Annual Report FY 2000

平成１２年度 活動報告

Institute for Geothermal Sciences

Graduate School of Science
Kyoto University

京都大学
大学院理学研究科

附属地球熱学研究施設

Institute for Geothermal Sciences
Graduate School of Science, Kyoto University

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Front Cover Image:
The strombolian explosion in the 1st crater of Mt.Nakadake, Aso volcano in October 1979.
(Photograph: M.Sako)
表紙の写真：
１９７９年１０月の阿蘇中岳第１火口のストロンボリ式噴火の様子
（迫幹雄撮影）

Editorial compilation by Y. Furukawa
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Preface

Fiscal Year 2000, covering the period between April 2000 and March 2001, was the transformative time marking an epoch for university people; the Ministry of Education, Culture, Sports, Science and Technology was newly established by reorganization of Japanese Government, and also the juridical personalization of national universities started to materialize. Such movements urge us to think about what is expected and what can be done. Publication of our annual report started in 1997 when the Institute was established. Various records accumulated in the four reports including this volume should give us basic data to think and act towards the future.

Some changes in staff occurred in the Institute. Firstly, Dr. T. Ohkura took up his position of Associate Professor in Research Section for Volcanic Structure on 16 October 2000, coming from the Faculty of Integrated Human Studies, Kyoto University. Secondly, Professor Y. Tatsumi retired from the Institute on 31 December 2000 to work in Japan Marine Science and Technology Center. Although he held the post shorter than three years and half, he inspired staff with leading ideas on the Earth Sciences, and consolidated the research organization and experimental facilities in the Institute. I would like to express my cordial gratitude for his intensive contributions. For visiting professors, Professor Udo O. Fehn (University of Rochester) joined us from 1 April to 30 September, 2000 working on an investigation entitled "Determination of I-129 in geothermal and volcanic waters in Japan: a search for the presence of marine sediments in subduction zones". From 1 October 2000, Dr. Gary M. Thompson (University of Hong Kong) has taken the position carrying on his investigation entitled "Evolution of the deep mantle inferred from Re-Pt-Os isotopes". In addition to the twelve regular faculty members, two teaching associates, one JSPS research fellow, four special research fellows, one visiting researcher, six graduate students worked at the Aso and/or the Beppu facilities.

Mr. T. Hoka, Technician, retired from Kyoto University by reaching retirement age on 31 March 2001. Over the last 42 years, he has made many important contributions to various observations and to the maintenance of the facilities at the Aso Laboratory. On the same day, Ms. M. Yamamoto, Secretary, left the Beppu Laboratory. I would like to express my cordial gratitude to them.

Under changing circumstances inside and outside the Institute, we must strengthen our efforts even more. I hope that this annual report will contribute to the mutual understanding among the members of the Institute, as well as present their activities to a broader audience. I would like to invite all people to investigate our activities through this report and am looking forward to hearing comments and advise concerning the further development of the Institute.

May 2001

Yuki Yusa, Director in Fiscal Year 2000

序

20 世紀から 21 世紀へと移る平成 12 年度は，大学に籍を置き，研究と教育にたずさわる私たちにとって，文部科学省が発足するとともに，国立大学の法人化への動きが具体化するという，節目の年であったと思います．そうした激動の中で，私たちは，何を期待されているのか，何をなすことができるのかを常に考えていくことが要求されているように思われます．当施設が発足した平成 9 年度から発行が始まった本施設の年報は，今回で第４号となりますが，それらに盛られている活動記録は，将来に向けて考え・行動する上での基盤的資料になるものと信じます．

平成 12 年度においても，施設人員の異動等がありました．教官では，平成 12 年 10 月 16 日付けで，京都大学総合人間学部より大倉敬宏助教授が着任されました．同助教授は阿蘇を主勤務地として，火山構造論研究分野を担当しています．これにより，施設の教官定員（12 名）が充足しましたが，平成 12 年 12 月 31 日付けで，巽好幸教授が退職され，海洋科学技術センター（JAMSTEC）に異動なさいました．同教授の在任は 3 年半足らずの短期間ではありましたが，本施設に新風を吹き込み，

地球物質科学に関連した研究組織と実験設備の整備・充実を推進されました．ここに深く感謝の意を捧げたいと思います．外国人客員研究員には，平成12年4月1日から9月30日まで Udo O. Fehn 教授が就任し，「日本の地熱及び火山水中に含まれる沃素 129 の測定：沈み込み帯における海成堆積物存在の探索」の研究を行い，次いで，平成12年10月1日からは Gary M. Thompson 助教授が就任し，「Re-Pt-Os 同位体から推定される深部マントルの進化」の研究を行っています．以上に加えて，教務補佐員2名，日本学術振興会特別研究員1名，特別予算による非常勤研究員4名，研修員1名，大学院生6名が研究活動を行いました．

行政職では，昭和 34 年度から 42 年間の長きにわたって，阿蘇における観測と施設の維持管理をご支援いただいた外輝明技官が，平成13年3月31日をもって定年により退官なさいました．また，同日付けで，別府の事務を担当していただいた山本美由紀事務補佐員が退職されました．これらの方々に，深く感謝を申し上げます．

先に述べた大学法人化を始めとする変革の潮流の中にあって，研究を始めとする諸活動のいっそうの活発化が望まれます．この活動報告が，施設全員の相互理解と研鑽の拠り所として活用されることを願い，また，施設外の方々には，私たちの活動をご理解いただき，ご指導ご助言をたまわりますよう，お願い申し上げます．

平成13年5月
平成12年度地球熱学研究施設長
由佐　悠紀

構　成　員　Member

教　　授　*Professors*

田中 良和　Yoshikazu Tanaka
巽　好幸　Yoshiyuki Tatsumi
平成１２年１２月 退職
由佐 悠紀　Yuki Yusa
（施設長　Director）

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大倉 敬宏　Takahiro Ohkura
平成１２年１０月 着任
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須藤 靖明　Yasuaki Sudo

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川本 竜彦　Tatsuhiko Kawamoto
小野 博尉　Hiroyasu Ono
柴田 知之　Tomoyuki Shibata
鈴木 勝彦　Katsuhiko Suzuki

外国人研究員　*Visiting Faculty*

Gary Thompson
平成１２年１０月 着任
Fehn Udo
平成１２年９月 退職

技　　官　*Technical Professionals*

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馬渡 秀夫　Hideo Mawatari
迫　幹雄　Mikio Sako
吉川　慎　Shin Yoshikawa

教務補佐員　*Research Assistant*

芳川 雅子　Masako Yoshikawa

研究支援推進員　*Technical Assistant*

増田 秀晴　Hideharu Masuda
平成１２年１１月 着任
Bogdan S. Vaglarov

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山本 美由紀　Miyuki Yamamoto
米沢 由佳　Yuka Yonezawa

臨時用務員　*Temporal Assistant*

増田 秀晴　Hideharu Masuda
平成１２年１０月 退職
山崎 咲代　Sakiyo Yamasaki

非常勤研究員　*Research Associates*

熊谷 一郎　Ichiro Kumagai　(JSPS)
松影 香子　Kyoko Matsukage
平成１２年１２月 着任
下田　玄　Gen Shimoda
宇津木 充　Mitsuru Utsugi

大学院生　*Graduate Students*

網田 和宏　Kazuhiro Amita　D４
長谷 英彰　Hideaki Hase　D3
John Makario　D2
中坊　真　Makoto Nakaboh　D４
山田　誠　Makoto Yamada　D1
吉川 美由紀　Miyuki Yoshikawa　D2

Compressional wave velocity of granite and amphibolite up to melting temperature at 1 GPa

Y. Aizawa and K. Ito

Compressional wave velocities (V_P) at above-solidus temperatures and at 1 GPa were obtained for an granite and amphibolite, which are considered to be major constituents of the continental crust. The temperature variation of velocities showed that the V_P values of granite decreased with raising temperature, but substantially increased beyond the melting temperature (850-900°C). Such an increase may be caused by the α–β transition of quartz (Fig. 1 (a)). The present results, together with estimated geotherms corresponding to the heat flow value, beneath the southern Tibet, suggest that the thickening of the felsic crust would lead to raise the temperatures within the crust sufficient to cause partial melting, yielding a low velocity and subsequent increase of the velocity due to the quartz transition (Fig. 2 (a)). The velocities of amphibolite decreased linearly with increasing temperature and dropped sharply at temperatures above the solidus (700°C), indicating that partial melting of amphibolite acts to significantly lower the seismic velocities (Fig. 1 (b)). Taking the density of the crust into account, the low average seismic velocities beneath central Andes, may be explained by the presence of partially molten amphibolite, which is probably originated from basaltic magmas underplated at the base of the crust (Fig. 2 (b)).

References

Owens, T.J. and Zandt, G. (1997) Implications of crustal property variations for models of Tibetan Plateau evolution, Nature, 387, 37-43.

Wigger, P. J. and 10 others (1994) Variation in the crustal structure of the southern Central Andes deduced from seismic refraction investigations, In: K-J. Reutter, E. Scheuber and P. Wigger (Eds), Tectonics of the Southern Central Andes. Springer, Berlin, pp. 23-48.

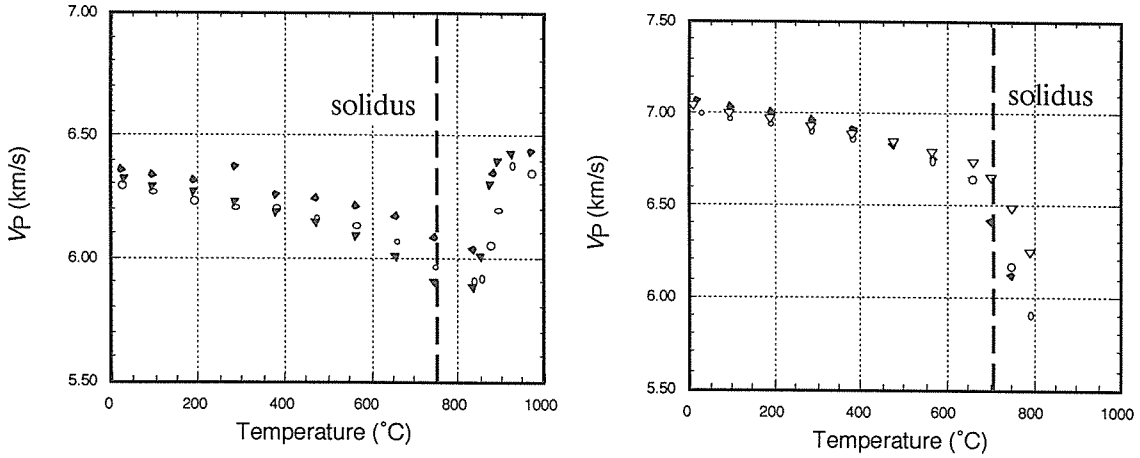


Fig. 1 Compressional wave velocity (V_P) of granite; (a) and amphibolite; (b) as a function of temperature.

