Taranaki Seismicity: July 2014 to June 2015

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EXECUTIVE SUMMARY

During the period July 2014 to June 2015, 251 earthquakes were located in the Taranaki region by GeoNet. This is similar to the annual numbers since 1994, and accounts for about 2% of the total number of earthquakes located in New Zealand in a typical year. The long-term pattern of earthquakes followed that seen in previous years with most of the shallow earthquakes (5-25 km) 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.

Although a few earthquakes were located near Mt Taranaki, we conclude that during the period July 2014 to June 2015 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.

Two GNSS[1] monitoring sites were installed in 2014 near Mt Taranaki. These stations/sites recorded stable conditions, i.e., no deformation of the volcano has occurred thus far

[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 in Taranaki for the period 1 July 2014 to 30 June 2015. It compares the location and rate of earthquake occurrence with recent historical activity and comments on the volcanic significance of the activity in 2014-15.

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.

1.1 ANALYSIS HISTORY

The Taranaki Research Group at Auckland University was responsible for processing 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.

In 2001, the GeoNet project began improving the existing network for monitoring earthquakes in New Zealand. In 2005, further 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.

2.0 SEISMOGRAPHS

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 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 small or moderate earthquakes that occur in Taranaki, aiding in locating these earthquakes.

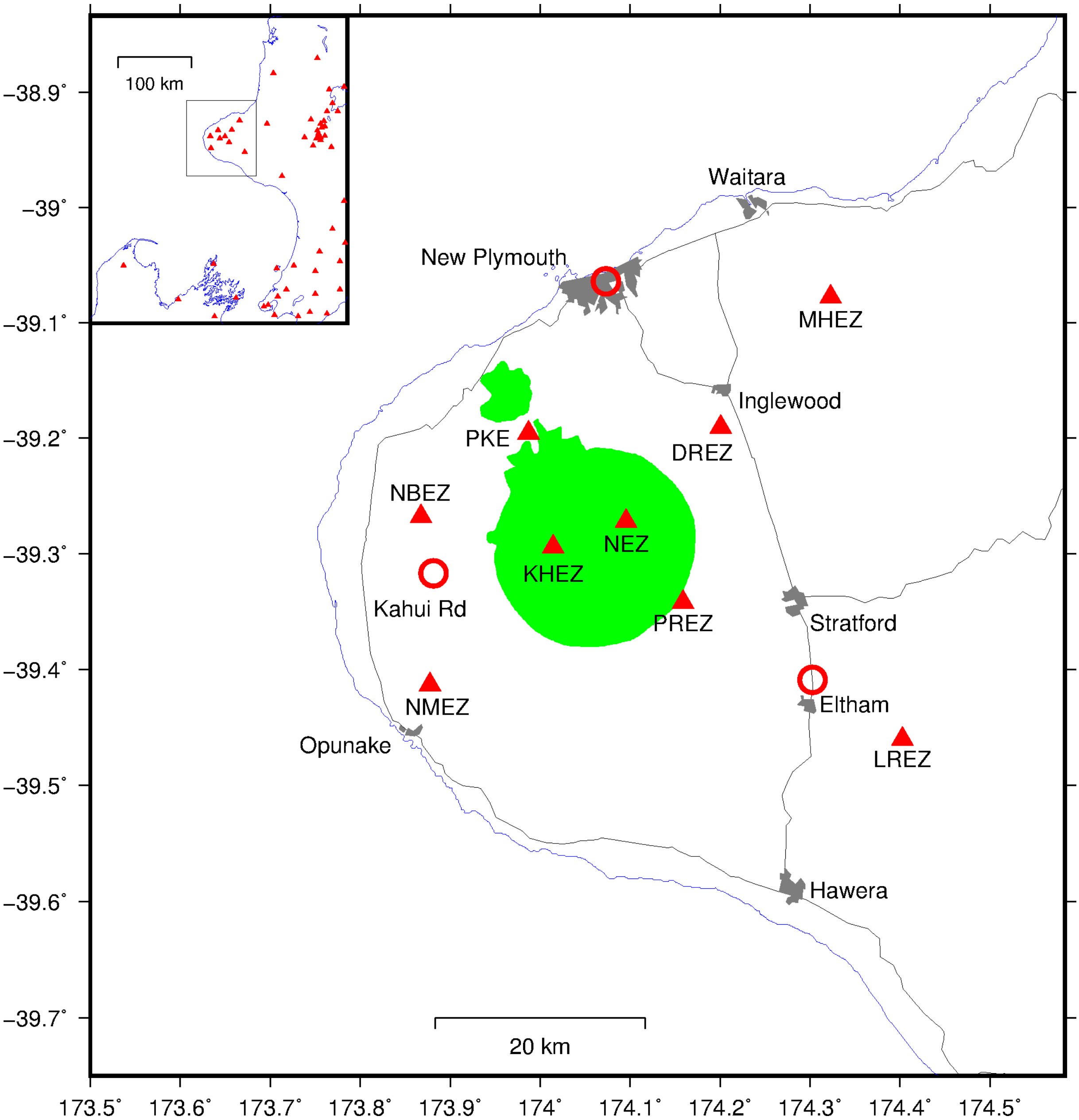

Figure 2.1 A map of the seismographs located in Taranaki. Seismograph sites are indicated by triangles and labelled by their three or four-letter site codes. The network shown (red triangles) is that at the end of the 2015 reporting period. NEZ is North Egmont, NBEZ is Newall Road Borehole, PKE is Pukeiti, 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 DATA ANALYSIS

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 is discussed later in Section 6.4.

