Taranaki Seismicity: July 2012 to June 2013

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EXECUTIVE SUMMARY

During the period July 2012 to June 2013, 312 earthquakes were located in the Taranaki region using the new GeoNet Rapid analysis system. This accounts for about 2% of the 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 either in a north-east – south-west trending swath west of Mt Taranaki, or in a cluster north-east of Stratford; the deeper earthquakes occur beneath south-east Taranaki. There was a magnitude 4.9 earthquake offshore of Cape Egmont on 31 December 2012 that was followed by a number of aftershocks.

Although a few earthquakes were located beneath Mt Taranaki, we conclude that during the period July 2012 to June 2013 seismic activity on the Taranaki Peninsula was not volcanologically significant.

During the year one seismograph was replaced by a nearby site where the sensor was placed down a borehole. This has given a substantial improvement in earthquake detectability in that area.

In terms of assessing the effectiveness of the network, technical problems are generally no longer an issue as the new and upgraded sites rarely experience problems.

The introduction of GeoNet Rapid has resulted in fewer small earthquakes being located in Taranaki as it is set up to automatically and rapidly locate earthquakes large enough to be felt, but not as many smaller earthquakes. This has implications for the effective monitoring of Mt Taranaki where smaller earthquakes might be precursors to eruptive activity. A suggestion to avoid this limitation in GeoNet Rapid will be discussed at the Taranaki Seismic and Volcanic Advisory Group meeting in October.

1.0 INTRODUCTION

This report summarises earthquake occurrence in Taranaki for the period 1st July 2012 to 30th June 2013.

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

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 started to improve the existing network for monitoring earthquakes in New Zealand. In 2005, planning began for upgrading seismographs in Taranaki to an equivalent standard to that in other parts of New Zealand. With this upgrade came two important changes. Firstly, the role of the network expanded from one of solely monitoring Mt Taranaki to both monitoring Mt Taranaki and contributing to the New Zealand network as a whole by providing essential earthquake recording capability in the western part of the North Island. Secondly, the concept of a “Taranaki network”, with all data sent to, and recorded at, a common point became less appropriate as multiple data hubs began to be used to send data to GeoNet data centres. Sites in Taranaki lost any distinction they may have had from other seismographs in New Zealand. For these reasons we feel that the term “Taranaki Volcano-Seismic Network” no longer has the meaning it used to, and to refer to a Taranaki-specific network can be both confusing and not convey the information that was intended. For these reasons we are no longer using the term.

2.0 SEISMOGRAPHS

The most recent upgrade to seismographs in Taranaki was completed in 2010 and only minor improvements were undertaken during 2012-13. In October 2012, the sensor at Newhall Road (NWEZ, Figure 2.1), which was badly affected by wind noise, was replaced by one in a 44 m deep borehole that had been drilled nearby. As the new site is some distance from the old site it has a new name and station code, Newhall Road Borehole (NBEZ, Figure 2.1). The signal from NBEZ is substantially quieter than that from NWEZ and should improve the detectability of small earthquakes west of Mt Taranaki. Newhall Road (NWEZ, Figure 2.1) was closed when the replacement site began operation.

There are currently nine seismographs in the Taranaki area continuously sending data to GeoNet data centres in Taupo and Wellington for analysis, via hubs at the Taranaki Emergency Management Office (TEMO) in New Plymouth, at Kahui Rd west of Mt Taranaki, and at Eltham.

As discussed in the introduction, the distinction between Taranaki seismographs and others in New Zealand has become less in recent years. Several seismographs outside Taranaki often record small or moderate earthquakes that occur in Taranaki and provide data that are often essential to locating these earthquakes. The nearest of these sites are Vera Rd – east of Whangamomona, Hauiti – inland from Awakino, and Wanganui – north-west of Wanganui city.