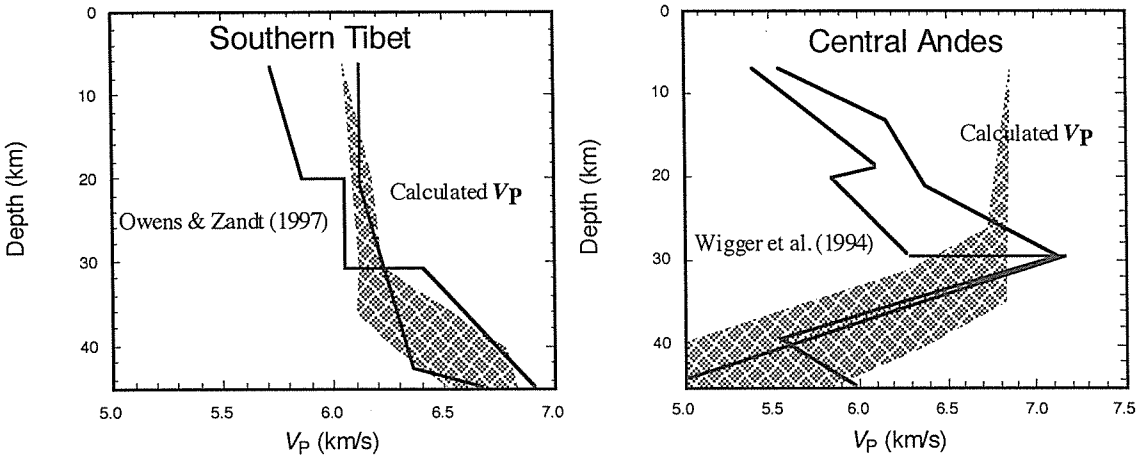
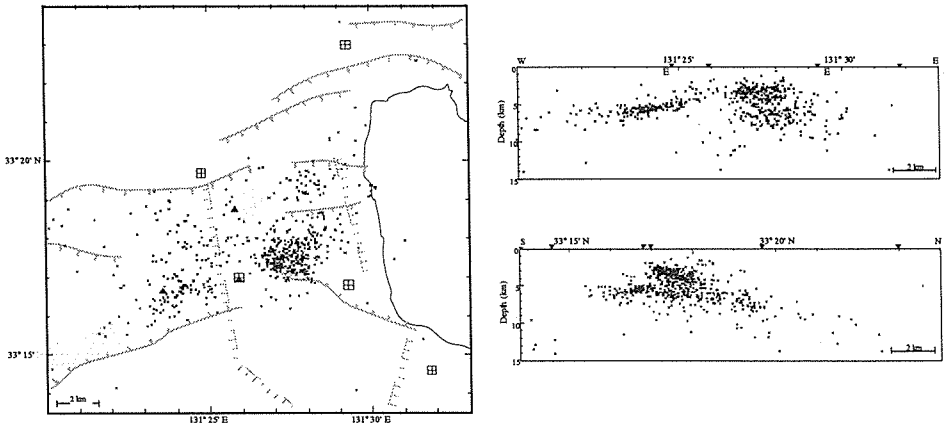


Fig. 2. Velocity (V_P)-depth relation of granite and amphibolite (this study), together with P-wave velocity data for southern Tibet (Owens and Zandt (1997)) and central Andes (Wigger et al. (1994)).

Seismic Activity in the Beppu graben, Kyushu, Japan: implications for earthquakes triggered by magmatic fluids

Y. Furukawa, H. Mawatari, and T. Ohkura

The Beppu graben is located at the eastern end of the Beppu-Shimabara rift zone in Southwest Japan, where E-W striking normal faults are dominated. In this graben we have installed five seismic stations and monitored seismic activity since March 1993. Focal distribution in this graben shows the following features: (1) there is an aseismic zone in the eastern flank of the Quaternary volcanoes: Mt.Garan and Mt.Tsurumi, (2) most of earthquakes in this graben have occurred in a region around the aseismic zone, (3) focal distribution shows a parabolic form in which focal depths increase with the distance from the aseismic zone, while seismicity is active at shallower depths between the Kannawa and the Asamigawa faults through which hydrothermal circulation of meteoritic water is very active. These features could be explained by high temperatures of the magmatic body in the aseismic zone and migration of magmatic and meteoritic fluids around the magmatic body. The deeper limit of the seismicity probably corresponds to an isotherm of the brittle-ductile transition of granitic rocks. Magmatic fluids from the magmatic body migrate upward, which causes seismicity with the parabolic focal distribution above the isotherm. In the area of the shallow seismicity between the Kannawa and the Asamigawa faults hydrothermal circulation of meteoritic water is very active, which could be the cause of the shallower seismicity.



Left: Epicenter distribution located in the period from April 1993 to Dec. 1999 for events with magnitude greater than 1.0. The shaded oval represents the location of the estimated high electric conductivity body. Fault structures estimated from gravity survey are also shown as shaded straight lines. Open rectangles and filled triangles denote seismic stations and volcanoes, respectively.
Right: Vertical cross sections of focal distribution in the N-S and E-W directions. The solid triangles denote the location of the seismic stations.

Self-potential measurements on the central cones of Aso Volcano (3)

H. Hase, T. Hashimoto, M. Utsugi, and Y. Tanaka

We have conducted self-potential (SP) surveys since 1998 on the central cones of Aso Volcano, southwestern Japan. As a result of the survey until last year, we detected some characteristic positive anomalies: (i) a regional anomaly, which centers on the Nakadake creter (+800mV); (ii) local anomalies around the hot spring areas (Jigoku-Tarutama, Yoshioka and Yunotani, +200mV); (iii) local anomalies around Mt. Kishima and Mt. Ojo (+300mV).

We also detected local positive anomalies on Mt. Eboshi and Mt. Neko. Positive SP anomalies are often considered as a sign of subsurface hydrothermal activity. Mt. Eboshi and Mt. Neko were formed about 25,000 and 100,000 years ago, respectively. They are older than most of other cones belonging to Aso Volcano. Besides, geothermal activity on the ground surface cannot be seen in these areas. Considering these matters above, it is difficult to attribute the cause of these positive anomalies to subsurface hydrothermal upflows around these areas. More plausible mechanism for the anomalies is the effect of impermeable layer in the vicinity of these peaks that interferes the water flow. Thus, positive anomalies of small scale appear there due to the calceling of topographic effects. In the case of (iii), we also recognize the same effect.

Geomagnetic variation and heat discharge at Aso volcano

T. Hashimoto, Y. Tanaka, M. Utsugi, S. Sakanaka, and H. Masuda

Thermomagnetic changes and its mechanism of Aso Nakadake volcano was investigated using geomagnetic changes observed in 1991-2000 near the active crater with special attention to the heat budget of geothermal system including the crater lake. The heating and cooling rate below the crater was estimated based on the thermomagnetic model. The heating/cooling rate at the 'thermal reservoir' inferred from geomagnetic changes was revealed to have decreased to one fifth after 1994. In addition, the rate during calm stage of the volcano was found to be about one tenth of the discharging energy from the crater lake. The authors maintain that the crater lake functions as a large heat radiator which suppress the temperature variation of the system during a calm stage and that the crater lake should not be regarded as a 'thermal cap' as had been considered by Tanaka (1993). The 'thermal reservoir' below the crater lake during a calm stage works as a field of efficient heat transport from depths to the lake rather than as an accumulator of the heat. Therefore the heat-transport system including the crater lake tends to keep a quasi-equilibrium during the calm stage of volcanic activity. The authors consider that the equilibrium is broken and an active stage starts when the efficient heat-transport process is lost.

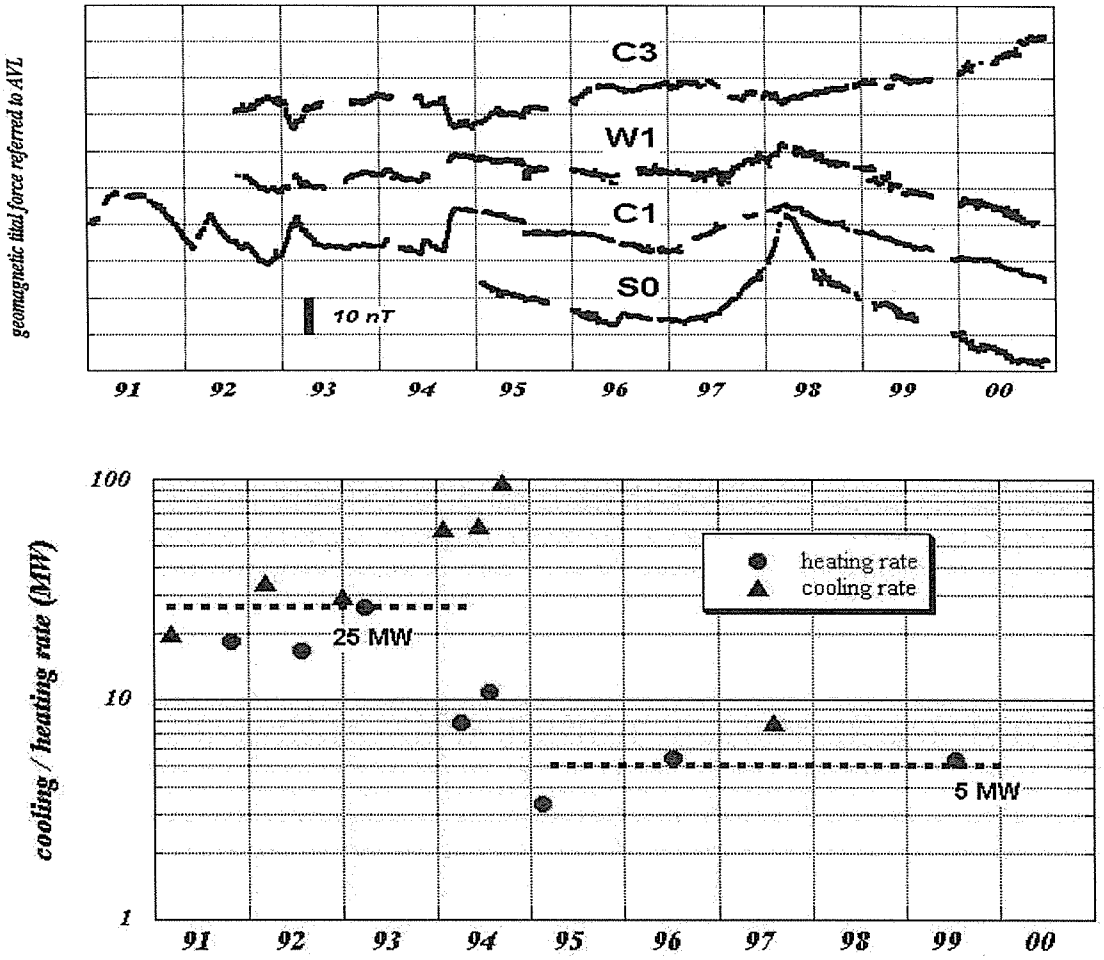


Figure1: (upper) Temporal change in geomagnetic total force observed at Aso volcano (daily values). (lower) Heating/cooling rate deduced from geomagnetic changes and powerloss from the surface of the crater lake.

Direct Observation of Complete Miscibility Between Andesitic Magma and H_2O at High Temperature and Pressure Conditions

T. Kawamoto

Knowledge of structures of magmas is important to model the evolution of the earth's interior. Much efforts has been made to understand structure of magmas by measuring properties of glasses quenched from high temperature and pressure conditions. Properties of silicates melts have been found to be different from those of quenched glasses (1). Therefore, the direct measurement of melts at high temperature and pressure conditions is desirable. Based on chemistry of partial melts of H_2O-saturated mantle peridotite, we have suggested structures of hydrous melts should change drastically with an increasing pressure (2). A series of direct observation of complete miscibility in H_2O and an island arc andesite has been conducted using Bassett's type externally heated diamond anvil cell (DAC, (3)). The starting material is an andesitic scoria which was erupted from the east frank of Fuji volcano at 1707 (Ho-2). There is less than 1 volume % crystals in the sample. Chemical characteristics of the andesite (61.2 weight % SiO_2, 0.97 % TiO_2, 16.45 % Al_2O_3, 7.25 % Fe_2O_3*, 0.14 % MnO, 2.29 % MgO, 5.7 % CaO, 3.9 % Na_2O, 1.8% K_2O, 0.3 % P_2O_5) is calc-alkaline andesite of Miyashiro, and of high alumina basalt series of Kuno , and medium K of Gill. Hydrous glasses were produced through melting of Fuji 1707 andesite powders and 2 weight % water at 1 GPa and 1300 ° C for 1 hour with piston cylinder type high

pressure apparatus. For direct observation using DAC, chips of the quenched glass were loaded into a sample room of Rhenium gaskets with distilled water and an air bubble. Upon heating the air bubble is found to diminish into the H_2O fluid at a homogeneous temperature, depending on a bulk density of H_2O. This allows us to estimate the pressure and temperature path inside of the sample room using equation of state of H_2O. Subsequent heating produces a single fluid phase with a small amount of crystalline phases left (Figure 1). Upon decompression or cooling, at around 1 GPa and 950 °C, the single supercritical fluid suddenly becomes milky (Figure 2) and is separated into two fluids (Figure 3), and they are coalesced to larger globules of H_2O rich andesitic melts surrounded by silicate rich H_2O fluid (Figure 4). Such a supercritical behavior has been reported in the albite and H_2O system (4) and the SiO_2-$Al2O_3$-Na_2O-K_2O-CaO-MgO system (5). Whether such a supercritical behavior occurs between H_2O fluids and magmas equilibrated with mantle peridotite system remains uncertain. This study is the first observation of a supercritical behavior of natural andesite. It is difficult to melt basaltic compositions in Bassett type DAC due to its temperature limitation of 1050 °C. The Fuji 1707 eruption produced ejecta in a compositional range from basalt to rhyolite (49 SiO_2 weight % to 70). We will examine the supercritical temperature and pressure conditions from andesite to rhyolite in order to estimate the PT conditions of possible supercritical fluid in the basalt-H_2O system.

