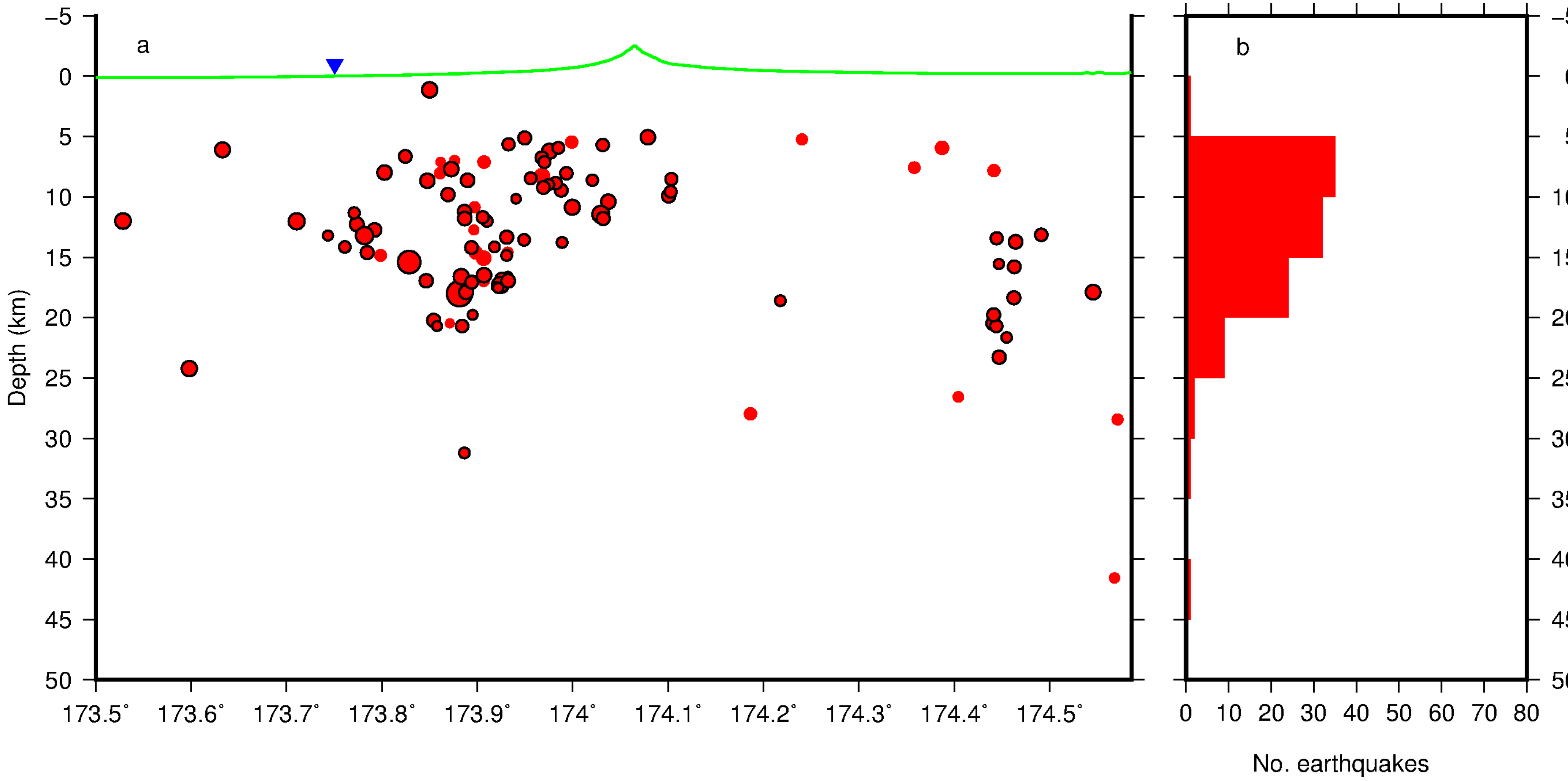

Figure 5.2 a. A projected east-west cross-section showing earthquakes less than 50 km deep located in Taranaki between July 2015 and June 2016. This figure projects hypocentres within 20 km of the position of the cross-section onto the cross-section. It appears as though there is a cluster of earthquake at c. 10 km deep beneath Mt Taranaki which are actually about 8 km south-west of New Plymouth. The symbols are the same as Figure 5.1, those that have been manually reviewed have a symbol that is surrounded by a black ring, those without the black ring are automatic locations. No distinction is made between earthquakes for which the depth was calculated and those for which it was fixed. Topography is shown in the upper part of the diagram, with the inverted triangle marking the position of the coast at Cape Egmont. The horizontal:vertical scale is 1:1. The location of the cross-section is shown as a dashed box in Figure 5.1.

b. Histogram of the depths of the earthquakes shown in Figure 5.2a.

6.0 EARTHQUAKE DISCUSSION

In this section we compare the seismicity for July 2015 to June 2016 with the activity in Taranaki since 1994. We include a discussion of any long-term similarities, differences and trends that may be apparent. We assess the volcanic significance of the recent data and comment on the network effectiveness.

6.1 LONG-TERM DATA

6.1.1 Larger earthquakes

In previous reports we have summarised the occurrence of all earthquakes located in Taranaki since January 1994. A seismic network can only locate earthquakes above a certain magnitude and records only some of the earthquakes of lower magnitudes[3]. Summarising all earthquakes may therefore be a little ambiguous. Differences in the distribution may reflect differences in location threshold rather than what earthquakes actually occurred. For an area similar to that shown in Figure 2.1, but excluding earthquakes more than 20 km offshore, Sherburn and White (2005) showed that for the period 1994-2001 the GNS Science catalogue was complete down to magnitude 2.7[4].