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 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. The final processing of locations since January 2012 is not fully completed due to the transition from the old to new system and this has resulted in a gap in the catalogue, a period during which no events are found. Once that processing is complete, the catalogue gap will cease to exist. Details on the current status of this data gap can be found on the GeoNet website[3].

Because automatic locations from GeoNet are sufficiently accurate for rapid notification, many of the locations, particularly for events smaller than magnitude 3 are not 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.

In some past reports, the felt earthquakes in Taranaki were discussed. It is currently not possible to extract from the New Zealand earthquake catalogue the locations of earthquakes that were reported felt so this discussion is not included in this report.

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

[3] http://info.geonet.org.nz/display/appdata/The+Gap

4.0 DATA 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 RESULTS

In this section we report on results obtained from the GeoNet earthquake catalogue and follow the format used for previous reports.

Two hundred and fifty-one (251) earthquakes were located in the Taranaki region by GeoNet between July 2014 and June 2015 (Figure 5.1). This accounts for about 2% of the total number of earthquakes located in New Zealand in a typical year.

Shallow earthquakes (for the purpose of this report, those with a depth less than 50 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 50 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 15 km deep, and most east of Mt Taranaki between 15 and 30 km deep.

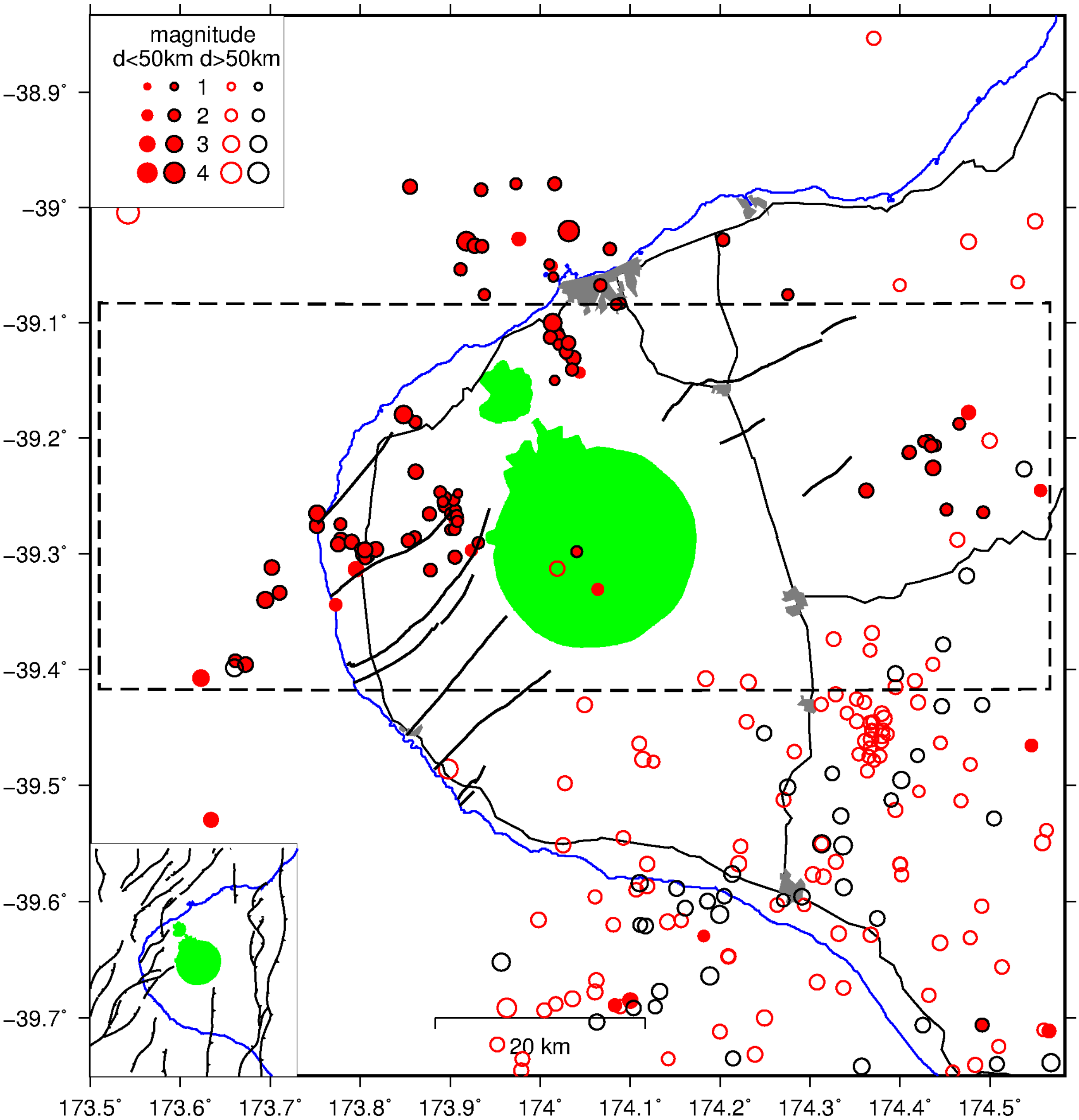

Figure 5.1 A map of all earthquakes located in Taranaki by GeoNet between July 2014 and June 2015. Closed circles indicate earthquakes less than 50 km deep and open circles those more than 50 km deep. Earthquakes that have been manually reviewed have a symbol that is surrounded by a black ring, those 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.*, in prep.). 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.

