Imperial Prize and Japan Academy Prize to:

Akira HASEGAWA
Emeritus Professor, Tohoku University

for "Seismological Study on Tectonics in Subduction Zones"

Outline of the work:

Oceanic plates moving on the earth's surface sink into the mantle at subduction zones where seismic and volcanic activities are very high. Subduction zones witness mainly three types of earthquakes: interplate earthquakes, intraslab earthquakes (wherein a slab is a part of the oceanic plate that has subducted into the mantle), and shallow inland earthquakes. By creating a highly sensitive and precise seismic-observation network in the northeast Japan subduction zone, which is one of the most typical subduction zones in the world, and developing a precise analysis method corresponding to such high-quality data, Dr. Akira Hasegawa revealed the structure of the crust and mantle as well as the seismic activity in the zone with a resolution and accuracy higher than those reported previously. Subsequent verification through many examples confirmed that the revealed phenomenon is common to subduction zones worldwide. Moreover, Dr. Hasegawa has opened up a new way to understand the relationship between the phenomena of earthquakes and volcanoes and the crust and mantle structure of the arc by considering "water migrating with plate subduction" as the key topic. Thus, he has made outstanding contributions to clarify important issues in this field.

Study of intraslab earthquakes

The first achievement of Dr. Hasegawa's unique research style is the discovery of the double-planed deep seismic zone. Prior to this discovery, earthquakes seemed to occur randomly in a slab. However, Dr. Hasegawa and his colleagues discovered that intermediate-depth intraslab earthquakes include two parallel planes in the slab. They then revealed that earthquakes in the upper plane occur in the crust of the slab, while those in the lower plane occur in the central part of the mantle of the slab. This discovery triggered the search for double seismic zones at subduction zones worldwide. It is now known that the formation of a double-planed seismic zone is a universal phenomenon in subduction zones and that the separation between the upper and lower planes is proportional to the age of the subducting plate. Furthermore, Dr. Hasegawa and his colleagues found that the seismic-velocity changes and concentration of earthquakes originate at depths where hydrous minerals in the slab are experimentally and theoretically estimated to undergo dehydration decomposition. The above mentioned series of their studies presents decisive observational evidence that slab-derived water plays an important role in generating intraslab earthquakes.

Study on the generation of arc volcanoes

Dr. Hasegawa and his colleagues discovered the ascending flow of the secondary convection facing a volcanic front, which is generated in the mantle wedge because of slab subduction, as a seismic low-velocity layer nearly parallel to the slab. Subsequently, the existence of such ascending flows was confirmed at many subduction zones in the world and their universality was clarified. Dr. Hasegawa and his colleagues revealed

how an ascending flow reaches the Moho directly under the volcanic front and how the melt in it reaches the volcanoes at the surface. In addition, they estimated the amount of melt and showed that it is generated because of the addition of water. They proposed an arc-volcano generation model that postulates that a portion of water expelled from the slab rises directly above and joins the ascending flow in the mantle wedge to generate a partial melting zone, which finally reaches the volcanoes at the surface.

Study of shallow inland earthquakes

Dr. Hasegawa and his colleagues also proposed a shallow inland earthquake generation model that postulates that water released from a slab reaches the arc crust and softens the crust to form a strain concentration zone; meanwhile, this water causes excess pore fluid pressure in the crust, lowers the frictional strength of faults, and causes shallow inland earthquakes. They found that the focal mechanisms of small earthquakes in the vicinity of the fault change slightly after large inland earthquakes. They also revealed that the frictional strength before such earthquakes is much smaller than that reported previously. Based on these observations, they pointed out that water is also involved in this process.

Study of interplate earthquakes

Dr. Hasegawa and his colleagues found that the frictional strength of fault decreased to almost zero immediately after the 2011 M9.0 Tohoku-Oki earthquake because the focal mechanisms of small earthquakes near the plate interface systematically changed after the earthquake, indicating the involvement of water. They found a large number of small repeating earthquakes on the plate interface, and based on the analysis of these events, they proposed an interplate earthquake generation model. This model postulates that aseismic slip causes stress concentration on asperities, which leads to interplate earthquakes. Using this model, they predicted the occurrence of an earthquake with a magnitude of ~5 off the coast of Kamaishi, northeast Japan. This was the first successful prediction made on the basis of the physical model.

