Short-term increase in earthquake risk at Macquarie Island

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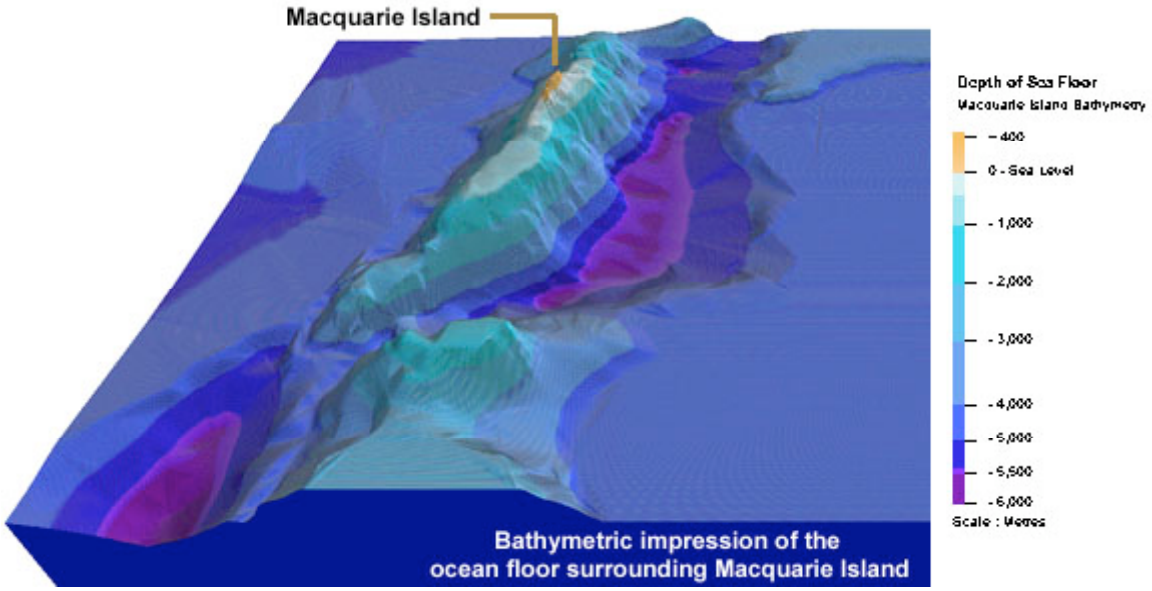
Summary: Major shallow earthquakes on the Macquarie Ridge in the past 100 years have exposed two seismic gaps, one centred on Macquarie Island. The Macquarie Ridge was created by crustal shortening due to oblique convergence of oceanic crust of the Pacific and Australian Plates. Computed earthquake mechanisms are either strike-slip or thrust. One of the gaps coincides with Macquarie Island but earthquake hazard estimates for the island, such as the values of the 475 year hazard coefficient in the 2008 Australian Loading Code, do not take account of this gap, based as they are on a purely random distribution of earthquakes. A major gap-filling earthquake could have serious consequences for both the residents and environment of Macquarie Island. The impact of a major (M≥7) close earthquake on the island would be to cause widespread landslides, and water and power supply disruption if not building damage. Damage risk is heightened by the possibility, perhaps 50:50, of a local tsunami being generated, depending only on the mechanism of the earthquake. The risk remains high for the next few decades, but reverts to the computed long-term value at the end of this period of enhanced activity. Coping with time-varying hazard is a novel but critical problem.



Pictures:
http://www.parks.tas.gov.au/macquarie/geology.html
http://www.environment.gov.au/heritage/places/world/macquarie/index.html

