2. Joint Volcanological Experiment on Volcanic Structure and Magma Supply System

Since 1994, joint experiments have been conducted in several volcanoes in Japan to reveal the structure and the magma supply system by the scientist group of national universities under the National Research Project for Prediction of Volcanic Eruptions (Fig.1). The experiments were conducted in Izu-Oshima Volcano in 1999, Iwate Volcano in 2000, Usu Volcano in 2001 and Hokkaido-Komagatake Volcano in 2002. The experiments were carried out by seismological, electromagnetic and other geophysical methods. These experiments succeeded in detecting some anomalous regions related to magma activity. The results of the previous experiments are briefly presented as follows.

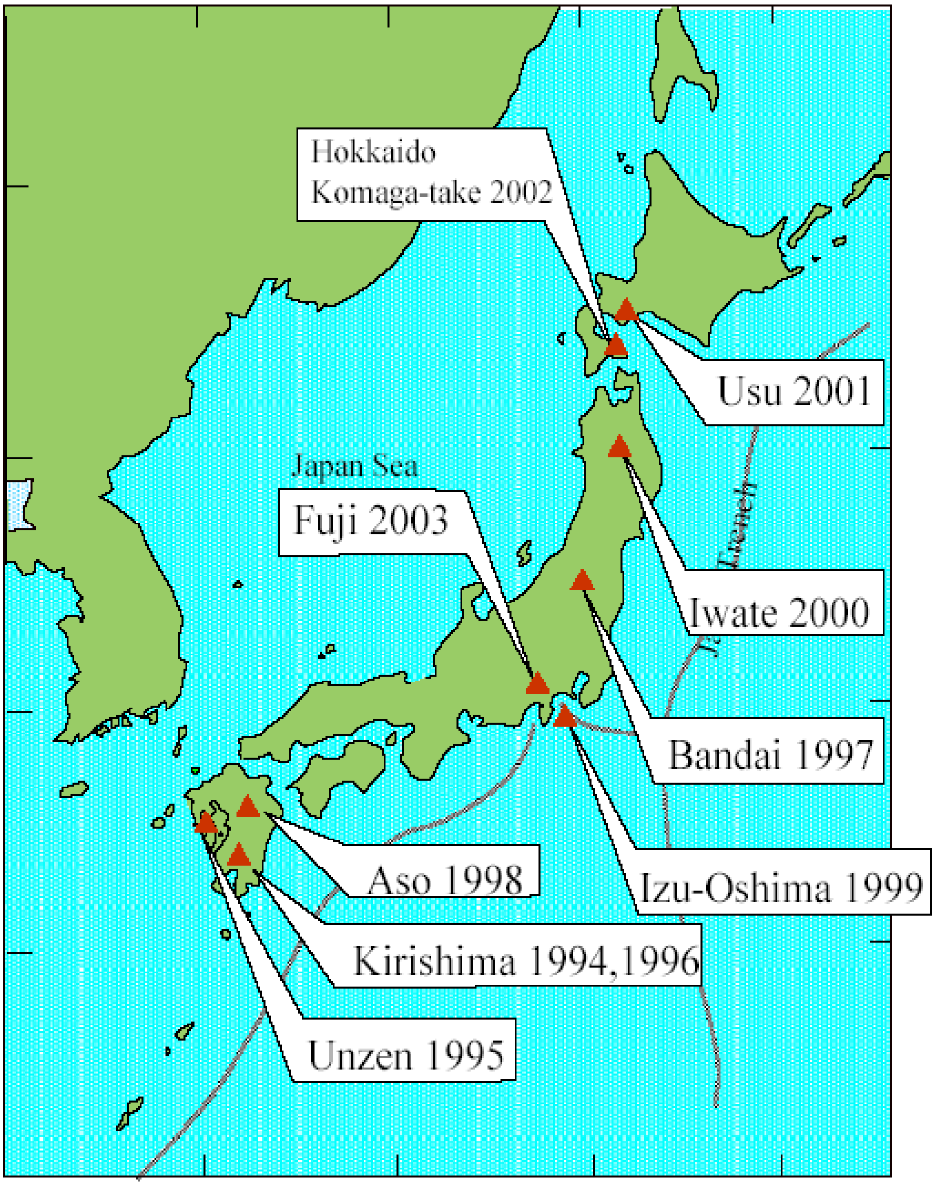

Fig. 1. Joint volcanological experiment on volcanic structure and magma supply system in Japan.

