Japan TRIZ Society 21st TRIZ Symposium 2025
Sept. 4 – 5, 2025, Waseda University, Nishi-Waseda Campus

Earthquake Prediction Research Based on the TRIZ Philosophy

(2) R&D with a Clear Vision of the Goal of Real Application

Toru Nakagawa (Professor Emeritus, Osaka Gakuin University)

Table of Contents

1. Introduction: Background and Purpose

Despite decades of R&D, seismology in Japan was unable to forecast or predict **the Great Hanshin-Awaji EQ (1995) and the Great East Japan EQ (2011)**.

Following this, the Seismological Society if Japan and the Government adopted the policy that "**EQ prediction is currently impossible** with existing technology. Instead of focusing on prediction research, we will prioritize EQ observation, basic research into EQ mechanisms, and EQ disaster prevention (mitigation) measures."

The public, however, still eagerly desires the EQs to be predictable for reducing human and social disasters caused by EQs.

The Earthquake Prediction Society of Japan was established in 2014 to address this desire.

Research into EQ prediction **has remained in a state of groping in the dark**, until very recently both in Japan and worldwide.

Since Dec. 2022, clear clues for EQ prediction have been obtained.

Detecting abnormal variations in crustal movement by analyzing GEONET data (Kamiyama)

Observing fluctuating signals in the DC electric field deep underground (Tsutsui)

Using these methods as a core, I have started to envision a real application of EQ prediction to reduce EQ disasters nationwide.

Developing a technical system of predicting short-term and imminent EQs.

Official operation of EQ prediction warnings by a government agency.

I will develop it based on the TRIZ philosophy and experimental science.

Clarify the vision of the ultimate goal (TRIZ ideal solution).

Consider the stepwise strategies to achieve the vision.

Solve problems creatively one by one for each technical method.

Develop, apply, and verify various methods, and integrate them into a system.

Stepwise progress of research, development, and application, while expanding the working organization in each stage.

Always make efforts to gain understanding, support, and cooperation from academia and society.

2. Our ultimate goal: Disaster mitigation through the public operation of EQ prediction notices/warnings

2A. Public issuance of EQ prediction warnings: division of roles

Our ultimate goal at the national level:

to detect some EQ precursors,
to predict impending EQs of a scale of causing severe damages,
to issue appropriate notices/warnings to the public in advance of the EQ,
so that people and society can take actions for reducing EQ damages.

EQ prediction research (and its researchers) is responsible for

predicting EQs, in advance, that could cause damage,
reporting the prediction results to government agencies, and
advising them on the issuance of notices/warnings.

National agencies, on the other hand, are responsible for

officially announcing notices/warnings to the public and society widely, and
urging and directing to take appropriate actions to mitigate EQ damage and casualties.

2B. Basic guidelines for public announcements of EQ predictions

We are well aware of how devastating the EQ damage can be.

If the EQ prediction warnings are issued appropriately,
they can **significantly contribute** to mitigate some of the damage.
However, taking action in response to such warnings always bare
a significant burden on the public and society.

Therefore, EQ prediction warnings should be appropriate in all the aspects, i.e.,
the estimation of location, magnitude, and timing of the predicted EQ,
and the content, expression, and timing of **the warning announcement.**

Incorrect or inappropriate warnings can erode public trust and
make subsequent warnings more difficult to issue and reduce their
effectiveness.

For issuing warnings, it is essential for us to take into account of both
the reliability of estimation of the predicted EQs and
the time necessary for the public and society to take damage-mitigating
actions.

Accordingly, I propose the public announcements of EQ prediction in the following three stages.

2C. Official warnings of EQ prediction in 3 stages (proposed by Nakagawa)

National agency announces the notices/warnings to the whole society in 3 stages

	(A) EQ Prediction Notices	(B) EQ Prediction Warnings	(C) EQ Prediction Emergency Warnings
Timing of issue	1 year ~ 1 month in advance to the EQ	10 days ~ half a day in advance to the EQ	2 hours ~ 10 minutes in advance to the EQ
Precursor	P1 is observed	P2 is observed	P3 is observed
Region, size, Timing	Region X1, Size Y1, Timing T1 are estimated	Region X2, Size Y2, Timing T2 are estimated	Region X3, Size Y3, Timing T3 are estimated
Judgment	Likely to occur	Very likely.to occur	Very high risk to occur
To relevant authorities	Prepare for warning in advance	Make preparatory measures for avoiding/reducing damages	Do emergency actions for reducing damages in the whole society
To the people	Keep calm	Prepare for evacuation and disaster prevention around you	Promptly do damage reducing actions and evacuate to keep safe
Attention in the future	Beware of possible EQ Prediction Warnings	Watch for possible Emergency Warnings at any time day or night	When an earthquake occurs, an Earthquake Early Warning is issued

These reflect the latest research findings, particularly regarding the timing of (A) and (C).