(1) Stebbins, J. F., McMillan, P. F., and Dingwell, D. B. ed., 1995, Reviews of Mineralogy, 32, Mineral. Soc. Am.

(2) Kawamoto, T. and Holloway J. R., 1997, Science, 276, 240-243.

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(4) Shen, A. H., and Keppler, H., 1997, Nature, 385, 710-712.

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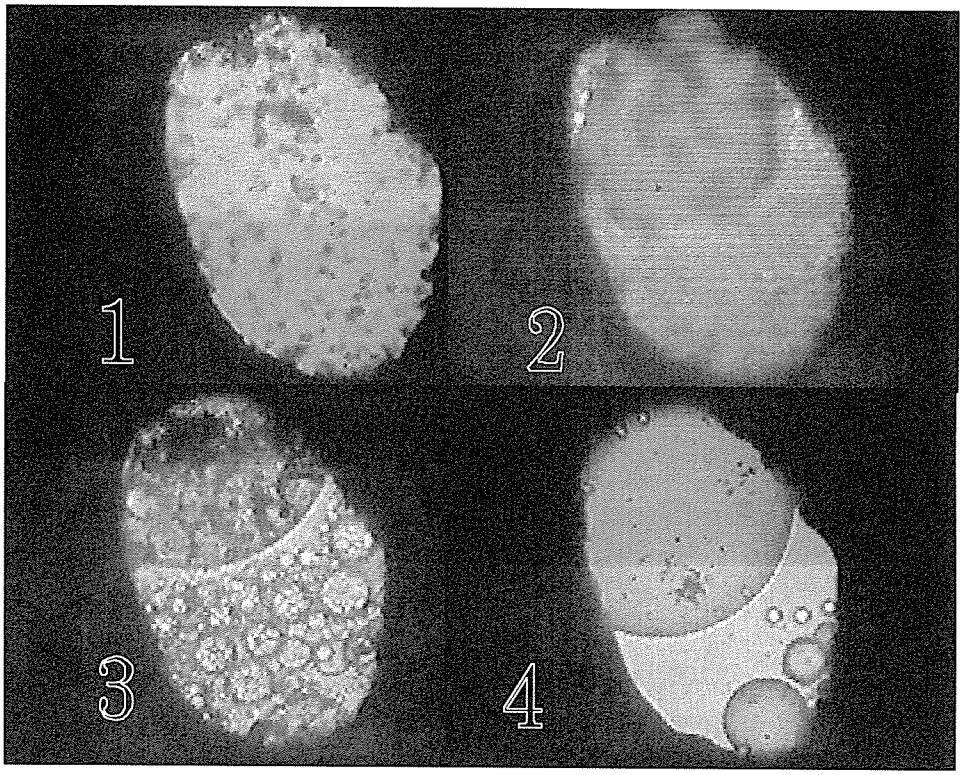


Figures. Supercritical behavior of H_2O and andesitic melt at around 1 GPa and 950 °C. A homogeneous fluid phase with a small amount of crystalline phases (1) becomes milky (2) and is separated into two fluids (3). Coalesced globules of H_2O rich andesitic melts are surrounded by silicate rich H_2O fluid (4). This sample room is 300 x 550 micrometers.

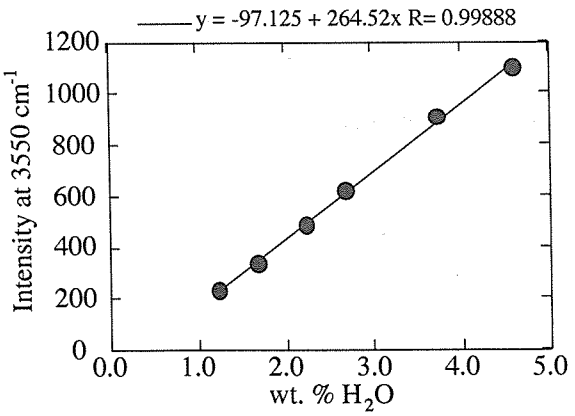
Determination of H_2O abundances in Andesitic glasses by micro-Raman spectroscopy

*T. Kawamoto and S. Yamashita**

*(*Institute for Study of the Earth's Interior, Okayama University at Misasa Campus)*

H is the most abundant and important volatile element to affect differentiation processes of earth forming materials. However, H_2O in deep-seated magmas escapes during ascending to the surface and is lost eventually at a moment of eruption, because H_2O solubility in silicate melts decreases with decreasing pressure to zero at the atmospheric pressure. Therefore much efforts have been made to determine H_2O concentrations of melt inclusions which can possess H_2O in the depths. Recently Thomas (2000) performed Raman spectroscopy with rhyolitic compositions and concluded that Raman microscope is a vital tool to determine H_2O concentrations of small melt inclusions. Raman microscope has a higher spatial resolution of a few micrometers than 10 micrometer of infra red microscope and SIMS and requires a single side polished section. We here report our results of Raman spectroscopy for hydrous andesitic glasses. The starting material is an andesitic scoria that was erupted from the east frank of Fuji volcano at 1707 (HoTa-1). Chemical characteristics of the andesite (58.21 weight % SiO_2, 1.12 % TiO_2, 16.92 % Al_2O_3, 8.45 % Fe_2O_3*, 0.17 % MnO, 2.97 % MgO, 6.6 % CaO, 3.76 % Na_2O, 1.47 % K_2O, 0.33 % P_2O_5) is calc-alkaline andesite of Miyashiro, and of high alumina basalt series of Kuno, and medium K of Gill. Hydrous glasses were synthesized through melting of Fuji 1707 andesite powders and desired water contents at 1 GPa and 1300 degree C for 1 hour using piston cylinder type high pressure apparatus at Beppu. Quenching rate of 200 degree C per a minute was achieved by switching off a power supply. We used $Au_{75}Pd_{25}$ capsule in order to minimize iron loss to the capsule material. Quenched glasses were crushed and separated to be used for density measurements and then H_2 manometry, and doubly polished thin sections originally for FTIR analysis. H_2 manometry was conducted by S. Y. at Misasa. Unpolarized Raman spectra of the andesitic glasses were measured with Raman microscope (Keiser HoloLab 5000 system) composed of 532 nanometer YAG laser, holographic transmission gratings, and CCD detector for 100 – 4500 cm^{-1} Raman shift. Low frequency region at 250-1250 cm^{-1} is characterized by bands from bending and stretching vibrations of Si – O - Si (Al). High frequency region is characterized by band at 3550 cm^{-1} from Si (Al) – OH and molecular H_2O. Absolute Raman intensity is difficult to obtain (Zotov and Keppler 1998). Therefore, we normalized the Raman spectra requiring that the integrated area in the range 250 – 1250 cm^{-1} equals to 1,000,000. We obtained a linear relationship between normalized intensity of 3550 cm^{-1} and total H_2O concentrations determined by manometry (Figure). We are now investigating Raman spectra of hydrous rhyolite and basalt glasses with known H_2O concentrations (Yamashita et al., 1997) and preliminary results show that we can use micro-Raman spectroscopy in a wide range of chemical compositions to determine 1 weight % or more H_2O concentrations. FTIR can provide us with information about the speciation of OH and molecular H_2O but require double polished section and the spatial resolution can be more than 10 micrometer. In order to know total water concentration of small melt inclusions micro-Raman spectroscopy can be a more useful tool than FTIR.

Refrences: Thomas, R., 2000, Am. Mineral., 85, 868-872., Yamashita, S., Kitamura, T., Kusakabe, M., 1997, Geochem. J., 31, 169-174., Zotov, N. and Keppler, H., 1 998, Am. Mineral., 83, 823-834.



Identification of iron-titanium oxides in a block-and-ash-flow deposit at Yufu Volcano, Southwest Japan: implication for lava dome collapse processes

T. Saito[1] and ***T. Kawamoto***
[1] Graduate School of Human and Environmental Studies, Kyoto Universityy

Since the 1990-95 eruption at Unzen Volcano, Southwest Japan, lava dome eruptions have been attracting many researchers in the field of volcanology. We have studied the Ikeshiro pyroclastic-flow deposit at Yufu Volcano in order to understand processes generating block-and-ash flows by dome collapse. By using paleomagnetic and rock-magnetic methods, we classified samples from the Ikeshiro pyroclastic-flow deposit into two types. Each type showed different magnetic properties. In this study, we characterized iron-titanium (Fe-Ti) oxides in samples of each type with an optical microscope in reflected light and an electron microprobe analyzer. We determined chemical compositions of Fe-Ti oxides with a JEOL JXA-8800K electron microprobe analyzer.

As a result, one type (type A) includes homogeneous titanomagnetite (TM) with $x \approx 0.2$ and TM attached to titanohematite (TH) with $y \approx 0.7$. Equilibrium conditions are estimated to be temperatures of 840°C and fO_2 of 10^{-6} atmospheres. Fe-Ti oxides in the other type (type B) show complex textures and composition. TH20 lamellae within TM10 grain indicates that deuteric oxidation occurred in type B samples. Equilibrium condition estimated from compositions of this grain is temperatures of 760°C and fO_2 of 10^{-1} atmospheres. Another grain consisting of TH50, rutile and pseudobrookite indicates that type B was oxidized extremely (figure). In addition, existence of TH50 indicates that samples were quenched from high temperature (above 700°C). These suggest that Fe-Ti oxides in type B samples suffered from strong oxidation at lava dome before generation of the Ikeshiro pyroclastic-flow, while type A samples did not.

On the basis of these results, we propose the generation of the Ikeshiro pyroclastic-flow as follows. Lava blocks exposed on the dome surface (type B) were strongly oxidized and variable lamellae textures were formed ,while lava blocks at the dome core (type A) were hardly oxidized. Collapse of the lava dome generated the Ikeshiro pyroclastic-flow and lava blocks were quenched from high temperature.

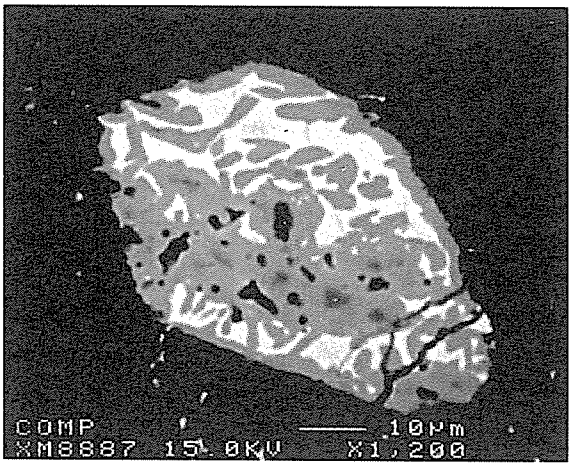


Figure. Photomicrograph of oxidized Fe-Ti oxides in type B samples. This grain consists of titanohematite with y ≈ 0.5 (white), pseudobrookite (light gray) and rutile (dark gray).

NMR evidence for a new water dissolution mechanism in depolymerized silicate melts: results for hydrous diopside composition

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The dissolution of water in silicate melts significantly affects their phase relations, and physical/thermodynamic properties. The mechanism of water dissolution is thus a subject of intensive interest in earth sciences and has been studied by various spectroscopic techniques. However, almost all the studies thus far have been on relatively polymerized systems, from fully polymerized silicates (e.g. SiO_2) to disilicate compositions (e.g. $Na_2Si_2O_5$). These studies have shown that water is dissolved in either molecular H_2O or SiOH

at least for Al-free systems. More depolymerized silicate melts, such as metasilicate compositions are also geologically important, because mantle-derived magmas are known to become less silica-rich with depth of generation. Such magma could be particularly important during the early evolution of the earth's mantle. We have studied a hydrous diopside ($CaMgSi_2O_6$) glass (quenched melt) using ^{29}Si and 1H NMR in an attempt to understand the water dissolution mechanism in a depolymerized system. The sample contains about 3.85 wt% H2O and has been synthesized at 1 GPa and 1500 °C in a piston cylinder apparatus. Both single-pulse ^{29}Si and ^{1}H-^{29}Si cross-polarization (CP) MAS NMR yield a single, asymmetric peak near -82 ppm, resembling that of anhydrous diopside glass. The ^{1}H-^{29}Si CP time constant has been found to be 0.39 ms, similar to those of SiOH in other hydrous silicate glasses and crystals. Thus at least some of the dissolved water are in the form of SiOH. The ^{1}H NMR spectra (both single pulse and spin-echo) contain two partially resolved peaks at 1.3 and 4.5 ppm. The 4.5 ppm peak is broader and asymmetric with a broad shoulder near 14 ppm. This peak and its shoulder are similar to those observed in more polymerized hydrous silicate glasses, such as $BaSi_2O_5$, and can be ascribed to SiOH and/or molecular H_2O with a range of H-bonding strengths. The 1.3 ppm peak is narrower and somewhat taller than the 4.5 ppm peak. The chemical shift of this peak indicates that it is due to OH groups that are not hydrogen-bonded. Peaks at this position has not been observed in any Al-free hydrous silicate glasses thus far and are not likely to be due to SiOH or molecular H_2O. On the other hand, MgOH in low-pressure hydrous magnesium silicates, such as talc, and CaOH in calcium silicate hydrates (CSH) are known to yield similar 1H NMR chemical shifts. We may thus assign this peak to MgOH/CaOH, suggesting that a substantial part of the dissolved water are in the form of free OH. Therefore the water dissolution mechanisms in silicate melts/glasses seem to change from molecular H_2O+SiOH in more polymerized systems to free OH groups pus SiOH/molecular H_2O in metasilicate compositions. Any model for water dissolution in depolymerized silicate melts/glasses must take this fact into consideration.