In summarising data since 1994 we therefore show all located earthquakes in Figure 6.1 and earthquakes above the M2.7 threshold in Figure 6.2. Although earthquakes immediately west of Mt Taranaki dominate the catalogue, this is largely a result of the location threshold onshore being substantially lower than that offshore. Considering only earthquakes of M2.7 and larger (Figure 6.2), there is not as strong a distinction between the level of activity onshore west of Mt Taranaki and that offshore north and south of the Taranaki Peninsula. However, by showing only the larger earthquakes we may inadvertently miss some important data (i.e., less well-located and smaller earthquakes). In Figure 6.1 there are more than 100 earthquakes shown beneath Mt Taranaki, which gives the impression that there is a low, but notable, level of seismicity beneath the volcano, and raises questions about the possible volcanic origin of these events. However, only a few of these earthquakes are large enough to be shown in Figure 6.2, and many may therefore have locations that are less reliable (particularly the majority which occurred in the 1990s, when locations were less reliable), and may possibly have been mis-located from the more active area immediately west of Mt Taranaki. This does not mean that we should only consider Taranaki earthquakes of M2.7 and larger because a sequence of small earthquakes beneath Mt Taranaki may still have significance as a volcanic unrest precursor. We just need to be careful to consider the magnitude and number of earthquakes as well as the location reliability when interpreting the data.

6.1.2 Long-term distribution

In terms of the distribution of earthquakes, the data for July 2015 to June 2016 (Figure 5.1) are similar to those since 1994 (Figure 6.1 and Figure 6.2). The swath of earthquakes west of Mt Taranaki represents part of the Cape Egmont Fault Zone, a region of seismically active faulting. The deep earthquakes in the Hawera region reflect the bottom of the Pacific plate

3 This is called the location threshold or magnitude of completeness, and can depend on the area considered, the time interval, and on the analysis procedures used.

4 With additional seismographs in Taranaki and improvements to existing instruments that completeness threshold is now a little conservative. For the area east of Mt Taranaki, recent work has shown that the completeness threshold is now closer to magnitude 2.0. However, for the sake of comparison with previous reports we will continue to use a threshold of magnitude 2.7.

subducting beneath the North Island. The cluster of earthquakes north-east of Stratford is the western part of a band of activity that continues almost to Mt Ruapehu. All of these are long-term features of the Taranaki seismicity. The persistence of these features implies that the causes of this seismicity have remained unchanged since detailed monitoring began in Taranaki.

6.1.3 Long-term rate

We use two measures to show the long-term rate of shallow (depth less than 50 km) seismicity in the Taranaki region: the number of located earthquakes each month (Figure 6.3) and the cumulative number of earthquakes located since 1994 (Figure 6.4). Both figures show that while there are short-term variations in the rate of activity, the long-term rate of shallow seismicity in the Taranaki region has been relatively uniform. Both figures also show a reduction in the rate of activity since 2012 when GeoNet changed its earthquake analysis system and introduced SeisComP3.

