2. Petrology and Mineralogy

In the period from 1999 to 2002, many studies on petrology and mineralogy have been made by Japanese earth scientists as well as the previous period.

Significant progress has been made at the Japanese-USA cooperative studies on Hawaiian volcanoes (Naka *et al*., 2000; see section VII of this report), including deep-sea survey with the submersible "Shinkai 6500", the world's most advanced deep-sea probe. Major part of the outcome was published as a monograph (Takahashi, E. *et al*., 2002), including petrological and geochemical studies on products collected by the deep-sea survey (Kaneoka *et al*., 2002; Sherman *et al*., 2002; Shinozaki *et al*., 2002; Tanaka *et al*., 2002) and melting experiments on basalt+peridotite (Takahashi, E. and Nakajima, 2002). Other studies on the Hawaii project were appeared as individual papers (e.g., Lipman *et al*., 2000).

Research on Unzen volcano also progressed significantly after its eruption of 1990-1995 (Chen, C. H. *et al*., 1999; Kusakabe *et al*., 1999; Nakada and Motomura, 1999; Sato *et al*., 1999; Tateyama *et al*., 2002; Watanabe, Ko. *et al*., 1999). At the volcano, international scientific drilling project (Unzen volcano Scientific Drilling Project) is going on (Sakuma and Nakada, 2002; Sakuma and Saito, 2000; Uto *et al*., 2000; see section VII of this report) and many publications will be appeared in the next period.

Research on subduction-zone magmatism around Japan was made energetically. As for Northeast Japan, spatial distribution of volcanoes was noticed (Umeda *et al*., 1999), and a new concept of "hot fingers" in the mantle wedge was proposed (Tamura, Y. *et al*., 2001, 2002). The magmatism in this region was summarized (Yoshida, 2001) and compared with Southern Chile arc (Takahashi, M. *et al*., 2002b). Also Cenozoic volcanism on Hokkaido area (Hirose, W. *et al*., 2000; Hirose, W. and Nakagawa, 1999; Ikeda, Y. *et al*., 2000; Nakagawa, 1999; Nakagawa *et al*., 1999a; Okamura *et al*., 2000; Takagi *et al*., 1999) was discussed in connection with its tectonic setting. As for Southwest Japan, many geochemical studies were made especially on the Setouchi volcanics or related rocks (Furukawa and Tatsumi, 1999; Hanyu *et al*., 2002; Nakashima *et al*., 2000; Seno and Matsuura, 2000; Shimoda and Tatsumi, 1999; Sumii, 2000; Tatsumi, 2000b, 2001; Tatsumi *et al*., 2002), including contemporary adakitic rocks in central Japan (Takahashi, T. and Shuto, 1999). Also studies on the region before (Kagami *et al*., 1999a, 2000) and after (Ikeda, Y. *et al*., 2001; Kamata and Kodama, 1999; Shukuno and Arai, 1999) the opening of the Japan Sea were made. Studies on premature arcs and active back-arc basins, such as Izu-Bonin arc (Hochstaedter *et al*., 2000; Ishii *et al*., 2000a-b; Ishizuka, O. *et al*., 2002), Mariana arc (Ishikawa and Tera, 1999; Ohara *et al*., 2002), Ryukyu arc (Shinjo and Kato, 2000; Shinjo *et al*., 2000; Watanabe, Ka., 2000, 2001) and West Philippine back-arc basin (Fujioka *et al*., 1999), were made mainly by deep-sea survey. In connection to the above studies, it was proposed that continental crust with andesitic composition was generated by delamination (Tatsumi, 2000a), and that silicic magma in oceanic arc was generated by remelting of an andesitic crust (Tamura, Y. and Tatsumi, 2002). Analyses on light elements in subduction-zone magma, such as boron (Sano, T. *et al*., 2001b), beryllium (Shimaoka and Kaneoka, 2000) and carbon (Nishio and Sano, 2000), were made to investigate contribution of recycled elements from subducting sediment. There were studies on high-pressure melting experiments for related rocks (see later) and numerical simulation for wedge-mantle convection (Iwamori, 1999a-b, 2000a-b, 2001a-b, 2002a-b; Iwamori and Zhao, 2000a-b; Zhao *et al*., 2000). A textbook on subduction-zone magmatism was published by Takahashi, M. (2000). Research on plume-origin magmatism (Hanyu and Nakamura, 2000; Hirano *et al*., 2001; Tatsumi *et al*., 1999b, 2000a-b) was also progressed in addition to the Hawaii project.