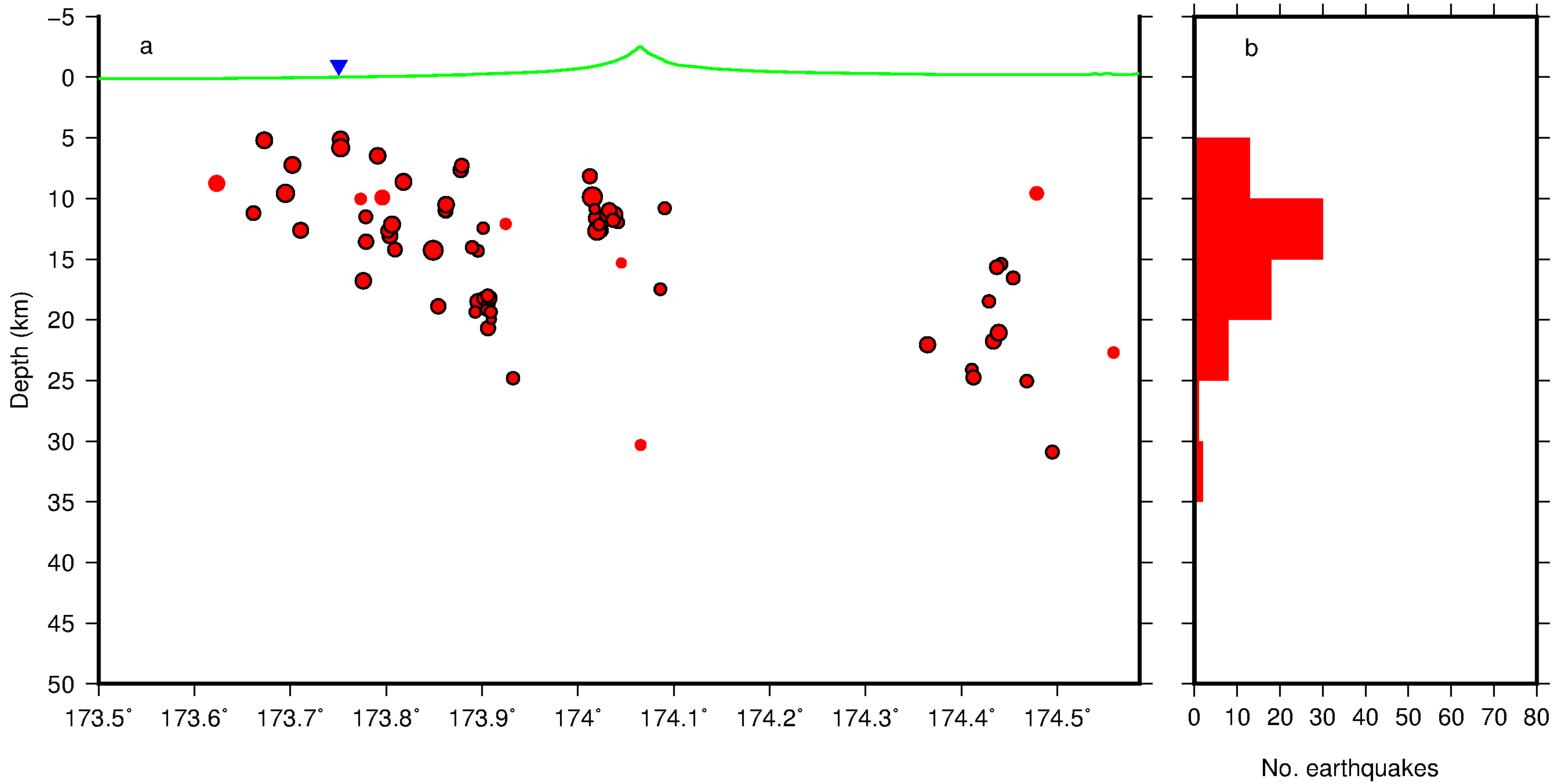

Figure 5.2 a. A projected east-west cross-section showing earthquakes less than 50 km deep located in Taranaki between July 2014 and June 2015. This figure projects hypocentres with about 20 km of the position of the cross-section onto the cross-section. It appears as though there is a cluster of earthquake 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 DISCUSSION

In this section we compare the seismicity for July 2014 to June 2015 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. We also include a brief discussion on the data being collected by GNSS[4] monitoring sites installed in 2014 that permit ground deformation near Mt Taranaki to be estimated.

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[5]. Summarising all earthquakes may therefore be a little misleading. 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 is complete down to magnitude 2.7[6].

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 doesn't appear to be as great 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 those from the 1990s), 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.

4 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.

5 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.

6 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.

6.1.2 Long-term distribution

In terms of the distribution of earthquakes, the data for July 2014 to June 2015 (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 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 has remained unchanged since detailed monitoring began in Taranaki.