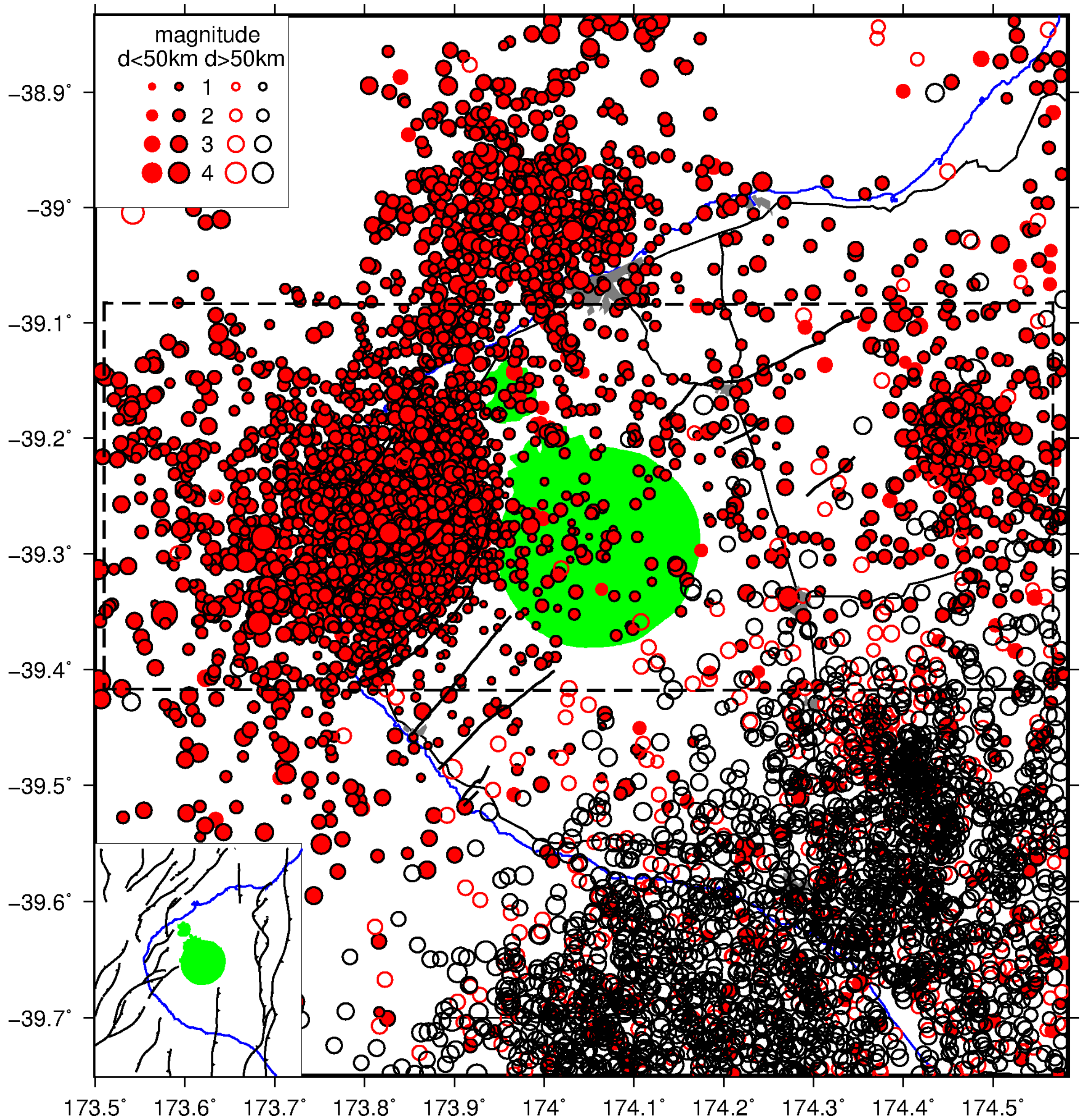

Figure 6.1 A map of all earthquakes located in Taranaki between January 1994 and June 2016. Symbols are as described in Figure 5.1.

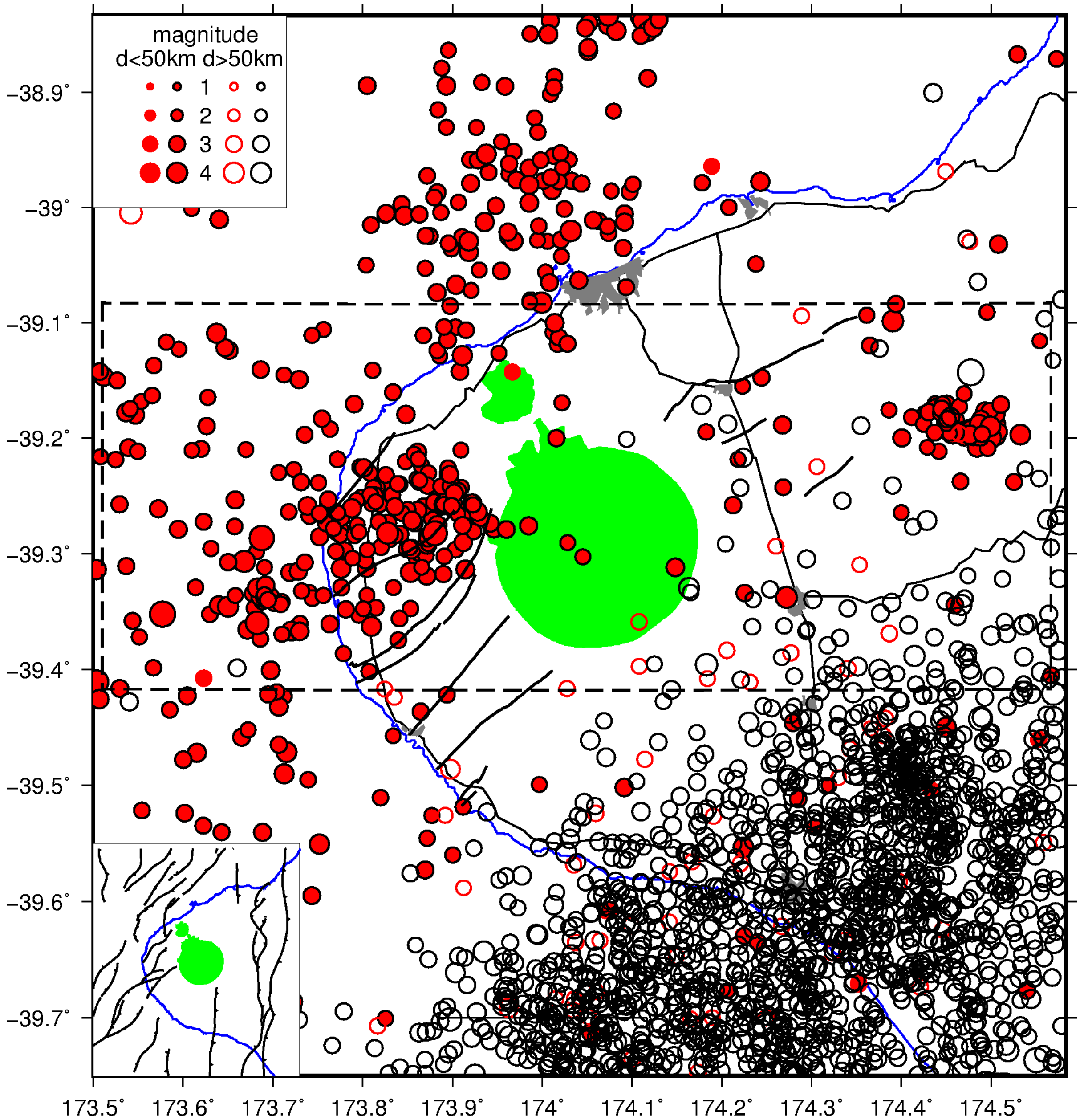

Figure 6.2 A map of earthquakes of M2.7 and larger located in Taranaki between January 1994 and June 2016. Symbols are as described in Figure 5.1.

