The late Professor Takahiro Hagiwara: His career with earthquake prediction

Masakazu Ohtake

Japan Nuclear Energy Safety Organization, Tokyo 105-0001, Japan

(Received December 9, 2003; Revised May 1, 2004; Accepted May 26, 2004)

Takahiro Hagiwara, Professor Emeritus of the University of Tokyo, was born in 1908, and passed away in 1999. His name is inseparably tied with earthquake prediction, especially as the founder of the earthquake prediction program of Japan, and as a distinguished leader of earthquake prediction research in the world. This short article describes the career of Prof. Hagiwara focusing on his contribution to earthquake prediction research. I also sketch his activities in the development of instruments, and the multi-disciplinary observation of the Matsushiro earthquake swarm to show the starting point of his scientific strategy: good observation.

Key words: Prof. Takahiro Hagiwara, earthquake prediction, IUGG, seismograph, Matsushiro earthquakes.

Takahiro Hagiwara, Professor Emeritus of the University of Tokyo, was born in Tokyo in 1908, 15 years before the great Kanto earthquake of 1923, and passed away in 1999 at the age of 91. Graduating from Tokyo Imperial University (now the University of Tokyo), he started his scientific career in 1933 as a research associate at the Earthquake Research Institute (ERI) of the university. His supervisor was Prof. Mishio Ishimoto, who is well known for finding a statistical law on the frequency distribution of earthquake size, which is equivalent to the Gutenberg-Richter relation. Prof. Hagiwara was promoted to a full professor in 1944 at the age of 36, and worked for ERI until his retirement in 1969. For the two years from 1965, he served at ERI as the Director General.

In 1967, Prof. Hagiwara was elected to the first chairperson of the International Commission on Earthquake Prediction, which was established at the 14th General Assembly of IUGG and hosted by IASPEI. He was also appointed first President of the Coordinating Committee for Earthquake Prediction in 1969, and first President of the Earthquake Assessment Committee for Tokai Earthquake in 1979. Prof. Hagiwara had presided over these key committees of earthquake prediction program in Japan, until 1981. In 1981, he founded a new enterprise, the Association for the Development of Earthquake Prediction (ADEP), to develop earthquake prediction research and to support endeavors of the governmental and private sectors to mitigate earthquake disaster. In recognition of his distinguished services to the nation and science, he was awarded a Purple Ribbon Medal in 1969, and decorated in 1978.

The name of Prof. Hagiwara is inseparably tied with earthquake prediction, especially as the founder of the Japanese earthquake prediction program, and as a prominent leader of earthquake prediction research in the world. However, his contribution to the scientific community extended over wide spectra. In this short article, I will also touch on two other topics; development of instruments, and intensified observation of the Matsushiro earthquake swarm.

In the 1930s, Prof. Hagiwara developed a series of mechanical seismographs, which are nicknamed as "Tokkuri's" after the shape of the pendulum box. Tokkuri is a bottle to contain sake, Japanese wine. The mechanical part is composed of an inverted pendulum, of which the natural period is 3 sec for the typical type, and an air-damper. The ground motion is recorded on smoked paper attached on a rotating drum. Later, he invented a new electro-magnetic seismometer, "HES", which is composed of a moving-coil transducer and optical recording system with a galvanometer. The natural period of the pendulum is 1 sec, and a galvanometer of 0.2 Hz is used for short periods, and that of 1 sec and 20 sec for longer periods. For its high sensitivity and high stability, HES was used as a standard seismometer in Japan for a long time. One HES is still working at the Syowa Base of Japan in the Antarctica, although the recording part is replaced by a pen-and-ink system.

In 1945, Prof. Hagiwara published a famous book entitled the "Shindou Sokutei (Groundmotion Measurement)" (Hagiwara, 1945). This book, totally describing the theoretical and practical aspects of seismometer design, has been studied by many students as a standard text book. His work also included development of the water-tube tiltmeter for continuous observation of crustal deformation. Prof. Hagiwara noted in his book that "an instrument is the window open to the nature" (Hagiwara, 1997).

