Taranaki Seismicity:
July 2008 to June 2009

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EXECUTIVE SUMMARY

During the period July 2008 to June 2009, 420 earthquakes were located in the Taranaki region. This accounts for about 2% of the earthquakes located in New Zealand in an average year. Most of the shallow earthquakes occurred in a northeast-southwest trending swath west of Mt Taranaki, and northeast of Stratford. The deeper earthquakes were all located beneath southeast Taranaki. This is similar to the long-term distribution. Five earthquakes in Taranaki were reported felt.

Three relatively small earthquakes were located beneath Mt Taranaki, but we conclude that during the period July 2008 to June 2009 seismic activity on the Taranaki Peninsula was not volcanologically significant.

Good progress continues to be made on upgrading seismographs in Taranaki. During the year two new sites were installed, one original site was removed, and testing was begun for the remaining sites planned to complete the upgrade.

Technical problems have become less of an issue as the number of original sites is reduced. Any problems that have occurred during the year probably have not been sufficient to compromise the effectiveness of the network.

1.0 INTRODUCTION

This report summarises earthquakes in Taranaki for the period 1st July 2008 to 30th June 2009.

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 solely one of 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 began to become less clear as multiple data hubs began to be used to send data to GeoNet data centres and 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 in some cases to refer to a Taranaki-specific network can be both confusing and not convey the information that was intended. For these reasons we will no longer use the term.

2.0 SEISMOGRAPHS

At the start of July 2008 there were four three-component seismographs in Taranaki (new sites or upgraded sites from the original network), and four of the original vertical-component seismographs. Data were continuously sent to GeoNet data centres in Taupo and Wellington for analysis via a hub at the Taranaki Emergency Management Office (TEMO) in New Plymouth and a hub at Kahui Rd west of Mt Taranaki.

As discussed in the introduction, the distinction between Taranaki seismographs and others in New Zealand has become less clear in recent years. Several seismographs outside Taranaki often record even relatively small 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 – northwest of Wanganui city.

2.1 Changes and improvements in the last year

Over the last year work has continued towards upgrading seismographs in Taranaki to three-component sensors and modern digital recording and telemetry.

In January 2009 site testing was carried out at three sites, at Tahurangi Lodge on the

northeast flank of Mt Taranaki, at Kahui Hut of the western flank of Mt Taranaki, and at Namu Rd northeast of Opunake. Kahui Hut and Namu Rd both tested well, but data from Tahurangi Lodge were badly affected by wind about half of the time and that site was deemed unsuitable.

A seismograph was subsequently installed at Namu Rd in April 2009 with telemetry to the Kahui Rd hub via a seismograph that was installed at Kahui Hut in May 2009 (Figure 1).

In May 2009 preliminary site investigations were begun for possible sites near Lake Rotokare and Kaponga, a repeater site near Lake Rotokare, and a hub in Eltham. In June 2009 site testing began at Maketawa Hut on the eastern flank of Mt Taranaki, and the original site at Ngariki Rd was removed, having been replaced by Namu Rd.

At the end of June 2009 there were nine seismographs in Taranaki, six with three-component sensors and modern GeoNet instruments and three of the original vertical-component seismographs (Figure 1).

During 2009-2010 it is hoped to install a site on the eastern flank of Mt Taranaki (possibly at Maketawa Hut), and two further sites southeast of Mt Taranaki (possibly near Lake Rotokare and Kaponga). When these are complete the original sites at North Egmont, Dawson Falls and Rainey Point will be removed. There will then be two sites on Mt Taranaki, an inner ring of five sites and a (partial) outer ring of two sites. Beyond that will be other GeoNet sites.

3.0 DATA ANALYSIS

Seismic data from Taranaki are continuously transmitted to GeoNet data centres in Taupo and Wellington. In near real-time (2-3 minutes), an automatic earthquake detection program is used to search for signals that may be 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, and those data are saved. Data from Taranaki are combined with recordings from any other seismographs that may have recorded the same earthquake, and using all of these data an attempt is made to automatically locate the earthquake. The automatic location is saved, and if it satisfies certain criteria[1], a message is sent to GeoNet staff pagers, noting the estimated location, time, and magnitude of the earthquake.

When the on-call GeoNet duty scientist receives the pager message they perform manual analysis of the earthquake to revise the location. If the earthquake is reported ‘felt’, or the duty scientist believes it may have been felt, they send the revised location information to the GeoNet web page, an email list (that includes TRC staff), and to GeoNet duty staff pagers.

Each day the GeoNet duty scientists also review all significant earthquakes recorded over the last 24 hours, a process known as ‘rapid analysis’. A revised location and magnitude are calculated for these earthquakes. This process is intended to produce a reasonably complete catalogue of the larger New Zealand earthquakes each day, but as all possible earthquakes are not examined, this catalogue is not complete. At this stage any earthquakes reported felt that did not trigger a pager message when they occurred are also sent to the GeoNet web page, an email list, and to GeoNet staff pagers.

[1] These criteria include position, depth, magnitude and location uncertainty, and are intended to select earthquakes that are felt or are likely to have been felt by a significant number of people.

The earthquake catalogue is updated as each earthquake is located. This catalogue can be searched via the GeoNet website[2].

3.1 Complete analysis

Until 1 July 2008 complete analysis of every earthquake recorded in New Zealand (including a review of earthquakes located by 'rapid analysis') occurred on a first in – first out basis, that is, analysts looked at the oldest unprocessed data first and worked towards the present day. At 1 July 2008 there was a backlog of 1-1½ years of unprocessed data which meant that the final analysis for earthquakes on, for example, 1 August 2009 would not be complete until sometime around December 2010.