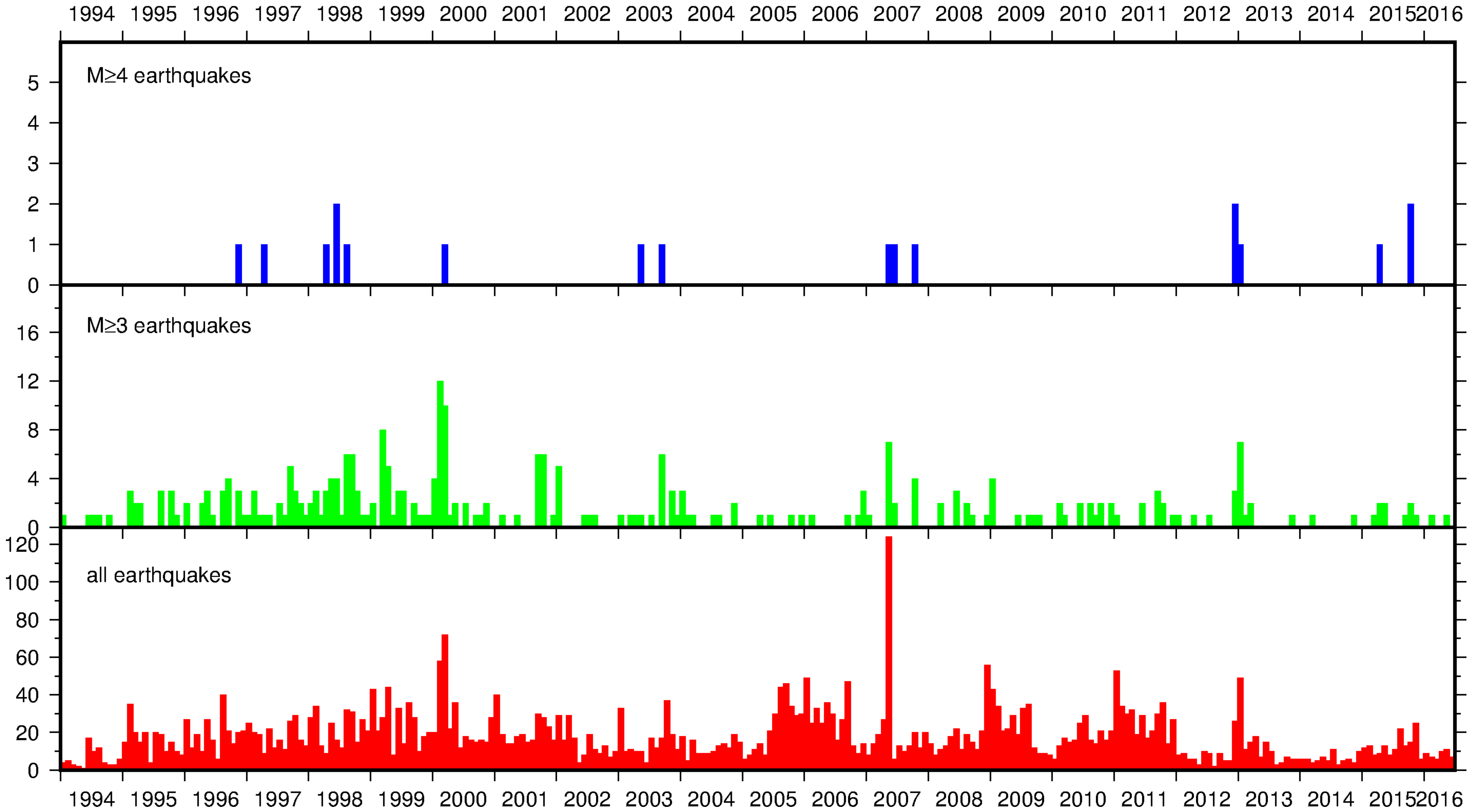

Figure 6.3 Histograms of the number of earthquakes less than 50 km deep that have occurred each month between January 1994 and June 2016 in the area shown in Figure 2.1. Three separate histograms are shown: all earthquakes (bottom), those of magnitude 3 and above (centre) and those of magnitude 4 and above (top). Data up to December 2011 are from the previous analysis system, and those from January 2012 are from the SeisComP3 system.