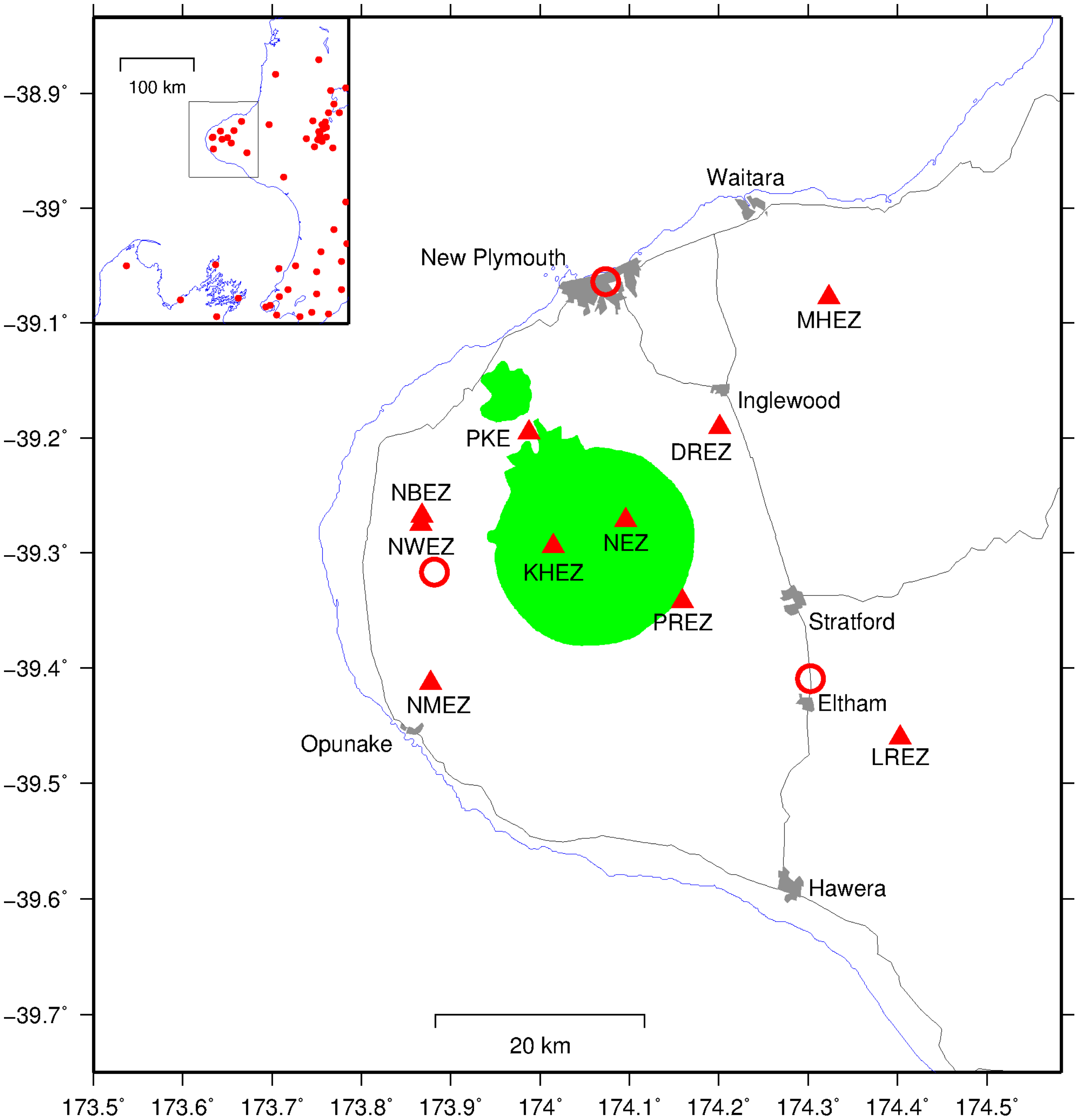

Figure 2.1 A map of the seismographs used to locate earthquakes in Taranaki. Seismograph sites are indicated by triangles and labelled by their three or four-letter site codes. The network shown (red triangles) is that at the end of the reporting period. NEZ is North Egmont, NWEZ is Newall Road, NBEZ 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. Newall Road Borehole (NBEZ) began operation in October 2012 at which time Newall Road (NWEZ) was closed. Data collection (hub) sites are shown by red circles. Population centres are shaded dark grey and named. The Egmont National Park is shown as a green shaded area. Major roads are shown as grey lines. The inset shows Taranaki and additional nearby GeoNet seismographs that are used in locating earthquakes in Taranaki.

3.0 DATA ANALYSIS

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

The real-time earthquake analysis system used by GeoNet changed in September 2012. The particular strength of the new system, known as GeoNet Rapid[1], is automatically obtaining a reasonably accurate location for all moderate size earthquakes within 1-2 minutes of an earthquake's occurrence. 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. GeoNet Rapid has been very successful in this regard, but there have been some negative impacts as well. GeoNet Rapid has located fewer small earthquakes in Taranaki than did the previous system, known as CUSP. The extent and consequences of this, and what is proposed to deal with that will be discussed later in this report.

In compiling this report we have used data from GeoNet Rapid and a beta-version of GeoNet Rapid that was running in parallel with the CUSP system. All data after 1 January 2012 that is retrieved from earthquake searches comes from GeoNet Rapid.

GeoNet intends to produce a separate version of GeoNet Rapid that will be used to populate a New Zealand earthquake catalogue. At the time of writing the catalogue version is still in development and its capabilities, and any limitations, are unknown.

In previous reports the earthquakes felt in Taranaki were discussed. It is currently not possible to extract from GeoNet Rapid the locations of earthquakes that were reported felt. Felt earthquakes are therefore not discussed in any detail in this report. Calibration of earthquake magnitudes determined by GeoNet Rapid has also not been carried out yet so there might be some magnitude differences between this and the CUSP system, though these are probably less than 0.5.

Because automatic locations from GeoNet Rapid are sufficiently accurate for rapid notification, many of the locations have not been manually reviewed. In displaying the locations of earthquakes in Taranaki we have distinguished between automatic and reviewed locations. Whether the reviewed locations are any more reliable than the automatic ones is something that has not been investigated.

The earthquake catalogue, comprising locations from the CUSP system up to 31 December 2011 and from GeoNet Rapid from 1 January 2013 can be searched via the GeoNet website[2].

[1] GeoNet Rapid uses the SeisComP3 software (www.seiscomp3.org) with appropriate tuning for New Zealand conditions.

[2] http://info.geonet.org.nz/display/appdata/Earthquake+Web+Feature+Service

4.0 DATA RELIABILITY

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

- the number of sites at which an earthquake is recorded; small earthquakes are often poorly recorded or recorded on only part of a network. Locations for these earthquakes are not as good as those for larger events which are well recorded at many more sites;
- 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 earthquake is farther from the nearest seismograph than it is deep. In the CUSP system ~20% of earthquakes in Taranaki had a fixed depth in a typical year. In GeoNet Rapid it is also possible to fix the depth of an earthquake, but the output of a web search of GeoNet Rapid locations does not currently indicate if an earthquake has a fixed depth or not.

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 will report on results obtained from GeoNet Rapid and will follow the format used for previous annual reports. We will address issues related to GeoNet Rapid's apparent “insensitivity” to smaller Taranaki earthquakes in the Discussion section.

Three hundred and twelve earthquakes were located in the Taranaki region by GeoNet Rapid between July 2012 and June 2013 (Figure 5.1). This amounts to about 2% of earthquakes located in New Zealand during a typical year.

Shallow earthquakes (those with a depth less than 50 km) were concentrated in a north-east – south-west trending swath west of Mt Taranaki, with a few in a cluster north-east of Stratford (Figure 5.1). A cluster of earthquakes was located offshore west of Cape Egmont, being made up of an event of magnitude 4.9 on 31 December 2012[3] and its aftershocks. Deep earthquakes (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. Although a search of GeoNet Rapid locations does not currently indicate if an earthquake has a fixed depth or not, it is evident from Figure 5.2 that many are fixed at a depth of 5 km.

[3] Dates and times are in Universal Time (UT) which is 12 hours behind New Zealand Standard Tme and 13 hours behind New Zealand Daylight Time.