2D. Template for the announcement of an EQ Prediction Notice (A) (draft)

This is an **official announcement of EQ Prediction Notice (A)**, issued today
by the **national government agency**.

Phenomenon P1 has been detected by the EQ prediction system, and
confirmed (by the **national experts team**) to be a precursor phenomenon
of an impending EQ.

An EQ is likely to occur in the X1 region (and its surrounding areas), with
a magnitude of approximately Y1 (± 0.5), at the timing estimated to be
within the next T1 (e.g., 3 months to 1 year).

Relevant authorities (government agencies, local governments, disaster
prevention-related organizations, etc.) in the predicted area (X1 region and
its surrounding broader area) are **advised to take preventive measures**
(as already established in **the EQ disaster prevention guidelines**).

The people in the predicted areas are **advised to remain calm** and pay
attention to any possible EQ prediction warning.

EQ prediction warning will be issued after observing clearer precursor
phenomena, between 10 days and half a day before the predicted EQ.

2E Systems and preparations necessary for the official issuance of EQ prediction

Issuance of EQ prediction has a significant impact on the whole society.
If it is appropriate, its contribution is much greater than its heavy burden.
If it is inappropriate, the burden is enormous. ---> **Our responsibility is heavy.**

It is essential for us to **establish reliable methods, technical systems, and verification records for EQ prediction.** ---> **The mission of EQ prediction researchers**

Issuance of EQ prediction is **decided by the national expert team** (led by leaders of Seismological Society of Japan). ---> **We must have the academic society (SSJ) understood the EQ prediction methods correctly.**

The scheme and procedures of issuance of EQ prediction **need to be established officially** following the discussions in the National Diet. ---> **We must obtain broad public understanding** through the media and other channels.

People and the whole society must be able to respond appropriately to EQ prediction warnings. ---> On the basis of correct understanding, **various systems and guidelines must be prepared for disaster mitigation and evacuation.**

Practical application of EQ prediction can progress through improvement cycles of research, verification, and social implementation. ---> **We should pursue this vision with scientific and social perspectives and with perseverance.**

3. Requirements, status, and selection of EQ prediction methods

3A. Requirements for EQ prediction methods

Comprehensive requirements for precursor phenomena, observation/analysis methods, prediction estimation methods, reliability, etc.

(0) Fundamental Requirements: Phenomenon X is related to and caused by EQs, and occurs shortly before for various types of EQs, ...

These requirements can only be proven after extensive observation and analysis.

The following requirements should be met step by step with the development process.

(1) Basic Req.: Observable/measurable **clearly with high S/N ratio,** and rarely blocked by natural/artificial noise.

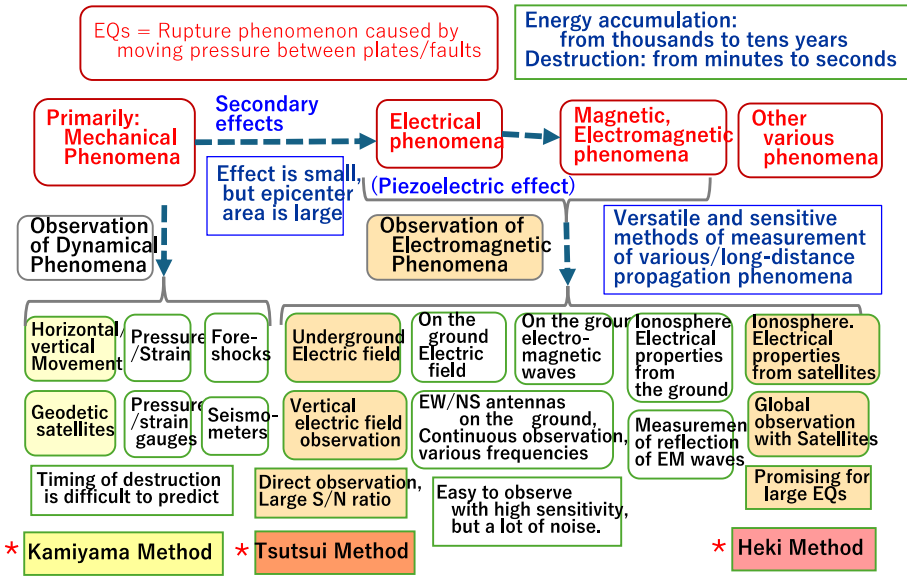
(2) Confirmation Req.: Similarly observable at **multiple sites**, for many EQs, confirming the occurrence of EQs as predicted.