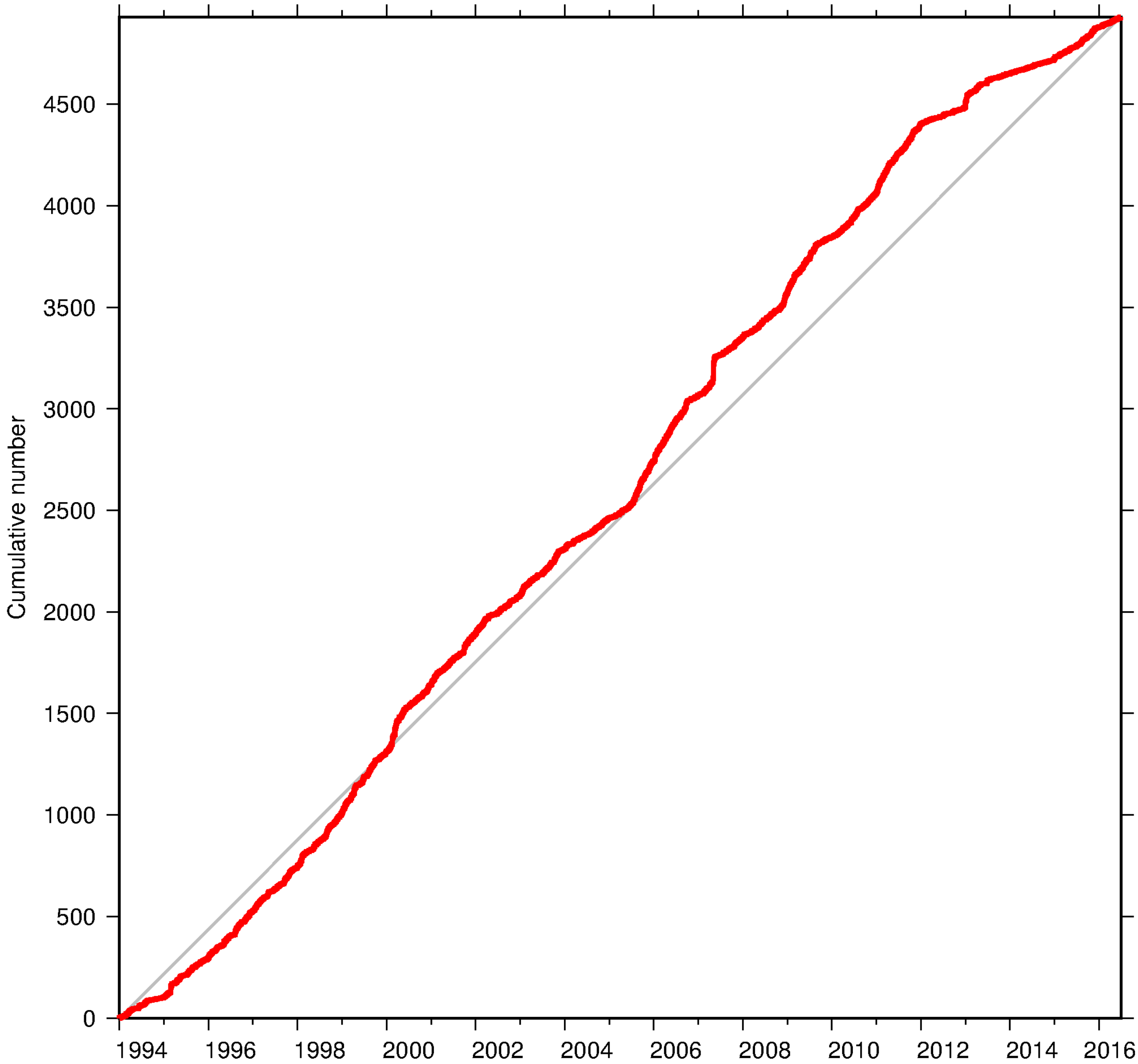

Figure 6.4 The cumulative number of all earthquakes (red line) less than 50 km deep located in the area shown in Figure 2.1 between January 1994 and June 2016. The grey line shows the mean rate. The main network upgrade began in 2009, but there was no significant change in the number of earthquakes. SeisComP3 data are from January 2012 and this corresponds to a reduction in the rate of located earthquakes.

6.2 VOLCANIC SIGNIFICANCE OF EARTHQUAKE DATA

While there are no strict rules for assessing whether an earthquake or group of earthquakes are volcanologically significant, the number of earthquakes, their magnitude and the presence or absence of low-frequency earthquakes (McNutt and Roman, 2015) are criteria that are often considered. The earthquakes located beneath Mt Taranaki in 2015-16 are not considered to be of volcanic origin.

6.3 SEISMIC NETWORK EFFECTIVENESS

In the past, the effectiveness of the network has been significantly affected by technical problems. However, the seismograph network upgrade between 2005 and 2010, and the borehole instrument added in 2012 means that they are much more reliable and technical problems are rare. There are always minor technical issues with any network, but none of these had a substantial effect on Taranaki data in 2015-16.

7.0 GROUND DEFORMATION MONITORING

In 2003 GeoNet installed a GNSS site on German Hill (station code NPLY) as part of a National geodetic framework. In 2014 two further sites (station codes PGKH and PGNE) were established on the volcano thus enabling the monitoring of local ground deformation.

Figure 7.1 shows the locations of the three GNSS sites on or near Mt Taranaki. All sites show no significant change in their height or in their longitude, but all are moving north at a rate of about 40 mm per year (Figures 7.2, 7.3 and 7.4). This movement is also observed at sites outside Taranaki and is the result of tectonic movement of the western portion of the North Island of New Zealand.

One technique to subtract the regional tectonic movements from the GNSS site data is to calculate the distance between sites (Figure 7.5). This is routinely used as a 'first pass' monitoring tool for these data in volcanic regions.