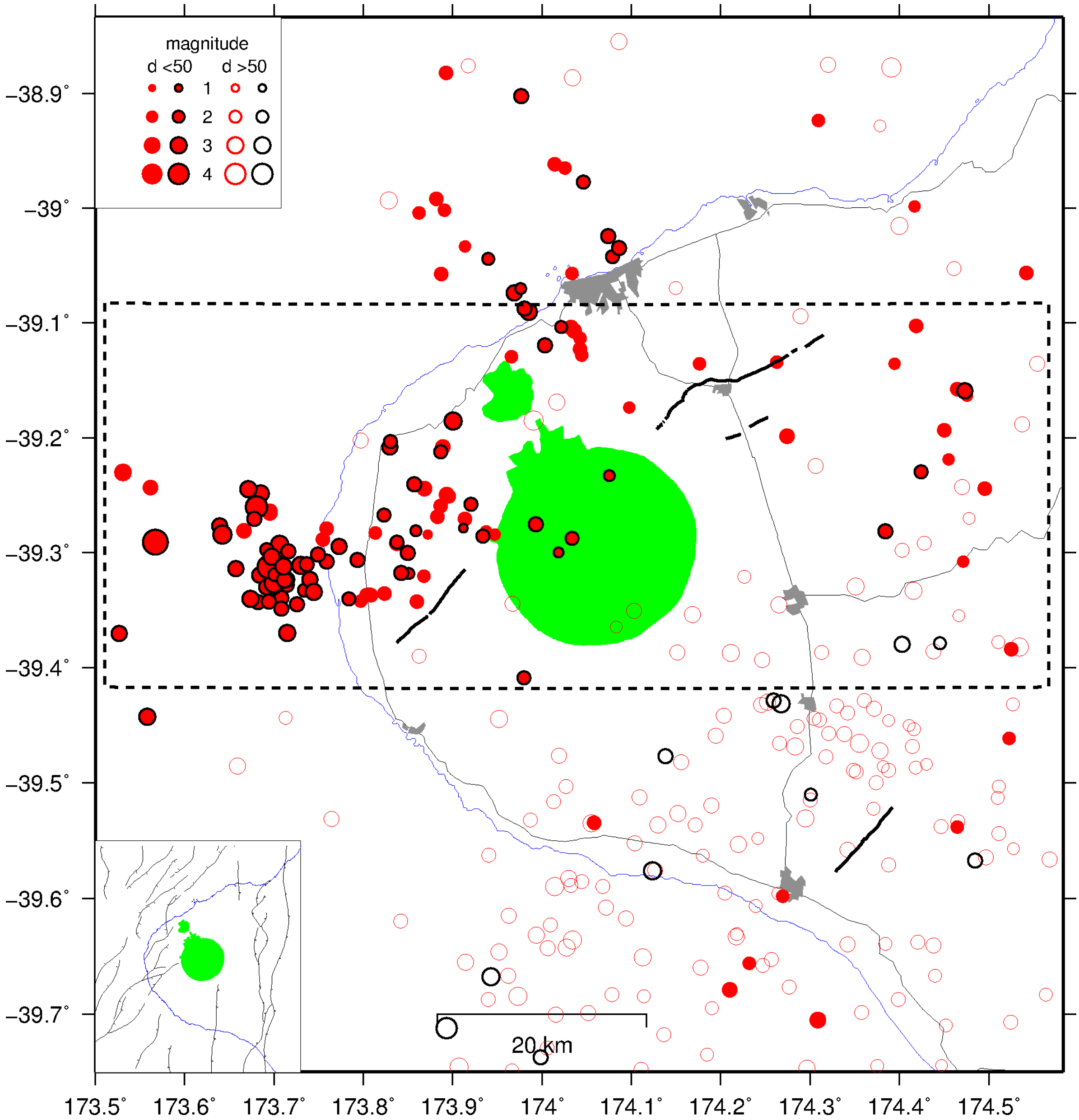

Figure 5.1 A map of all earthquakes located in Taranaki by GeoNet Rapid between July 2012 and June 2013. Closed circles indicate earthquakes less than 50 km deep and open circles those more than 50 km deep. Earthquakes that have been manually reviewed have a symbol that is surrounded by a black ring, those without the black ring are automatic locations. The size of the symbol is proportional to magnitude of the earthquake, and representative symbols are shown in the top left corner of the diagram. Population centres are shaded dark grey and Egmont National Park is shaded green. Major roads and mapped active faults (thick black lines) are also shown. 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.