In August 1965, the most exciting and busy days for Prof. Hagiwara started with the beginning of the Matsushiro earthquake swarm that rocked Nagano Prefecture, central Japan for several years (Hagiwara and Iwata, 1968). At the peak of activity, the number of felt earthquakes reached nearly 700 in one day, or one every two minutes on average. The swarm activity was initially restricted in a small area of several kilometers in diameter, but gradually extended in the NE-SW direction until the longer axis attained 35 km at a later stage. Under the strong leadership of Prof. Hagiwara, who took office as the Director General four months before, ERI com-

Professor Takahiro Hagiwara, 1908–1999 (courtesy of the Association for the Development of Earthquake Prediction).

mitted all the available resources to field observations in the focal area. The field work included microearthquake and strong-motion observation, geodetic survey, continuous observation of crustal deformation, geomagnetic and geoelectric observation, groundwater observation, and geological investigation. The integrated observation brought a new hypothesis that the earthquake swarm was generated by "water eruption" (see Ohtake, 1976). This, together with the study of the Denver earthquakes, led to later researches on the physical relation between the interstitial liquid and earthquake occurrence.

When I was in charge of microearthquake observation at Matsushiro, an electric motor driving the recording drum got out of order at midnight. I immediately called Prof. Hagiwara in Tokyo to ask a new motor to replace. His answer was, "Alright, an ERI driver will arrive at Matsushiro tomorrow morning with a new motor." However, my happy dream was soon crashed by the next word. "But, you shouldn't stop the observation. Keep the drum rotate by your arm until tomorrow morning." Prof. Hagiwara sometimes played the role of cruel tyrant to demand perfect observation. But, his inherent humor and broad-minded personality were loved by all the people.

During spare hours, he enjoyed a baseball game with staff members. He was also an ardent supporter of a professional baseball team, the Tokyo Giants. In Japan, two baseball terms, "minogashi" (to let a good ball go by) and "karaburi" (to swing at a ball in failure) are frequently used for "failure" and "false alarm" in earthquake prediction. I suspect that Prof. Hagiwara may be the originator of these popular metaphors.

The Matsushiro earthquake swarm triggered the start of a national program for earthquake prediction. Through the concentrated observation of the swarm, Prof. Hagiwara was convinced that multi-disciplinary observation and integrated judgement are key elements for earthquake prediction.

In Japan, the so-called "Blue Print" for earthquake prediction (Group for the Study of Earthquake Prediction Program, 1962) was published in 1962 after rigorous discussion among active scientists. Prof. Hagiwara was one of the representatives of the group with Prof. Chuji Tsuboi and Dr. Kiyoo Wadati. Based on the Blue Print, the national program for earthquake prediction started in 1965, with the initiative of Prof. Hagiwara. It was the first national program in the world to challenge earthquake prediction, and strongly encouraged scientists in the world including the United States and China to launch similar endeavors.

In 1964, the first U.S.-Japan Conference on Earthquake Prediction Research was held in Tokyo and Kyoto, which was probably the first international meeting on earthquake prediction in the world. Prof. Hagiwara was an excellent organizer of the conference. The international conference, together with the occurrence of the great Alaska earthquake just after the meeting, led to a growing interest of U.S. scientists in earthquake prediction, and Prof. Frank Press and his colleagues proposed a ten-year program of earthquake prediction to the U. S. government in 1965.

Professor Frank Evison once told me an episode at a reception at the Japanese Embassy in Wellington. The Ambassador asked him, "Who is the distinguished elderly professor who is so prominent in earthquake prediction research?" Prof. Evison answered that it must be Prof. Hagiwara. The response of the Ambassador was, "That's the man! When Professor Hagiwara says something about earthquake prediction, everyone listens, but when anyone else says something, no one listens!"

We can see the basic concept of the national program in the first proposal, which was in force for the initial four years from 1965 to 1968 fiscal years. Among the eight sections of the proposal, seven components are for strengthening various kinds of observations; geodetic survey, tide-gauge observation, continuous observation of crustal deformation, seismic observation, observation of seismic velocity change, field study of active faults, and geomagnetic and geoelectric observations. Under the umbrella of the national program, the Coordinating Committee for Earthquake Prediction was established in 1969 to effectively promote the program, and the Earthquake Assessment Committee for the impending Tokai earthquake in 1979.