From 1 July 2008 the priority changed and analysts began complete analysis of data recorded just two weeks earlier. This means that the earthquake catalogue is now effectively complete and finalised within 2-3 weeks of events occurring. The downside of this change is that the remaining backlog is given lower priority and will be cleared more slowly. As of July 2009 the backlog is about April 2007 to June 2008.

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 and 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. They can also produce noise which can significantly increase the number of false detections, and thereby make finding real events more difficult.

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 nearest seismograph is further from the earthquake than it is deep. Some of the earthquake locations calculated in Taranaki are less reliable than others and have been located with a depth fixed.

During the reporting period problems caused the loss of some data from sites used to locate earthquakes in Taranaki. At Ngariki Road there were no useful data until December 2008 and North Egmont was affected by daytime construction noise throughout most of the year. Upgraded or new sites operated without problems.

[2] http://magma.geonet.org.nz/resources/quakesearch/

5.0 RESULTS

Four hundred and twenty earthquakes were located in the Taranaki region between July 2008 and June 2009 (Figure 2). This amounts to about 2% of earthquakes located in New Zealand in an average year.

Shallow earthquakes (those with a depth less than 50 km) were concentrated in a northeast-southwest trending swath west of Mt Taranaki, with a few north-east of Stratford (Figure 2). Three earthquakes were located beneath Mt Taranaki, all were small. Deep earthquakes (those with a depth greater than 50 km) were mainly located in the Hawera region beneath south-east Taranaki (Figure 2).

Depths were calculated for 73% of the located earthquakes, with the remaining ones fixed at a depth of 5, 12, or 33 km. Earthquakes with a fixed depth were often offshore or were small and less well recorded (Figure 3). Earthquakes for which the depth was not fixed occurred between 5 and about 30 km deep (Figure 4a, b).

Five earthquakes located in Taranaki (the area shown in Figure 1) were reported felt during the reporting period[3] one was deep and four shallow. These were:

- 22 July 2008, 207 km deep, beneath Hawera, magnitude 4.9;
- 9 January 2009, 14 km deep, 30 km west of New Plymouth, magnitude 3.7;
- 20 January 2009, 5 km fixed depth, 20 km west of Cape Egmont, magnitude 3.8;
- 14 May 2009, 10 km deep, 10 km west of New Plymouth, magnitude 2.9;
- 11 June 2009, 8 km deep, Cape Egmont, magnitude 3.4.

6.0 DISCUSSION

In this section we compare the seismicity for July 2008 to June 2009 with the earthquake activity in Taranaki since 1994; we discuss any long-term similarities, differences and trends that may be apparent. We also 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 earlier reports we have summarised 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 1, but excluding earthquakes more than 20 km offshore, Sherburn and White (2005) showed that for the period 1994 – 2001 the GNS catalogue is complete down to magnitude 2.7.

[3] Other earthquakes may have been felt, but were not reported. Felt reports can be registered using the GeoNet web site: http://magma.geonet.org.nz/felt/app?service=external/Felt.
[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.

In summarising data since 1994 we therefore show all located earthquakes in Figure 5 and earthquakes above the M2.7 threshold in Figure 6. 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. Plotting only earthquakes of M2.7 and larger (Figure 6), 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. A plot of earthquakes larger than the location threshold can therefore be one way of showing earthquakes that have more reliable locations. However, by showing only the larger earthquakes we may inadvertently miss some important data. In Figure 5 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, and many may therefore have locations that are unreliable (particularly those from from the 1990s), possibly 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.

6.1.2 Long-term distribution

In terms of the distribution of earthquakes, the data for July 2008 to June 2009 (Figure 2) are very similar to those since 1994 (Figures 5 and 6). Both time periods are dominated by a swath of shallow earthquakes (depth less than 50 km) west of Mt Taranaki that trend northeast – southwest, deep earthquakes (depth greater than 50 km) in south-east Taranaki, and a cluster of shallow activity northeast of Stratford.

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 northeast 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.

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 7) and the cumulative number of earthquakes located since 1994 (Figure 8). 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 is relatively uniform. Short periods of above average activity occurred in early 2000 (a sequence of earthquakes about 20 km northeast of Stratford), May 2005 to March 2006 (widespread activity, but especially west of Mt Taranaki), and May 2007 (several clusters of activity north and west of Mt Taranaki), and possibly in early 2009 (west and northwest of Mt Taranaki).

As noted earlier, significantly more earthquakes were located in Taranaki in 2008-09 than 2007-08, 420 compared to 191. Closer examination of the data shows that this was reflected equally in both shallow and deep earthquakes (deep earthquakes were 28% of the total in

both 12 month periods). Also, the rate of activity during 2007-2008 was a little lower than the long-term average (Figures 7 and 8), though this must be affected by the incompleteness of the catalogue for this period. Considering these two points we tentatively suggest that the difference in activity between 2007-08 and 2008-09 was due to a combination of the change in analysis procedure discussed earlier and natural variability in the rate of seismicity in Taranaki. No special significance is therefore attached to there being significantly more earthquakes in 2008-09 than 2007-08

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 2008-09 are not unusual in any of these respects, and they are therefore not thought to be volcanologically significant.

6.3 Network effectiveness

At times the effectiveness of the network has been significantly affected by technical problems at some of the original sites. New or upgraded sites are much more reliable so as original sites are replaced by newer technology network effectiveness is less likely to be compromised. Whether technical and noise issues in 2008-09 were enough to compromise the network's capability to record volcanic unrest at Mt Taranaki is difficult to assess and would have depended on the magnitude and location of any seismicity that might have accompanied unrest. Given that in the last year almost 200 of the located earthquakes less that 50 km deep were of magnitude smaller than 2, any seismic unrest would probably have had to have been dominated by earthquakes of magnitude smaller than about 1.5 for all signs of unrest to be missed, though only earthquakes this small is thought to be unlikely.