Experiments in Izu-Oshima Volcano in 1999

The 6th experiment was conducted in Izu-Oshima Volcano during 27 October - 5 November 1999. The purpose of the experiment is to clarify the subsurface structure of the volcano including the location of magma reservoir, and to understand the magma feeding system and its temporal change. Observations were made along a 30-km major line lying in the NNW-SSW direction and other sub-lines which across the major line at the center of Izu-Oshima. Survey lines and 2-dimensional arrays cover about 160 and 60 seimometers, respectively. Along these lines, 6 shots with a charge size of 200-250 kg were fired in the island, and 6 dinamite shots and air-gun shots and OBS observation were also included in the sea-area. All shots were successfully fired and significant data were obtained by most of the loggers.

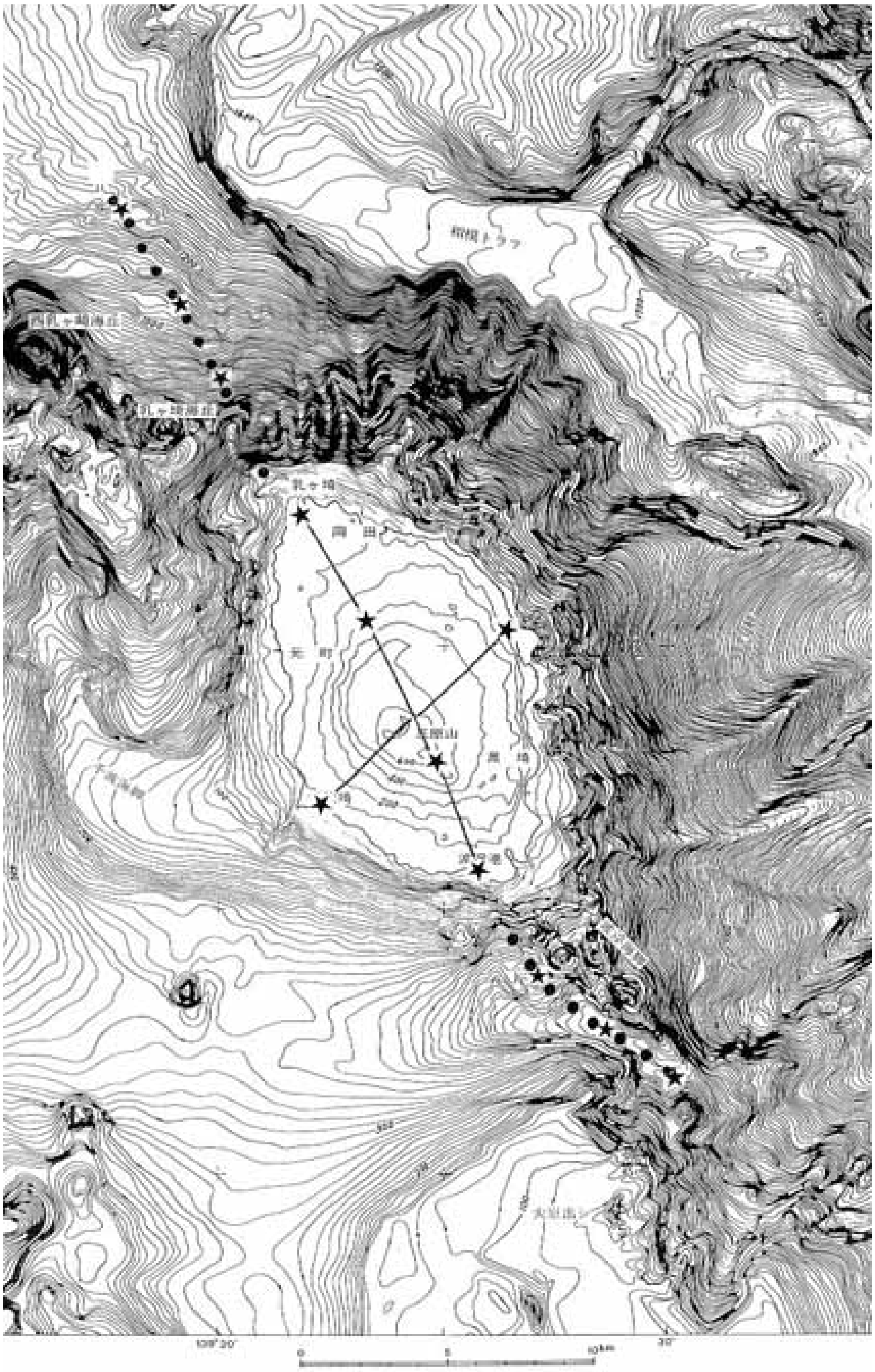

Fig. 2. Map of Izu-Oshima and the surrounding sea bottom.
Star: dynamite explosion
Dots in the sea=OBS sites

Experiment in Iwate Volcano in 2000

The 7th seismic survey of the volcanic structure was conducted around the Iwate volcano, northeastern Japan, in October 2000. The outline of the experiment and the arrival times of first motions were reported by Tanaka *et al*. (2002a). Here we show a brief summary of the survey and its scientific result. Seventy scientists