The prediction program was reviewed and revised every fifth year to propose "five-year plans". Although some new components such as laboratory experiment and construction of telemetry seismic nets were added in later plans, the program had been continued for 34 years until it was completely reformed after the Kobe earthquake of 1995. I will refer to the prediction program of those 34 years as the "old program" in this article.

The old program largely served to strengthen and modernize observations of crustal activity. Although successful short-term prediction was not attained, several important results were obtained including the success in long-term prediction of the 1973 Nemuro-Hanto-Oki earthquake (M7.4), and detection of precursory phenomena to the 1978 Izu-Oshima-Kinkai earthquake (M7.0). However, the old program had been led by an experience-based strategy that was characterized by the search for earthquake precursors and integrated judgment, and the limitation of this traditional approach became clear in the light of modern seismology.

Under those circumstances, scientists started a serious discussion to effectively develop earthquake prediction research, and published the "New Observational Research Program for Earthquake Prediction" (Group for the Promotion of Earthquake Prediction Research, 1998; new program, hereafter). The new program, emphasizing the importance of scientific understanding of the whole earthquake cycle, is characterized by two "Ms"; modeling and monitoring. Future seismic activity is predicted by a model. The model is checked and revised by monitoring actual crustal activity.

This strategy is not necessarily a new one but is rather common to modern sciences. However, it should be emphasized that this strategy would have been premature to adopt until great innovations both in theory and in observation were attained in the past decade. The theoretical innovation includes the laboratory-driven new friction law, rupture nucleation theory, and the modernized asperity model of earthquake occurrence. For observation, the Japanese Islands are now covered by thousands of seismic and GPS stations of high performance. Thus, the goal of the new program is not restricted to short-term prediction, but prediction of the whole process of the earthquake cycle. Some of the newest output of the new prediction program will be presented in this symposium.

The Japanese program for earthquake prediction, which was founded by Prof. Hagiwara four decades ago, was renewed to a modern science. However, we should remember that good observation has been the most important basis of earthquake prediction research throughout the old and new programs. Prof. Hagiwara clearly showed this direction, and contributed to modernize the observation by developing new instruments, organizing the Matsushiro operation, and promoting the prediction program.

I will conclude this article by citing a short sentence from Hagiwara (1997). "For challenging earthquake prediction, we need deep scientific understanding of the nature of earthquake."

Acknowledgments. I deeply thank Prof. A. Takagi for valuable suggestions and many helps in preparing the manuscript. Dr. S. Kubota kindly checked and corrected the publication list. I also thank Prof. F. Evison for the permission of citing his personal memory. Comments of Prof. K. Mogi and an anonymous reviewer were quite helpful to revise the manuscript. Several paragraphs are added to the original manuscript following the suggestions of the two reviewers.

Appendix. Selected Publications of Professor Takahiro Hagiwara

A.1 Books

Hagiwara, T., *Seismographs*, Iwanami Shoten, Tokyo, 78 pp., 1936 (in Japanese).

Hagiwara, T., *Groundmotion Measurement*, Houbunkan, Tokyo, 355 pp., 1945 (in Japanese).

Hagiwara, T., *Geophysical Prospecting*, Asakura Shoten, Tokyo, 256 pp., 1951.

Hagiwara, T., *Earthquake Prediction*, Chigaku Shuppansha, Tokyo, 187 pp., 1966 (in Japanese).

Hagiwara, T., *Challenge to Earthquakes: Basic Knowledges of Earthquake Prediction*, Kodansha, Tokyo, 1972 (in Japanese).

Hagiwara, T., *One-Hundred Years of Seismology*, Tokyo Univ. Press, Tokyo, 233 pp., 1982 (in Japanese).

Hagiwara, T. (ed.), *Paleo-Earthquakes: Exploring Historical Documents and Active Faults*, Tokyo Univ. Press, Tokyo, 312 pp., 1982 (in Japanese).

Hagiwara, T. (ed.), *Encyclopedia of Earthquakes*, Sanseido, Tokyo, 255 pp., 1983 (in Japanese).

