Journal of Asian Earth Sciences 114 (2015) 431–434

Contents lists available at ScienceDirect

Journal of Asian Earth Sciences

journal homepage: www.elsevier.com/locate/jseaes

Current affairs in earthquake prediction in Japan

Seiya Uyeda

Japan Academy, Tokyo 110-000, Japan

ARTICLE INFO

Article history:
Received 11 September 2014
Received in revised form 5 June 2015
Accepted 6 July 2015
Available online 7 July 2015

Keywords:
Earthquake
Prediction
Precursor
Private sector

ABSTRACT

As of mid-2014, the main organizations of the earthquake (EQ hereafter) prediction program, including the Seismological Society of Japan (SSJ), the MEXT Headquarters for EQ Research Promotion, hold the official position that they neither can nor want to make any short-term prediction. It is an extraordinary stance of responsible authorities when the nation, after the devastating 2011 M9 Tohoku EQ, most urgently needs whatever information that may exist on forthcoming EQs. Japan's national project for EQ prediction started in 1965, but it has made no success. The main reason for no success is the failure to capture precursors. After the 1995 Kobe disaster, the project decided to give up short-term prediction and this stance has been further fortified by the 2011 M9 Tohoku Mega-quake. This paper tries to explain how this situation came about and suggest that it may in fact be a legitimate one which should have come a long time ago. Actually, substantial positive changes are taking place now. Some promising signs are arising even from cooperation of researchers with private sectors and there is a move to establish an "EQ Prediction Society of Japan". From now on, maintaining the high scientific standards in EQ prediction will be of crucial importance.

1. Introduction

Earthquake (EQ hereinafter) prediction must specify the time, epicenter, and size of an impending EQ with useful accuracy. Among the so called long-, intermediate- and short-term predictions, only short-term prediction is meaningful. Some precursors are absolutely needed for short-term prediction. There have been many kinds of EQ precursors, *e.g.*, Uyeda et al. (2011). Seismological events like foreshocks can be precursors. However, the majority of precursors are non-seismological. The national project for EQ prediction in Japan, started in 1965, has not made even a single success. The main reason for no success was failure to grasp precursors as described by Uyeda (2013).

Seismology has two major branches. One is to investigate Earth' internal structure by means of seismic waves and the other is to study EQs themselves. The latter is called EQ seismology, although it may sound tautological. So called "EQ seismology" may be said to have started in California, after the 1906 M.8.3 San Francisco EQ with the presentation of the elastic rebound theory by Reid (1910). It was in the 1960s that national projects for EQ prediction started in several countries including Japan, USSR, China and USA. Optimism prevailed globally in the early 1970s perhaps due to the advent of the dilatancy-diffusion model of Sholtz et al. (1973), and the success of prediction of the 1975 M7.3 Haisheng EQ, *e.g.*, Press (1975).

However, this optimism was short-lived because no success but failures were made in the following years. The Chinese failed to predict the 1975 M7.8 Tangshan EQ (Chen et al., 1988) and the Americans failed prediction of the Parkfield EQ (Langbein et al., 2005). The whole community became pessimistic, *e.g.*, Evernden (1982). This pessimism has persisted, except in a minority community consisting of researchers who remained positive on EQ precursors (Uyeda et al., 2009). This work, following Uyeda (2013), tries to catch up the current affairs in EQ prediction in Japan.

2. Modern history of EQ prediction in Japan

(a) Before 1995

EQ prediction was discussed as early as in 1946, the next year after Japan lost the World War II, between US and Japanese seismologists through orders of the General Headquarters (GHQ) of the US occupation forces (Hagiwara, 1979; Rikitake, 2001). This stimulated the Japanese community to EQ prediction. Then in 1962 a plan, generally called the "Blueprint for EQ prediction" (Tsuboi et al. (1962), was put forward.