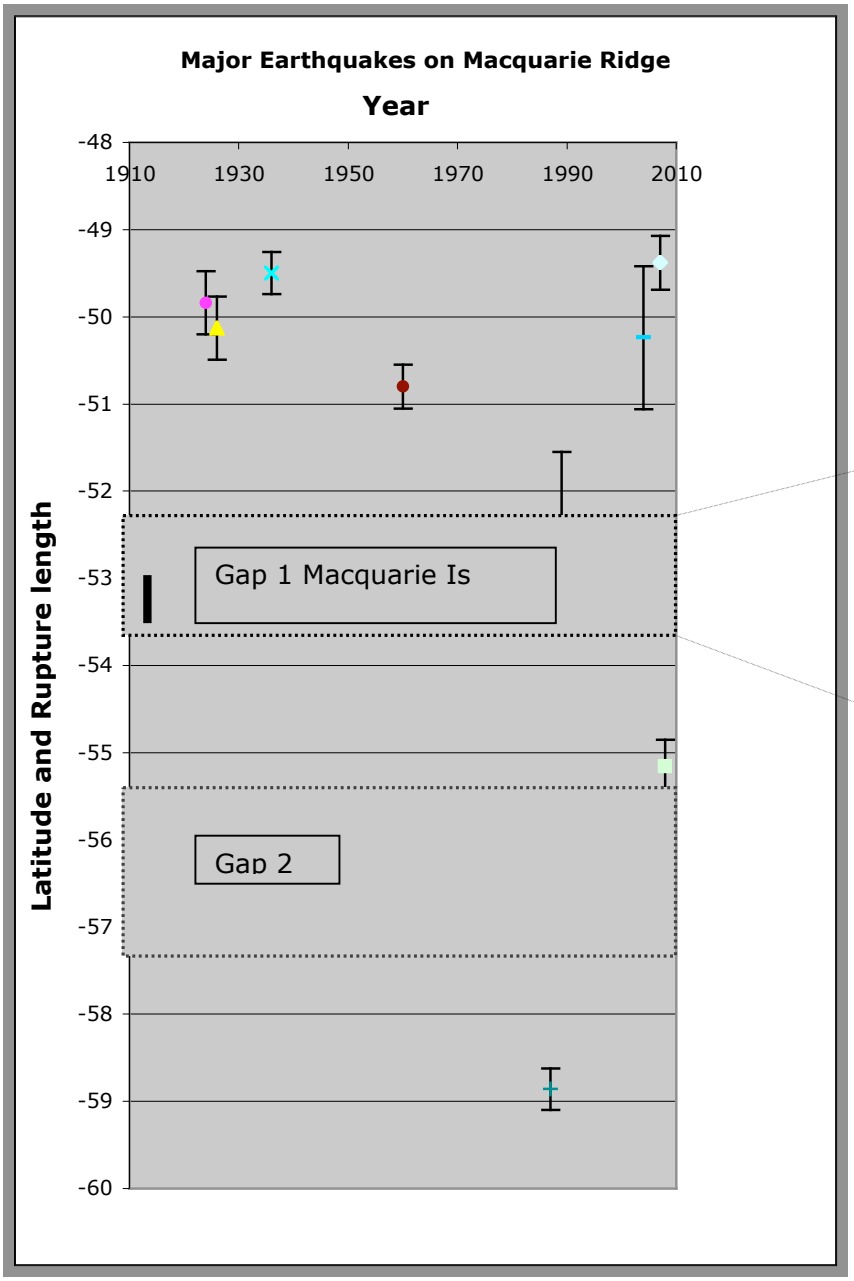
We can estimate the size of the gap by making an estimate of earthquake rupture length as a function of magnitude:

- Das (1993) found that the few small aftershocks of the M8.1, 1989 ss mainshock were distributed along a 220 km section of the plate boundary and that slip was bilateral.
- Ruff and others (1989) estimated the rupture length of the 1981 M7.7 thrust earthquake as 100 km.
- Worldwide, the rupture length L of a magnitude M6 earthquake is about 10 km.

From these we derive an indicative relationships between magnitude M and rupture length L:

$$M = 1.64 \log L(km) + 4.36$$
$$\text{or } \log L(km) = 0.6M - 2.6$$

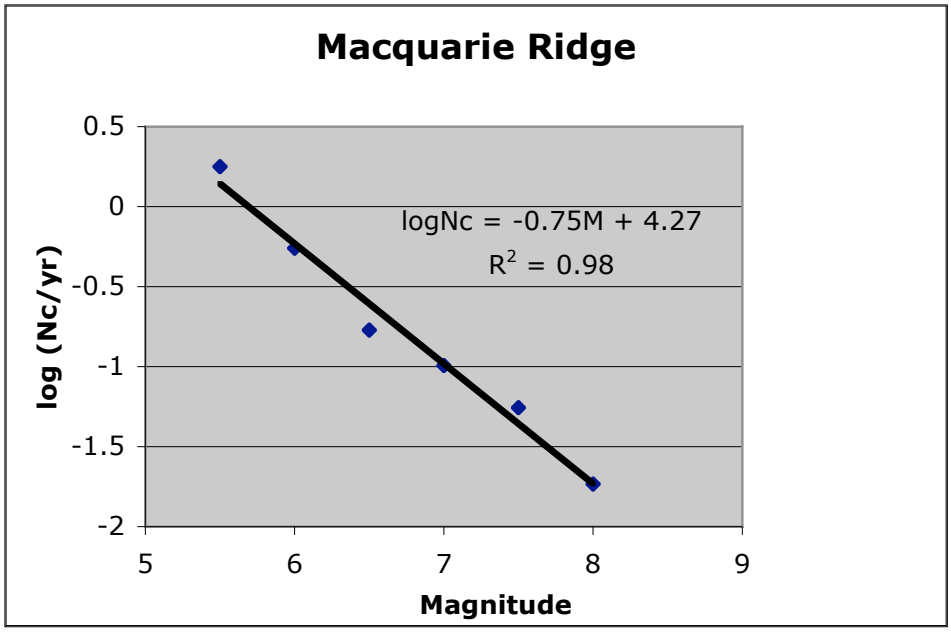
If we assume that all events are bilateral, indicated by scarce data, that the rupture zone of each earthquake is given by the equation above, and that the relocated early epicentres are reliable, then the gap near the island is at least 130 km long, sufficient to generate a magnitude 7.9 earthquake, or several magnitude 7^+ events. The southern gap, though larger, is too far from the island to be a threat.



http://www.environment.gov.au/biodiversity/science/abbbs/images/wandering-albatross.jpg
photo Michael Double

Table 1 Major shallow earthquakes on the Macquarie Ridge 1901 - 2008

Date	Time	Latitude	Longitude	**M**
19360222	153154.0	-49.5	164.0	7.2
19870903	64011.82	-58.859	158.476	7.2
19601213	73616.4	-50.8	160.3	7.25
20070930	52335.0	-49.38	164.01	7.4
20080412	3016.0	-55.16	159.04	7.4
19240724	45517.0	-49.84	160.08	7.5
19261003	193801.0	-50.13	159.43	7.5
19240626	13734.0	-56.0	157.5	7.8
19430906	34130.0	-53.0	159.0	7.8
19890523	105446.24	-52.371	160.642	8.1
20041223	145904.0	-50.24	160.13	8.1



Data ISC M≥5.5, 1962 – 2008.25, M≥7, 1901 – 2008.25

Table 2 Predicted magnitudes vs earthquake return period on the Macquarie Ridge

Return Period (years)	1	10	100	*Reference*
Magnitude	5.7	7.0	8.3	this study
Magnitude	6.2	7.2	8.2	Jones and McCue (1988)

Discussion

Earthquakes do not occur at regular intervals but are clustered in time and space. On plate boundaries events may be coupled (earthquakes on the North Anatolian Fault since 1939 clearly migrate from east to west along the fault, behaviour that is strongly non-stochastic). Hazard estimates average the time between events over several cycles and neglect the short-term increase in hazard during an earthquake cluster.

On the evidence of earthquake activity since 1989, it is concluded that a seismic gap about 130 km long is centred on Macquarie Island, and that we are at the height of the earthquake cycle. There is a heightened risk of a major earthquake occurring near the island in the next few decades.

Such an earthquake would cause severe landslides and threaten vulnerable facilities; the diesel generator, diesel-tank farm, communications systems and water supply. The living quarters were built to survive strong winds and are unlikely to suffer structural damage. Should a major gap-filling earthquake occur, there is a high risk that consequent events, a tsunami and damaging aftershocks, will follow.

The Australian Government is responsible for the welfare of the expeditioners on this very remote island and for the environmental consequences of a major fuel leak. They should develop a strategic plan to provide a rapid response should a major earthquake occur there.

Photos of Pillow lavas

References

Coffin, M.F., Karner, G.D., and Falvey, D.A., 1994. Research cruise yields new details of Macquarie Ridge Complex, Eos, 75, 561-564.

Das S., 1993. The Macquarie Ridge earthquake of 1989. Geophysical Journal International, 115 (3), pp 778-798.