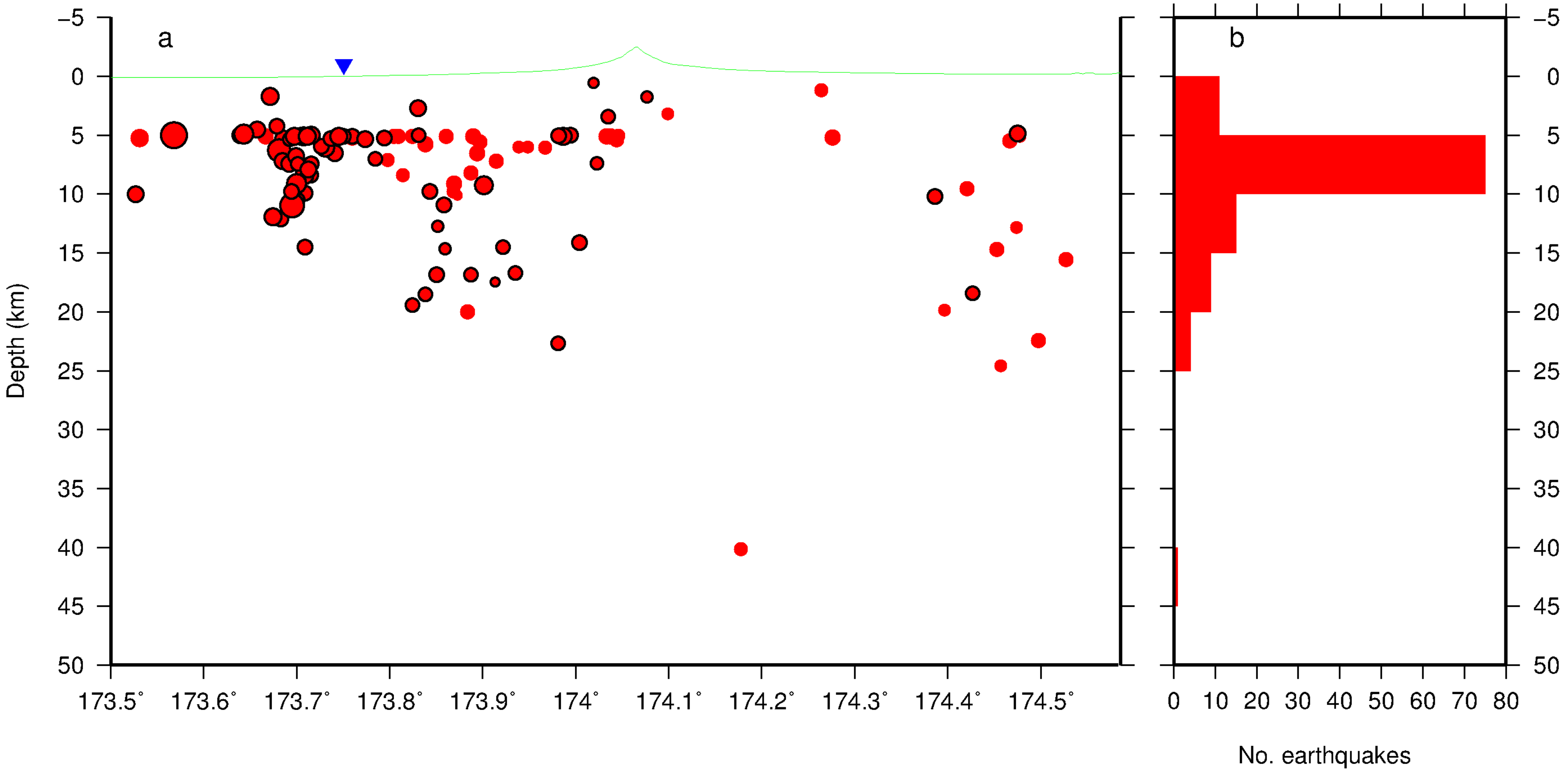

Figure 5.2 a. An east-west cross-section showing earthquakes less than 50 km deep located in Taranaki between July 2012 and June 2013. The symbols are the same as Figure 5.1, those that have been manually reviewed have a symbol that is surrounded by a black ring, those without the black ring are automatic locations. No distinction is made between earthquakes for which the depth was calculated and those for which it was fixed, although is it clear that many have been fixed at 5 km. 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. The 5-10 km range includes events fixed at 5 km depth.

6.0 DISCUSSION

In this section we compare the seismicity for July 2012 to June 2013 with the earthquake activity in Taranaki since 1994, including 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 discuss some consequences of the introduction of GeoNet Rapid for locating seismicity in Taranaki, including monitoring of Mt Taranaki volcano.

6.1 LONG-TERM DATA

6.1.1 Larger earthquakes

In earlier reports we have summarised the occurrence of all earthquakes located in Taranaki since January 1994. A seismic network can actually only locate all earthquakes above a certain magnitude, and records only some of the earthquakes of lower magnitude[4]. Summarising all earthquakes may therefore be a little misleading because 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[5].

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 significantly lower than that offshore. By plotting only earthquakes of M2.7 and larger (Figure 6.2), it is clear that the level of activity onshore west of Mt Taranaki is quite similar to that offshore north and south of the Taranaki Peninsula.

A result of showing only earthquakes of M2.7 and larger is that less well-located earthquakes, which tend to be of lower magnitude, are not shown. In one respect, a plot of earthquakes larger than the location threshold might be thought of as showing earthquakes that have more reliable locations. However, by showing only the larger earthquakes we may inadvertently miss some important data. In Figure 6.1 there are more than 100 earthquakes shown beneath Mt Taranaki, which gives the impression that there is a low, but significant, level of seismicity beneath the volcano, and raises questions about the possible volcanic significance 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 precursor. This point is discussed later in regard to GeoNet Rapid.

[4] 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.

[5] 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.

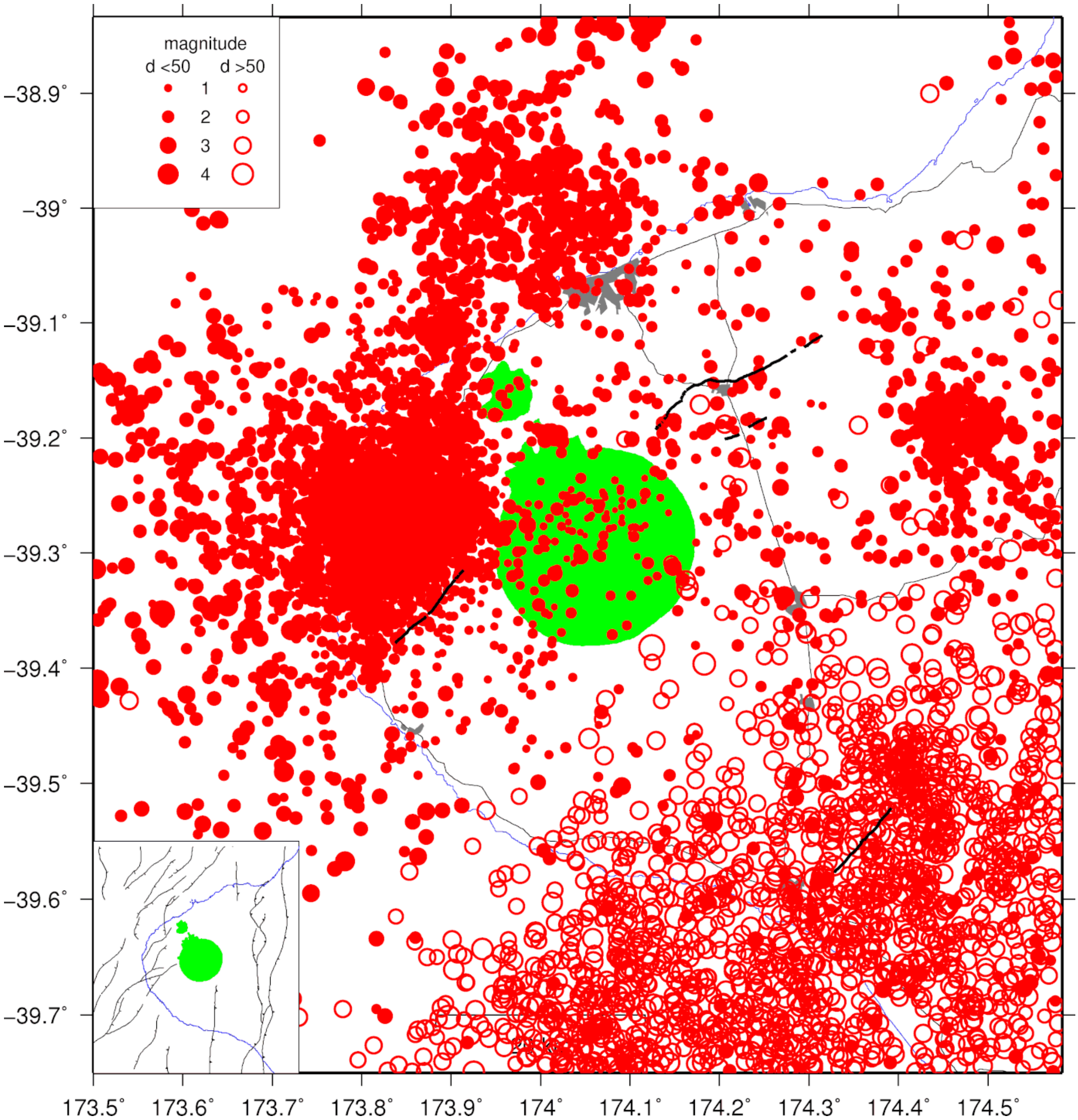

Figure 6.1 A map of earthquakes located in Taranaki between January 1994 and June 2013. Data up to 31 December 2011 are from the CUSP analysis system, and those from 1 January 2012 are from the GeoNet Rapid system. Closed circles indicate earthquakes less than 50 km deep and open circles those more than 50 km deep. 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 shaded dark grey and Egmont National Park is shaded green. Major roads and mapped faults (thick black lines) are also shown. The lower left inset shows mapped faults that offset the basement rocks but are not considered active.