The contents of the "Blueprint", written long before the advent of plate tectonics, were essentially empirical, proposing enhancement of every possible monitoring, including even geomagnetism

E-mail address: suyeda@st.rim.or.jp

http://dx.doi.org/10.1016/j.jseaes.2015.07.006
1367-9120/© 2015 Published by Elsevier Ltd.

and geoelectric currents. However, to begin with, the government asked seismologists to formulate a practical program for the "EQ Prediction Research Project". Naturally, the program they produced was heavily biased to seismology, emphasizing installations of seismic network, which is not useful for precursor search. The project was started in 1965 and has continued until now through consecutive five year plans. Because of the ample funds secured for multiple years, however, strengthening seismic network became an endless enterprise and the quest for non-seismic precursor was left disdained. From the second five year plan, the name of the project became "EQ Prediction Project" as if the "research" stage was over. The project prospered after every disastrous event without any success of prediction. Although the need for non-seismological measurements was obvious, they would not change their vested interest policy.

(b) After 1995–2011

The 1995 M7.3 Kobe EQ occurred without prediction, during the seventh five year plan (Fig. 1). The national project, which never made a prediction, was fiercely attacked. After prolonged deliberations at various levels, they decided to give up short-term prediction because precursors are too difficult to deal with, *e.g.*, Swinbanks (1997) and that efforts should concentrate on the "fundamental research", which actually was seismology. By this maneuver, the project not only survived the criticism but also funding was increased. Thanks to this success, dense high-power seismic and GPS networks were installed to cover the whole country and seismology greatly benefitted. But, of course, hardly any precursory information was obtained. After this, the no short-term prediction policy was escalated even to "decide" that precursors do not exist and the research on them is not science.

(c) After 2011 Tohoku EQ to present

On 11 March 2011, the M9.0 Tohoku-Oki EQ hit Japan (Fig. 2). This EQ produced a huge tsunami, resulting in a large scale devastation, including the loss of over 20,000 human lives, and explosions and melt down at Fukushima No.1 Nuclear Plant (Tanaka, 2012). This type of EQ was considered well explained by the so called asperity model but they could not even imagine that M9 EQ is possible. By this complete failure, seismologists at large lost their last bit of confidence. They now talk about even abolishing the Working Group for EQ Prediction of the Seismological Society of Japan (SSJ). The present official attitude of the Headquarters

Fig. 1. A damaged high rise by 1995 January 17, M7.2 Kobe EQ. Picture taken by the author on February 25, 1995.

Fig. 2. Tsunami on March 3, 2011, overriding the Sekii River breakwater. Photo by courtesy of the Miyako City Office (Iwate Prefecture).

for EQ Research Promotion of Ministry of Education, Culture, Sports, Science and Technology, (MEXT) is that their role is long-term statistical forecasting of seismicity and they are not interested in short-term EQ prediction. These are extraordinary positions for responsible authorities at the very time when the nation really urgently needs all possible information on forthcoming EQs, for instance the hyper EQ (Fig. 3) suggested in (Furumoto, 2007), especially after the devastating 2011 M9 Tohoku EQ. This is irresponsible. Now, even the title of the national project has been changed to "Promotion of EQ and Volcano Observation Research Project to Contribute to Disaster Mitigation", dropping the word "prediction". Realizing that EQ prediction is no longer an easy financial source, the boat shifted the helm to "disaster prevention".

Putting these affairs aside, let us examine if there were some precursors to the M9 Tohoku-Oki EQ. Although this EQ was a complete surprise, there were some precursors. Naturally, they are all post-seismic findings. Recently Nagao et al. (2014) have reviewed the relevant papers reporting precursors. We will pick up here mainly short-term precursors.