Salad dressing tells us differentiation of the Earth: laboratory experiments on differentiation process of multiphase fluids

I. Kumagai and T. Yanagisawa

After shaking a bottle of salad dressing, the oil separates from the other ingredients such as water, soy sauce and sometimes sesames. This is analogous to differentiation process of the magma ocean that consists of multiphase fluids and solid particles. In order to identify the main parameters that control the rate of differentiation and the mode of separation, we have conducted laboratory fluid experiments on differentiation process of the multiphase fluids (olive oil, syrup and water mixture, perfluorocarbon) with varying density, viscosity and volume fraction. At present we attempt to construct a model for differentiation process and also consider stirring effect of multiphase fluids, because the rate of differentiation in the Earth's interior depends on the competition between processes tending to differentiate components and other tending to homogenize everything such as mantle convection. This connects with production and removal of geochemical heterogeneities in the Earth's mantle.

Anatomy of mantle plumes

I. Kumagai

Recent developments of seismological studies have a great success in detecting much smaller structure of geological units such as mantle plumes. For example, the seismic images for P- and S-waves under Iceland show a cylindrical region of low velocity, extending from the surface to the core-mantle boundary. Not only the

external structure of the plumes but their anatomy (internal structure) are focused because geochemical studies about mantle plume products have revealed that they consist of more than two components of geochemically distinct sources. This multi compositional structure is generally interpreted as a product by the entrainment and mixing between plume sources and ambient mantle materials.

Here, laminar entrainment of starting plumes with a compositionally buoyancy has been explored based on laboratory experiments. Two types of starting plumes are identified in viscosity ratio 10.4 to 856 of the ambient to the buoyant fluid. The first is "vortex ring" type for a small viscosity ratio (11). The plumes entrain the ambient fluids and form a multi-layered and swirled structure within their heads. This is similar to the well-known structure as observed in the thermal starting plumes with the fluids having a strong temperature-dependent viscosity. In contrast, the second one, "chaotic mixing" type is observed for a higher viscosity ratio (104-856). No report has been published on this type. At the earlier stage, the plume head forms a double-layered structure by the entrainment, having a buoyant fluid as the upper layer and an entrained fluid as the lower. Thereafter, the shear-flow at the interface between the layers promotes the shear instability and produces a mixing layer between them. This mixing layer grows with time and finally all fluids in the plume head mingle together. Depending on the viscosity ratio, the resultant internal structure of the plume head is different: layered structure preserving the initial compositions vs. chaotically mixing tending to homogenize everything. The anatomy of the plume heads presented here will provide a new point of view for the spatial and temporal variation of the geochemical data obtained from mantle plume products.

Melting of Dry Peridotite KLB-1 Revisited: Precise Determination of Phase Relations and Composition of Solids

K. Matsukage, K. Kubo and E. Takahashi

Nearly all-melting experiments on mantle peridotite so far were designed primarily to determine melt compositions. In this study, we report an attempt to determine equilibrium solid composition and their modes in the mantle melting. To search the most suitable sample container, we tested three different materials, Re, graphite and Pt. Sample assemblies were designed to minimize the loss of Fe and Ni and to maintain the oxygen fugacity close to that of the Earth's upper mantle (about FMQ buffer). Powder peridotite, KLB-1 (spinel lherzolite; Takahashi, 1986), was used as starting material. The starting material was dried with a 1atm furnace at 1000 °C under oxygen fugacity controlled at NNO ~ FMQ buffer using CO_2/H_2 gas mixture. The high-pressure experiments were carried out using a piston cylinder apparatus with 1/2 inch-diameter furnace assembly including talc, pyrex grass outer sleeves and AlSiMg inner sleeve with straight graphite heater.

At 1.5GPa, the experiment with Pt capsule near the solidus (1375 °C) shows highly variable Mg# (=Mg/(Mg + Fe) atomic ratio) of olivine from 0.9 (center of capsule) to 0.99 (margin of capsule). On the other hand, the Mg# of olivine is homogeneous around 0.9 in the Re/Pt and graphite/Pt double capsules. At the 1425 °C (about 15% melting), the Mg# of olivine is 0.91 in graphite/Pt, 0.92 in Re/Pt and 0.95 in Pt. Oxygen fugacity of the run products was calculated from the reaction (Bryndzia and Wood, 1990): $6Fe_2SiO_4$(olivine) + O_2 = $3Fe_2Si_2O_6$(opx) + $2Fe_3O_4$(spinel). The calculated delta FMQ (= log(fO_2)-log(FMQ)) of the run products with Pt, Re and graphite are 4 to 5, -2 to 0 and <-10, respectively. Accordingly the Re/Pt double capsule is found to be most suitable for melting experiments of dry peridotite at high temperature (above 1350 °C) and the oxygen fugacity of the Earth's upper mantle.

Using the Re/Pt capsule, melting experiments of KLB-1 were made at pressures between 1.0 to 2.5 GPa, temperatures between 1250 and 1600 °C and the phase relation and mineral chemistries were determined by EPMA. An important difference was observed between our experiment and natural mantle peridotites in the stability field of chromian spinel. Spinel, which is common in natural mantle peridotite regardless of the bulk chemistry (e.g., lherzolite, harzburgite, and dunite), disappeared at much lower degree of melting in our

experiments (Fig. 1). It appears that the lithological and chemical variation of natural peridotite cannot be formed by simple batch melting but are the results of more complex melting processes (fractional melting and/or influx melting).

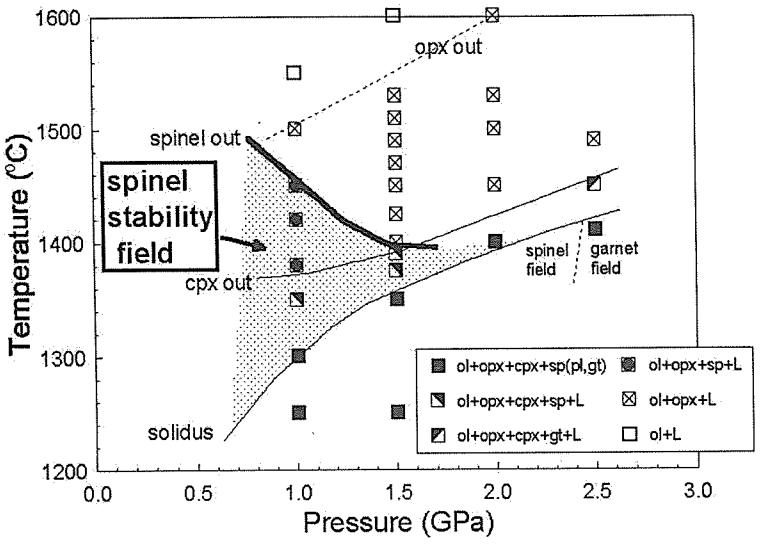

Fig.1. Phase relation of above solidus for lherzolite (KLB-1). Note that the stability field of chromian spinel significantly decreases with increase in pressure. ol, olivine; opx, orthopyroxene; cpx, clinopyroxene; sp, chromian spinel; gt, garnet; pl, plagioclase; L, liquid.

References

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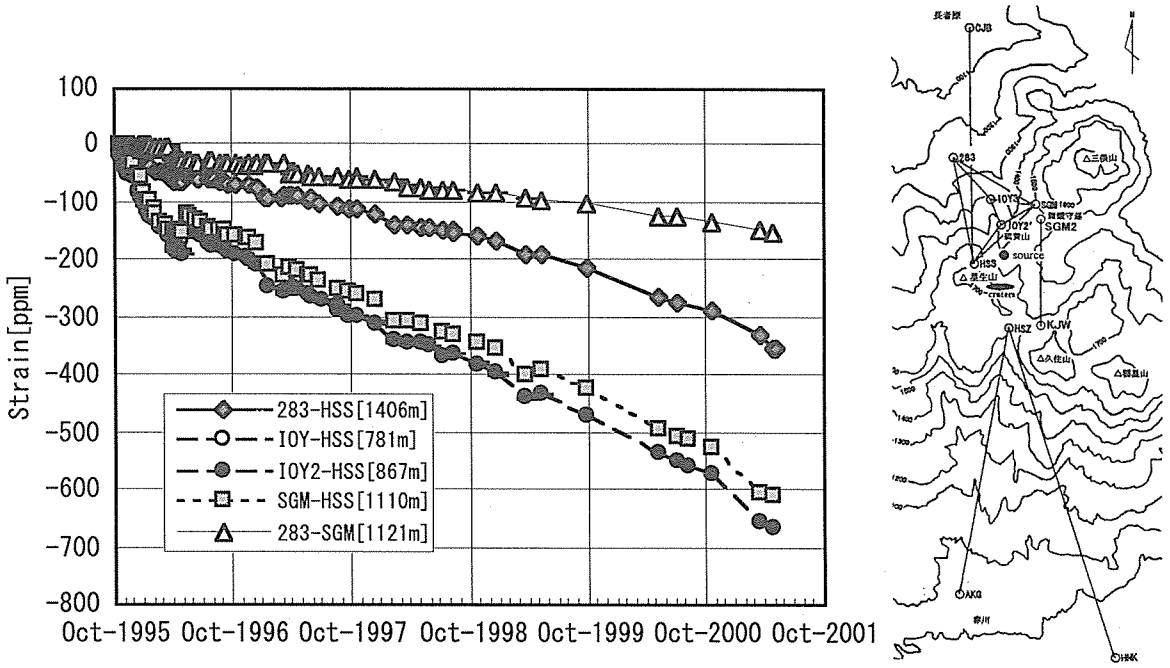
Ground deformation detected by EDM at Kuju Volcano

M. Nakaboh, H. Ono, and M. Sako

We have repeated EDM survey at Kuju Volcano since Oct. 1995 when a phreatic eruption occurred at the east flank of Mt. Hossho. There are geothermal region called Ioyama. New craters opened about 500m south from the pre-existing geothermal region. The fumarolic activity at pre-existing geothermal region activated after the phreatic eruption.

We constructed EDM network around the geothermal region, and extended the network step by step. The slope distance around Ioyama contracted rapidly in first a few months after the phreatic eruption. The contraction trend is still continued for more than 5 years since the phreatic eruption in 1995. For example, the slope distance of SGM-HSS contracted 67cm for about 5.5 years. The deflation source of Mogi model was located in a part of existing geothermal region where was the most active fumarolic region. The depth of source is about 800m from surface.

We infer that the ground deformation around Ioyama is caused by depression of the geothermal reservoir at deflation source by fumarolic activity. Because there are a good correlation between the temporal variations of the fumarolic activity and the slope distance.



Ground deformation in and around central cones of Aso Volcano, Detected by GPS survey between 1999 and 2001

M. Nakaboh, H. Ono and M. Utsugi,

Monitoring of the ground deformation is useful for detecting the movement and location of magma under the Volcano. At Aso Volcano, the vertical ground deformation has been monitored by leveling survey during more than 60 years since 1936. This leveling survey revealed that the region near Furubouchu (2km west from Nakadake crater) in the central cones subsided. The deflation source was located at the area where Eboshi, Kusasenri, Jigoku and Yunotani are surrounding. Its depth was about 4-6km from the surface.