6.3.1 Recommendations

With GeoNet upgrade work well underway the loss of data from some of the original sites for extended periods is less critical than it used to be. Despite this, every effort should be made to continue to keep these sites operating as well as possible until they are upgraded or removed. This is a shared responsibility between TRC and GNS Science.

7.0 CONCLUSIONS

Seismic activity on the Taranaki Peninsula continues to be dominated by a swath of earthquakes west of Mt Taranaki, with no significant activity beneath the volcano. No earthquakes have been recorded that might indicate ongoing volcanic processes beneath Mt Taranaki. We therefore conclude that during the period July 2008 to June 2009 seismic activity on the Taranaki Peninsula was not volcanologically significant.

8.0 REFERENCES

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McNutt, S.R., 2000. Volcano seismicity. In H. Sigurdsson (Editor-in-Chief), Encyclopaedia of Volcanoes. Academic Press, pp. 1015-1033.

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.

FIGURES

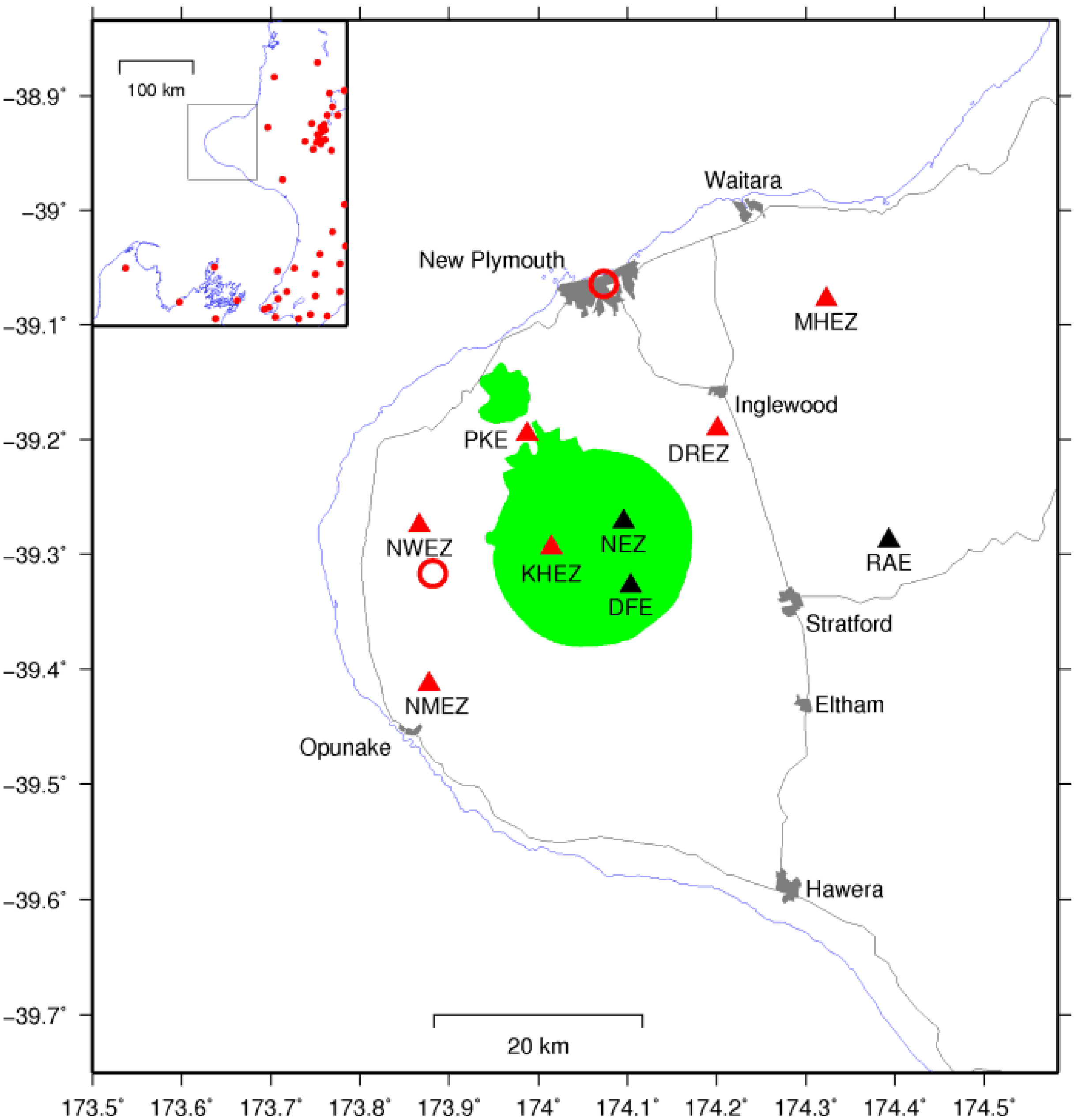

Figure 1. A map of the seismographs used to locate earthquakes in Taranaki. Seismograph sites are indicated by triangles and labelled by their three or four-letter site codes. The network shown is that at the end of the reporting period. DFE is Dawson Falls, NEZ is North Egmont, NWEZ is Newall Road, PKE is Pukeiti, RAE is Rainy Point, DREZ is Durham Road, MHEZ is Mangahewa, NMEZ is Namu Road, and KHEZ is Kahui Hut. Red triangles are three-component sites and black triangles are vertical component sites. 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 nearby GeoNet seismographs (red dots) that are also used in locating earthquakes in Taranaki.

