

COMMENT

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Emergency drills such as this mislead the public into believing that the Tokai district is due a magnitude-8 quake soon.

Shake-up time for Japanese seismology

Robert J. Geller calls on Japan to stop using flawed methods for long-term forecasts and to scrap its system for trying to predict the ‘Tokai earthquake’.

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For the past 20 years or so, some seismologists in Japan have warned of the seismic and tsunami hazards to the safety of nuclear power plants, most notably Katsuhiko Ishibashi, now professor emeritus at Kobe University. Their warnings went unheeded. Yet in the immediate aftermath of the magnitude-9.1 earthquake that struck Tohoku on 11 March, pundits could be found on many Japanese TV stations saying that it was “unforeseeable”.

The ‘foreseen’ earthquakes were presumably the hypothetical future earthquakes used by the Japanese government to produce national seismic hazard maps for Japan¹. The modellers assume that ‘characteristic earthquakes’ exist for various zones, choose the fault parameters for each zone as the input to their model, and then produce probabilistic hazard maps.

Although such maps may seem authoritative, a model is just a model until the ▶

SUMMARY

- The Japanese government should admit to the public that earthquakes cannot be reliably predicted.
- Use of the misleading term ‘Tokai earthquake’ should cease.
- The 1978 Large-Scale Earthquake Countermeasures Act should be repealed.

► methods used to produce it have been verified. The regions assessed as most dangerous are the zones of three hypothetical 'scenario earthquakes' (Tokai, Tonankai and Nankai; see map). However, since 1979, earthquakes that caused 10 or more fatalities in Japan actually occurred in places assigned a relatively low probability. This discrepancy — the latest in a string of negative results for the characteristic earthquake model and its cousin, the seismic-gap model²⁻⁴ — strongly suggests that the hazard map and the methods used to produce it are flawed and should be discarded.

Globally, in the past 100 years, there have been five subduction-zone earthquakes of magnitude 9 or greater (Kamchatka 1952, Chile 1960, Alaska 1964, Sumatra 2004, Tohoku 2011), which suggests that the upper limit on the possible size of a subduction-zone earthquake may not much depend on the details of the subduction modality⁵. Large tsunamis have frequently struck the Pacific coast of the Tohoku district. The

well-documented 1896 Sanriku tsunami had a maximum height of 38 metres and caused more than 22,000 deaths. The 869 Jogan tsunami is documented to have had a height roughly comparable to, or perhaps slightly less than, that of the 11 March tsunami.

If global seismicity and the historical record in Tohoku had been used as the basis for estimating seismic hazards, the 11 March Tohoku earthquake could easily have been 'foreseen' in a general way, although not of course its particular time, epicentre or magnitude. Countermeasures for dealing with such events could and should have been incorporated in the initial design of the Fukushima nuclear power plants.

THE 'TOKAI EARTHQUAKE'

In the 1960s, plate tectonics became generally accepted as the fundamental paradigm of solid-Earth geoscience. Researchers in several countries made efforts to combine plate tectonics with seismicity data to make

long-term forecasts of large earthquakes. The idea was very simple. It was hypothesized that zones where no large earthquakes had occurred for a while, dubbed 'seismic gaps', were ripe for imminent large events. However, the seismic-gap hypothesis failed the test of reality². Over tens of thousands of years or longer, the net slip released by earthquakes and aseismic slip must match net inter-plate motion. But we now know that this catching-up process does not occur regularly or cyclically, as is further underscored by the 11 March earthquake.

In the mid-1970s, when enthusiasm for the seismic-gap model was still widespread in the global geoscience community, several researchers in Japan proposed that the plate boundary off the Tokai district was a seismic gap where a magnitude-8 earthquake could be expected⁶. The neighbouring Tonankai and Nankai districts were also labelled as being seismic gaps⁷. No large earthquake has occurred in any of these districts since 1975, but they are still classified as the most hazardous regions in the country by the Japanese government (see map).

Over the past 30 years or so, government spokesmen and university scientists associated with the government's Headquarters for Earthquake Research Promotion (or its various predecessors) have used the term 'Tokai earthquake' so often that the public and news media have come to view it as a 'real earthquake' rather than merely an arbitrary scenario (1.78 million hits in a Japanese-language Google search). This misleads the public into believing that the clock is ticking down inexorably on a magnitude-8 earthquake that is certain to strike the Tokai district in the near future. Use of the term 'Tokai earthquake' (and its companions 'Tonankai earthquake' and 'Nankai earthquake') should therefore cease.