Hagiwara, T. (ed.), *Paleo-Earthquakes, Second Volume: Real and False Images*, Tokyo Univ. Press, Tokyo, 434 pp., 1989 (in Japanese).

Hagiwara, T. (ed.), *Earthquakes of the Japanese Islands*, Kajima Shuppankai, Tokyo, 215 pp., 1991 (in Japanese).

Hagiwara, T. (ed.), *Study on Paleo-Earthquakes: Approach to Oceanic Earthquakes*, Tokyo Univ. Press, Tokyo, 306 pp., 1995 (in Japanese).

Hagiwara, T., *Earthquake Prediction and Disaster*, Maruzen, Tokyo, 174 pp., 1997 (in Japanese).

A.2 Papers

Ishimoto, M., T. Hagiwara, and Y. Yoshida, Mesure du moment de frottement au pivot, *Bull. Earthq. Res. Inst.*, **10**, 858–863, 1932 (in Japanese with French abstract).

Hagiwara, T., Design of a horizontal pendulum seismograph, *Zisin 1*, **4**, 196–209, 1932 (in Japanese).

Haeno, S., I. Mikawa, T. Hagiwara, and R. Yoshiyama, Seismic prospecting of the basement of Tamagawa bridge, Chuo railway line, *Zisin 1*, **4**, 465–473, 1932 (in Japanese).

Fukutomi, K. and T. Hagiwara, Propagation of the acoustic wave associated with the explosion of the Takinogawa Magazine on April 19, 1932, *Zisin 1*, **4**, 528–547, 1932 (in Japanese).

Hagiwara, T., Influence of solid friction on dynamical magnification, *Bull. Earthq. Res. Inst.*, **11**, 14–24, 1933.

Hagiwara, T., Design and production of a portable seismograph, *Zisin 1*, **5**, 739–749, 1933 (in Japanese).

Hagiwara, T., Earthquakes and earthsounds on Mt. Tukuba, *Bull. Earthq. Res. Inst.*, **12**, 222–233, 1934.

Hagiwara, T., On the magnetic damper, *Bull. Earthq. Res. Inst.*, **12**, 482–491, 1934.

Hagiwara, T., A velocity seismograph, *Bull. Earthq. Res. Inst.*, **12**, 776–787, 1934.

Ishimoto, M. and T. Hagiwara, The tunami considered as a phenomenon of sea water overflowing the land, *Bull. Earthq. Res. Inst.*, Suppl. Vol. I, 17–24, 1934.