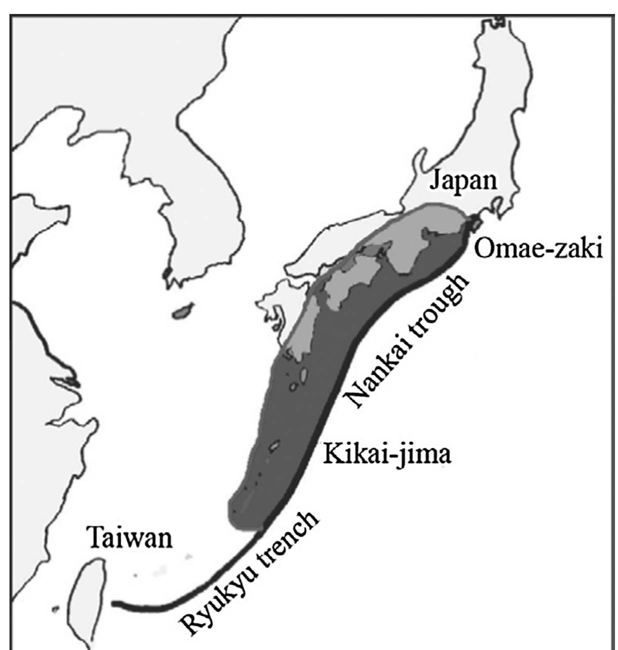

Fig. 3. Possibility of a hyper earthquake along the trench from Tokai to Ryukyuu regions, Japan (Furumoto, 2007).

(1) Seismicity: Nagao et al. (2011) demonstrated seismic activation started in about mid-2009 and culminated at the main shock. Using also JMA's catalog, Sarlis et al. (2013), based on the concept that EQs are critical phenomena, showed that fluctuation of an order parameter of seismicity revealed a deep minimum a few months before the Mega-quake. Kato et al. (2012) described propagation of slow slip up to the short-term period. Encouraging is that reports are starting to come out from seismology. Apparently, the high power seismic network of the national project finally became productive.
(2) Electric–Magnetic: There were reports on the pre-seismic reception of anomalous VLF and LF waves (Hayakawa et al., 2012) and on the anomalous diurnal variations of the geomagnetic field approximately 2 months prior to the main shock (Xu et al., 2013). An issue of hot debate is the pre-seismic variation of the ionospheric electron content (TEC). Ouzounov et al. (2011) claimed that they observed short-term signals such as outgoing long-wave radiation (OLR) near the epicenter.
(3) Land movements: Another highly promising new development is the detection of pre-seismic land movements using GPS data (*e.g.*, Chen et al., 2013). The recent paper Kamiyama et al. (2014) thoroughly treats the GPS and EM precursors of the Tohoku EQ.

3. Outlook for the future

The future of short-term prediction funding looks bleak. However, the present author would like to point out that the present extraordinary looking situation may in fact be a sound "legitimate" one, which should have been reached a long time ago in Japan. The reason is that the job of short-term EQ prediction is finally transferred from the hands of those who unduly monopolized it for a long time to the hands of proper researchers who are eager and possibly capable of doing the job. It is crucial here to understand that short-term EQ prediction should be possible by conducting proper scientific endeavors, which in this case is the precursor study.

In fact, we already have a number of undeniable accomplishments. Reports on electromagnetic and geochemical precursors started to come out even soon after the 1995 Kobe EQ. It was found that anomalous changes in the telluric current on Niijima-island and in the geomagnetic field on Izu Peninsula started a few months before the onset of the 2000 major volcano-seismic swarm activity in the Izu island region, and culminated immediately before the nearby M6 class EQs. Also in the Izu island region, 19 anomalous changes in the telluric current on Kozu-shima Island were identified as precursors to nearby EQs because their coincidence was statistically shown to be far beyond by chance (Orihara et al., 2012). Moriya et al. (2010) modified the method to observe anomalous pre-seismic transmission of VHF-band radio waves, initiated in 1995 by Kushida and Kushida (2002), in Hokkaido and obtained significant results. An also significant contribution was made by Oyama et al. (2008) through the satellite Hinotori observation of ionospheric electron temperature anomaly a few days before large EQs.

Another remarkable new aspect in the short-term EQ prediction is the rise of private companies. The reason for the rise is obvious. Now the demands for short-term prediction are unprecedentedly acute from industries, hospitals, elder care facilities, schools, local governments, public transport, individuals and so on. They realize that the national projects cannot be counted on and are willing to pay necessary costs for their safety. This situation, however, seems to be raising new problems at the same time. Now a number of enterprises for short-term EQ prediction are beginning their business but some of them are money-driven and hardly trustworthy. We have to be very careful to maintain the scientific level of EQ prediction high.