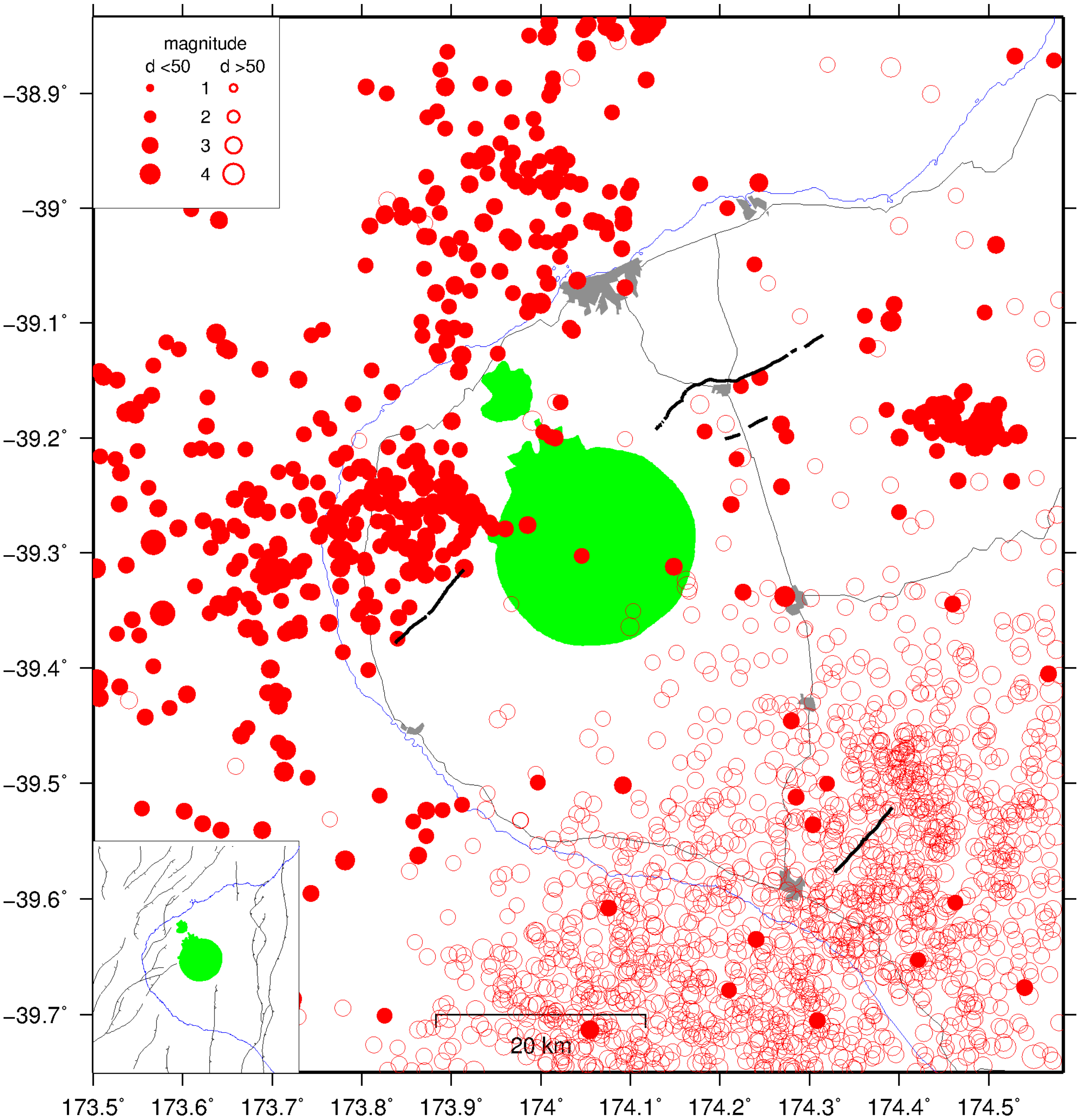

Figure 6.2 A map of earthquakes of M2.7 and larger located in Taranaki between January 1994 and June 2013. Data up to 31 December 2011 are from the CUSP analysis system, and those from 1 January 2012 are from the GeoNet Rapid system. Closed circles indicate earthquakes less than 50 km deep and open circles those more than 50 km deep. 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 shaded dark grey and Egmont National Park is shaded green. Major roads and mapped faults (thick black lines) are also shown.

6.1.2 Long-term distribution

In terms of the distribution of earthquakes, the data for July 2012 to June 2013 (Figure 5.1) are largely very 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 zone 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 cluster of earthquakes offshore of Cape Egmont that occurred from the end of 2012 is not a long-term feature of Taranaki seismicity, but represents aftershocks of the magnitude 4.9 earthquake on 31 December 2012. Rather it is part of the natural variation within the long-term activity of that area.

6.1.3 Long-term rate

We use two measures to show the long-term, 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.

6.2 VOLCANIC SIGNIFICANCE

Although a few earthquakes are usually located beneath Mt Taranaki most years, they are not thought to be volcanologically significant.

While there are no hard and fast 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, 2000) are criteria that are often considered. The earthquakes located beneath Mt Taranaki in 2012-13 are not unusual in any of these respects, and they are therefore not thought to be volcanologically significant.

6.3 NETWORK EFFECTIVENESS

In the past the effectiveness of the network has been significantly affected by technical problems. However, the seismograph upgrade several years ago means that they are much more reliable and technical problems are relatively rare. There are always minor technical issues with any network, but none of these had a substantial effect on Taranaki data in 2012-13.

6.4 GEONET RAPID

In June 2013, we noticed that an automatically produced plot of seismic activity in the Taranaki region had shown no shallow earthquake activity for about 40 days. Further investigation showed that the apparent rate of activity in Taranaki had, with the exception of the sequence offshore from Cape Egmont that began on 31 December 2012, reduced suddenly at the start of 2012 (Figure 6.4). This change had been highlighted in a presentation to the Taranaki Seismic and Volcanic Advisory Group in September 2012, but at that time the change was not sufficiently well developed for it to be confidently attributed to a particular cause.