Hagiwara, T., A newly produced portable seismograph, *Zisin 1*, **6**, 645–648,

1934 (in Japanese).
Hagiwara, T., A comparison of the displacement, the velocity, and the acceleration seismograms, *Bull. Earthq. Res. Inst.*, **13**, 138–145, 1935.
Hagiwara, T., The air damper, *Bull. Earthq. Res. Inst.*, **13**, 783–789, 1935.
Hagiwara, T., The Sizuoka earthquake of July 11, 1935, *Bull. Earthq. Res. Inst.*, **13**, 951–965, 1935 (in Japanese with English abstract).
Nasu, N. and T. Hagiwara, The Kawati-Yamato earthquake of February 21st, 1936, *Bull. Earthq. Res. Inst.*, **14**, 285–289, 1936 (in Japanese with English abstract).
Nasu, N. and T. Hagiwara, Determination of the proper periods of the ground in Osaka, *Bull. Earthq. Res. Inst.*, **14**, 290–296, 1936 (in Japanese with English abstract).
Nasu, N., T. Hagiwara, and S. Omote, Studies on earthquakes in the Kwanto District, Part 1, *Bull. Earthq. Res. Inst.*, **14**, 427–437, 1936 (in Japanese with English abstract).
Nasu, N., T. Hagiwara, and S. Omote, Studies on the propagation of the artificial earthquake waves through superficial soil or sand layers and the velocity of soil and sand, *Bull. Earthq. Res. Inst.*, **14**, 560–581, 1936 (in Japanese with English abstract).
Hagiwara, T., Observation of the predominating periods in the earthquake motions at Daiho-mura and Kamiotu-mura, Ibaraki Prefecture, *Bull. Earthq. Res. Inst.*, **14**, 599–603, 1936 (in Japanese with English abstract).
Hagiwara, T., Observation of changes in earth potential at Syukkoko and Kinsui, Formosa, *Bull. Earthq. Res. Inst.*, Suppl. Vol. III, 87–92, 1936 (in Japanese with English abstract).
Nasu, N., T. Hagiwara, and S. Omote, Studies on the propagation of the artificial earthquake waves through superficial soil or sand layers and the velocity of soil and sand (Part 2), *Bull. Earthq. Res. Inst.*, **15**, 87–89, 1937 (in Japanese with English abstract).
Hagiwara, T. and S. Omote, The Niizima earthquake of December 27, 1936, *Bull. Earthq. Res. Inst.*, **15**, 559–568, 1937 (in Japanese with English abstract).
Hagiwara, T., Observations of changes in the inclination on the earth's surface at Mt. Tukuba, *Bull. Earthq. Res. Inst.*, **16**, 366–371, 1938.
Hagiwara, T. and S. Omote, Comparative observations of the acceleration of earthquake motions in the compound of the Tokyo Imperial University. (Part I), *Bull. Earthq. Res. Inst.*, **16**, 632–637, 1938 (in Japanese with English abstract).
Hagiwara, T., Mud avalanche at Mt. Tukuba, Ibaraki Prefecture, *Bull. Earthq. Res. Inst.*, **16**, 779–783, 1938 (in Japanese with English abstract).
Hagiwara, T., A method of travel-time curve analysis for the basement surface with varying dip, *Zisin 1*, **10**, 463–468, 1938 (in Japanese).
Hagiwara, T. and S. Omote, Land creep at Mt. Tyausu-yama. (Determination of slip plane by seismic prospecting), *Bull. Earthq. Res. Inst.*, **17**, 118–138, 1939.
Hagiwara, T. and S. Omote, Comparative observations of the acceleration of earthquake motions in the compound of the Tokyo Imperial University. (Part II), *Bull. Earthq. Res. Inst.*, **17**, 139–143, 1939 (in Japanese with English abstract).
Hagiwara, T., The Ogasima earthquake of May 1st, 1939, *Bull. Earthq. Res. Inst.*, **17**, 627–637, 1939 (in Japanese with English abstract).
Hagiwara, T., The Ogasima earthquake and its aftershocks, *Bull. Earthq. Res. Inst.*, **18**, 252–264, 1940.
Hagiwara, T. and S. Omote, Seismic prospecting on a sea bottom, *Bull. Earthq. Res. Inst.*, **18**, 305–317, 1940.
Hagiwara, T., Observations of changes in the inclination on the earth's surface at Mt. Tukuba (Second report), *Bull. Earthq. Res. Inst.*, **19**, 218–227, 1941.
Tsuya, H., R. Takahasi, T. Hagiwara, T. Minakami, T. Nagata, S. Omote, and K. Hirano, The eruption of Miyake-sima, one of the seven Izu Islands, in 1940, *Bull. Earthq. Res. Inst.*, **19**, 260–401, 1941.
Hagiwara, T., A new device for remote mechanical recording of slow movements, *Bull. Earthq. Res. Inst.*, **19**, 523–526, 1941.
Hagiwara, T., A note on the theory of the vertical motion seismograph, *Bull. Earthq. Res. Inst.*, **20**, 337–346, 1942.
Hagiwara, T. and S. Omote, Some investigations on the crustal deformations at the foot of Mt. Huzi. (Part I), *Bull. Earthq. Res. Inst.*, **21**, 243–275, 1943 (in Japanese with English abstract).
Hagiwara, T., Movement along the fault that appeared in the Tottori earthquake and the change in the inclination of the earth's surface, *Bull. Earthq. Res. Inst.*, **22**, 66–71, 1944 (in Japanese with English abstract).