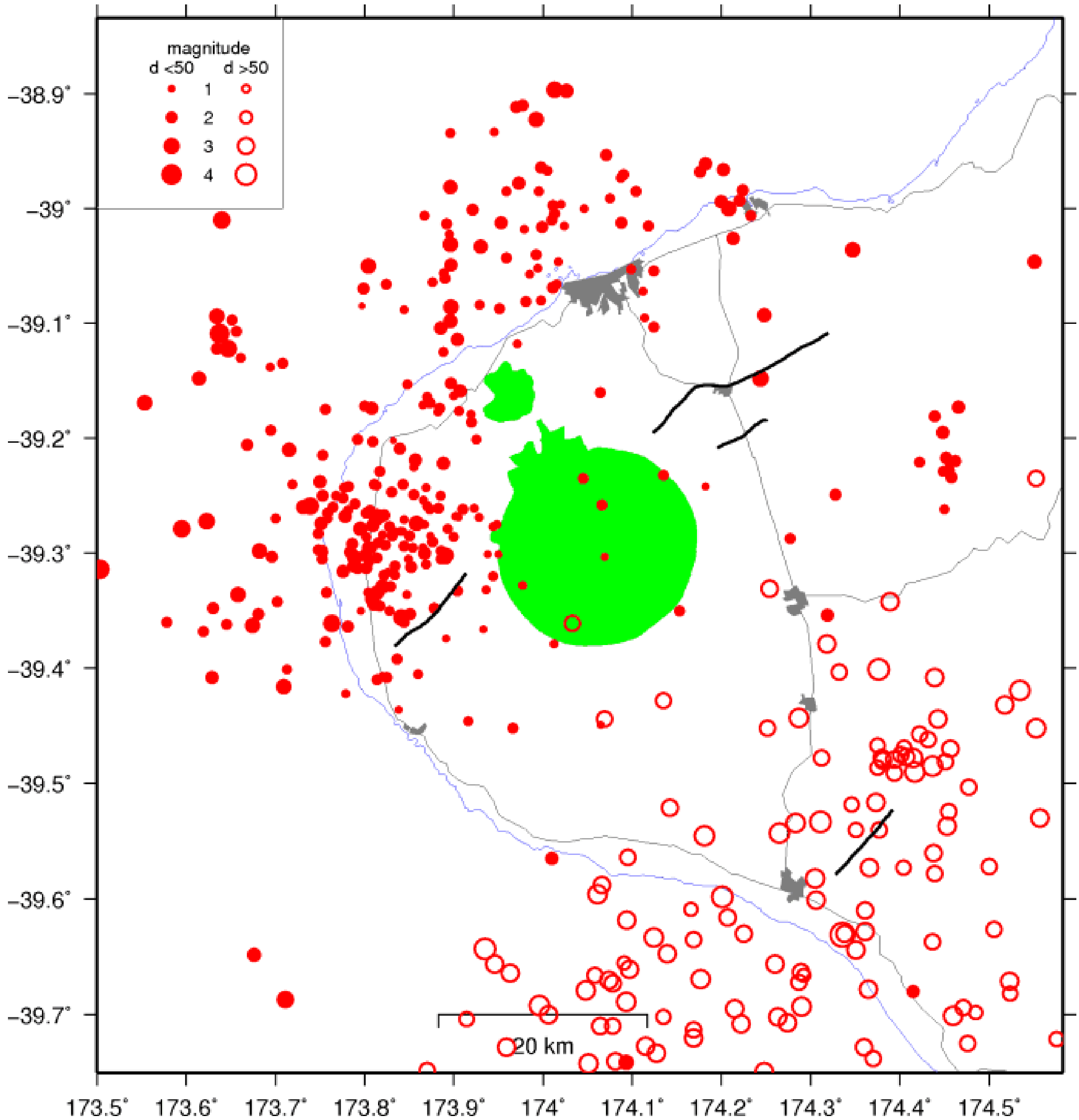

Figure 2. A map of all earthquakes located in Taranaki between July 2008 and June 2009. Closed circles indicate earthquakes less than 50 km deep and open circles those more than 50 km deep. The size of the symbol is proportional to magnitude of the earthquake, and representative symbols are shown in 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.