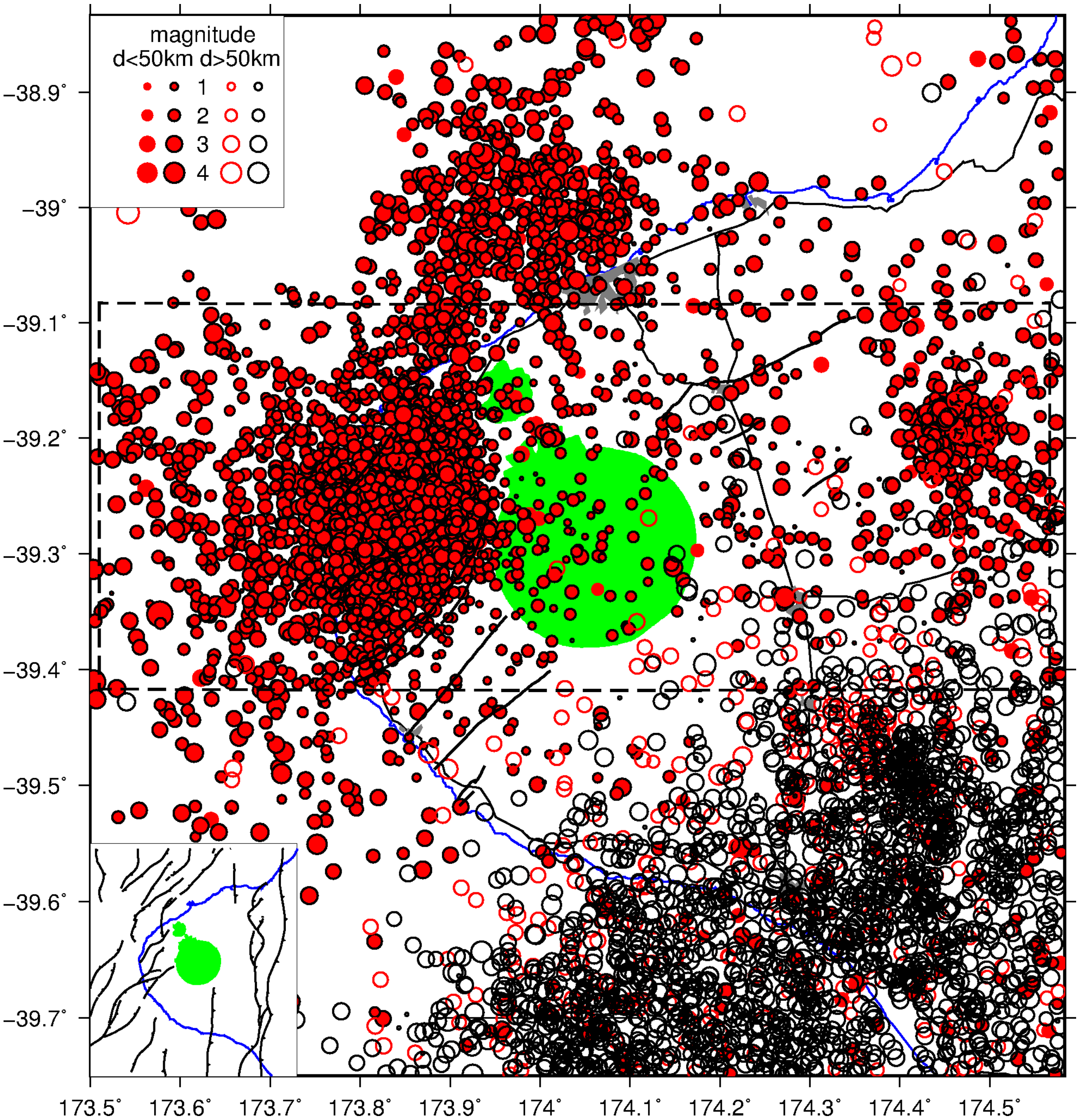

Figure 6.1 A map of all earthquakes located in Taranaki between January 1994 and June 2015. Symbols are as described in Figure 5.1.