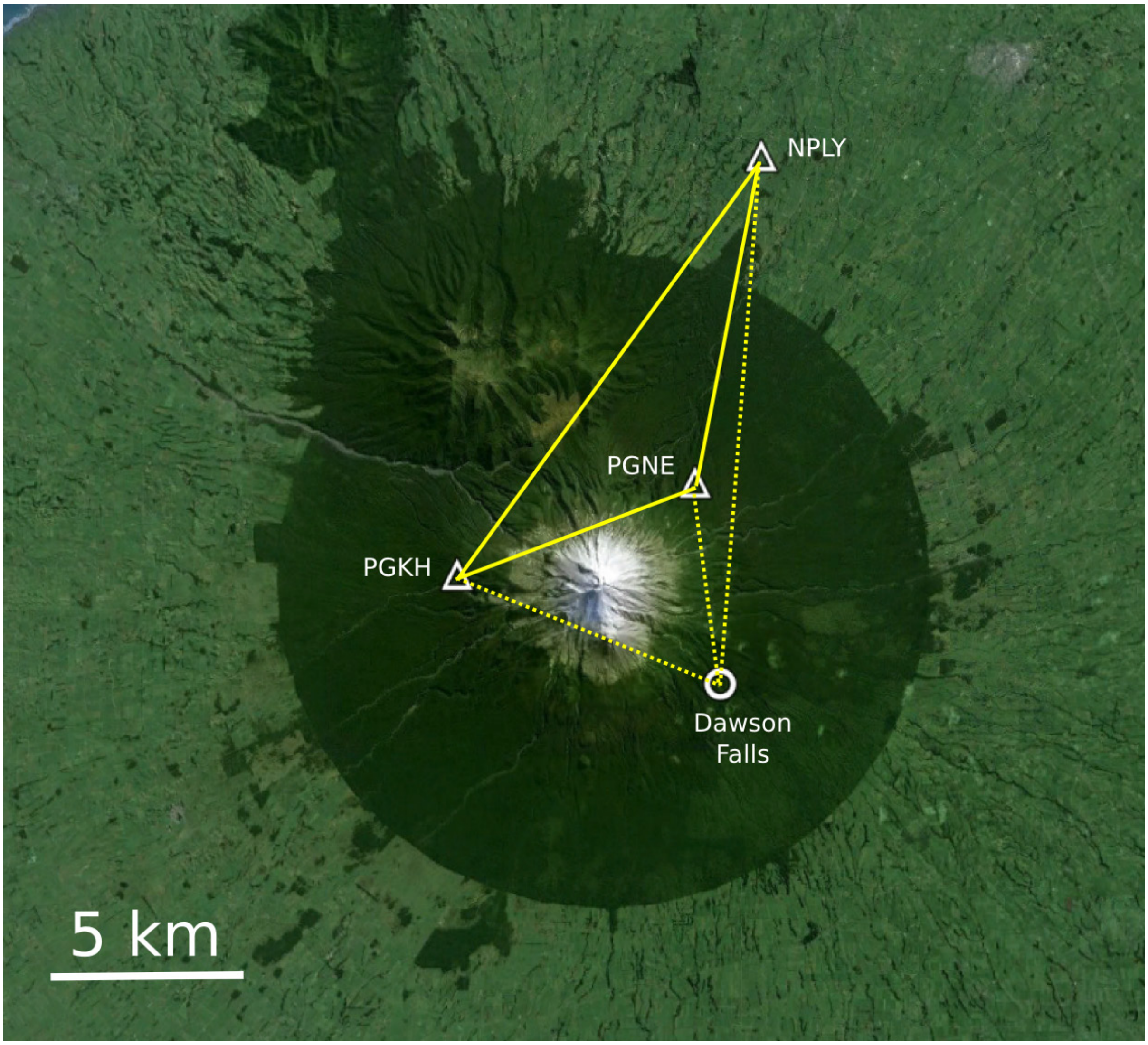

Figure 7.1 Locations of GNSS sites on or near Mt Taranaki. Sites are labelled by their 4-letter site codes. NPLY is New Plymouth (but is located on German Hill), PGKH is Kahui Hut and PGNE is North Egmont. The intention is to also install a site at Dawson Falls once redevelopment work planned in that area is completed. Solid lines indicate line lengths currently able to be monitored. Dashed lines can be monitored when instruments are installed at Dawson Falls. The base map is from Google Earth.