There were two major eruptions during this period, on which many studies were made (see section II of this report). One was the 2000 eruption of Usu volcano, Hokkaido (phreatomagmatic/phreatic). In this eruption, it was pointed out that detailed petrographical research was needed for detection of essential materials of phreatomagmatic eruptions (Tomiya *et al*., 2001) because apparently fresh and clear volcanic glass from this eruption was found to be accidental fragment. Studies on the magmatic process of the eruption in comparison with the past eruptions (Tomiya, 2001; Tomiya and Miyagi, 2002), on vesiculation of the magma during ascent (Suzuki and Nakada, 2001, 2002), on fragmentation of country rocks due to explosion within the conduit (Yahata, 2002) and on petrographical and geochemical analyses of the volcanic ash (Nakagawa *et al*., 2002b; Nogami *et al*., 2002; Shimano *et al*., 2001) were also made. The other major eruption in this period was the 2000 eruption of Miyakejima volcano, Izu Islands (phreatomagmatic/phreatic). Again, the detection of essential materials in the eruptive products required detailed and complex researches (Miyagi, I. and Tomiya, 2002a-b; Miyagi, I. *et al*., 2001a-c). Studies on mechanism of the voluminous emission of SO_2 gas (Uto *et al*., 2001; Yasuda *et al*., 2001, 2002), on magmatic process of the eruption (Amma-Miyasaka and Nakagawa, 2002; Geshi *et al*., 2002) and on formation history of the volcano (Tsukui *et al*., 2001) were also made.

Petrological studies of other individual volcanoes (volcanic areas) around Japan include: Abu Monogenetic Volcano Group (Kakubuchi *et al*., 2000), Adatara (Fujinawa *et al*., 2001b), Akagi (Kobayashi, K. and Nakamura, 2001), Akan (Ikeda, Y., 2002), Akusekijima (Furuyama *et al*., 2002), Aoso (Toya and Ban, 2001), Aso (Obata *et al*., 2001), Bishamon-dake (Ujike *et al*., 1999), Chokai (Ban *et al*., 2001), Daikonjima basalt (Morris *et al*., 1999), Daisen (Tamura, Y. *et al*., 2000), Daisetsu (Nakamura, Y. and Hirakawa, 2000), Fuji (Fujibayashi *et al*., 1999; Ui *et al*., 2002), Hachijo-Nishiyama (Tsukui and Hoshino, 2002), Hachimantai (Ohba and Umeda, 1999), Hakone (Hirata *et al*., 2001), Higashi-Izu Monogenetic Volcano Group (Suzuki, 2000; Takahashi, M. *et al*., 2002a), Iwate (Nakagawa and Togari, 1999), Kikai and Satsuma-Iwojima (Maeno *et al*., 2002; Saito *et al*., 2002), Kita-Hakkoda Volcano Group (Kudo *et al*., 2000), Kurikoma (Fujinawa *et al*., 2001a), Myojin-sho (Ueda *et al*., 2001), Nasu (Ban and Yamamoto, 2002), Nekoma (Kimura *et al*., 2001, 2002b), Norikura (Kimura *et al*., 1999), Numazawa (Numazawa Volcano Research Group, 1999), Ontake (Kimura and Yoshida, 1999), Rausu (Miyaji *et al*., 2000), Rishiri (Ishizuka, Y. and Nakagawa, 1999; Kuritani, 1999a-b, 2001), Sannome-gata (Yoshinaga and Nakagawa, 1999), Toga (Kano *et al*., 2002), Towada (Kuri and Kurita, 1999), Tyatya (Nakagawa *et al*., 2002a) and Ueno volcano (Ueno basalts) (Kimura *et al*., 2002a; Nakano, S. *et al*., 2000; Ujike and Stix,

2000).

Studies focused on a special eruption include: the 1929 eruption of Hokkaido-Komagatake (Takeuchi, 2000; Takeuchi and Nakamura, 2001), the 1813 eruption of Suwanose (Shimano and Koyaguchi, 2001) and the 100-ka eruption of Hijiori (Matsu'ura *et al*., 2002).

Studies on volcano-related geothermal areas include: Yuzawa-Ogachi-Doroyu area (Takashima *et al*., 1999; Zhang *et al*., 1999), Hachimantai-Appi area (Takashima *et al*., 2001) and Yanaizu-Nishiyama (Okuaizu) area (Mizugaki, 2000).