4. Conclusion

Japan's National Program for EQ prediction started in 1965, but it has achieved no success. The main reason for no success is the failure to capture precursors. Most of the financial resources and manpower have been devoted to strengthening the seismic networks, which are not effective for detecting EQ precursors. After the 1995 Kobe disaster, the project decided to give up short-term prediction and this decision has been further fortified by the failure in 2011. After the Tohoku Mega-quake, there has been considerable confusion, and now the National Project carries an arcane title "Earthquake and Volcano Observation Research Project to Contribute to Disaster Mitigation", dropping the word "prediction".

This situation however, may be a sound legitimate state, which should have come a long time ago, because this gives the job of EQ prediction to the scientists of diverse disciplines, including even seismologists, who devote to the real short-term prediction. Actually, substantial changes are taking place at present. Recently, some promising signs are arising from the private sectors. Precursor research is being carried out by the interested scientists and actual prediction alerts are issued through private companies or the local authorities of high EQ/tsunami risk areas. There is a move to establish an "EQ Prediction Society of Japan".

We look forward to a big-bang in the earthquake prediction. The EQ prediction will be the best international contribution that Japanese science and technology can make to the circum-Pacific and other earthquake countries.

Acknowledgments

The author wishes to express sincere thanks to his life-long friend Tom Hilde for many pertinent advices on the present paper. This work has been partially supported by the Ministry of Education, Science, Sports and Culture, Grant-in-Aid for Scientific Research (C), 26350483, 2011.

References

Chen, Y., Tsoi, K., Chen, F., Gao, G., Zou, Q., Chen, Z., 1988. The Great Tangshan Earthquake of 1976. Pergamon, Tarrytown, 153 pp.
Chen, C.H., Wen, S., Liu, J.Y., Hattori, K., Han, P., Hobara, Y., Wang, C.H., Yeh, T.K., Yen, H.Y., 2013. Surface displacements in Japan before the 11 March 2011 M9.0 Tohoku-Oki earthquake. J. Asian Earth Sci. 80, 165–171.
Evernden, J., 1982. Earthquake prediction: what we have learned and what we should do now. Bull. Seismol. Soc. Am. 72, 343–349.
Furumoto, M., 2007. Possibility of a hyper earthquake along the trench from Tokai to Ryukyuu regions, Japan. Report of The Coordinating Committee for Earthquake Prediction (CCCP), Japan, vol. 78, pp. 602–605.
Hagiwara, T., 1979. In: Coordinating Committee for EQ Prediction – Progress in Ten Years (in Japanese). Geographical Survey Institute, 262 pp.
Hayakawa, M., Hobara, Y., Yasuda, Y., Yamaguchi, H., Ohta, K., Izutsu, J., Nakamura, T., 2012. Possible precursor to the March 11, 2011, Japan Earthquake: ionospheric perturbations as seen by subionospheric very low frequency/low frequency propagation. Ann. Geophys. 55 (1), 95–99. http://dx.doi.org/10.4401/ag-5357.
Kamiyama, M., Sugito, M., Kuse, M., Schekotov, A., Hayakawa, M., 2014. On the precursors to the 2011 Tohoku earthquake: crustal movements and electromagnetic signatures. Geomatics, Nat. Hazards Risk. http://www.tandfonline.com/doi/abs/10.1080/19475705.2014.937773#.VeGvW_btlBc.
Kato, A., Obara, K., Igarashi, T., Tsuruoka, H., Nakagawa, S., Hirata, N., 2012. Propagation of slow slip leading up to the 2011 Mw 9.0 Tohoku-Oki Earthquake. Science 335, 705–708. http://dx.doi.org/10.1126/science.1215141.
Kushida, Y., Kushida, R., 2002. Possibility of earthquake forecast by radio observations in the VHF band. J. Atmos. Elect. 22, 239–255.
Langbein, J., Dreger, D., Fletcher, J., Harde-beck, J.L., Hellweg, M., Ji, C., Johnston, M., Murray, J.R., Nadeau, R.M., Rymer, M., 2005. Preliminary report on the 28 September 2004, 6.0 Parkfield, California earthquake. Seismol. Res. Lett. 76, 10–26.