UNPREDICTABLE EARTHQUAKES

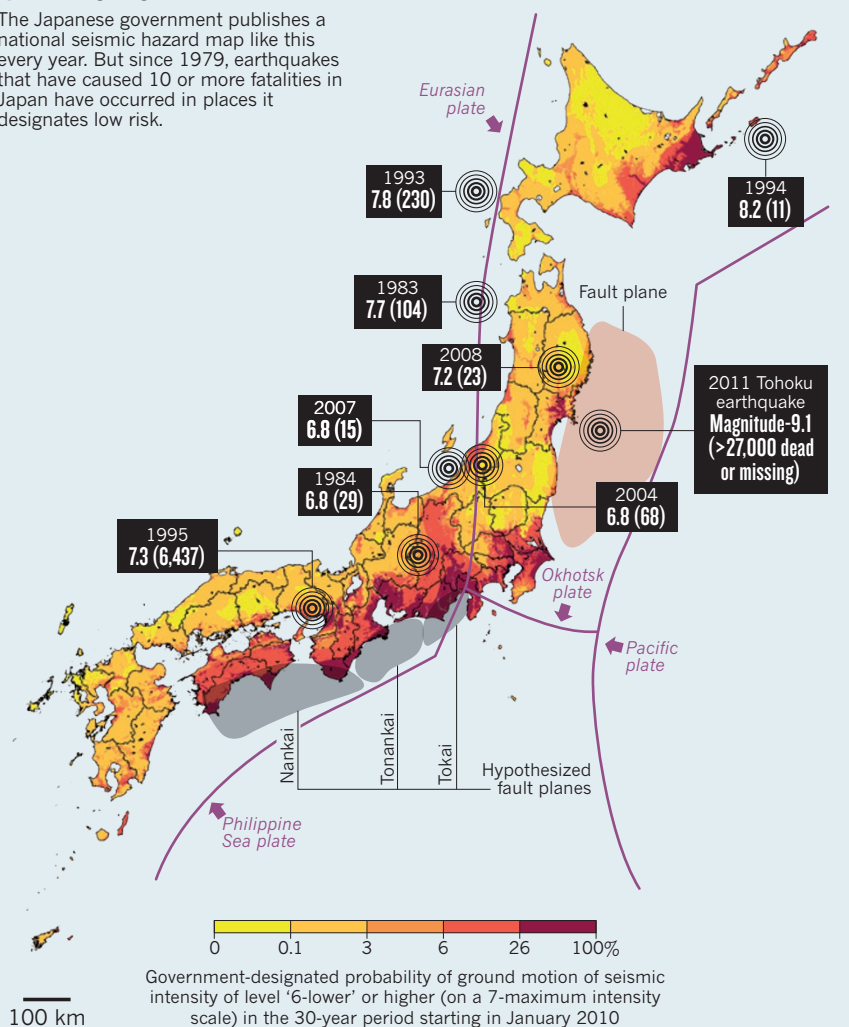
Throughout most of seismological history, the prediction of earthquakes hours or days in advance has, for good reason, been regarded with great scepticism⁸ (see go.nature.com/ahc6nx). However, in the late 1960s and early 1970s, several studies, initially by researchers in the Soviet Union, and followed by similarly positive studies from major US institutions, led to a burst of optimism. The editors of *Nature* wrote in 1973 that the "situation is in some ways similar to that in 1939 when nuclear fission suddenly became a reality"⁹. Positive results were also published at roughly the same



WWW.NATURE.COM/JAPANQUAKE

REALITY CHECK

The Japanese government publishes a national seismic hazard map like this every year. But since 1979, earthquakes that have caused 10 or more fatalities in Japan have occurred in places it designates low risk.



time in *Science* and some leading speciality journals.

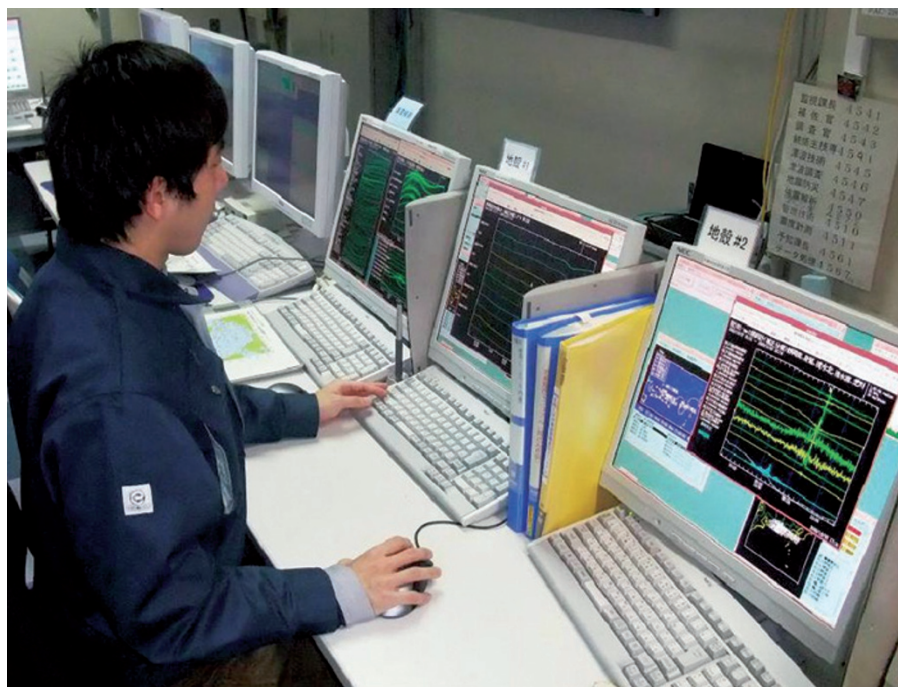
The positive reports were based on claims to have observed 'precursors' of earthquakes. For example, some studies of the type discussed in *Nature's* 1973 article claimed to have observed decreases of 10–20% in crustal seismic velocities before earthquakes, with the return of the velocities to their normal values being the sign that an earthquake was imminent. But the 1976 earthquake in Tangshan, China, which caused a reported 240,000 fatalities, was not predicted, and by the late 1970s it had become clear to most researchers that the supposed precursors were artefacts. The prediction boom then largely died out, but like many similar examples (such as poly-water and cold fusion), die-hard holdouts in several countries continue to make precursor claims.