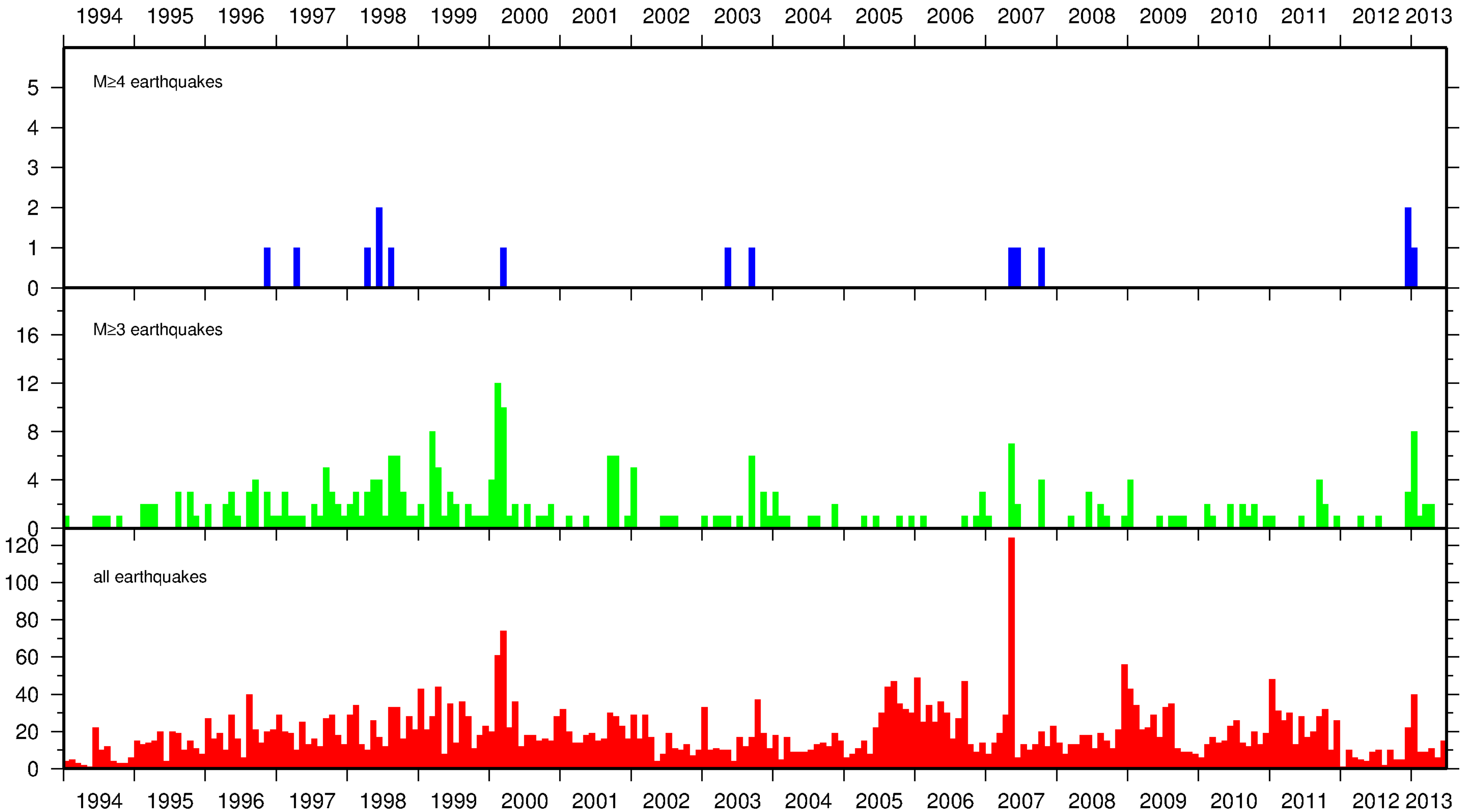

Figure 6.3 A histogram of the number of earthquakes less than 50 km deep that have occurred each month between January 1994 and June 2013 in the area shown in Figure 2.1. Three separate histograms are shown: all earthquakes (bottom), those of magnitude 3 and above (centre) and those of magnitude 4 and above (top). Data up to 31 December 2011 are from the CUSP analysis system, and those from 1 January 2012 are from the GeoNet Rapid system.