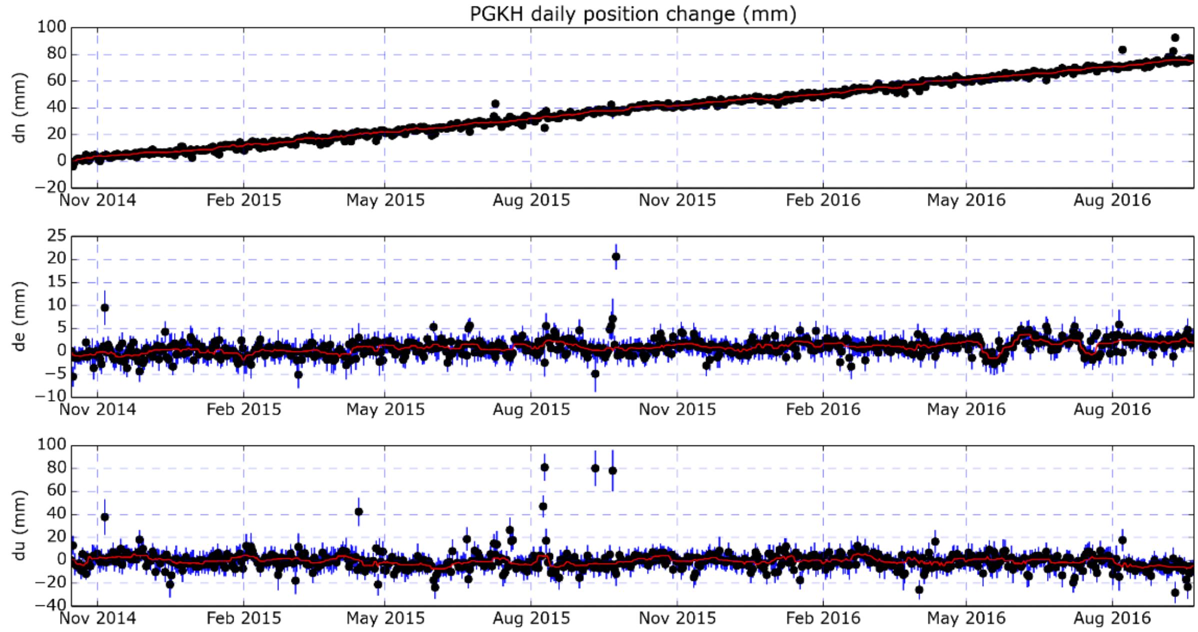

Figure 7.2 The displacement of the GNSS site PGKH at Kahui Hut on Mt Taranaki. Displacements in the north-south (dn), east-west (de), and up-down (du) directions are shown. All positions are relative to the initial position when the sites were installed, and thus represent a displacement from the initial position. The black circles represent smoothed daily displacements. The vertical blue lines are the estimated errors for each daily displacement. The red lines are the smoothed daily displacement curves. Similar displacements are seen at all sites in Taranaki. The movement to the north is also seen at other sites in the North Island and does not reflect deformation of Mt Taranaki, instead it represents the large-scale crustal deformation of the North Island.

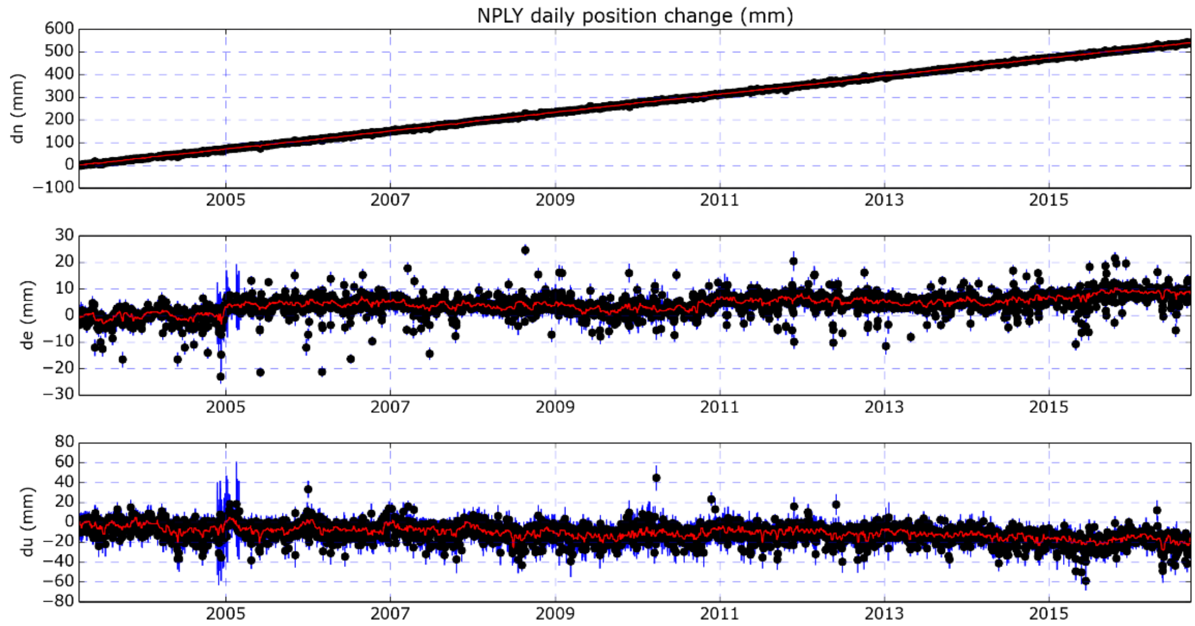

Figure 7.3 The displacement of the GNSS site NPLY at German Hill. Displacements in the north-south (dn), east-west (de), and up-down (du) directions are shown. All positions are relative to the initial position when the sites were installed, and thus represent a displacement from the initial position. The black circles represent smoothed daily displacements. The vertical blue lines are the estimated errors for each daily displacement. The red lines are the smoothed daily displacement curves. Similar displacements are seen at all sites in Taranaki. The movement to the north is also seen at other sites in the North Island and does not reflect deformation of Mt Taranaki.