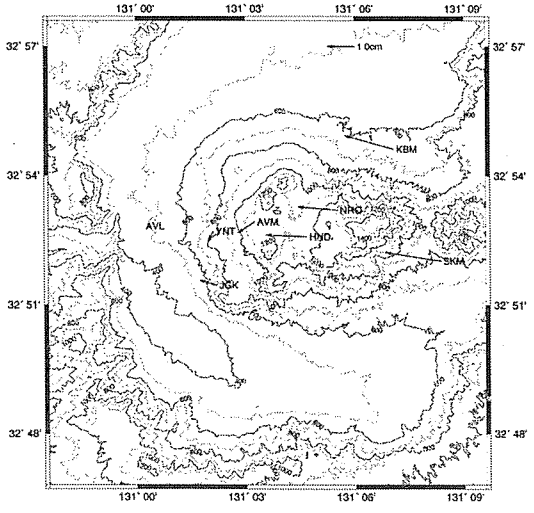


Fig.1

Horizontal displacement between 1999 and 2001
(AVL Fixed)

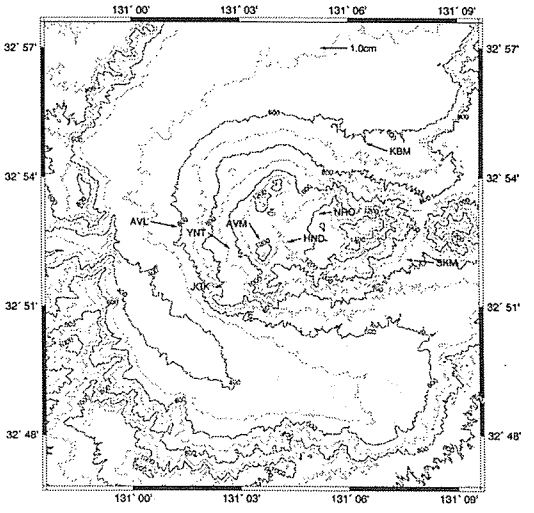


Fig.2

Horizontal displacement between 1999 and 2001
(AVL moves 1.0cm East, 0.2cm South)

We started GPS survey to locate the center of the deflation source in 1999. The first survey was carried out in February 1999. The second survey was in February and March 2001. Fig.1 shows the horizontal displacement of ground deformation. In this case, the station AVL is fixed. Most of the points moved to West. At stations, SKM and KBM, the displacement is large (about 2cm west against AVL). Fig.2 shows the horizontal displacement at the case of AVL moving 1.0cm to east and 0.2cm to south. In this case, the location of deflation source is near the center of descending area detected by leveling survey.

There are another three permanent GPS station constructed by GSI (Geographical Survey Institute) in Aso Caldera. We will analyze the location of deflation source together with GSI data in the near future.

GPS Observation of Crustal Movements in the Macolod Corridor, Philippines

T.Ohkura, G.M. Besana, T. Nakano, M. J. Sicat, Y. Hoso, E. Mangao, I. Geraldo, M. Ando, and R. S. Punongbayan

GPS measurements were undertaken in order to detect crustal movements related to the origin of the Macolod Corridor in the Luzon island, Philippines. We established thirteen stations and made five campaigns from April 1996 to April 1998.

Most of the stations were found to be moving toward NW or WNW at 4-6 cm/yr with respect to the stable interior of the Eurasian plate. Moreover, the stations in the southern regions are moving noticeably toward ENE or East at about 2-3 cm/yr relative to northwestern part.

If we take into consideration the block motion determined through a recent paleomagnetic research and the young ages of volcanic, the obtained movements could be closely related to the formation of the Macolod Corridor caused by the collision of the Mindoro and Palawan blocks. The movements of these blocks may have been reactivated by the initiation of subduction of the Philippine Sea plate along the Philippine trench around 4 Ma.

Fig.1 a)

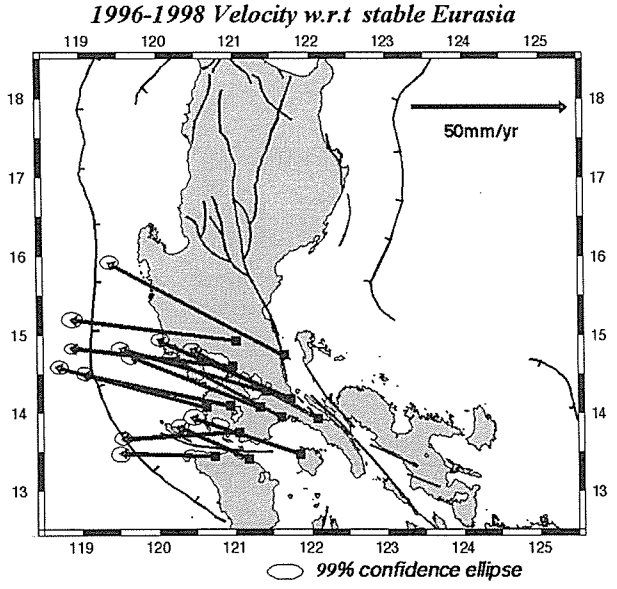


Fig.1 b)

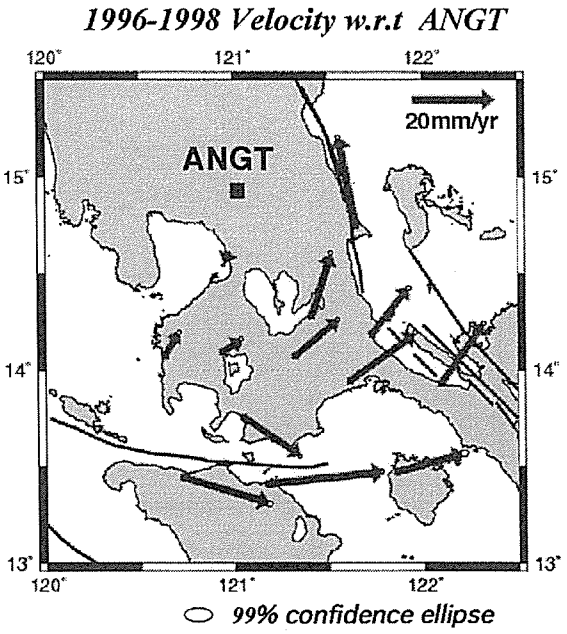


Fig.1 a) Velocity vectors at thirteen stations and Manila are shown with respect to stable Eurasia. The 99%

confidence ellipse is shown at the tip of each vector. b) Velocity vectors obtained by data analysis from April 1996 to April 1998. In this figure, ANGT is fixed. The 99% confidence ellipse is shown at the tip of each vector.

Rayleigh scattering by aqueous colloidal silica as a cause for the blue color of hydrothermal water

S. Ohsawa, T. Kawamura, N. Takamatsu and Y. Yusa

Thermal waters in hydrothermal ponds, bathing pools and the brines of geothermal electric power plants commonly have a characteristic blue color. Although many researchers have assumed that the blue color is due to a colloidal suspension and/or absorption by dissolved ferrous iron or by water itself, there has been no specific effort to identify the physical nature of this phenomenon. We have tested, in synthetic and natural solutions, whether aqueous colloidal silica is responsible for the blue color. Aqueous colloidal silica is formed by silica-polymerization in thermal waters of the neutral–chloride type which contain initially monomeric silica in concentrations up to 3 times above the solubilities of amorphous silica. The hue of the blue thermal waters in the pools tested agrees with that of a synthesized colloidal silica solution. Grain size analyses of aqueous colloidal silica in the blue colored thermal waters demonstrate that the color is caused by Rayleigh scattering from aqueous colloidal silica particles with diameters (0.1-0.45μm) smaller than the wavelengths of visible radiation.

(Submitted to JVGR)

Some geochemical features of hyper-acid brine of the summit crater lake on Aso Volcano, Japan

S. Ohsawa, Y. Onda, K. Amita, G. Shimoda, M. Yamada and K. Iwakura,

On August 4 in 2000, water samples for chemical and isotope analyses were collected from Yudamari crater lake formed in the 1st crater of Mt. Nakadake, Aso Volcano, central Kyushu, Japan. The lake water has very high acidity (below pH 1) and contains chloride and bisulfate ions in large quantities. After sampling, gypsum precipitated from the sampled waters at an ambient temperature. Calculation of gypsum saturation indices with a modified SOLVEQ indicates that the lake water is near saturation with gypsum at the lake water temperature (ca. 55℃) and gypsum becomes supersaturated as the result of increase of activity of sulfate ion by dissociation of bisulfate ion as the sample water is cooled. Aqueous SiO_2 concentration of the lake water samples (430mg/L) is extremely higher than saturation value with respect to the most soluble SiO_2 mineral (amorphous silica) at the temperature of lake water. Dissolved sulfate enriched in ^{34}S ($\delta^{34}S$; ca. +16‰) is probably formed by SO_2 disproportionation and/or hydrolysis of elemental sulfur at an elevated temperature. These may be signs that sublimnic hydrothermal environment has been established under the lake. Temperature of the hydrothermal system is inferred to be about 160℃ from oxygen isotopic equilibration between dissolved sulfate and lake water.

(Submitted to Geochemical J.)

Simplified analysis of stable carbon isotopic composition of dissolved inorganic carbon in hydrological samples

S. Ohsawa

Recently, source and behavior of dissolved inorganic carbon (DIC; $CO_2 + HCO_3^- + CO_3^{2-}$) in groundwater and river water, etc. have been actively discussed based on the investigation about its stable carbon isotope ratio and concentration. This study proposes a simplified preparation method for the carbon isotope measurement of DIC in hydrological samples. In this method, $SrCO_3$ for the isotope measurement is directly precipitated from the sample water by adding carbonate-free $Sr(OH)_2$. In spite of boiling of the treated sample water and exposure to atmospheric-CO_2 through the preparing process, it was shown that this isotopic analysis has constant systematic error (-0.5 ‰ — -0.6 ‰) no more than precision of the mass-spectrometry (less than ±0.1 ‰). A linear relationship between reciprocal of concentration and $\delta^{13}C$ value of DIC: $\delta^{13}C = 6.59 \times 1/DTC - 21.8$, is recognized by the application of the established method to river water samples from 8 small rivers in the Shimabara Peninsula, Nagasaki Prefecture. This relationship is likely to indicate that the river waters are mixture of groundwater equilibrated with soil CO_2 and surface water equilibrated with atmospheric CO_2, and/or are soil CO_2-equilibrated groundwater interacted with atmospheric CO_2 while the river waters flow through the drainage basins.

(Submitted to Japanese J. Limnology)

Cenozoic volcanism in northern Sikhote Alin, Far East Russia and its implication for the opening of the Japan Sea

K. Sato, R.T. Arai, Y. Tatsumi, T. Sano, T. Tagami, and V.S. Prikhodko

K-Ar ages and major/trace element compositions were obtained from 59 fresh lavas from the northern Sikhote Alin, Far East Russia, in order to document the secular variation in volcanism and upper mantle processes during backarc opening. This region is distinct in that it was the home of the NE Japan arc sliver before the opening of the Japan Sea backarc basin. Also, the distribution of lavas from the coastal region to the inner part of the continent is the characteristic feature of this region. Northern Sikhote Alin can be divided into two volcanic belts, that is, the East Sikhote Alin volcanic belt (ESAVB) along the Japan Sea coast, the West Sikhote Alin volcanic belt (WSAVB).

The volcanic activity in the north Sikhote Alin took place during 40-25 Ma and 20-5 Ma, and was separated by a marked hiatus in volcanism during 25-20 Ma, which is synchronous to the period of the major rifting event in the Japan Sea backarc basin. It should be stressed that the volcanic activity during the pre-rifting stage of the Japan Sea occurred in the entire ESAVB along Japan sea, whereas no volcanism in the WSAVB. Such an arc-like distribution of volcanism may suggest the location of a continental arc-trench system in this region before the formation of the backarc basin. On the other hand, the volcanism during 20-5 Ma exhibits "spot-like" distributions both in the WSAVB and ESAVB.

All lavas erupted in the ESAVB during 40-25 Ma have compositions typical of subduction-zone magmas, implying that the ESAVB formed a continental-margin arc before the opening of the Japan Sea. It is further suggested that the backarc rifting is initiated at the volcanic front, not in the backarc region. Thus, the present data clearly demonstrate that the opening of the Japan Sea initiated at least 25-20 Ma, earlier than 15 Ma as suggested previous based on paleomagnetic data. On the contrary, the arc magma chemistry is not confirmed for any lava erupted during 20-5 Ma, indicating that such subduction-related volcanism was terminated due to the opening of the Japan Sea. During 20-5 Ma, intraplate-type lavas with typical hotspot magma compositions typifies the Sikhote Alin volcanism and may be caused by mantle upwelling beneath the Cenozoic intraplate basalt province in the northeast China and Far East Russia.