participated in the active seismic survey from 11 national universities of Japan (Tohoku, Hokkaido, Hirosaki, Akita, Iwate, Tokyo, Tokyo Institute of Technology, Nagoya, Kyoto, Kyushu, and Kagoshima), the National Institute of Polar Research (NIPR) and the Japan Meteorological Agency (JMA). Fig. 3 shows a geographical configuration of the survey. Nine chemical explosions using dynamite charges of 200-250 kg excited seismic waves. The seismic signals were recorded at 330 temporary seismic stations deployed around the volcano within 20 km from the summit (study area 40 x 40 km2). Each station consisted of a vertical short-period seismometer with a natural frequency of 2 Hz and a small data logger. More than 3000 seismograms were acquired with sampling interval of 4 ms, and they showed good signal-to-noise ratios. Additional seismograms with sampling interval of 10 ms from 33 permanent stations established to monitor volcano-seismic activity by Tohoku University, JMA and the National Research Institute for Earth Science and Disaster Prevention (NIED) are also collected.

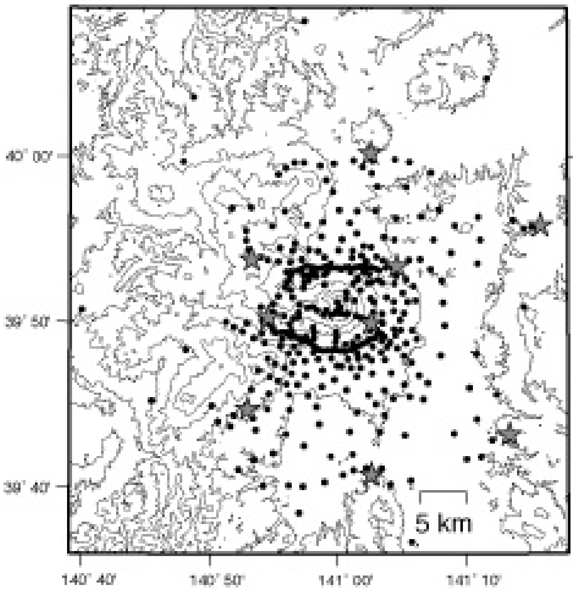

Fig. 3. Geographical configuration of the seismic survey at Iwate volcano in 2000. Starts are 9 shots. Dots are 330 temporary seismic stations deployed during the survey and 33 permanent stations by Tohoku University, NIED, and JMA.