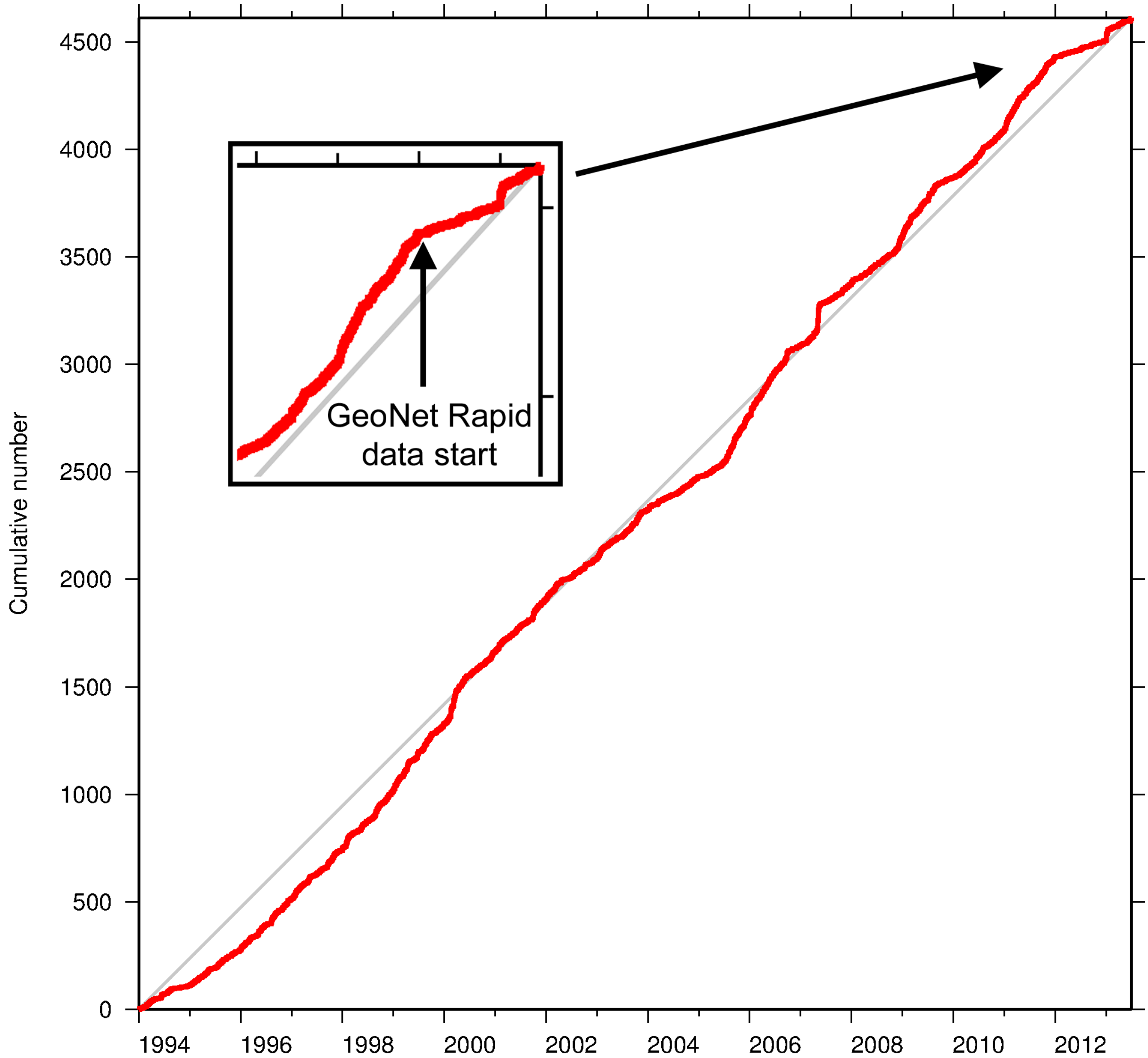

Figure 6.4 The cumulative number of all earthquakes (red line) less than 50 km deep located in the area shown in Figure 2.1 between January 1994 and June 2013. The grey line shows the mean rate, 235 events per year. The main network upgrade began in 2009, but there was no significant change in the number of earthquakes. GeoNet Rapid data are from 1 January 2012 and this corresponds to a reduction in the rate of located earthquakes.

As noted earlier, when searching for earthquakes on the GeoNet web site all data after 1 January 2012 is from GeoNet Rapid. The timing of the apparent reduction in the rate of Taranaki seismicity (Figure 6.4) corresponds with the change from the CUSP analysis system to GeoNet Rapid.

GeoNet Rapid requires 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 and picked at fewer Taranaki sites, at correspondingly more sites outside Taranaki. The CUSP analysis system operated in a different way to GeoNet Rapid so it cannot be directly compared, but was able to create events without P-phase arrival picks being required at all seismographs on the Taranaki peninsula.

Given that the purpose of GeoNet Rapid is to automatically obtain a reasonably accurate location for all moderate size earthquakes (in other words, likely to be felt) within

1-2 minutes, the threshold to include events would ideally be set higher than 10 P-phase picks, but the value of 10 was chosen as a compromise so that it would include some smaller earthquakes. However, in the case of Taranaki this threshold seems to have resulted in a substantial reduction in the number of smaller earthquakes that are located, with obvious implications for the monitoring of Mt Taranaki. There is no similar issue apparent in other volcanic areas, possibly because of Taranaki's position on the “edge” of the North Island with no seismographs to the west.

In order the test our explanation for the reduction in the number of smaller earthquakes located we ran the Taranaki seismic data for July 2012 to June 2013 through the SeisComP3 software that runs GeoNet Rapid, but with the threshold for event creation reduced to 6 P-phase picks, the minimum permitted. We refer to this process as SC3Tar (SeisComP3 Taranaki). SC3Tar gave 584 events in the area shown in Figure 5.1, compared to 312 from GeoNet Rapid (an 87% increase), with all of the SC3Tar locations being automatic. The distribution of earthquakes between GeoNet Rapid and SC3Tar is quite similar (Figure 6.5), although there are scattered shallow earthquakes in Hawera region which have not been seen before. Those earthquakes are not believed to be real, but are thought to be an artefact of the limited number of stations used in this test.

If we count the number of shallow (depth less than 50 km) earthquakes in Taranaki in several magnitude ranges (Figure 6.6) we can see that for magnitudes above ~2.5 GeoNet Rapid and SC3Tar located similar numbers of events, but for smaller earthquakes SC3Tar located substantially more.

We conclude that GeoNet Rapid is achieving what it was designed to do, but because of the way it is configured cannot locate many of the smaller earthquakes in Taranaki.

6.4.1 Implications for monitoring Mt Taranaki

GeoNet Rapid located almost the same number of earthquakes beneath Mt Taranaki between July 2012 and June 2013 that SC3Tar did (Figure 6.5), but GeoNet Rapid struggles to locate some Taranaki earthquakes smaller than magnitude 2.5 and many smaller than magnitude 2.0 (Figure 6.6).

The test outlined earlier suggests that GeoNet Rapid probably did not miss any potentially important earthquakes that might be a sign of a reawakening Mt Taranaki. However, the magnitude of any earthquake activity that might precede an eruption at Mt Taranaki is unknown. As a comparison the majority of earthquakes that occurred before the August 2012 Tongariro eruption were smaller than magnitude 2. This comparison suggests that we should at least be concerned that if we monitor Mt Taranaki using only locations from GeoNet Rapid we might miss some potentially important precursory seismicity.

6.4.2 A suggested forward path

It is not possible to change the configuration of GeoNet Rapid to what is best for monitoring Mt Taranaki as it will have an effect on what earthquakes are located in the whole of New Zealand. What can be done is to run SC3Tar and use its list of earthquakes and locations to more effectively monitor Mt Taranaki. In most cases these locations would be automatic and would not routinely be reviewed. This suggestion will be discussed at the Taranaki Seismic and Volcanic Advisory Group meeting in October and will be implemented if that group considers it a suitable solution.