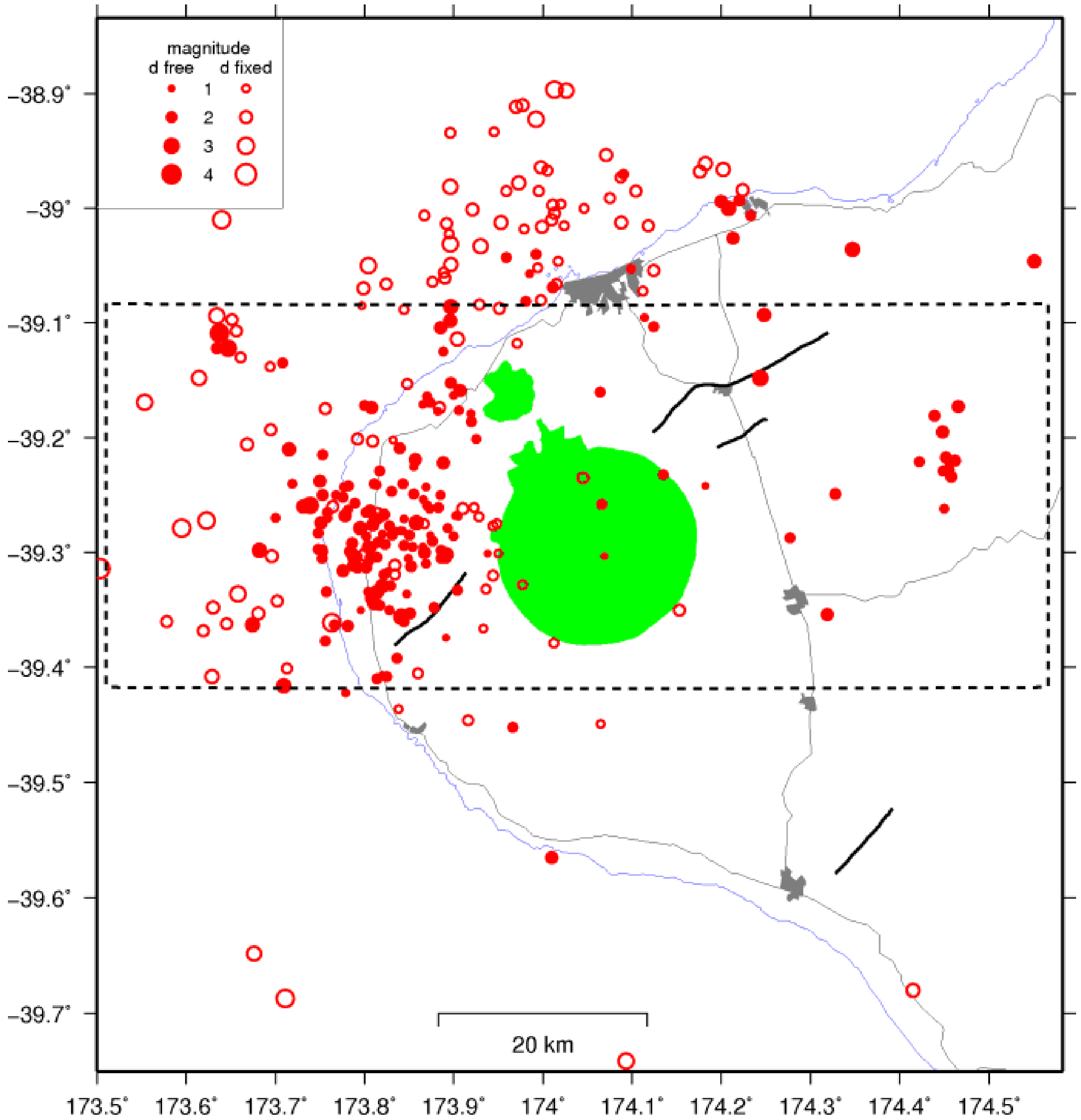

Figure 3. A map of earthquakes less than 50 km deep located in Taranaki between July 2008 and June 2009. Closed circles indicate earthquakes for which a depth was calculated and open circles those for which a depth could not be calculated and was therefore fixed at some appropriate value. The size of 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 active faults (thick black lines) are also shown. The dashed box marks the location of the cross-section in Figure 4a.

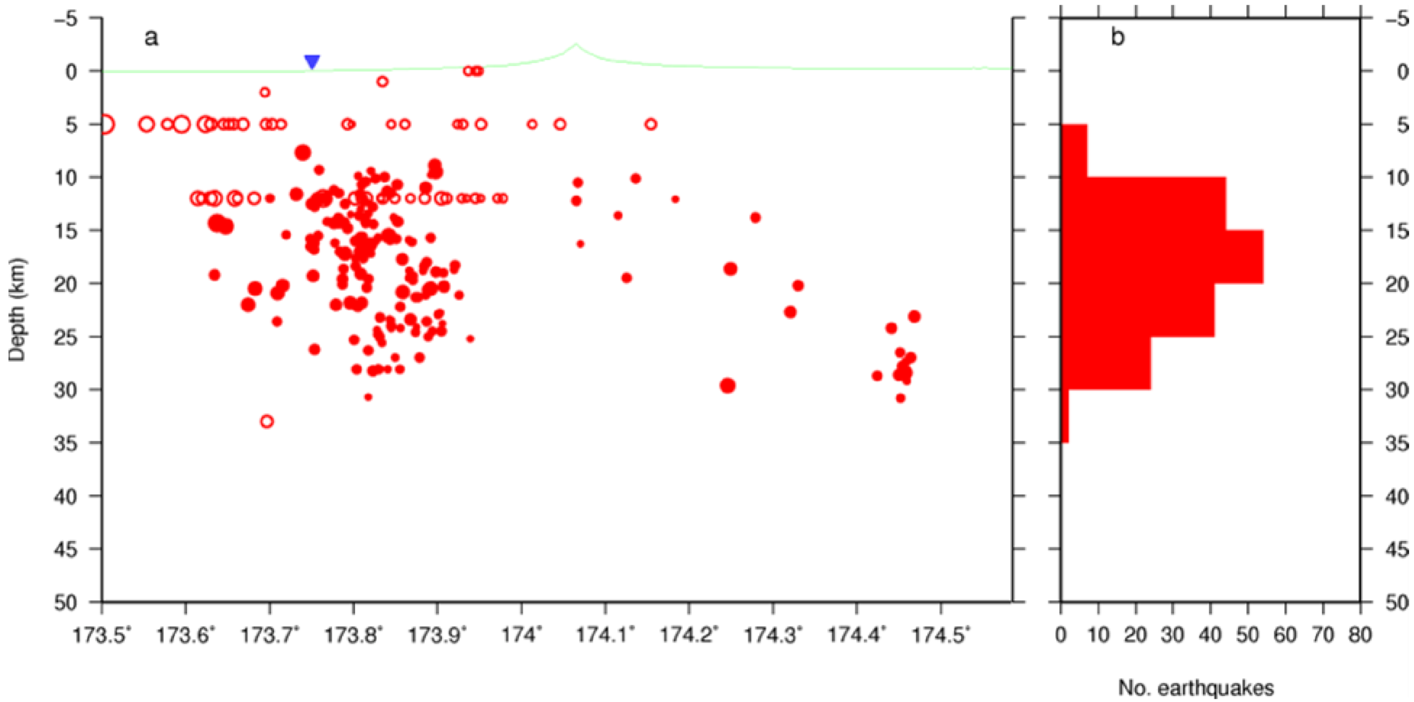

Figure 4a. An east-west cross-section showing earthquakes less than 50 km deep located in Taranaki between July 2008 and June 2009. The symbols are the same as Figure 3, closed circles for earthquakes for which the depth was calculated and open circles for those for which the depth was fixed. Topography 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 3.