The three-dimensional P-wave velocity structure of the volcano is determined to depths of 2 km through seismic tomography using the approximately 2700 travel-time data (Tanaka *et al*., 2002b). Fig. 4 shows the vertical cross-section of tomographic image of the volcano passing through the summit in the east-west direction. The most prominent discovery is an existing of column-like high-velocity body (V_P > 5.4 km/s) that extends vertically for 2 km beneath the caldera. While the western part of the volcano extending from the caldera is characterized by a moderate-velocity region (4.8 < V_P < 5.4 km/s), the summit and eastern flank of the volcano are covered with very low-velocity material (V_P < 4 km/s) that represent relatively younger volcanic edifices. The spatial difference in the velocity structures between the western and eastern parts of the volcano is explained by the evolutionary history of the volcano. And we find that the western structure may give constraints on the volcanic unrest in 1998.

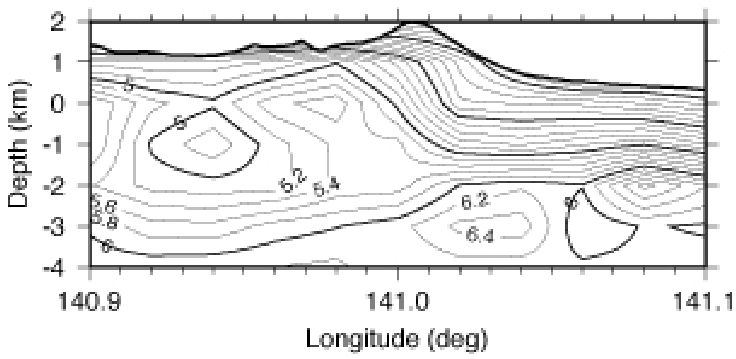

Fig. 4. Vertical cross-section of tomographic image of Iwate volcano passing through the summit in the east-west direction. Contour interval is 0.1 km/s.

Experiment in Usu Volcano in 2001

Mt. Usu erupted four times during 100 years, in 1910, 1943-1945, 1977-1982, and 2000. Noticeable characteristics common to these four eruptions are formation of a new mountain (lava dome or cryptdome) with remarkable ground deformation and violent earthquake swarm due to dacitic magma. These four eruptive activities, however, have different features. The 1977-1982 eruption occurred at the summit crater, whereas the 1910, 1943 and 2000 eruption took place at the northern foot, the eastern foot and the western foot of the volcano respectively. The duration of precursory earthquakes and eruptive activities are also different among them.

The 2000 eruption was accompanied by remarkable lateral migration of precursory earthquakes with drastically increases in number and intensity. A seismic tomography using precursory earthquakes and the following earthquakes suggests that these earthquakes mainly occurred within the layer with V_P = 6 km/s (Onizawa, *et al*., 2002a). This implies that magma intrusion and the resultant seismic activity are affected by the subsurface structure.

In order to investigate subsurface structure in more detail and discuss the magma intrusion processes, a seismic exploration using active sources was conducted on November 5, 2001. We deployed 290 seismic stations with vertical-component seismometer (a natural frequency of 2 Hz) and a compact data-logger with precise GPS clock in the volcano and its surrounding region. Dynamite charges of 200-250 kg were fired at 7 shot points around the volcano. The seismic signals were acquired with sampling interval of 4 ms

(Onizawa *et al*., 2003).