Hagiwara, T., On the periods of the vibration that is produced by superposing several simple harmonic vibrations of different period and amplitude, *Bull. Earthq. Res. Inst.*, **23**, 1–22, 1945 (in Japanese with English abstract).
Hagiwara, T., S. Omote, S. Murauchi, K. Akashi, and Z. Yamada, The eruption of Mt. Sakura-zima in 1946, *Bull. Earthq. Res. Inst.*, **24**, 143–160, 1946 (in Japanese with English abstract).
Hagiwara, T., Observations of changes in the inclination on the earth's surface at Mt. Tsukuba (Third report), *Bull. Earthq. Res. Inst.*, **25**, 27–32, 1947.
Hagiwara, T., T. Rikitake, and J. Yamada, Observations of the deformation of the earth's surface at Aburatsubo, Miura Peninsula. Part I, *Bull. Earthq. Res. Inst.*, **26**, 23–26, 1948.
Hagiwara, T., T. Rikitake, K. Kasahara, and J. Yamada, Observations of the deformation of the earth's surface at Aburatsubo, Miura Peninsula. Part II, *Bull. Earthq. Res. Inst.*, **27**, 35–38, 1949.
Hagiwara, T., T. Rikitake, K. Kasahara, and J. Yamada, Observations of the deformation of the earth's surface at Aburatsubo, Miura Peninsula. Part III, *Bull. Earthq. Res. Inst.*, **27**, 39–44, 1949.
Hagiwara, T. and K. Kasahara, On aftershocks accompanied the Imaichi earthquake, December 26, 1949, *Bull. Earthq. Res. Inst.*, **28**, 393–400, 1950.
Hagiwara, T. and T. Rikitake, Observation of the deformation of the earth's surface in the vicinity of epicentres of the Imaichi earthquake, *Bull. Earthq. Res. Inst.*, **28**, 435–441, 1950.
Hagiwara, T., K. Kasahara, J. Yamada, and S. Saito, Observations of the deformation of the earth's surface at Aburatsubo, Miura Peninsula. Part IV, *Bull. Earthq. Res. Inst.*, **29**, 455–468, 1951.
Hagiwara, T., K. Kasahara, and J. Yamada, Observations of the deformation of the earth's surface at Aburatsubo, Miura Peninsula. Part V, *Bull. Earthq. Res. Inst.*, **29**, 557–561, 1951.
Hagiwara, T., A note on the theory of the electromagnetic seismograph, *Bull. Earthq. Res. Inst.*, **36**, 139–164, 1958.
Hagiwara, T. and I. Kayano, Seismological observations of the Kita Mino earthquake, August 19, 1961 and its aftershocks, *Bull. Earthq. Res. Inst.*, **39**, 873–879, 1961 (in Japanese with English abstract).
Hagiwara, T., T. Iwata, Y. Maeda, and I. Kayano, Aftershocks of the northern Miyagi earthquake, April 30, 1962 observed at the Tsukuba station, *Bull. Earthq. Res. Inst.*, **40**, 625–637, 1962 (in Japanese with English abstract).
Hagiwara, T., I. Karakama, I. Kayano, and K. Kaminuma, Foreshocks, aftershocks and an earthquake swarm detected by the micro-earthquake observation, *Bull. Earthq. Res. Inst.*, **41**, 659–680, 1963.
Hagiwara, T. and T. Iwata, On the earthquake detection capability of Tsukuba seismological station, Earthquake Research Institute, *Zisin 2*, **18**, 113–122, 1965 (in Japanese with English abstract).
The Party for Seismological Observation of Matsushiro earthquakes, and the Seismological Section, Matsushiro earthquakes observed with a temporary seismographic network. Part 1, *Bull. Earthq. Res. Inst.*, **44**, 309–333, 1966.
Hagiwara, T., J. Yamada, and M. Hirai, Observation of tilting of the earth's surface due to Matsushiro earthquakes. Part 1, *Bull. Earthq. Res. Inst.*, **44**, 351–361, 1966.
Takano, K. and T. Hagiwara, Preliminary observation of microearthquake with a deep well seismometer, *Bull. Earthq. Res. Inst.*, **44**, 1135–1148, 1966 (in Japanese with English abstract).
Hamada, K. and T. Hagiwara, High sensitivity tripartite observation of Matsushiro earthquakes. Part 1, *Bull. Earthq. Res. Inst.*, **44**, 1213–1238, 1966.
Hamada, K. and T. Hagiwara, High sensitivity tripartite observation of Matsushiro earthquakes. Part 2, *Bull. Earthq. Res. Inst.*, **44**, 1239–1268, 1966.
Hamada, K. and T. Hagiwara, High sensitivity tripartite observation of Matsushiro earthquakes. Part 3, *Bull. Earthq. Res. Inst.*, **44**, 1665–1687, 1966.
The Party for Seismological Observation of Matsushiro earthquakes, and the Seismological Section, Matsushiro earthquakes observed with a temporary seismographic network. Part 2, *Bull. Earthq. Res. Inst.*, **44**, 1689–1714, 1966.
Hamada, K. and T. Hagiwara, High sensitivity tripartite observation of Matsushiro earthquakes. Part 4, *Bull. Earthq. Res. Inst.*, **45**, 159–196, 1967.
The Party for Seismological Observation of Matsushiro earthquakes, and the Seismological Section, Matsushiro earthquakes observed with a temporary seismographic network. Part 3, *Bull. Earthq. Res. Inst.*, **45**, 197–223, 1967.
Ohtake, M., H. Chiba, and T. Hagiwara, Ultra micro-earthquake activity at the southwestern border of the area of Matsushiro earthquakes. Part 1, *Bull. Earthq. Res. Inst.*, **45**, 861–886, 1967.