Figure 4b. A histogram of the depths of the earthquakes shown in Figure 4a. Only earthquakes for which the depth was calculated are shown (closed circles in Figure 4a).

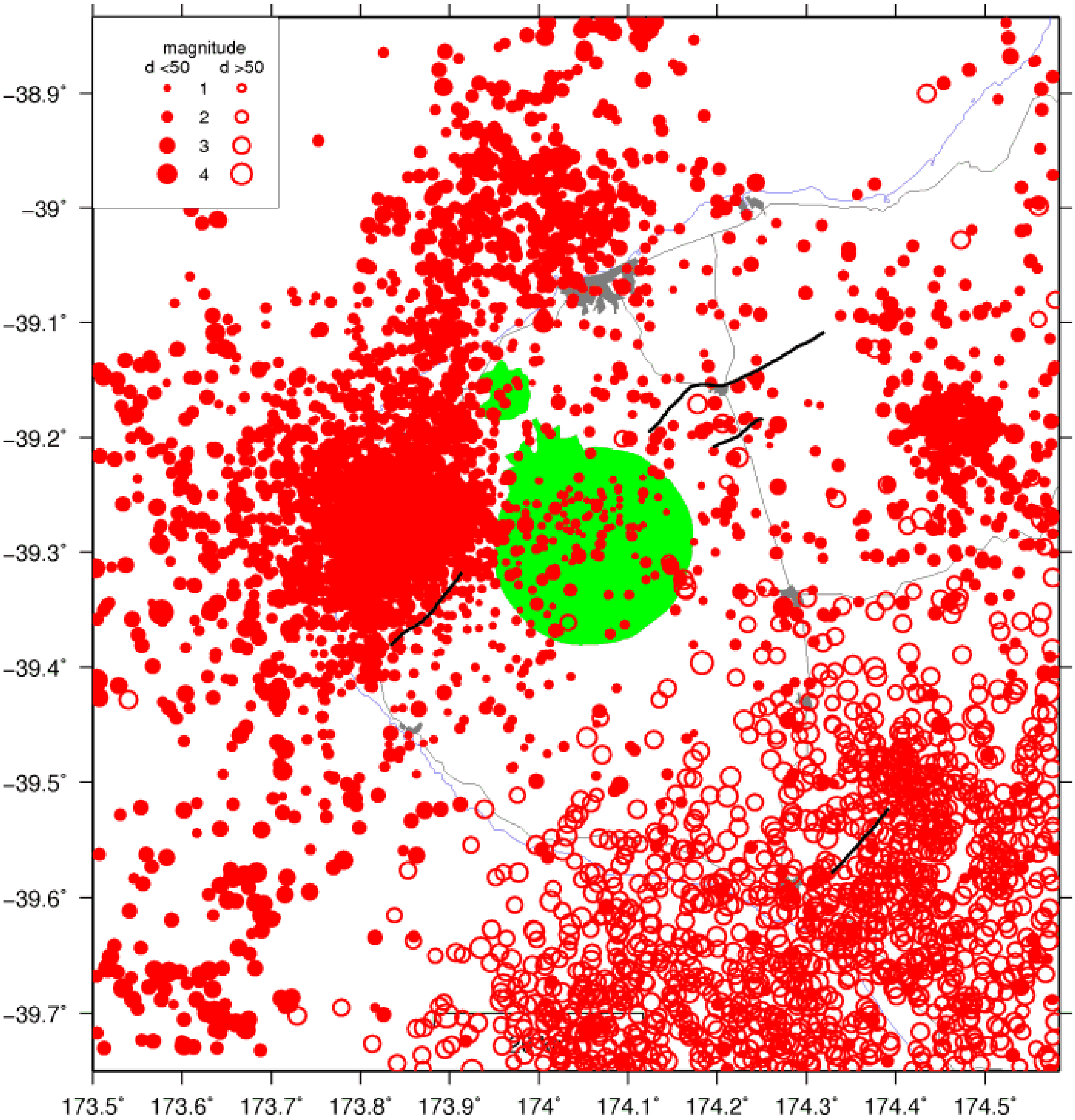

Figure 5. A map of earthquakes located in Taranaki between January 1994 and June 2009. Data are from the GNS earthquake database. Closed circles indicate earthquakes less than 50 km deep and open circles those more than 50 km deep. The size of the symbol is proportional to the magnitude of the earthquake, 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.