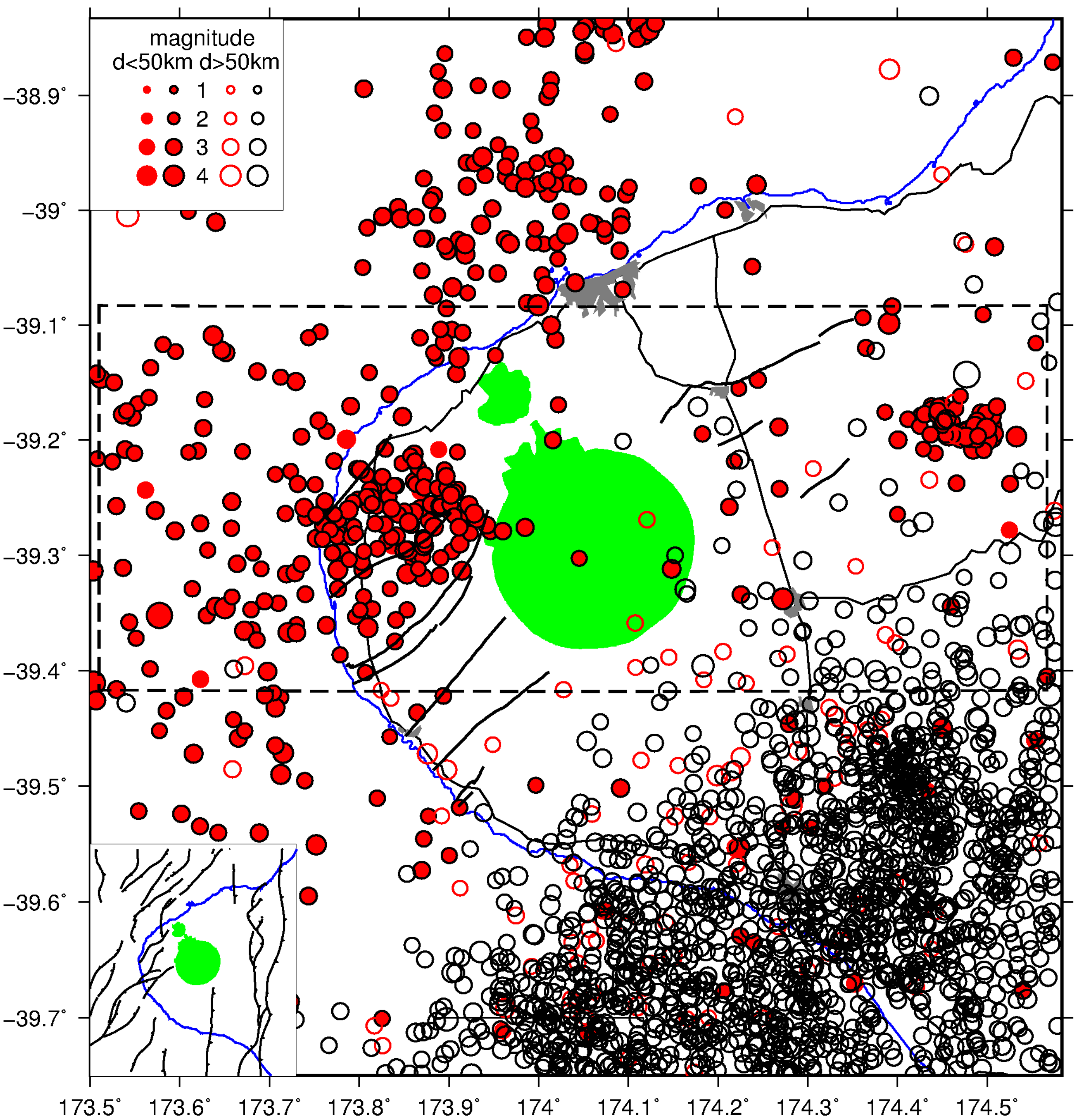

Figure 6.2 A map of earthquakes of M2.7 and larger located in Taranaki between January 1994 and June 2015. Symbols are as described in Figure 5.1.

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.