A 3D tomographic inversion reveals the south dipping well-layered P wave velocity structure (Fig. 5). The structure is consistent with resistivity structure obtained by a magnetotelluric soundings (Matsushima *et al*., 2001) and geological structure. The high velocity region ($V_P > 6$ km/s) is correlated with the Pre-Neogene system with high resistivity (1000-10000 ohm-m). The moderate velocity region (3 km/s < V_P < 6 km/s) corresponds to the Neogene-Tertiary system with low resistivity (< 500 ohom-m). The obtained velocity structure also reveals the focal cluster extending from the source of long period tremors suggesting vibration of a magma chamber at about 5.5 km to the pressure source causing inflation of the volcano edifice at about 3.5 km deep. This focal cluster implies the path of magma intrusion within the Pre-Neogene system beneath Usu volcano, although there remain unsolved problems such as the magma ascent from the pressure source and the lateral migration of the hypocenters.

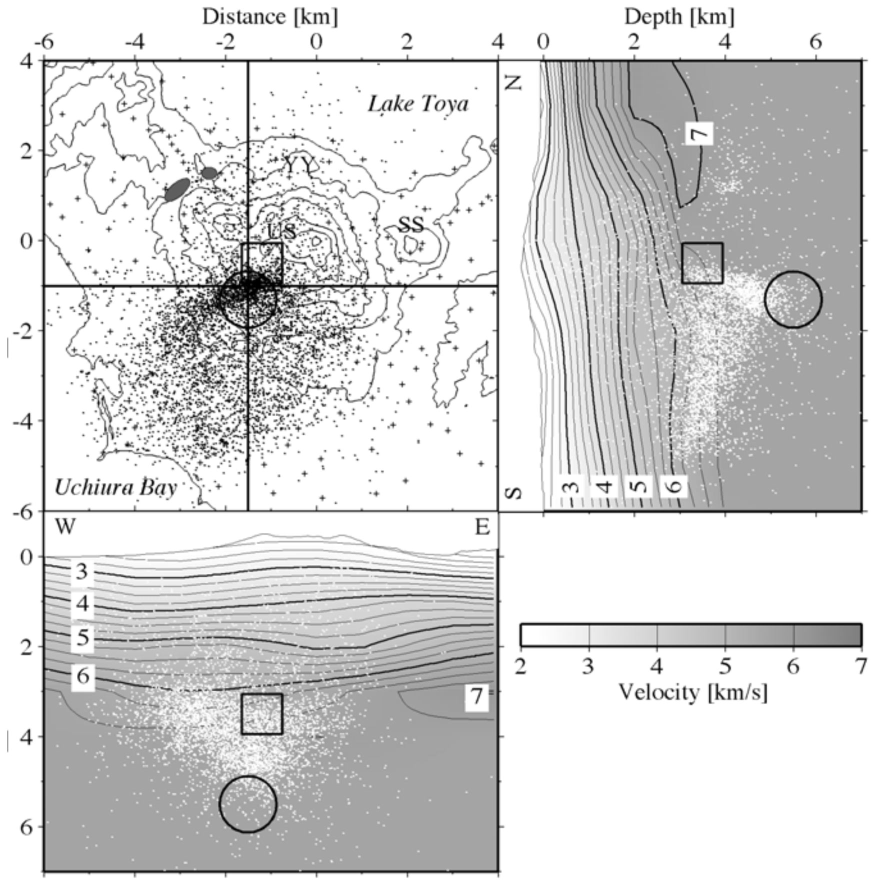

Fig. 5. N-S and E-W cross section of P wave velocity obtained by the 3D tomographic inversion and hypocenters of precursory earthquakes re-located with this velocity model (Onizawa *et al*., 2002b). The open circle and square denote the source of long period tremors (Yamamoto *et al*., 2002) and the pressure source of the vertical deformations (Mori *et al*., 2000) respectively. Shaded ellipses represent the west of Nishiyama (N) and Kompirayama (K) craterlets group. MS, SS, US show Meiji-shinzan cryptodome formed in 1910, Showa-shinzan lava dome in 1943-1945 and 77 new mountain in 1977-1982.

Experiment in Hokkaido-Komagatake Volcano in 2002

Mt. Komagatake (1133 m), one of the most active volcanoes in Japan, is located in southwest Hokkaido. It is a truncated stratvolcano crowned with a horseshoe-shaped crater at the summit. The edifice consists andesite lavas and pyroclastic rocks and is covered by pyroclastic falls, flows, surges and debris avalanche deposits.