BASELESS PREDICTION LAW

By the mid-1970s, public discussion of the supposedly imminent Tokai earthquake reached quasi-panic levels. This was exploited by the Japan Meteorological Agency (JMA) and university scientists, who persuaded the Japanese parliament to enact the Large-Scale Earthquake Countermeasures Act (LECA) in 1978. This law in effect requires the JMA to operate a 24/7 monitoring system to detect precursors indicating that the 'Tokai earthquake' (see map) will occur within up to three days. If and when signals thought to be precursors are ever observed, a panel of five geophysicists will review the data, the JMA director will inform the prime minister, and the cabinet will then declare a state of emergency, which will stop almost all activity in a wide area around the Tokai district.

This law, which has no precedent in any other country, presumes of course that reliable precursors exist. In particular, on the basis of one report of a geodetic precursor of an earthquake in Japan in 1944 (see Fig. 2 in ref. 6), geodetic slip is the main target of the JMA observations. The 1944 data, taken far from the epicentral region, were interpreted as possibly suggesting uplift of a few centimetres due to slow slip on a deep part of the fault shortly before the main shock. Unfortunately, the data were measured using antiquated surveying techniques, and are subject to considerable uncertainty. Nothing of this type has ever been observed using Global Positioning System devices or other modern measurement techniques. A famous report of a supposed geodetic precursor, the 'Palmdale

"We should instead tell the public and the government to 'prepare for the unexpected'."



The Japan Meteorological Agency control room conducts monitoring to predict the 'Tokai earthquake'.

Bulge', in the United States in the 1970s was later shown to be an artefact⁸.

Basing even a large-scale programme of observational research on the 1944 data would be uncalled for. It beggars belief, then, that the Japanese government operates a legally binding earthquake-prediction system on this basis. The JMA's official home page says (author's translation): "At present the only place a system for predicting earthquakes exists is for a magnitude-8 earthquake with an epicenter offshore Suruga Bay, i.e. the 'Tokai earthquake'. Science and technology have not progressed sufficiently to allow other earthquakes to be predicted." But there are many more observatories now than in 1978. If it really were possible to predict the 'Tokai earthquake' then, surely it would be possible to predict all magnitude-8 earthquakes now.

TIME FOR OPENNESS

How is it that the Tokai prediction system has been in place for more than 30 years, with barely a whimper from most mainstream Japanese seismologists? The reasons for this silence are complex. First, many researchers have been co-opted in various ways (such as with funding and committee memberships). Second, government decisions are nominally reviewed, but review panels are chosen by bureaucrats of the agency being reviewed. Third, cogent criticisms do get reported by print media, but are usually ignored by broadcasters, so critics don't get much traction. Fourth, through the 'press club' system, the government pipes its views directly into the media, often through reporters lacking in

scientific knowledge. Finally, as long as the LECA stays on the books, the government can claim that it is obligated by law to try to predict the Tokai earthquake.

It is time to tell the public frankly that earthquakes cannot be predicted, to scrap the Tokai prediction system and to repeal the LECA. All of Japan is at risk from earthquakes, and the present state of seismological science does not allow us to reliably differentiate the risk level in particular geographic areas. We should instead tell the public and the government to 'prepare for the unexpected'¹⁰ and do our best to communicate both what we know and what we do not. And future basic research in seismology must be soundly based on physics, impartially reviewed, and be led by Japan's top scientists rather than by faceless bureaucrats. ■

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1. Headquarters for Earthquake Research Promotion, National Seismic Hazard Maps for Japan (2005); available at <http://go.nature.com/yw5e92>.
2. Kagan, Y. Y. & Jackson, D. D. *J. Geophys. Res.* **96**, 21419–21431 (1991).
3. Kagan, Y. Y. *Bull. Seism. Soc. Am.* **86**, 274–285 (1996).
4. Newman, A., Schneider, J., Stein, S. & Mendez, A. *Seismol. Res. Lett.* **72**, 647–663 (2001).
5. McCaffrey, R. *Geology* **36**, 163–266 (2008).
6. Ando, M. *Tectonophysics* **25**, 69–85 (1975).
7. Ando, M. *Tectonophysics* **27**, 119–140 (1975).
8. Geller, R. J. *Geophys. J. Int.* **131**, 425–450 (1997).
9. *Nature* **245**, 174 (1973).
10. Kanamori, H. *Seismol. Res. Lett.* **66**(1), 7–8 (1995).