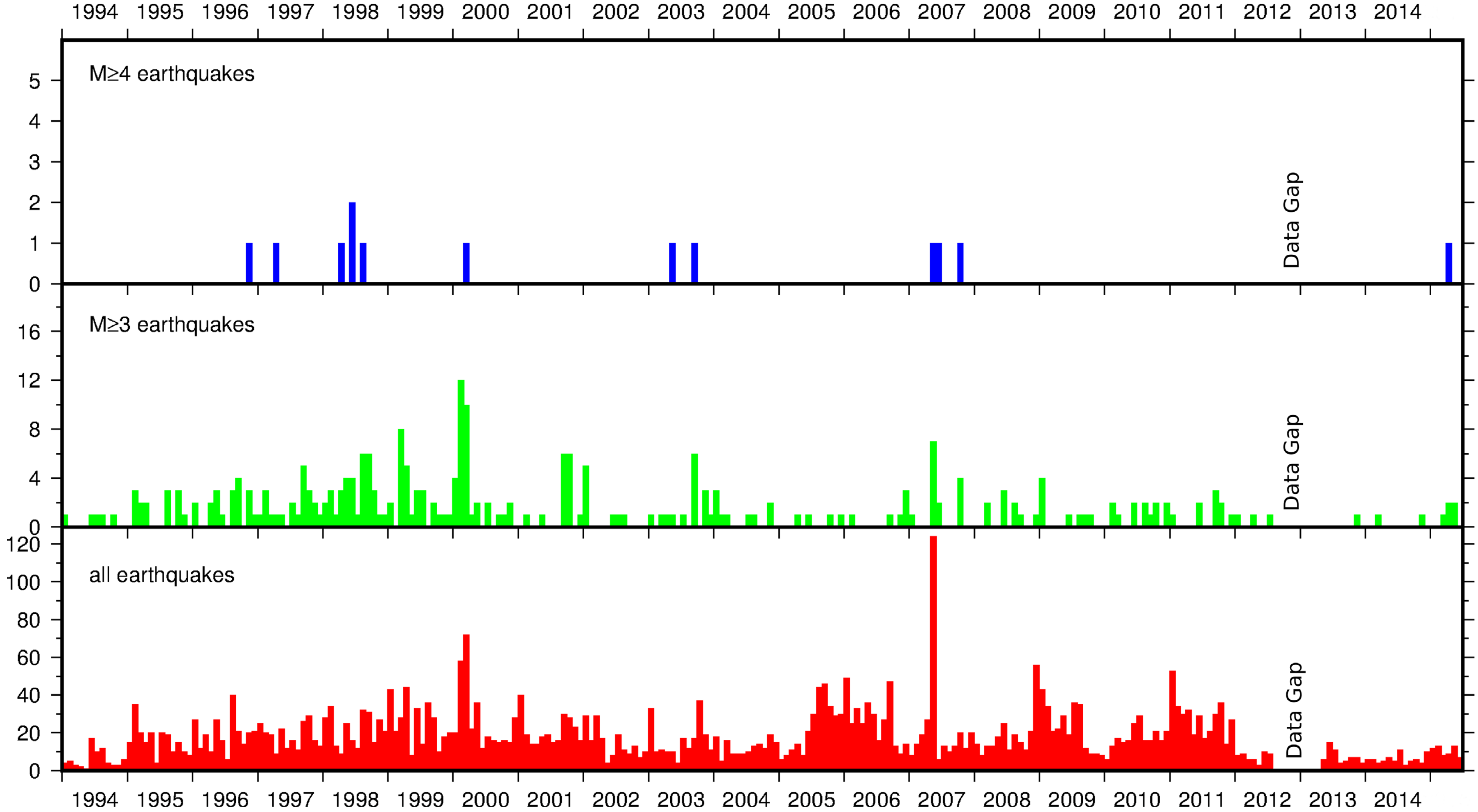

Figure 6.3 Histograms of the number of earthquakes less than 50 km deep that have occurred each month between January 1994 and June 2015 in the area shown in Figure 2.1. Three separate histograms are shown: all earthquakes (bottom), those of magnitude 3 and above (centre) and those of magnitude 4 and above (top). Data up to December 2011 are from the previous analysis system, and those from January 2012 are from the SeisComP3 system. The gap in the plots in 2012-13 represents 'The Gap', a period for which the analysis of the catalogue is not yet complete, and is discussed in Section 3.