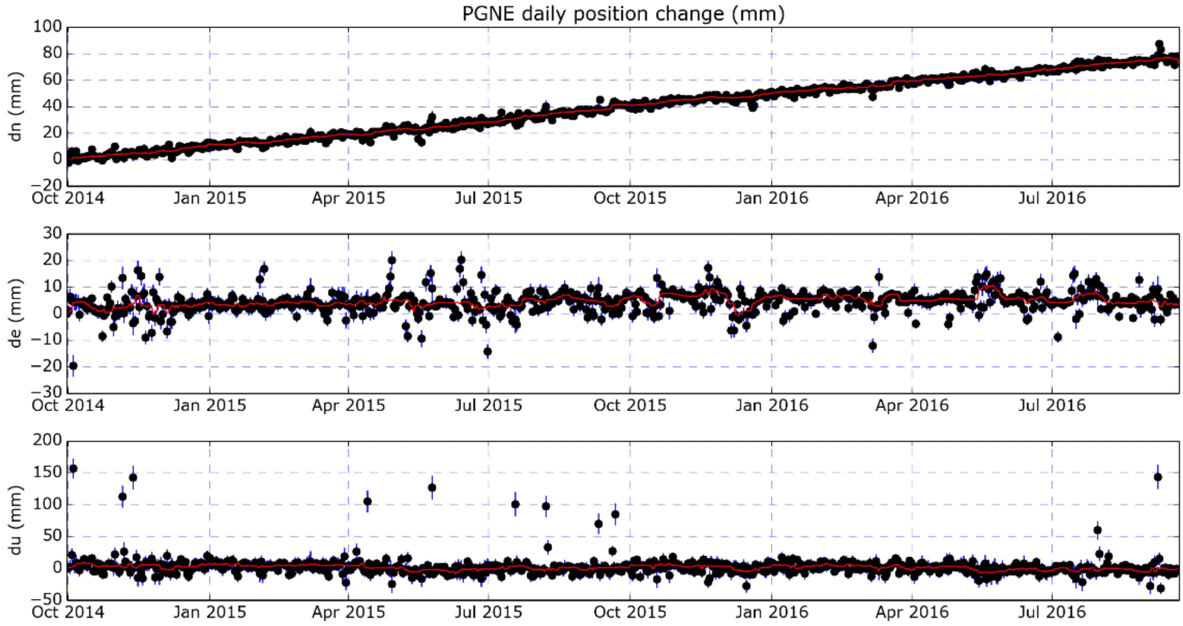

Figure 7.4 The displacement of the GNSS site PGNE at North Egmont on Mt Taranaki. Displacements in the north-south (dn), east-west (de), and up-down (du) directions are shown. All positions are relative to the initial position when the sites were installed, and thus represent a displacement from the initial position. The black circles represent smoothed daily displacements. The vertical blue lines are the estimated errors for each daily displacement. The red lines are the smoothed daily displacement curves. Similar displacements are seen at all sites in Taranaki. The movement to the north is also seen at other sites in the North Island and does not reflect deformation of Mt Taranaki.

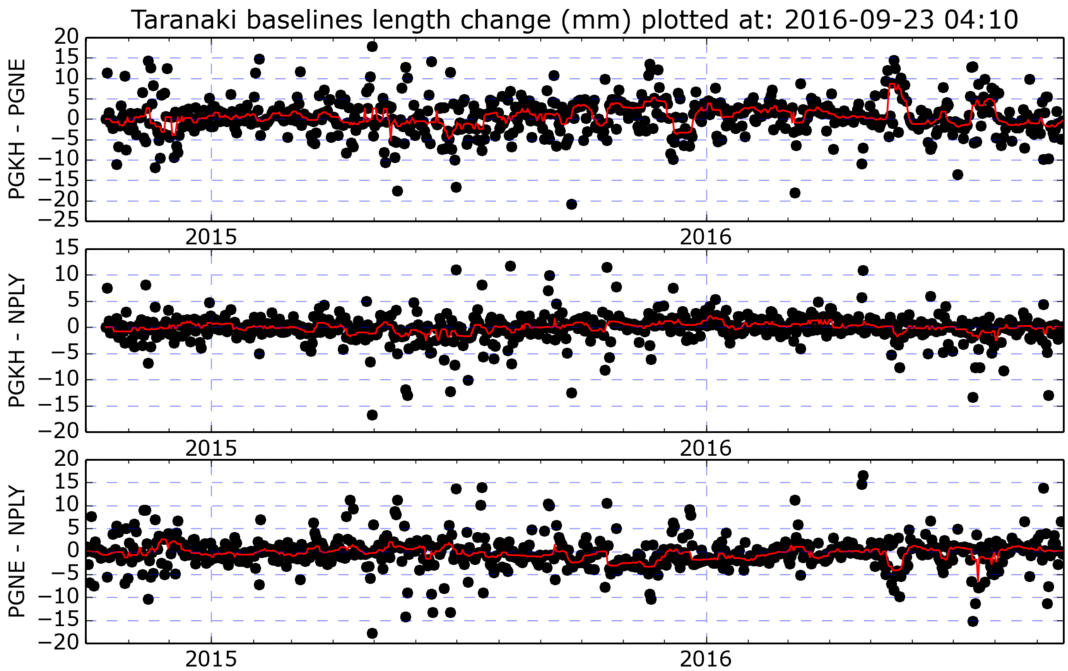

Figure 7.5 The length of lines between GNSS monitoring sites in Taranaki. The black circles represent daily line lengths and the red line a smoothed average.

8.0 CONCLUSIONS

Seismic activity on the Taranaki Peninsula continues to be dominated by a swath of earthquakes west of Mt Taranaki, with a few events beneath the volcano. No earthquakes have been recorded that might indicate ongoing volcanic processes or precursors of an eruption at Mt Taranaki. We therefore infer that during the period July 2015 to June 2016 seismic activity on the Taranaki Peninsula was not volcanologically significant.

Data from three deformation monitoring sites in Taranaki show no deformation of the volcano is apparent since 2014.

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