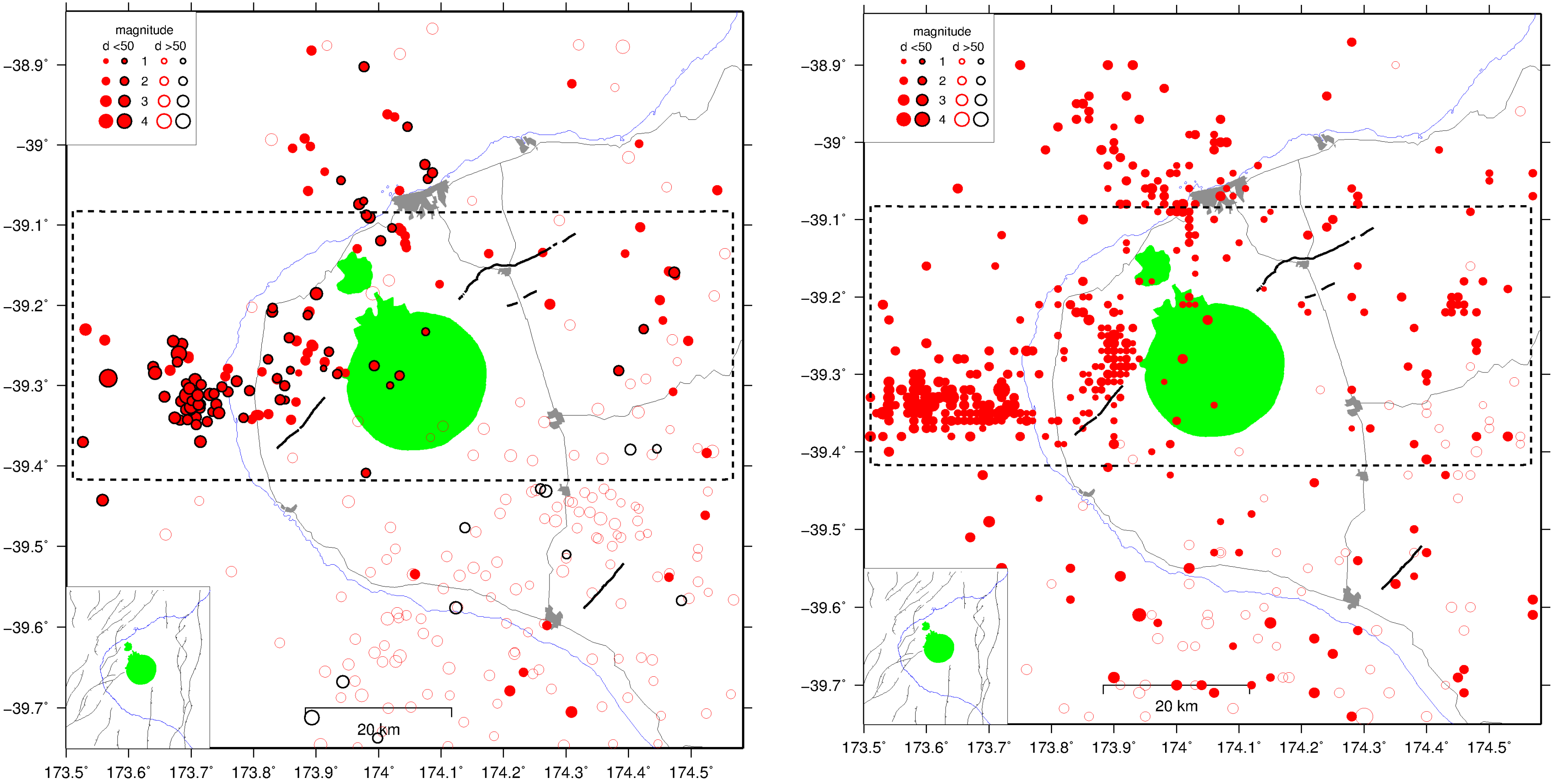

Figure 6.5 A comparison of earthquakes between 1 July 2012 and 30 June 2013 that were located in the Taranaki region by GeoNet Rapid (left) and SC3Tar (right). All locations from SC3Tar are automatic. For further explanation refer to Figure 5.1. The ‘grid-like’ pattern in SC3Tar locations occurs because only two decimal places (of degrees) were output for plotting.

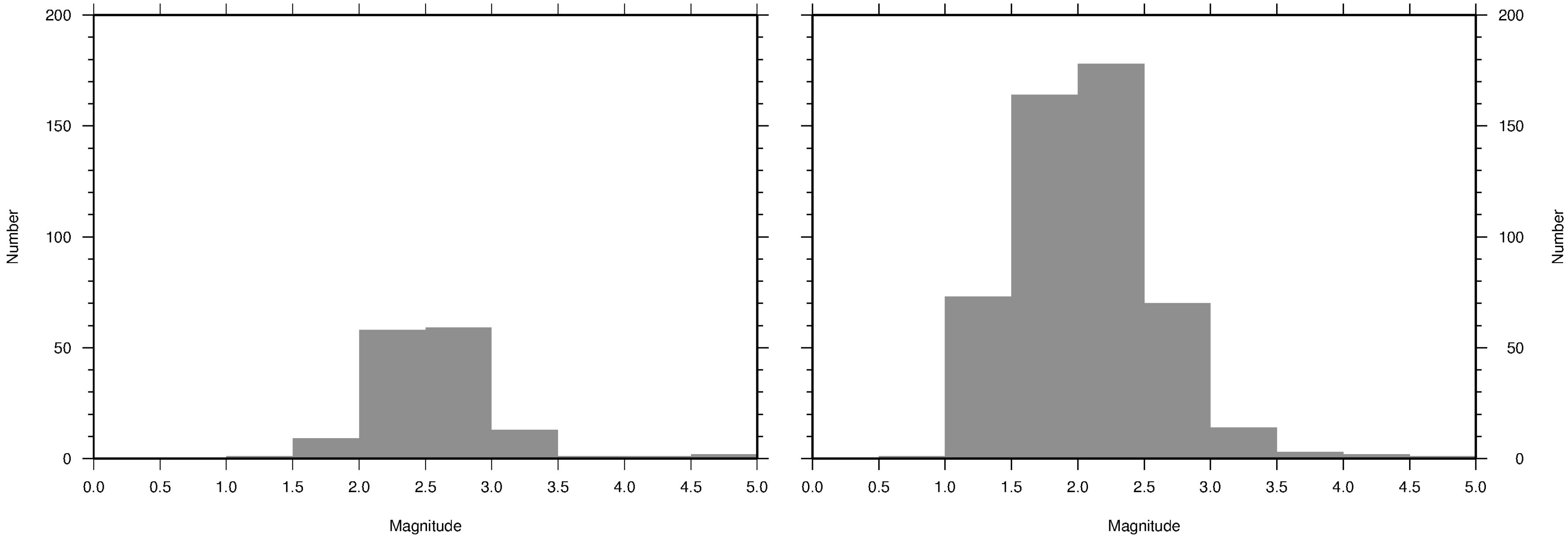

Figure 6.6 A comparison of the number of earthquakes in different magnitude ranges in the Taranaki region between 1 July 2012 and 30 June 2013 from GeoNet Rapid (left) and SC3Tar (right). Only earthquakes shallower than 50 km are shown.

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 beneath Mt Taranaki so we infer that during the period July 2012 to June 2013 seismic activity on the Taranaki Peninsula was not volcanologically significant.

The introduction of GeoNet Rapid as the new earthquake analysis system has resulted in many of the smaller earthquakes not being located. A solution that will locate the smaller earthquakes GeoNet Rapid misses has been suggested.

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