The Party for Seismological Observation of Matsushiro earthquakes, and the Seismological Section, Matsushiro earthquakes observed with a temporary seismographic network. Part 4, *Bull. Earthq. Res. Inst.*, **45**, 887–917, 1967.

Hagiwara, T., K. Okano, and T. Asada, History of the seismic observation technology, *Zisin 2*, **20**, Special Issue, 122–126, 1967 (in Japanese).

Hagiwara, T., Subjects of earthquake prediction research, *Zisin 2*, **20**, Special Issue, 181–187, 1967 (in Japanese).

Hagiwara, T., Summary of the Matsushiro earthquake swarm, *Zisin 2*, **20**, Special Issue, 192–218, 1967 (in Japanese).

Hagiwara, T. and T. Iwata, Summary of the seismographic observation of Matsushiro swarm earthquakes, *Bull. Earthq. Res. Inst.*, **46**, 485–515, 1968.

Takano, K. and T. Hagiwara, Observation of microearthquake with a deep well seismometer (Second paper), *Bull. Earthq. Res. Inst.*, **46**, 1293–1300, 1968 (in Japanese with English abstract).

Hagiwara, T. and M. Ohtake, Seismic activity associated with the filling of the reservoir behind the Kurobe Dam, Japan, 1963–1970, *Tectonophys.*, **15**, 241–254, 1972.

Hagiwara, T., History of the Seismological Society of Japan, *Zisin 2*, **34**, Special Issue, 135–138, 1981 (in Japanese).

Hagiwara, T., History of the Investigation Committee for Earthquake Disaster Prevention, *Zisin 2*, **34**, Special Issue, 139–143, 1981 (in Japanese).

References

Group for the Promotion of Earthquake Prediction Research, *New Observational Research Program for Earthquake Prediction*, 41 pp., 1998 (in Japanese).

Group for the Study of Earthquake Prediction Program, 1962, *Earthquake Prediction: The State of Arts and Promotion Program*, 32 pp., 1962 (in Japanese).

Hagiwara, T., *Groundmotion Measurement*, Houbunkan, Tokyo, 355 pp., 1945 (in Japanese).

Hagiwara, T., *Earthquake Prediction and Disaster*, Maruzen, Tokyo, 174 pp., 1997 (in Japanese).

Hagiwara, T. and T. Iwata, Summary of the seismographic observation of Matsushiro swarm earthquakes, *Bull. Earthq. Res. Inst.*, **46**, 485–515, 1968.

Ohtake, M., A review of the Matsushiro earthquake swarm, *Kagaku*, **46**, 306–313, 1976 (in Japanese).

M. Ohtake (e-mail: otake-masakazu@jnes.go.jp)