Moriya, T., Mogi, T., Takada, M., 2010. Anomalous pre-seismic transmission of VHF-band radio waves resulting from large earthquakes, and its statistical relationship to magnitude of impending earthquakes. Geophys. J. Int. 180, 858–870.

Nagao, T., Takeuchi, A., Nakamura, K., 2011. A new algorithm for detection of seismic quiescence. Introduction of RTM algorithm, a modified RTL algorithm. Earth Planets Space 63, 182–183.

Nagao, T., Orihara, Y., Kamogawa, M., 2014. Precursory phenomena possibly related to the 2011 M9.0 off the Pacific coast of Tohoku earthquake. J. Disaster Res. 9, 303–310.

Orihara, T., Kamogawa, M., Nagao, T., Uyeda, S., 2012. Pre-seismic anomalous telluric current signals observed in Kozu-shima Island, Japan. Proc. Natl. Acad. Sci. USA 106 (47), 19125–19128. http://dx.doi.org/10.1073/pnas.1215669109.

Ouzounov, D., Pulinets, S., Romanov, A., Romanov, K., Tsybulya, D., Kafatos, M., Taylor, P., 2011. Atmosphere-ionosphere response to the *M*9 Tohoku earthquake revealed by multi-instrument space-borne and ground observations: preliminary results. Earthquake Sci. 24, 557–564.

Oyama, K., Kakinami, Y., Liu, J.Y., Kamogawa, M., Kodama, T., 2008. Reduction of electron temperature in low-latitude ionosphere at 600 km before and after large earthquakes. J. Geophys. Res. 113, A11317. http://dx.doi.org/10.1029/2008JA013367.

Press, F., 1975. Earthquake prediction. Scientific Am. 232 (5), 14–23.

Reid, F.H., 1910. The Mechanics of the Earthquake, the California Earthquake of April 18, 1906. Report of the State Investigation Commission, vol. 2, Carnegie Institution of Washington, Washington, D.C.

Rikitake, T., 2001. Earthquake Prediction – Progress and Outlook, Nihon Senmontosho, 617 pp. (in Japanese but contains substantial supplementary documents in English).

Sarlis, N., Skordas, E., Varotsos, P., Nagao, T., Kamogawa, M., Tanaka, H., Uyeda, S., 2013. Minimum of the order parameter fluctuations of seismicity before major earthquakes in Japan. Proc. Natl. Acad. Sci. USA 110, 13734–13738. http://dx.doi.org/10.1073/pnas.1312740110.

Sholtz, C., Sykes, L., Aggarwal, Y., 1973. Earthquake prediction: a physical basis. Science 181, 803–810.

Swinbanks, D., 1997. Quake panel admits prediction is 'difficult'. Nature 388, 4.

Tanaka, S., 2012. Accident at the Fukushima Dai-ichi nuclear power stations of TEPCO – outline & lessons learned. Proc. Japan Acad., Ser. B 88, 471–484. http://dx.doi.org/10.2183/pjab.88.471.

Tsuboi, C., Wadati, K., Hagiwara, T., 1962. Prediction of Earthquakes – Progress to Date and Plans for Further Development. Earthquake Prediction Research Group, Tokyo University.

Uyeda, S., 2013. On earthquake prediction in Japan. Proc. Japan Acad., Ser. B 89, 391–400.

Uyeda, S., Nagao, T., Kamogawa, M., 2009. Short-term earthquake prediction, current status of seismo-electromagnetics. Tectonophysics 470, 205–213.

Uyeda, S., Nagao, T., Kamogawa, M., 2011. Earthquake Prediction and Precursor. In: Encyclopedia of Solid Earth Geophysics, Part 5, Springer, pp. 168–178 http://dx.doi.org/10.1007/978-90-481-8702-7_4.

Xu, G., Han, P., Huang, Q., Hattori, K., Febriani, F., Yamaguchi, H., 2013. Anomalous behaviors of geomagnetic diurnal variations prior to the 2011 off the Pacific coast of Tohoku earthquake (Mw9.0). Asian Earth Sci. 77 (0), 59–65.