(3) Practical Req.: Automatic/stable/continuous measurement, and possible to estimate the **predicting EQs (where, when, magnitude)**

(4) Advanced Req.: Integration of various methods for predicting different types of EQs. Possible to understand in relation to the EQ process.

(5) Social Req.: Reliable operation of EQ prediction notices/warnings system.

3B. Candidates of EQ precursor phenomena and their observation methods



3C. Evaluation overview of various methods (prospects) (Nakagawa)

Evaluate various EQ prediction methods with the basic and practical requirements:

Observable/measurable clearly with high S/N ratio;
Automatic/stable/continuous measurement, and possible to estimate the predicting EQs (where, when, magnitude).

Kamisama's method: Observation of crustal movement and strain using GEONET data
---> Promising for EQ prediction notice (A) (1 year to 1 month in advance)

Tsutsui's method: Continuous observation of DC electric fields deep underground
---> Promising for EQ prediction emergency warning (C) (2 hrs to 10 mins in advance)

Hekis method: Observation of ionospheric TEC using GNSS satellite data
---> Useful for EQ prediction emergency warning (C) for major EQs (M>7) worldwide

Various methods for observing (horizontal) electric fields, electromagnetic waves, electrical properties of the ionosphere, etc. on the ground

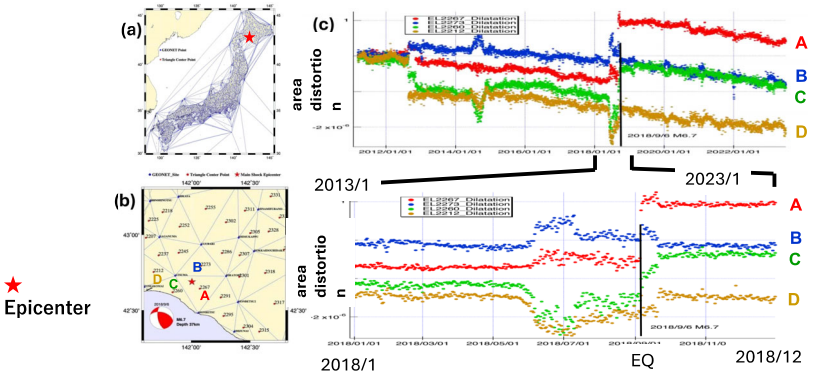
---> Various methods exist, which are easy to observe and highly sensitive but very noisy. No methods of them meet the basic and practical requirements yet.

4. Proposal of five stages to promote EQ prediction research

Stage	Principal actor	Issues and activities	Current state
(0) Explore/ consider/pre pare	Individual researcher	Clarify the goal of EQ prediction, consider the phenomena to measure, the method and equipment for measurement with noise elimination, etc., and prepare them.	Diverse trials
(1) Develop/ implement a method	A research group	Develop/implement a method at an observation site, and demonstrate that a characteristic phenomenon is (was) observed just before the EQ in some cases of EQs.	Tsutsui; Kamiyama
(2) Verify the method	A research project of multi-groups	Implement the (similar) method at multiple observation sites to obtain similar signals for an EQ in parallel to prove they are not noise. Verify that an EQ precursor phenomenon is observed for many EQs (of some type).	Project within EPSJ (proposed)
(3) Widely deploy the method	Research project supported by KAKENHI	Deploy the method nationwide to observe many EQs in different regions. Then create a method to estimate (in advance) the area, scale, and timing of the predicted EQ, and propose/verify a procedure for issuing when and what kind of information of EQ prediction. Clarify the features and application limitations of the method.	
(4) Establish a technical system of EQ prediction	National project	By integrating different methods, create a technical system that can properly issue EQ prediction notices/warnings for various types of EQs. Verify its reliability by applying it to a large number of past/present EQs (with simulation).	
(5) Official operation of EQ prediction warnings	National institution	Operate always the EQ prediction technical system. Whenever a damaging EQ is predicted, officially issue the EQ prediction notices/warnings on time to request/direct the public and society to take action to reduce EQ damage and causality.	Needs 20 years (or more)