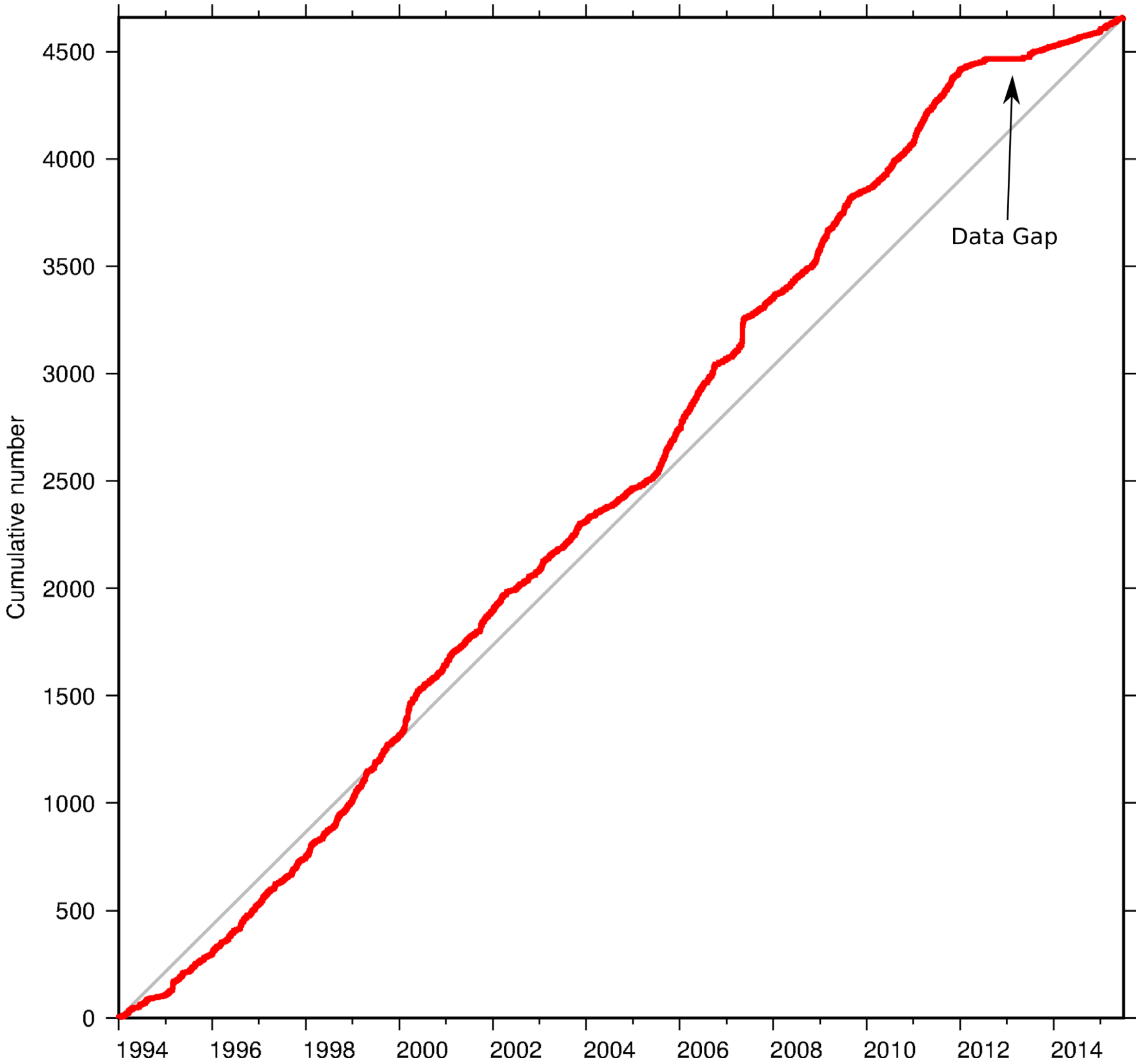

Figure 6.4 The cumulative number of all earthquakes (red line) less than 50 km deep located in the area shown in Figure 2.1 between January 1994 and June 2015. The grey line shows the mean rate. The main network upgrade began in 2009, but there was no significant change in the number of earthquakes. SeisComP3 data are from January 2012 and this corresponds to a reduction in the rate of located earthquakes.

6.2 VOLCANIC SIGNIFICANCE

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 2014-15 are not unusual in any of these respects.

Several earthquakes are located each year beneath Mt Taranaki, but to date they are not deemed to be of volcanic origin.

6.3 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 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 2014-15.

6.4 SEISCOMP3

As mentioned above, the introduction of SeisComP3 was accompanied by a reduction in the number of locatable earthquakes in the Taranaki region. 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.

GeoNet has configured SeisComP3 to require 10 compatible, automatic P-phase arrival picks to create an earthquake event. There are 9 seismographs on the Taranaki peninsula so for an event to be created by the automated system, the seismic waves must be detected and picked at all Taranaki sites plus at least one site outside Taranaki, or, if detected at fewer Taranaki sites, more sites outside Taranaki must also detect it.

SeisComP3 is designed to automatically obtain a reasonably accurate location for all moderate sized earthquakes (in other words, likely to be felt) in New Zealand within 1-2 minutes, and does that successfully. However, in the case of Taranaki, the threshold of required picks has resulted in a substantial reduction in the number of smaller earthquakes that are located, with obvious implications for the monitoring of Mt Taranaki.

Since mid-2013 GNS Science has been running a special SeisComP3 system that requires only 6 P-phase arrival picks to create an earthquake event. This system can locate more earthquakes in Taranaki than the official SeisComP3 because it can detect smaller events. It commonly locates earthquakes in Taranaki smaller than magnitude 1.5. The purpose of the special system is not to produce an unofficial catalogue of Taranaki seismicity that contains smaller earthquakes, but to provide a degree of assurance that smaller earthquakes are not occurring beneath Mt Taranaki that might be an indication of volcanic unrest.

GNS Science considers that to improve the sensitivity of SeisComP3 in Taranaki, the most appropriate action is to increase in the number of seismographs on the Taranaki peninsula. The GeoNet SeisComP3 will not be reconfigured to improve sensitivity.

Testing and selecting potential additional seismograph sites on the Taranaki peninsula was scheduled for 2014-15, but was not achieved because appropriate resources were not available. This work will be done once resources are available.

6.5 DEFORMATION MONITORING

Two GNSS monitoring sites installed in 2014 permit monitoring of ground deformation near Mt Taranaki. A detailed discussion of the data collected at these and an existing site has not been included in this report. Whether this report is expanded to include reporting on these data has not been discussed between TRC and GNS Science. However, a brief discussion is included here so readers of this report are aware of these monitoring developments.

Figure 6.5 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 (Figure 6.6). 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. No deformation of the volcano is apparent in the data collected so far.