Faraday cup efficiency in a multicollector mass spectrometer, Finnigan MAT 262 at Beppu Geothermal Research Laboratory

T. Shibata, M. Yoshikawa and Y. Furukawa

Abstract

Relative Faraday cup efficiencies in the Nd isotope analysis with static multicollection technique were determined to eliminate the difference in Faraday cup efficiencies by measuring the Nd isotope ratio with nine different cup configurations. The result shows that a part of Faraday cups in thermal ionization mass spectrometer of BGRL were already damaged and correcting calculation with relative Faraday cup efficiencies is necessary to obtain reliable isotope ratios by static malticolection technique.

Introduction

The development of the technology of mass spectrometer with static multicollection mass spectrometry (SMCMS) (e.g. Wagner et al., 1984), in which multiple collectors measure all isotopes concerned simultaneously, has realized the improvement of the analytical precision and reduction of the time for data acquisition (e.g. Noble et al., 1990; Thirlwall, 1991). In this technique, Faraday cup efficiencies (FCEs) of each Faraday cup must be same within the analytical error, because FCEs of each collector are assumed to be equal when the static multicollection technique is applied. However, it is well known that large ion beams damage Faraday cups resulting the change and instability of FCE. This change and instability of FCE induce systematic errors in analytical result (Makishima and Nakamura, 1991). Therefore, we determined RFCEs of thermal ionization mass spectrometer (TIMS) at BGRL following the method described in Makishima and Nakamura (1991) to obtain reliable isotope ratios by SMCMS.

Experiment

TIMS of Finnigan MAT 262® was employed in this report. This TIMS is equipped with 8 movabal Faraday cups and fixed one. In order to eliminate the difference in the characteristics between amplifiers attached to the individual collectors, amplifier gain factors (A-Gain) were measured for SMCMS prior to data acquisition by supplying a uniform current into the amplifiers. Accelerating voltage was adjusted to 10 kV.

Table 1. Faraday cup configurations for the Nd isotope static analysis.

Configration No.	*Faraday Cup No.*							
	Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8
1				146		144	143	
2			146		144	143		
3		146		144	143			
4	146		144	143				
5	146	144	143					
6		146	144	143				
7				146	144	143		
8					146	144	143	
9						146	144	143
Isotope ratio	R1	R2	R3	R4	R5	R6	R7	R8

La Jolla standard was used as a standard of Nd isotope composition. The detailed procedure of the Nd isotope measurement was described in Yoshikawa et al. (in this issue). As given in Table 1, $^{143}Nd/^{144}Nd$ ratios were measured with nine different cup configurations. The obtained results with different configurations are denote as Ri (i= 1, 2, ..., 9). In each cup configuration, three separate runs were made.

Result and discussion

The Nd isotope ratios measured with different nine cup configurations are shown in table 2. The averaged values of three measurements (Ri) for each cup configurations are also shown in Table 2. The range of Ri is 0.511821 (R5) to 0.511858 (R3). The difference of R3 and R5 apparently exceeds the analytical errors. Similar result was observed by Makishima and Nakamura (1991), and they concluded the diversity was caused by the difference in FCE. They further established the method to calculate the RFCEs for individual cups using the measured ratios of Ri. Follwing their method, we calculated RFCEs in TIMS at BGRL. Our TIMS have nine Faraday cups, and we determined RFCEs for seven of eight cups aginst Col. 4. The equations of RFCEs can be described as follows:

$$f_1/f_4 = R1^{-2} \times R2^{-2} \times R3^{-2} \times R5^{2} \times R6^{2} \times R9^{2}$$

$$f_2/f_4 = R1^{-2} \times R2^{-2} \times R6^{2} \times R9^{2}$$

$$f_3/f_4 = R1^{-2} \times R6^{2}$$

$$f_5/f_4 = R0^{2} \times R7^{-2}$$

$$f_6/f_4 = R0^{3} \times R1^{2} \times R2^{-1} \times R5 \times R6^{-3} \times R7^{-3} \times R9$$

$$f_7/f_4 = R0^{3.5} \times R1^{5} \times R2^{-3.5} \times R5^{2.5} \times R6^{-6.5} \times R7^{-4.5} \times R9^{3.5}$$

$$f_8/f_4 = R0^{3.45} \times R1^{8.5} \times R2^{-5.25} \times R5^{4.25} \times R6^{-10.25} \times R7^{-5.25} \times R8^{-1} \times R9^{5.25}$$

Table 2. Analytical results of Nd isotope ratios with eight different cup configurations

Configration No.	$^{143}Nd/^{144}Nd$	
1	0.511861±21	
	0.511844±17	
	0.511831±11	a.v. 0.511845±15 (R1)
2	0.511849±17	
	0.511855±13	
	0.511857±12	a.v. 0.511854±04 (R2)
3	0.511848±13	
	0.511870±12	
	0.511856±09	a.v. 0.511858±11 (R3)
4	0.511822±14	
	0.511850±11	
	0.511821±11	a.v. 0.511831±16 (R4)
5	0.511829±11	
	0.511820±11	
	0.511815±11	a.v. 0.511821±07 (R5)
6	0.511815±11	
	0.511841±08	
	0.511829±09	a.v. 0.511828±13 (R6)
7	0.511824±10	
	0.511837±09	
	0.511852±10	a.v. 0.511829±14 (R7)
8	0.511850±14	
	0.511854±10	
	0.511867±08	a.v. 0.511857±09 (R8)
9	0.511838±09	
	0.511828±12	
	0.511841±08	a.v. 0.511836±07 (R9)

Table 3. Calculated RFCEs against Col. 4.

	RFCE
f_1/f_4	0.999977
f_2/f_4	0.999988
f_3/f_4	0.999937
f_5/f_4	1.000004
f_6/f_4	1.000094
f_7/f_4	1.000192
f_8/f_4	1.000302

From those equations, RFCEs were calculated and listed in Table 3. We can also calculate the true value of $^{143}Nd/^{144}Nd$ (R), and the result was 0.511846. This value of R is same as presented by Makishima and Nakamura (1991) with different mass spectrometer. The result shows that the RFCEs of Col. 1 to 3 are less than unity, and those of Col. 5 to 8 are more than unity. This indicates that Col. 1 to 3 are less sensitive compared to Col. 5 to 8, may be caused by the damaged with large ion beams. Using those RFCEs, we can eliminate difference of FCEs in TIMS for the measured isotope ratios.

Volcanic short-period tremor at Aso Volcano
Its amplitude variation and ratio variation of characteristic frequency bands

Y. Sudo and M. Sako

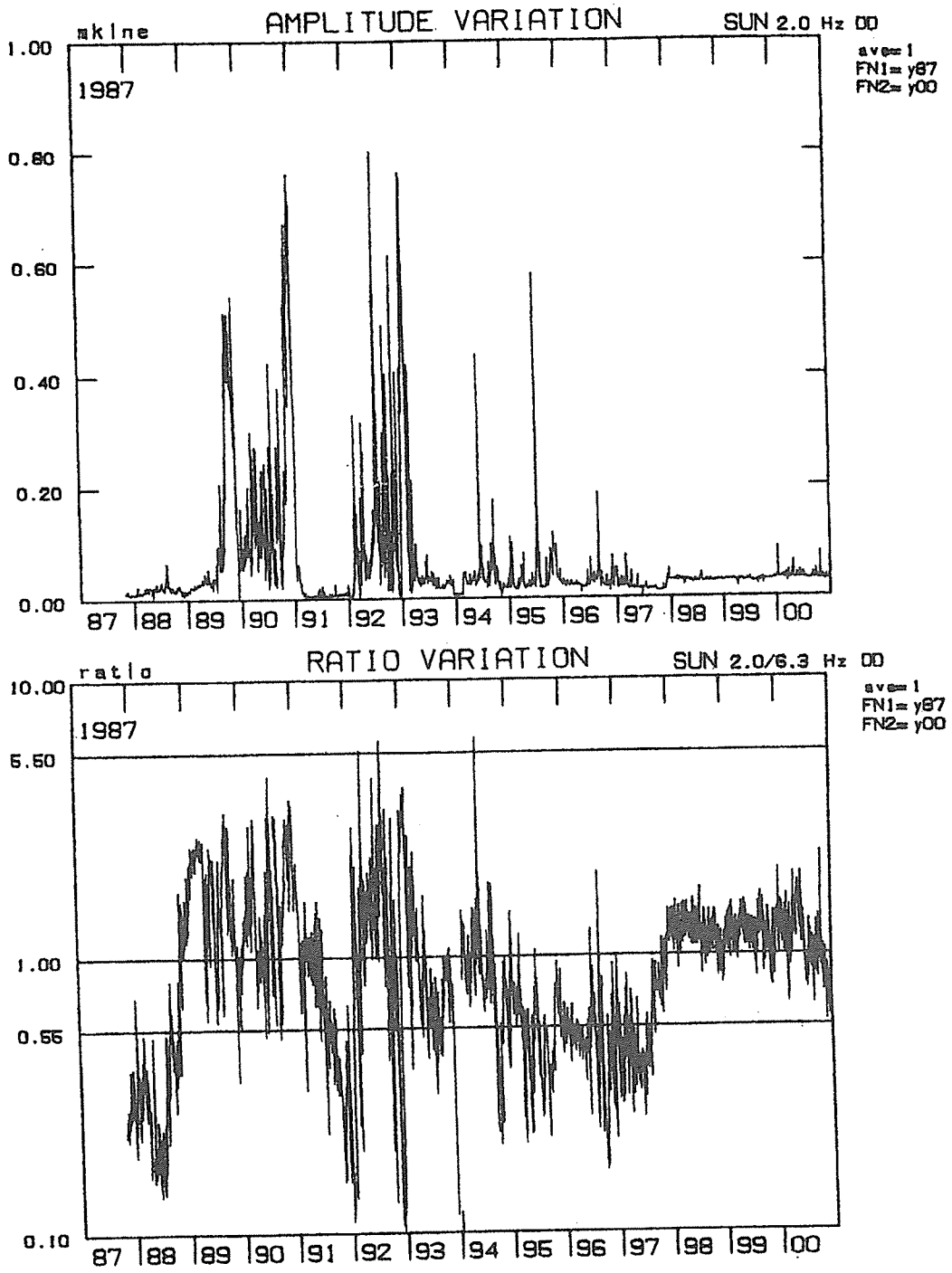
Comparison with Volcanic Activity

At Aso Volcano, the changes in volcanic short-period tremor amplitude closely correspond to the volcanic activity. The top of figures shows the amplitude variation of tremor, of which the frequency band was 2.0Hz, observed at Station SUN, about 1km south from the center of the active crater. This figure is a good indication of

the state of volcanic activity. The volcanic states in the crater had been observed in this period, i.e. the state of Strombolian eruptions from September 1989 to January 1990, from November 1990 to January 1991, and from January to February 1993; the incandescent state at the crater from November 1988 to June 1989; the state of the crater lake and mud eruptions from 1987 to September 1988, February to October 1990, April 1991 to December 1992, and from May 1993 to now. In order to compare the volcanic activities with this figure, the activities are summarized as follows. ***1989:*** After the eruptive activity in 1985, a hot crater lake had appeared in 1st Crater. In October 1988, the crater floor was first seen to be incandescent. At the end of 1988, ash ejections were observed. In April 1989, ash ejections became gradually more active and small blocks were ejected. In July numerous eruptions occurred at irregular intervals with ash columns of 2.5 km height. The flames of burning gases and glows were frequently observed. From September to November many large eruptions occurred with ash falls as far as about 40 km to 50 km from the crater. In October there were ash eruptions every day and scoria ejections, including bombs greater than 1 m in size, reached a height of several hundred meters. In late October rumbling sounds became stronger and were audible around the caldera at a distance about 10 km from the crater. In late November strong Strombolian explosive eruptions recommenced. In December these eruptive activities became a little weaker and rumbling sounds were not heard but ash emissions continued. Associated with these activities, the amplitude of volcanic tremor was high from March to December. In October and November, low frequency and large amplitude tremors were generated and they were recorded by seismic stations more than 100 km from the crater. ***1990:*** The 1989 activity continued intermittently until February 1990. Thereafter no eruption was observed until April. In April an eruption occurred with a lot of ash. The eruptive activity continued until June with heavy ashfalls. In June the crater lake appeared again. From July to early December no eruptive activity occurred. In November the crater floor became incandescent. In December the activity again became eruptive. Strong rumbling sounds were heard in the caldera as in the preceding year. Responding to this volcanic state, the tremors increased in amplitude and remained at a high level. ***1991:*** The 1990 activity continued until early January 1991. Thereafter the amplitude remained at a low level. In March the crater bottom was buried with mud and sand, and a pool of water was formed. Through most of 1991, emissions from the crater were limited white clouds of water vapor. ***1992:*** From June to October 1992 the tremor-regime was characterized by isolated tremors corresponding to individual mud eruptions. In December a small new vent opened with emission of ash and flames. ***1993:*** At the beginning of 1993 the crater lake dried up and the ash eruptions continued. The plume of steam and ash rose to about 1,000 m to 1,500 m above the vent. This activity continued, with tremor amplitude remaining at a high level, until the early of February 1993. Then a small lake again formed and the whole surface of the crater gradually occupied by the hot water. ***1994:*** The quiet state continued to the end of March 1994. In March and May small mud eruptions occurred. From June to August the crater was calm. However, from September to October the tremor amplitude increased with mud eruptions. Then in December mud eruptions occurred again and the amplitudes further increased. This activity continued until April 1995. ***1995:*** Sometimes the tremors amplitudes increased with the small mud eruptions. From July to the following year the activity remained at a low level. ***1996:*** The activity remained at a low level through this year. There was a hot water pool in the crater. From June to August the amplitude began gradually increasing. This phenomenon was associated with the occurrence of volcanic earthquakes. In the entire period from 1989 to 1996, the volcanic activity was most vigorous from September to November 1989. At the depth of 150 m, where there were large long-period temperature fluctuations, with only small quasi-annual variations, the temperature reached a maximum in November and December 1989 and then fell gradually, and so could be the result of these volcanic activities with a delay of about one month.