From March 1996, after 54 years of dormancy since the 1943 phreatomagmatic eruption, Mt. Komagatake have repeated a small phreatic explosion on the summit, which is regarded as intermediate-term precursor of the coming major eruption because several minor eruption took place during 1919-1924 prior to the 1929 Plinian eruption.

In order to make monitoring of volcanic activities more accurate and to understand magma-plumbing system, a seismic exploration using active sources was conducted on 30 September 2002. A three-component seismometer (a natural frequency of 2 Hz) was installed at 129 stations to observe S phase or later phases, and 92 stations was equipped with a vertical-component (a natural frequency of 2 Hz) (Fig.6). Seismic wave excited by the 300 kg charge explosion at five shot point, were recorded on compact data-logger with precise GPS clock at each station.

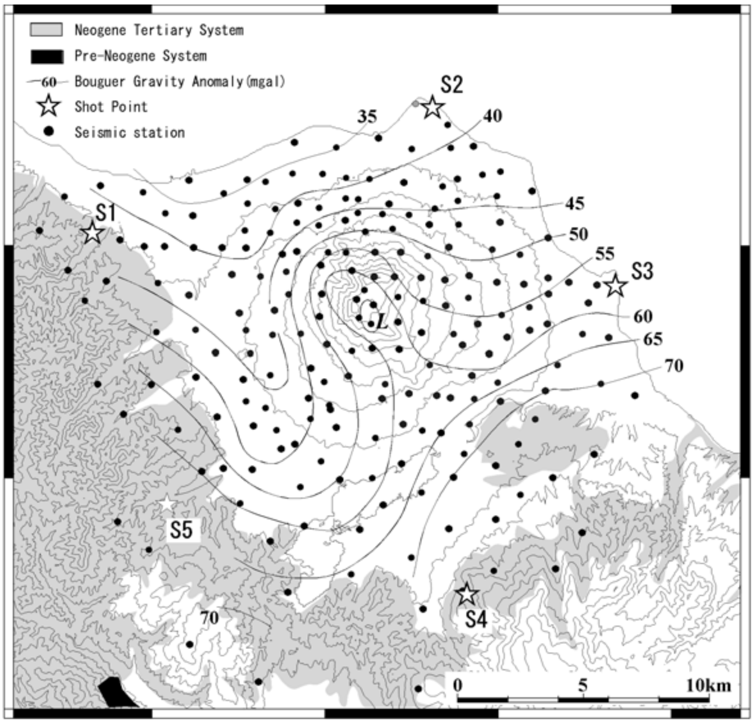

Fig. 6. Map showing topography of komagatake volcano, geological sketch, bougour anomaly, temporal seismic stations (solid circles) and shot points (open stars).

The Preliminary time term analysis for first P arrival-times reveals that a ridge of the basement extends from the southeastern mountain region to the summit of Komagatake volcano. The NW-SW trending high velocity zone corresponding to the ridge is also imaged by a 3D tomographic inversion, and the low velocity region invading from Achier bay lies in the west of it (Fig.7). Such P wave velocity distribution reflects the geological structure in Mt. Komagatake and the surrounding district. Thick Neogene-Tertiary system occurs in the low velocity region, and the high velocity zone corresponds with the uplift zone of Pre-Neogene system presumed from gravity anomaly and geology of thermal water wells.