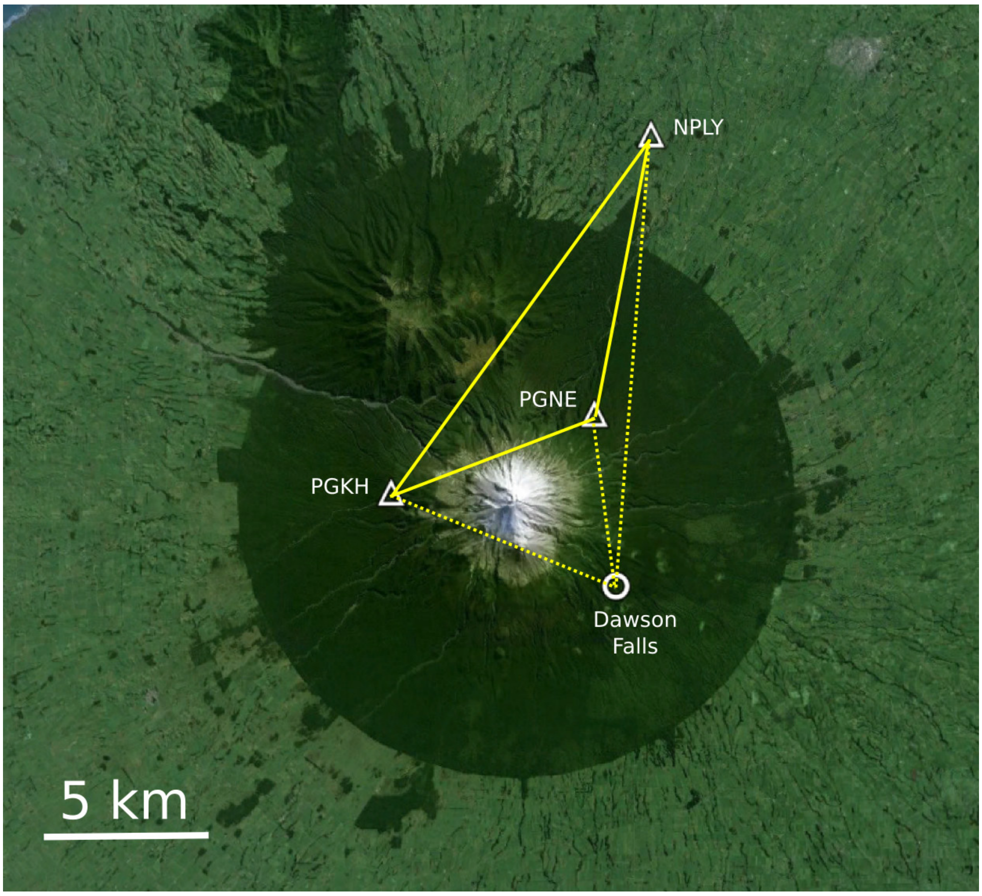

Figure 6.5 Locations of GNSS sites on or near Mt Taranaki. Sites are labelled by their 4-letter site codes. NPLY is New Plymouth, PGKH is Kahui Hut and PGNE is North Egmont. The intention is to also install a site at Dawson Falls once redevelopment work planned in that area in completed. Solid lines 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.

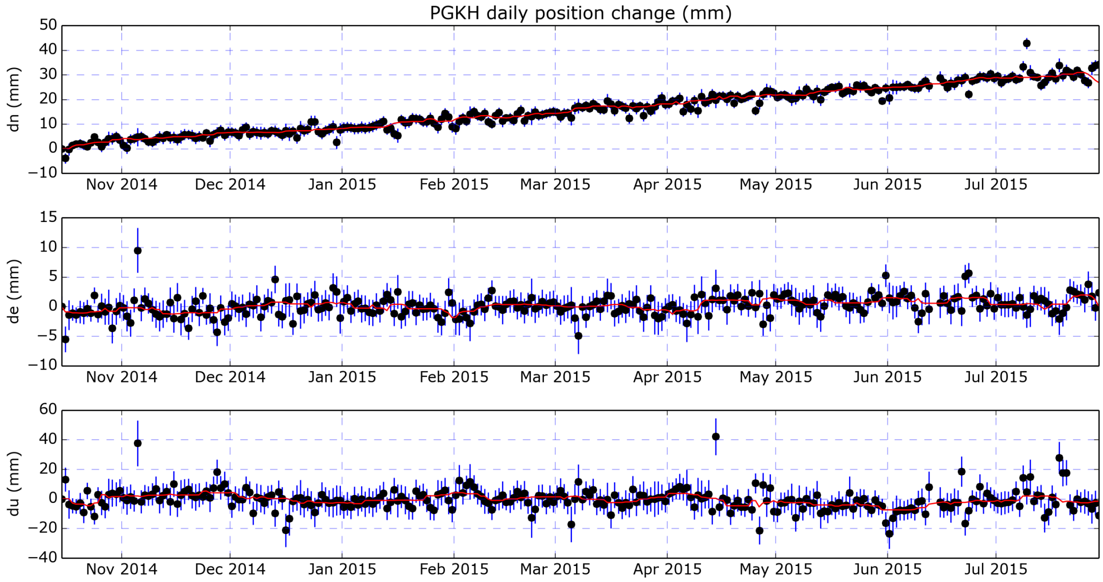

Figure 6.6 The displacement of the GNSS site PGKH at Kahui Hut on Mt Taranaki. Displacements in the north-south (dn), east-west (de), and up-down (du) directions are shown. All positions are relative to the initial position when the sites was installed, and thus represent a displacement from the initial 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.

7.0 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 2014 to June 2015 seismic activity on the Taranaki Peninsula was not volcanologically significant.

Two deformation monitoring sites were installed in 2014. No deformation of the volcano is apparent in the data collected so far.

8.0 REFERENCES

Cavill, A.W.; Cassidy, J.; Brennan, B.J. 1997 Results from the new seismic monitoring network at Egmont Volcano, New Zealand: tectonic and hazard implications. *New Zealand Journal of Geology and Geophysics 40*: 69-76.

Langridge, R.; Ries, W.; Litchfield, N.; Vilamor, P.; Van Dissen, R.; Barrell, D.; Rattenbury, M.; Heron, D.; Townsend, D.; Lee, J.; Berryman, K.; Nico, A. in preparation. The New Zealand Active Faults Database: NZAFD250 view. Submitted to *New Zealand Journal of Geology and Geophysics.*

McNutt, S.R.; Roman, D.C. 2015 Volcano seismicity. In H. Sigurdsson (Editor-in-Chief), Encyclopaedia of Volcanoes. Academic Press, pp. 1011-1033.

Sherburn, S.; White, R.S. 2005 Crustal seismicity in Taranaki, New Zealand using accurate hypocentres from a dense network. *Geophysical Journal International 162*: 494-506.

Sherburn, S.; Scott, B.J. 2014 Taranaki Seismicity: July 2013 to June 2014. *GNS Science Consultancy Report* 2014/228 18 p.

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