Amplitude Ratio Variation between Low and High Frequencies

The ratio change of 2.0Hz band tremor to 6.3Hz band (the bottom of figures) indicates also the volcanic activity. The ratio gradually increased from the end of 1988. This pattern can be explained that the low frequency band tremors is dominant according to the volcanic activity. As seen in figures and already mentioned, the volcanic activity at October 1989 was vigorous. The amplitude of tremors closely correspond to the states of volcanic activity in 1st Crater. During the active state, when the crater was ejecting a lot of ash and scoria-blocks as Strombolian eruptions, or producing very strong rumbling sounds or mud eruptions, the amplitude of volcanic tremor was always at a high level.



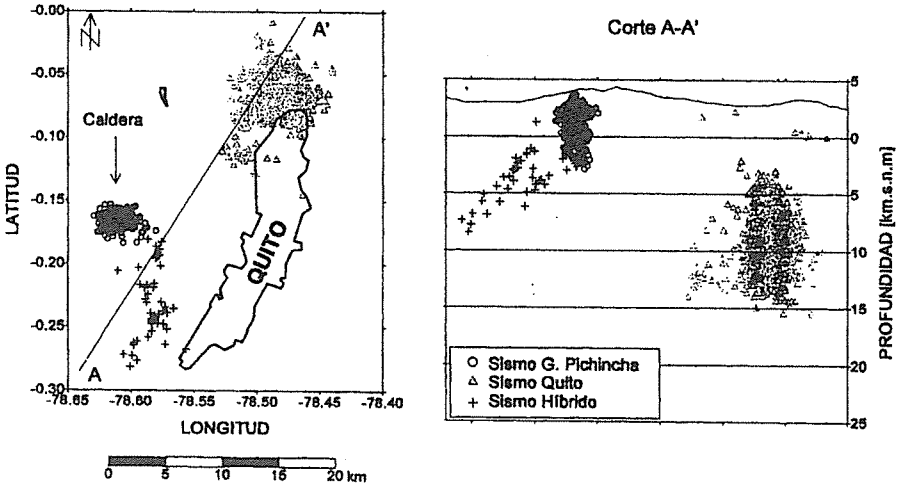
Precursors and Seismic Sequence of 1999 Guagua Pichincha Eruption

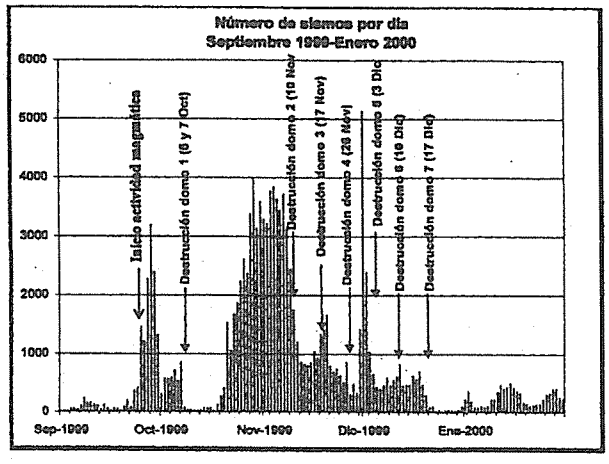
Y. Sudo, T. Hashimoto, M. Ruiz-Romero, H. Yepes, D. Villagomez and D. Viracucha

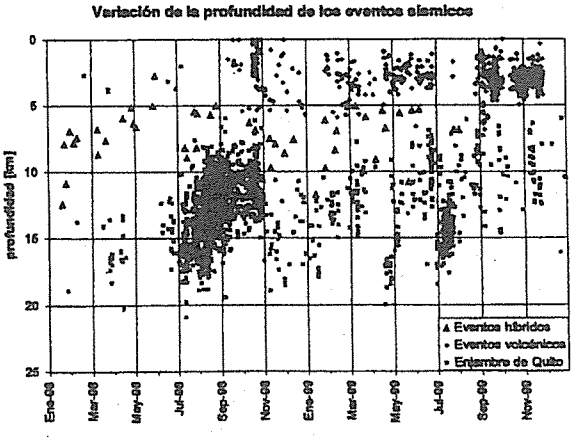
The 18 years-long period phreatic activity and the occurrence of swarms of tectonic events have characterized the precursory activity of Guagua Pichincha volcano. We present a brief description of this activity in order to discuss its significance for comparison with other volcano's precursors.

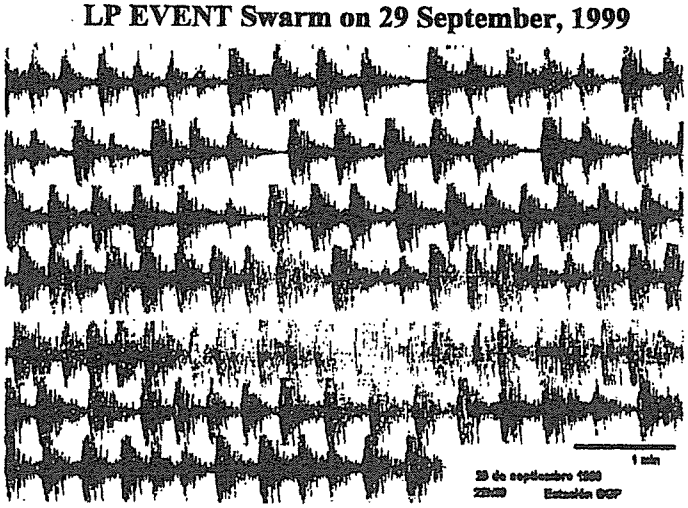
The first renewal signal on Guagua Pichincha was noticed in 1981 with the appearance of a new fumarolic field and the occurrence of phreatic explosions. Since 1981 up to 1997 the activity remained with few phreatic explosions per year especially during rainy seasons. Meanwhile in August 1988 a swarm of 200 events per month occurred below the southern flank at 8-10 km depth. Besides, since June 1989 an increase of seismicity of Quito fault was showed. In August 1990, a 5.1 Ms earthquake caused important damage in Pomasqui town, 20 km far from the crater. In June 1998 begun a very energetic swarm of tectonic events in the northern segment of Quito fault. Between July 24 and October 31, the swarm showed an average of 1200 events per month, a few of them with a magnitude larger than 4.0. A strong phreatic activity started in August 7, 1998 in the dry season. This activity was characterized by the occurrence of 19 phreatic explosions per month and a high number of seismic events. Phreatic activity showed three main phases, one from August to November 1998, the second one from December 1998 to April 1999 and the last one from July to September 1999. A monthly average of seismic events reached 1160 events. Upon their waveforms and spectral contents, the seismic events were classified in volcano-tectonic, long period, medium period and hybrid and explosion events. Since September 22, very energetic swarms of long period events precede the eruptions with magmatic origin. Until December 17, nine eruptions were detected. They allowed the formation of eight domes in the western edge of the caldera and their further destruction. The eruptions provoked five important ash falls in Quito city, the capital of Ecuador.

Distribution of Volcanic and Tectonic Events near Quito (1998-1999)









Re-Os and Sm-Nd systematics of basaltic komaitites and banded cherts in Pilbara, NW Australia: Implications for early continental growth

K. Suzuki, H. Shimizu, M. Okamoto, Y. Hattori, M. Minami, G. Shimoda, Y. Tatsumi, and M. Adachi.

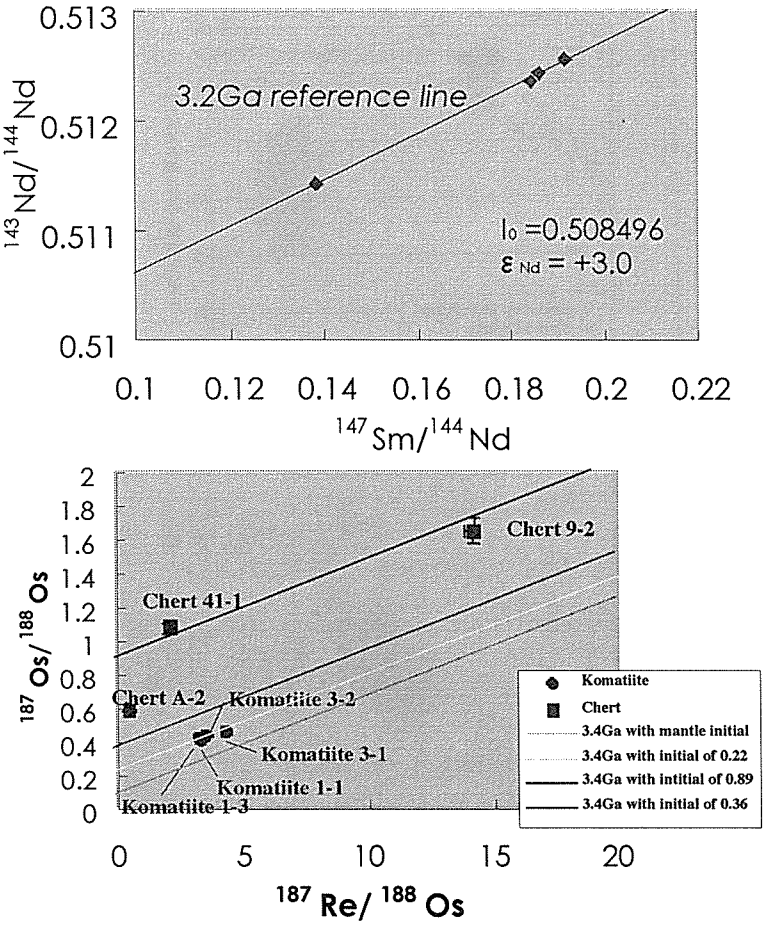


Fig. 2. Re-Os diagram of Marble Bar komatiites and cherts.

Re-Os and Sm-Nd isotopic data of Marble Bar mafic volcanic rocks (komatiitic basalts) and cherts in Pilbara, NW Australia, were obtained in order to investigate chemical evolution of the Archean crust and mantle. The Re-Os and Sm-Nd isotopic ratios of mafic volcanic rocks of Marble Bar have been plotted on the 3.4 Ga Re-Os and 3.2 Sm-Nd reference lines, respectively (Fig. 1, 2), which is consistent within analytical uncertainties with 3.4Ga U-Pb age of the zircon in dacite, strata between komatiitic basalts and cherts in Marble Bar. These results indicate that the volcanic rocks were formed around 3.4 Ga.