Studies on volcanics of around Neocene, besides those described above (e.g., Setouchi volcanics), include: Anamizu Formation (Lopez and Ishiwatari, 2002), Beppu-Shimabara graben (Kita, I. *et al*., 2001; Yokose *et al*., 1999), Daiyama and Nisshou areas (Shimakura *et al*., 1999), Hahajima (Yajima *et al*., 2001), Hamamasu area (Aoki *et al*., 1999), Hisatsu area (Nagao *et al*., 1999), Inaniwadake (Yasui and Yamamoto, 2000), Masuda basanite (Sawada and Takasu, 1999), Oki-Dogo (Kobayashi, S. *et al*., 2002), Shimane Peninsula (Iizumi *et al*., 1999), Shirogishi Tuffs (Imaoka *et al*., 1999) and southern Fossa Magna region (Miyagi, S. and Kanai, 2002). Studies on volcanics and granites of Paleogene or older (Aoya, 2001; Ikawa *et al*., 1999; Kagami *et al*., 1999b; Kanayama *et al*., 1999; Kawano, Y. and Kagami, 1999; Owada *et al*., 1999; Rezanov *et al*., 1999; Sugii and Sawada, 2000; Tsuchiya *et al*., 1999a) were made to investigate the relation between the arc crust and felsic magmatism in Japan.

Volcanic fields outside Japan were also studied, such as: Ruapehu volcano (Nakagawa *et al*, 1999b, 2002c), Flores island (Muraoka *et al*., 2002; Otake *et al*., 2002), East African Rift Zone and related areas (Kabeto *et al*., 2001a-b; Orihashi *et al*., 2001; Sawada *et al*., 2001; Tadesse *et al*., 1999), Deccan trap (Sano, T. *et al*., 2001a), Korea (Kim *et al*., 1999), China and Mongolia (Kanisawa, 1999; Liu and Taniguchi, 2002; Nozaka and Liu, 2002; Zheng *et al*., 2002), Siberia (Agashev *et al*., 2001; Hasenaka *et al*., 1999; Litasov, K. and Taniguchi, 2002; Litasov, K. *et al*., 2000, 2001c-d, 2002; Litasov, Y. *et al*., 2002; Morikiyo *et al*., 2000), Sikhote Alin (Shimazu and Kawano, 1999; Tatsumi *et al*., 2000c) and Kokchetav 'lamproite' (Zhu *et al*., 2002).

Research on peridotite/ophiolite masses of various fields was made, such as Horoman peridotite (Kaneoka *et al*., 2001; Morishita and Arai, 2001a-b; Takazawa *et al*., 1999; Yoshikawa and Nakamura, 2000), Iwanaidake peridotite (Kubo, 2002), Nikanbetsu peridotite (Takahashi, N., 2001), Shiokawa peridotite (Uesugi and Arai, 1999), Oeyama peridotite (Tsujimori, 1999), Oman ophiolite (Ahmed and Arai, 2002; Ishikawa *et al*., 2002; Kawahata *et al*., 2001), Ronda peridotite (Morishita *et al*., 2001), Harzburg intrusion (Sano, A. *et al*., 2002), Elistratova ophiolite (Miyashita and Sokolov, 1999) and other Japanese peridotites (Abe *et al*., 1999; Kadoshima and Arai, 1999; Matsumoto and Arai, 2001; Tamura, A. *et al*., 1999). Volcanics closely related to ophiolites were also studied (Imanaka and Miyashita, 1999; Ishiwatari, 1999; Kawabata and Kiminami, 1999; Kiminami *et al*., 1999; Miyashita, 1999; Miyashita and Kiminami, 1999; Niida and Kito, 1999; Ozawa, H. *et al*., 1999; Sakakibara *et al*., 1999; Tsuchiya *et al*., 1999b). In addition, mantle xenoliths (Arai *et al*., 2000, 2001; Hattori, K. H. *et al*., 2002; Yamamoto *et al*., 1999) and inclusions in diamonds (Akagi, 1999; Wang *et al*., 2000) and Cr-spinel (Shimizu, K. *et al*., 2001) were investigated for mantle studies.