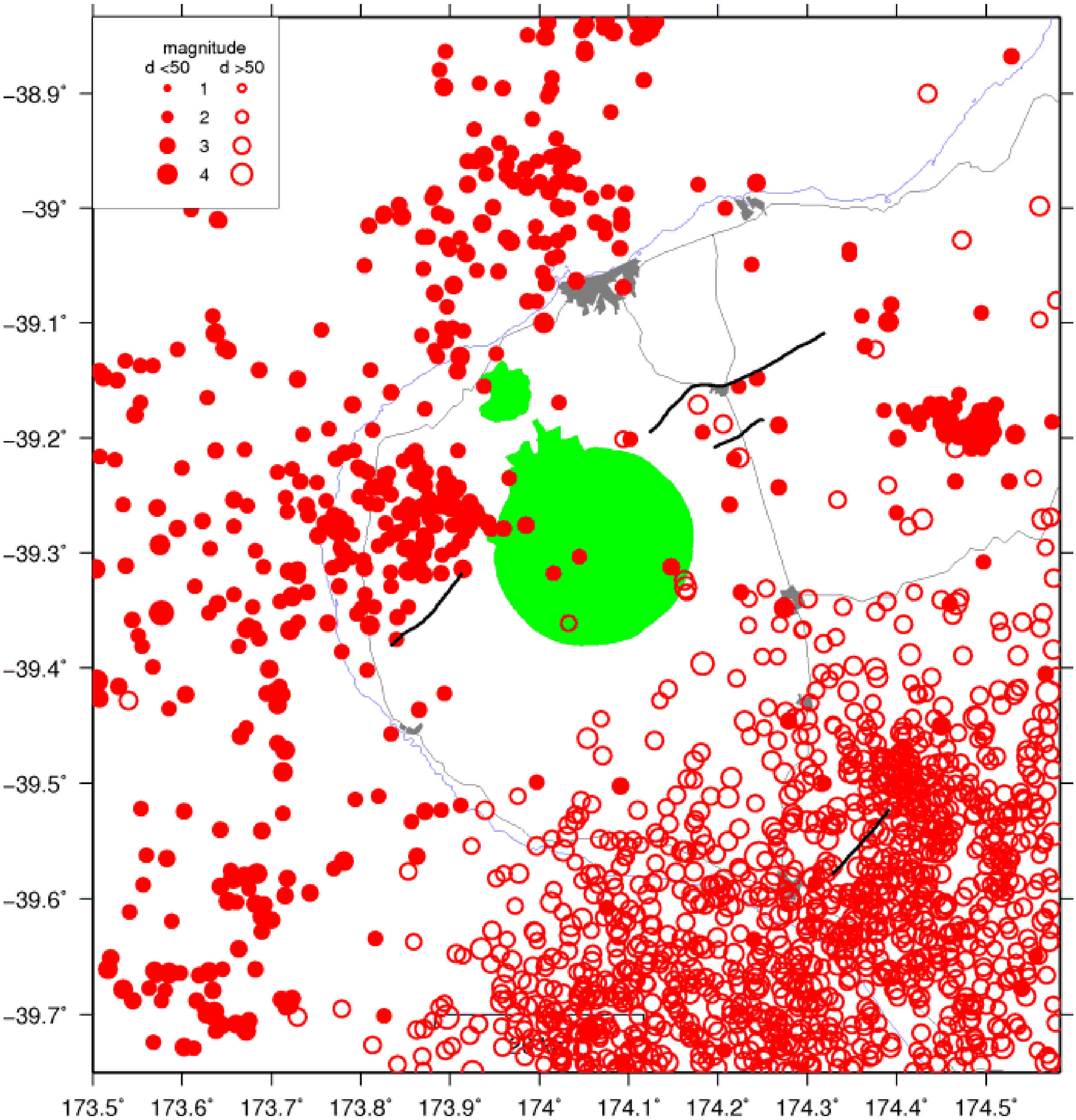

Figure 6. A map of earthquakes of M2.7 and larger located in Taranaki between January 1994 and June 2009. Data are from the GNS earthquake database. Closed circles indicate earthquakes less than 50 km deep and open circles those more than 50 km deep. The size of the symbol is proportional to the magnitude 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.