5. Three novel methods: Stage 1 results and stage 2 challenges

5A. Kamiyama method: Observation of crustal distortion using GNSS satellite data



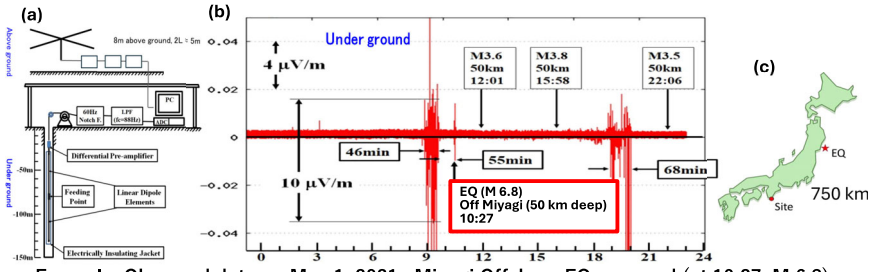
Analysis example: 2018 Hokkaido Iburi East Earthquake (2018/9/6 M_J 6.5).

Main Finding: Areas of triangles were shrinking slowly, then abnormal variations 3 months before the EQ.

Future tasks: ▶ Analyze past damaging EQs to survey the onsets and patterns of abnormal variations.
▶ Devise a method to estimate in advance the region, scale, and timing of the predicted EQs.
▶ Develop it into a method of EQ prediction (several years to several months in advance).

5B. Tsutsui method: Observation of underground DC electric field for immediate EQ prediction

At a site on the southern tip of Kii Peninsula, a DC electric field sensor (100 m long) is installed in a borehole (150 m deep), and the signal is measured continuously every second.



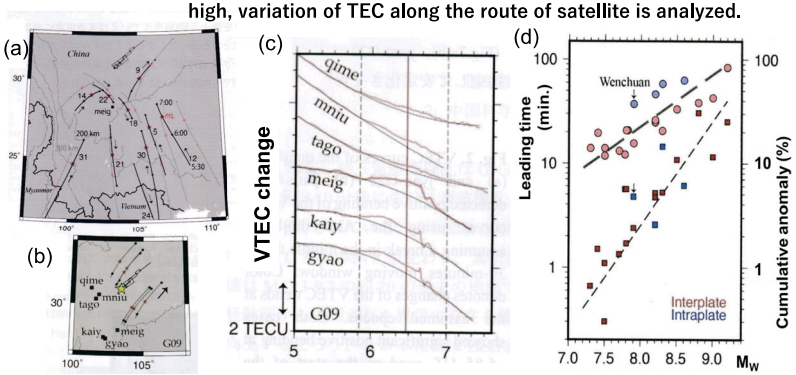
Example: Observed data on May 1, 2021. Miyagi Offshore EQ occurred (at 10:27, M 6.8).

Main findings: Observation data shows high sensitivity and low noise (high S/N ratio) with continuous measurements every second. The signals from a remote epicenter (750 km away) show clear fine-structure from several hours before to several hours after the EQ.

Future tasks: ▶ We should inherit the technology and know-how from Tsutsui as soon as possible, and establish the second, third, ... research groups/observation sites.
▶ Observe many EQs and accumulate signal patterns (especially the onset timing) of EQs.
▶ Devise a method to estimate (in advance) the region, scale, and timing of the predicted EQs.
Note: Some additional information is necessary to estimate the EQ location.
▶ Important to establish this method to predict EQs immediately (a few hours to ten minutes) before EQs.