There was mass production of papers in the field of high-pressure experiment on mantle mineralogy (Chen, J. *et al*., 2002; Hattori, T. *et al*., 2000; Hirose, K. *et al*., 1999, 2001a-b; Katsura, 2002; Kuroda *et al*., 2000; Miura *et al*., 2000; Miyajima *et al*., 1999, 2001; Murakami *et al*., 2002; Nakatsuka *et al*., 1999a-b; Oguri *et al*., 2000; Ono, 2000; Ono *et al*., 2001a-b, 2002a; Shinmei *et al*., 1999; Shirasaka *et al*., 2002; Suito *et al*., 2001) and melting experiments on MORB-like or mantle-related rocks (Aizawa *et al*., 1999; Chung and Kagi, 2002; Funamori *et al*., 2000; Hirose, K., 2002; Hirose, K. and Fei, 2002; Inoue *et al*., 2000; Kogiso and Hirschmann, 2001; Litasov, K. *et al*., 2001a-b; Niida and Green, 1999; Okamoto and Maruyama, 1999; Ono, 1999; Pati *et al*., 2000; Singh *et al*., 2000; Sumita, 2000; Tatsumi *et al*., 1999a; Wang and Takahashi, 1999, 2000) including diamond-forming experiments with carbonate melt (Arima *et al*., 2002). There was also an experimental study on water solubility in natural rhyolite melt at crustal pressure (Yamashita, 1999).

Various types of analytical or experimental techniques were improved, such as electron microprobe (Geshi and Yoshida, 2001; Kato, 1999; Sugawara, 2001a; Ujike, 2000), ICP-MS (Fukuda and Nakai, 2002; Nakai *et al*., 2001), FT-IR (Ogo and Yamashita, 1999; Okumura *et al*., 2000), TL measurement (Shimao *et al*., 1999), Pb-isotope measurement (Nohda, 1999) and 1-atm gas-mixing furnace (Sugawara, 1999). New types of analyses of rock texture were introduced such as X-ray CT (Nakano, T. *et al*., 2000; Ohtani *et al*., 2000, 2001; Tsuchiyama *et al*., 2000), high-resolution TEM (Hiraga, 1999) and polarized laser-scanning microscope (Shimizu, I. and Shimada, 2002).

Fluid connectivity (wetting angle) in porous rocks and its role on various processes were noticed. Mibe *et al*. (1999, 2000) suggested that the generation of arc magma and, therefore, the location of the volcanic front may be controlled by aqueous fluid connectivity in the mantle. The connectivity of fluid was also thought to be important on water transport within mantle (Ono *et al*., 2002b), crust (Nakamura, M., 2000; Nakamura, M. and Watson, 2001; Yoshino *et al*., 2002) and metamorphic rocks (Hiraga *et al*., 2001, 2002). Connectivity of melt in crystal-rich magma was also studied in relation to the textural development of igneous rocks in the stage of their crystallization (Ikeda, S. *et al*., 2002).

There were various types of studies on dynamics of magma from petrological points of view, such as, melt migration within dikes (Geshi, 2000, 2001), crystallization and cooling history of magma (Miyake and Shimobayashi, 2000; Nishimura and Yanagi, 2000; Sano, Y. *et al*., 2002), solidification of lava domes (Smith *et al*., 2001), and formation of layered structure of gabbro (Akatsuka *et al*., 1999) and peridotite (Toramaru *et al*., 2001). A series of analogue experiments on crystallization of magma within meltable material (a binary eutectic system) was carried out (Kaneko and Koyaguchi, 2000) in order to discuss evolution of a magma chamber within the crust (Koyaguchi and Kaneko, 1999). There was also a numerical experiment of crystallization for a binary eutectic system for the purpose of applying to igneous textures (Toramaru, 2001). A textbook on dynamics of petrogenesis was published by Banno *et al*. (2000). Theoretical approach to viscosity of magma (Taniguchi,

2000) and a review on magma science (Taniguchi, 2001) was made.

Thermodynamical and mineralogical research was made on mixing properties of Ca in olivine (Kawasaki, 1999, 2001a-b), phase relations of enstatite at high temperatures (Jiang *et al*., 2002), behavior of Sr in CaAl-silicates (Enami, 1999), fine structure of amphiboles (Ishida *et al*., 2002) and oxybiotite (Kogure and Nepolo, 2001), partition of Mg between olivine/orthopyroxene and melt (Sugawara, 2000a), Fe and Mg between plagioclase and melt (Sugawara, 2000b, 2001b) and trace-elements within mantle materials (Kanzaki, 2000; Taura *et al*., 2001) in even open magmatic systems (Ozawa, K., 2001). Studies on other kinetic processes include: diffusion in garnet (Nishiyama, 1999) and biotite (Utsuki, 2002), equilibrium form of negative crystals in quartz (Asada *et al*., 2002), and weathering/hydration of volcanic glass or minerals (Kawano, M. and Tomita, 2001; Kita, S. *et al*., 1999; Nakamura, Y. *et al*., 2002).

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