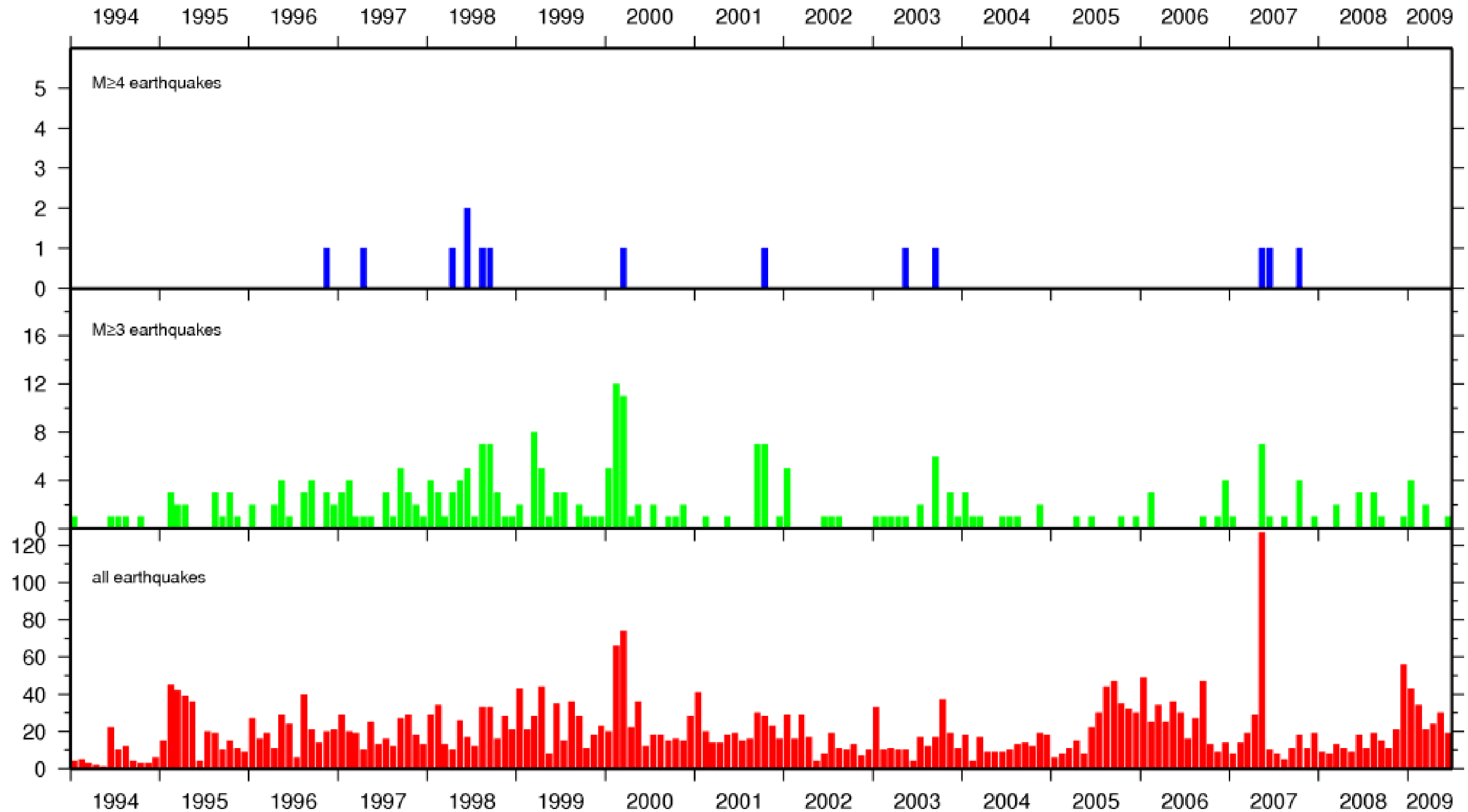

Figure 7. A histogram of the number of earthquakes less than 50 km deep that have occurred each month between January 1994 and June 2009 in the area shown in Figure 1. Three separate histograms are shown: all earthquakes (bottom), those of magnitude 3 and above (centre) and those of magnitude 4 and above (top)

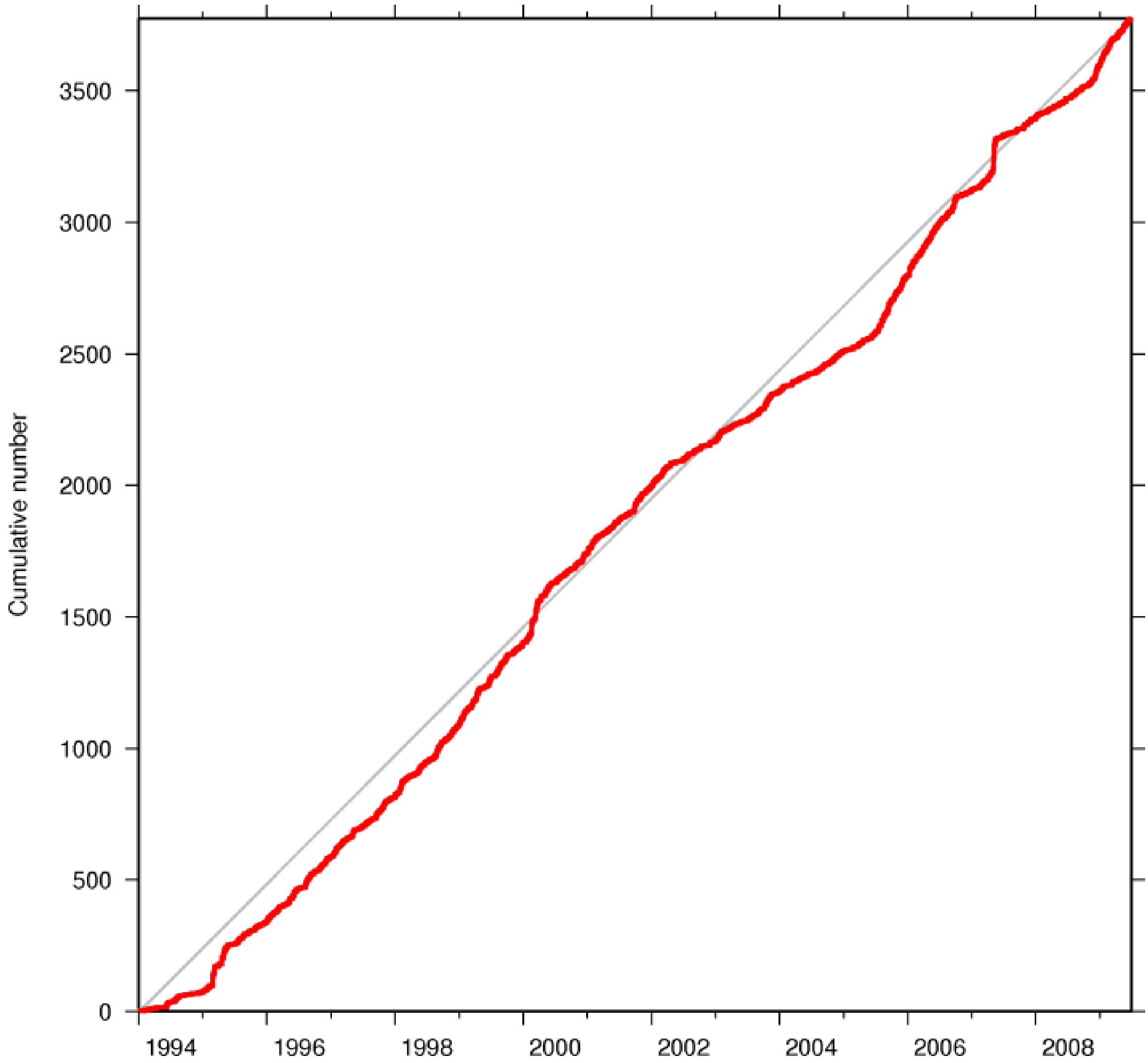

Figure 8. The cumulative number of earthquakes (red line) less than 50 km deep located in the area shown in Figure 1 between January 1994 and June 2009. The grey line shows the mean rate.

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