5C. Heki method: Observation of TEC in the ionosphere using GNSS satellite data

GNSS satellites can measure the TEC (total electron content) on a straight line to ground stations. Assuming the TEC is located at 200 km high, variation of TEC along the route of satellite is analyzed.



Analysis examples (a) - (c) EQ in Yunnan, China (M_W 7.8), (d) Summary results for 20 EQs.

Main findings: For 20 major EQs (M 7-9) worldwide, TEC anomalies range from 0.2 to 40% in magnitude and from 10 to 80 minutes in leading time of EQs.

Future tasks: ▶ For practice, satellite data must be constantly observed, quickly analyzed, and judged if the variation is related to an EQ or other.
▶ This method may have unique application to immediate prediction of big EQs around the world.

6. Current challenges in EQ prediction research

Earthquake Prediction Society of Japan (EPSJ), established in 2014, is still a small organization with less-than-70 regular members, including nearly half 'amateur' members.

Research groups are mostly small in scale, and pursue diverse themes on EQ prediction methods at the Stage 0 or Stage 1.

Under the influence of Seismological Society of Japan (SSJ), saying "EQ prediction is impossible", few laboratories join from major universities and we have very few young researchers and graduate students.

In this situation, **we have had ground-breaking results** that Kamiyama et al. and Tsutsui have achieved the Stage 1 tasks (Method development & implementation) to **obtain clear clues useful for EQ prediction notices (A) and EQ prediction emergency warnings (C)**.

With these pioneering works, **we, EPSJ, should proceed to Stage 2** (Verifying the methods by a research project with multi-groups).

Centering on these two themes, we should urge various research groups and (young) researchers, both within and outside EPSJ, to join and collaborate in the EQ prediction project.

The experimental methods developed by Tsutsui should be a particular focus of this project.

Currently, Professor Emeritus Tsutsui is continuing his research for himself alone with his personal funding.

The observation site must be located in a remote area with minimal artificial noise.

Making a deep borehole and installing observation equipment requires specialized expertise.

Software is required for storing continuous observation data in PC, transferring the data to a center, and creating charts and graphs.

Tsutsui's method produces clear signals, is versatile, and can detect distant EQs, contains rich information for several hours before and after an EQ, makes it most effective for EQ prediction emergency warnings.

For verifying the method, it is essential to observe EQs simultaneously at multiple sites, especially for estimating the epicenter.

It is urgent to learn all his expertise and actually implement the second, third, and subsequent sites by multiple research groups.

I propose to establish the EQ Prediction Research Foundation (a general incorporated foundation) for operating the Stage 2 Research Project.

Tsutsui's method requires over 10 million yen for the setup of a single site, and the entire project would require funding on the scale of tens of millions of yen.

I propose that EPSJ (a general incorporated association) establish and operate the aforementioned foundation as a sister organization.

This organization would serve as the primary entity responsible for **the Stage 2 project (verification of the method)**.

7. Summary

Our objective is to make short-term/immediate EQ prediction possible for reducing EQ damage.

Our ultimate goal is to detect clear precursor phenomena, estimate the location, magnitude, and timing of an EQ in advance, and to advise government agencies to issue EQ prediction notices/warnings/ emergency warnings publicly for the evacuation of people and the mitigation of EQ damage of society.

For such warnings to be effective, the EQ prediction must be appropriate for a wide types of EQs, the national agencies respond swiftly, and the whole society and people take appropriate actions for disaster mitigation and evacuation.

Among various trials/methods of EQ prediction, we should select the most promising methods based on the basic/practical requirements, and validate and further develop them.

A five-stage development of EQ prediction technology has been proposed, with the clear definition of tasks and the principal entity of activities at each stage.

Currently, **Kamiyama's method** of analyzing abnormal crustal movements and **Tsutsui's method** of continuous observation of underground DC electric fields have achieved the Stage 1 tasks and are promising for EQ prediction notice (A) and emergency warning (C).
However, no method has been found useful for issuing warnings (B) 10 days to half a day before an EQ.
This remains a major challenge for the EQ prediction research.

Now we should advance to Stage 2 (verification of methods by multiple research groups), and we should establish "Japan EQ Prediction Research Foundation" for operating the research project.

Each stage may take 5 years, and the Stage 5 final goal would take 20 years if things go smoothly.
It is essential for us to **gain the understanding and cooperation** of many people, including academic community, society, and public institutions.