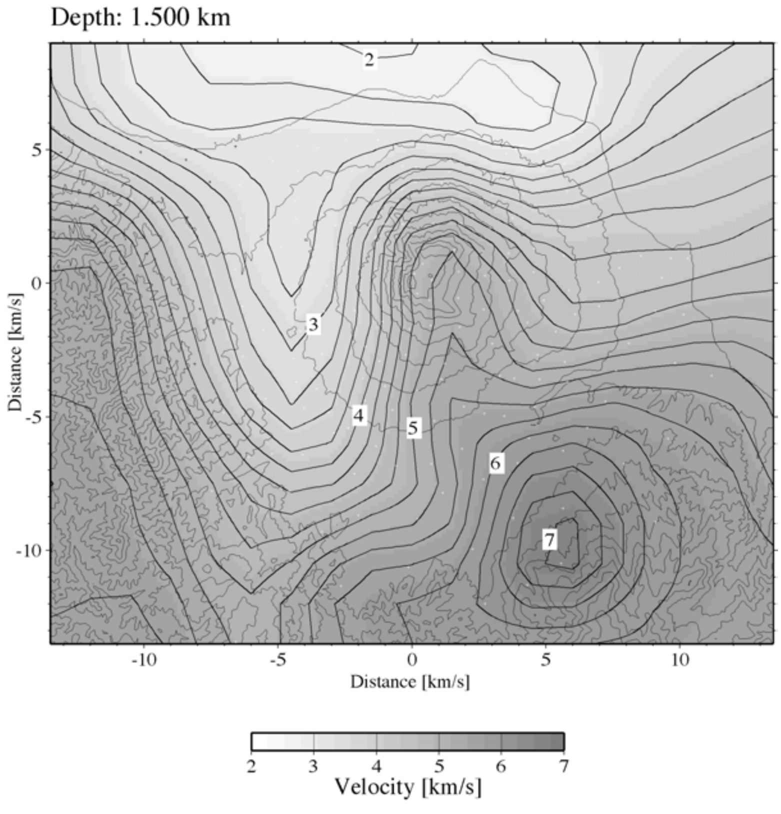

Fig. 7. Distribution of P wave velocity at the depth of 1.5 km b.s.l. obtained by the 3D tomographic inversion. The grid interval is 1 km in the vertical direction, and is 3 km in the horizontal direction.

(Tsuneomi Kagiyama, Satoru Tnaka and Hiromitsu Oshima)

References

*Tanaka, S. *et al*. (2002a) Seismic exploration at Iwate volcano with active sources —The outline of the experiment and the first arrival time data —, *Bull. Earthq. Res. Inst. Univ. Tokyo*, **77**, 1-25 .

Tanaka, S., H. Hamaguchi, T. Nishimura, T. Yamawaki, S. Ueki, H. Nakamichi, T. Tsutsui, H. Miyamachi, N. Matsuwo, J. Oikawa, T. Ohminato, K. Miyaoka, S. Onizawa, T. Mori, and K. Aizawa (2002b) Three-dimensional P-wave velocity structure of Iwate volcano, Japan from active seismic survey, *Geophys. Res. Lett.*, **29** (10), 10.1029/2002GL014983.

Matushima N. *et al*. (2001) Magma prospecting in Usu volcano, Hokkaido, Japan, using magnetitelluric soundigs. *J. Volcanol. Geoterm. Res.*, **109**, 263-277.

**Onizawa S. *et al*. (2002a) The 2001 artificial seismic experiment in Usu volcano -Three-dimensional P wave velocity structure -. Gekkan-Chikyu special ed., 39, 14-21.

*Onizawa S. *et al*. (2002b) Three-dimensional seismic velocity structure around Usu volcano, Japan. Bull. Volcanol. Soc. Japan, 47,495-506.

*Onizawa S. *et al*. (2003) Siesmic exploration at Usu volcano with active sources- The outline of the experiment and the first arrival time data -. Bull. Earthq. Res. Inst, in submitted.

Yamamoto M. *et al*. (2002) Long-period (12 sec) volcanic tremor observed at Usu 2000 eruption: Seismological detection of a deep magma plumbing system. *Geophys. Res. Lett.*, **29**, 43-1 - 43-4.

*Mori H. *et al*. (2000) Crust deformation and Eruptive activities of Mt. Usu in 2000. J.JSNDS,19-3,383-390.

(* in Japanese with English abstract ** in Japanese)