As described above, Dr. Hasegawa significantly contributed toward elucidating the generation mechanisms of earthquakes in subduction zones and showed that water expelled from slabs plays a critical role in the occurrence of all types of earthquakes. Moreover, he proposed an arc-volcano generation model in which slab-derived water plays an important role and clarified the ascending path of the water to the arc crust. These studies have significantly contributed to better our understanding of material circulation, especially water circulation, inside the earth. Considering the impact of his studies, *ScienceWatch* by Thomson Reuters ranked Dr. Hasegawa 7th among the Top 20 Authors in 10 years (Citation in Seismology) in 2010. Further, he was elected a Fellow of the American Geophysical Union and the Japan Geoscience Union owing to these achievements.

List of Main Publications

1) Study of intraslab earthquakes

Hasegawa, A., N. Umino and A. Takagi, Double-planed structure of the deep seismic zone in the northeastern Japan arc, Tectonophysics, 47, 43–58, 1978.

Hasegawa, A., N. Umino and A. Takagi, Double-planed deep seismic zone and upper-mantle structure in the northeastern Japan arc, Geophys. J. Roy. Astron. Soc., 54, 281–296, 1978.

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Matsuzawa, T., T. Kono, A. Hasegawa and A. Takagi, Subducting plate boundary beneath the northeastern Japan arc estimated from *SP* converted waves, Tectonophysics, 181, 123–133, 1990.

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Zhao, D., A. Hasegawa and H. Kanamori, Deep structure of Japan subduction zone as derived from local, regional, and teleseismic events, J. Geophys. Res., 99(B11), 22313–22329, 1994.

Kita, S., T. Okada, J. Nakajima, T. Matsuzawa and A. Hasegawa, Existence of a seismic belt in the upper plane of the double seismic zone extending in the along-arc direction at depths of 70–100 km beneath NE Japan, Geophys. Res. Lett., 33, L24310, 2006.

Hasegawa, A., J. Nakajima, S. Kita, T. Okada, T. Matsuzawa and S. H. Kirby, Anomalous deepening of a belt of intraslab earthquakes in the Pacific slab crust under Kanto, central Japan: Possible anomalous thermal shielding, dehydration reactions, and seismicity caused by shallower cold slab material, Geophys. Res. Lett., 34, L09305, 2007.

Nakajima, J., Y. Tsuji and A. Hasegawa, Seismic evidence for thermally-controlled dehydration reaction in subducting oceanic crust, Geophys. Res. Lett., 36, L03303, 2009.

2) Study on the generation of arc volcanoes

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Nakajima, J., T. Matsuzawa, A. Hasegawa and D. Zhao, Three-dimensional structure of V_p, V_s, and V_p/V_s beneath northeastern Japan: Implications for arc magmatism and fluids, J. Geophys. Res., 106(B10), 21843–21857, 2001.

Nakajima, J. and A. Hasegawa, Estimation of thermal structure in the mantle wedge of northeastern Japan from seismic attenuation data, Geophys. Res. Lett., 30, 1760, 2003.

Hasegawa, A. and J. Nakajima, Geophysical constraints on slab subduction and arc magmatism, in *The State of the Planet: Frontiers and Challenges in Geophysics* (Eds. R. S. J. Sparks and C. J. Hawkesworth), Geophys. Monogr. Ser., 150, 81–93, American Geophysical Union, Washington, D. C., 2004.

Nakajima, J., Y. Takei and A. Hasegawa, Quantitative analysis of the inclined low-velocity zone in the mantle wedge of northeastern Japan: A systematic change of melt-filled pore shapes with depth and its implications for melt migration, Earth Planet. Sci. Lett., 234, 59–70, 2005.

Tsuji, Y., J. Nakajima and A. Hasegawa, Tomographic evidence for hydrated oceanic crust of the Pacific slab beneath northeastern Japan: Implications for water transportation in subduction zones, Geophys. Res. Lett., 35, L14308, 2008.

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3) Study of shallow inland earthquakes

Hasegawa, A., D. Zhao, S. Hori, A. Yamamoto and S. Horiuchi, Deep structure of the northeastern Japan arc and its relationship to seismic and volcanic activity, Nature, 352, 683–689, 1991.

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4) Study of interplate earthquakes

Matsuzawa, T., T. Igarashi and A. Hasegawa, Characteristic small-earthquake sequence off Sanriku, northeastern Honshu, Japan, Geophys. Res. Lett., 29, 1543, 2002.

Igarashi, T., T. Matsuzawa and A. Hasegawa, Repeating earthquakes and interplate aseismic slip in the northeastern Japan subduction zone, J. Geophys. Res., 108(B5), 2249, 2003.

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