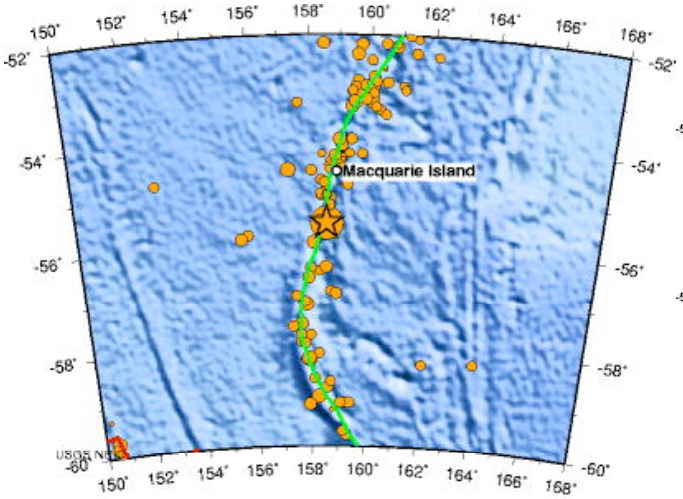
Jones T.D. & McCue K.F., 1988. The Seismicity and Tectonics of the Macquarie Ridge. in Eds Banks and Smith, Papers & Proceedings of the Royal Society of Tasmania, 122(1). pp 51-57.

Ruff, L.J., Given, J.W., Sanders C.O., and Sperber C.M., 1989. Large Earthquakes in the Macquarie Ridge Complex: Transitional Tectonics and Subduction Initiation. PAGEOPH, Birk Niuser Verlag, Basel Vol. 129, Nos. 1/2, pp 71-129.

Macquarie Ridge seismicity 1990 - 2008

North

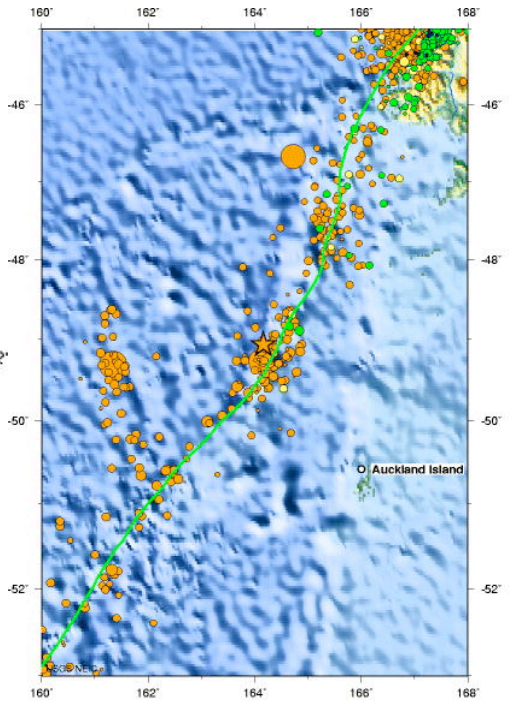
South



MACQUARIE ISLAND REGION

2008 04 12 00:30:12 UTC 55.61S 158.57E Depth: 16 km, Magnitude: 7.1

Seismicity 1990 to Present

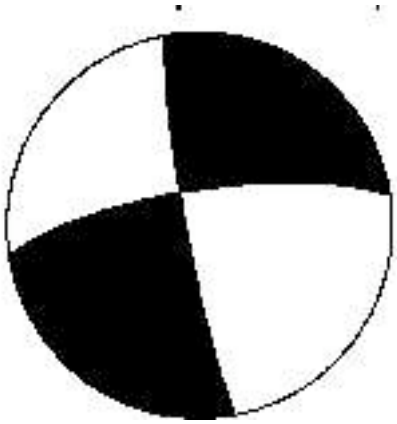


AUCKLAND ISLANDS, N.Z. REGION

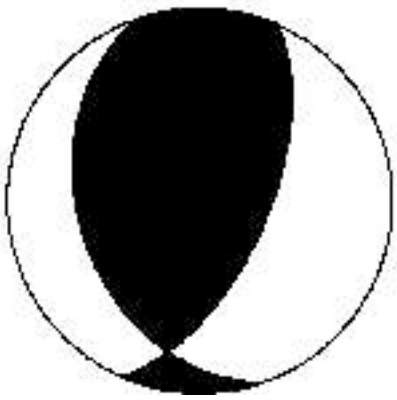
2008 04 26 23:34:49 UTC 49.06S 164.16E Depth: 10.0 km, Magnitude: 6.1

Seismicity 1990 to Present

Typical earthquake focal mechanisms on Macquarie Ridge



2004-12-23 earthquake, USGS focal mechanism
Epicentre 500 km north of the Island



2008-04-12 earthquake, USGS focal mechanism
Epicentre 115km south of the Island

At Risk!

Photos
1-3 Mike Preece
4-6 Noel Carmichael
http://www.environment.gov.au/heritage/places/world/Macquarie/gallery.html