The initial $^{187}Os/^{188}Os$ ratio of the reference line of the mafic volcanic rocks is around 0.22 (Fig. 2), much higher than that of the upper mantle (ca. 0.125, Shirey and Walker, 1998). Therefore, probably these mafic volcanic rocks are closely associated with the crustal materials which possess

much higher Os isotopic ratios than the mantle components ($^{187}Os/^{188}Os$ = 0.1 – 0.14, e.g., Shirey and Walker, 1988). However, further investigation is required to make conclusion on this matter, because the Re-Os isotope ratio of komatiite-37 with relatively large analytical uncertainties defines the slope and initial Os ratio of the 3.4 Ga reference line. Therefore, the initial $^{187}Os/^{188}Os$ ratio may include a large error.

Marble Bar cherts contain banded iron formation (BIF). Results of the Sm-Nd isotope analyses (Minami et al., 1995) revealed that the banded and yellowish cherts gave isochrons ages of 3.23 +/- 0.29 with εNd of 1.0 +/- 3.0 and 2.54 +/- 0.20 with εNd of –5.4 +/- 2.0 (Fig. 3). They suggested that the yellowish cherts record the event of reset of the Sm-Nd isotopic system at around 2.54 Ga. The $^{187}Os/^{188}Os$ ratios of banded (Chert 41) and yellowish cherts (Chert 9) are 1.08 and 1.65, respectively (Fig. 2) These values are extremely high (Fig. 2), which strongly implies involvement of the continental crust component with high Os isotopic ratios in the formation of the cherts. Both Re-Os isotopic data of the banded and yellowish cherts are roughly plotted on the 3.4 Ga reference line (Fig. 2), which supports the idea that the cherts were formed at ca. 3.4 Ga. This result is consistent with the Sm-Nd data (Fig. 3). If true, the initial $^{187}Os/^{188}Os$ ratio yields an extremely high value of approximately 0.9, indicating that involvement of the continental crust is the essential process in formation of the cherts. In contrast, the initial Nd ratio is identical within analytical uncertainties to that of the chondritic mantle, indicating the cherts were formed from the hydrothermal solution originated from the mantle component (Minami et al., 1995). We propose that the crustal component is more likely associated with the formation of Marble Bar cherts. The Nd isotope evolve slowly in the early Earth system, because both Sm and Nd belong to REEs, Sm/Nd could not be fractionated much. It results in difficulty in detection of deviation in Nd ratios of the Archan cherts from the chondritic evolution curve. On the contrary, much higher resolution of the Re-Os system can be obtained, because Re/Os is highly fractionated in geological processes and the $^{187}Os/^{188}Os$ ratio evolve at much higher rate. As a result, the Re-Os isotopic data obtained for the cherts in the present study strongly suggest the cherts are originally associated with the continental crust. Also, it may be important that the continental crust had been already developed at 3.4 Ga.

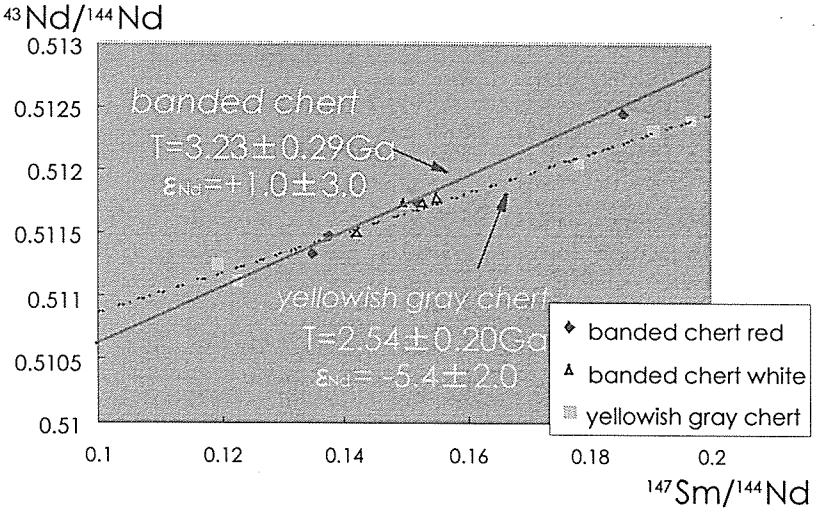


Fig. 3. Sm-Nd diagram of two types of Marble Bar cherts from Pilbara. (Minami et al.,1995)

Rhenium loss during later alteration of the cherts is the possible process to shift the Re-Os isotopic data plot to the left region of the reference line of komatiitic basalts, If true, the original Re concentration of the cherts may several times higher than the present value, which is unreasonable.

The above result suggest that the Re-Os isotopic system may be more resistant to later alteration, because the Re-Os plot of the yellowish cherts, whose Sm-Nd system was reset and Rb-Sr system was disturbed, are located near the 3.4 Ga Re-Os reference line of the banded chert without disturbance of the Sm-Nd system.

Re-Os isotopic systematics of Setouchi high-Mg andesites, SW Japan: Evidence for slab melting

K. Suzuki, and Y. Tatsumi

Re-Os isotopic compositions have been determined for the primitive high-magnesian andesites (HMAs) and basalts in the Setouchi volcanic belt, SW Japan. The HMAs possess higher Os isotopic ratios and lower Os concentration (0.1718 - 0.2236 and 8.1 – 11.9 ppt) than basalts (0.1556 - 0.1769 and 31.0 – 53.7 ppt), indicating that the composition of Setouchi magma source lies on a mixing line of a rather depleted upper mantle and an enriched component (Fig. 1). One of the candidates of such an enriched endmember would be the subduction component from the sinking lithosphere, because the Setouchi primitive lavas show little evidence for crustal contamination. The observed Os isotopic compositions of HMAs are consistent with overprinting of slab (sediment)-melt not slab-fluids, because aqueous fluids cannot transport radiogenic Os effectively. Mixing calculations based on isotopic signatures reveals that the addition of several percent of terrigenous and/or pelagic sediment-derived melt can account for the Os-Pb-Sr-Nd isotopic compositions of Setouchi magma source.

(To be submitted to Geology)

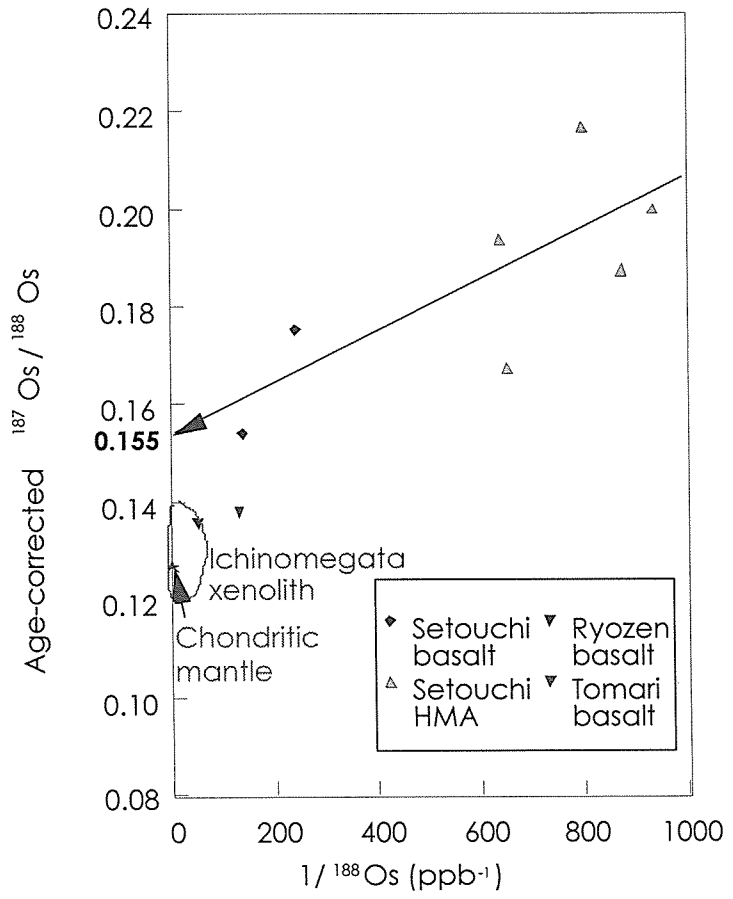


Fig. 1. $1/^{188}Os$ vs. $^{187}Os/^{188}Os$ diagram of the Setouchi basalts and HMAs and Ryozen and Tomari basalts.□

Osmium transport during serpentinite dehydration at 1.0 GPa: Experiments and implications for the Os isotopic compositions of arc magmas

K. Suzuki, Y. Aizawa and Y. Tatsumi

Dehydration experiments on natural serpentinites were conducted at 1.0 GPa and 850 °C in order to examine the behavior of osmium during dehydration processes in subduction zone. The results (Table 1) confirm that 20% of Os in the starting serpentinite is moderately transported with aqueous fluids in the absence of sulfide phases during dehydration processes. If we consider two stage model where Os in the slab moves into overlying hydrous peridotite layer and is subsequently transferred into mantle wedge (Fig. 1), only less than 5 % Os is likely transferred from the subducting slab to the mantle wedge. It is thus suggetesed that arc lavas having higher $^{187}Os/^{188}Os$ ratios than the mantle value may be produced by overprinting of slab-derived melts, not fluids, onto the original mantle wedge, although possible effect of crustal contamination cannot be ruled out.

Table 1. Os concentration of serpentinite used as starting material and run products of dehydration experiment.

	Os conc (ppb)	Re conc (ppb)
Starting material A	2.74 ± 0.19	0.676 ± 0.002
run product	2.42 ± 0.07	0.4 ± 0.02
Escaped water corrected	2.1 ± 0.06	0.34 ± 0.02
Mobility (%)	23 ± 2	49 ± 2
	Os conc (ppb)	Re conc (ppb)
Starting material B	0.4 ± 0.07	0.46 ± 0.08
run product	0.42 ± 0.07	0.31 ± 0.07
Escaped water corrected	0.36 ± 0.06	0.27 ± 0.09
Mobility (%)	9 ± 2	42 ± 16

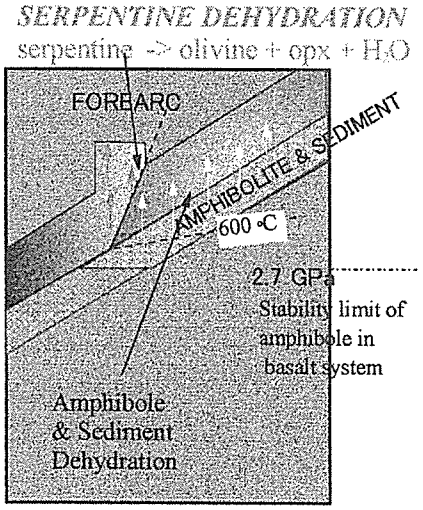


Fig. 1. A model for fluid migration and magma generation in subduction zones, after Tatsumi and Eggins (1995).

(Submitted to Geophy. Res. Lett. 2001/04/20)

Os-Sr-Nd-Pb systematics of tholeiites and alkali basalts in Weichang, NE China: Implications for the intracontinental magmatism

K. Suzuki, T. Shibata, and Y. Tatsumi

The Cenozoic basaltic rocks are widely distributed in NE China, which has been called "Hot region" (Fig. 2, Miyashiro, 1986). The mechanism of the basaltic rock production under the thick and cold continental crust is poorly constrained. Here we have analyzed Os, Sr, Nd, and Pb isotopic abundance of the tholeiites and alkali basalts in Weichang, NE China, in order to investigate the volcanic activity in NE China.

Sr-Nd and Pb-Pb isotopic diagrams (Fig. 1 (a), (b)) imply mixing of the DMM-like depleted mantle reservoir and enriched sediments. However, the tholeiites possess the enriched feature in the Nd isotope, whereas they

show the depleted characteristics in the Pb isotopes, which cannot be explained by simple mixing of the depleted mantle source and the enriched component.

The very high Os isotopic ratios (0.2 – 1.1) beyond those of ocean island basalts were obtained for both the Weichang tholeiites and alkali basalts (Fig. 3). This storongly suggests that the enriched component such as crustal materials were involved in formation of Weichang volcanic rocks, because none of the mantle component known at present possess such high Os isotopic ratios. The possible enriched component is material in the subducting slab and the continental crust through which Weichang magma ascended.

Results of mixing calculation between Os abundance and isotopic ratios of Weichang basalts reveal that more than 95 % continental crust materials are required to generate Os signature of the Weichang basalts. It is unlikely, because 95 % continental crust involved would not produce rocks with basaltic chemical compositions.

It is difficult at present to explain all the data consistently. Further consideration such as the behavior of Re and Os in the subducting slab under the continental crust and the isotopic signatures of the lower crust is required.

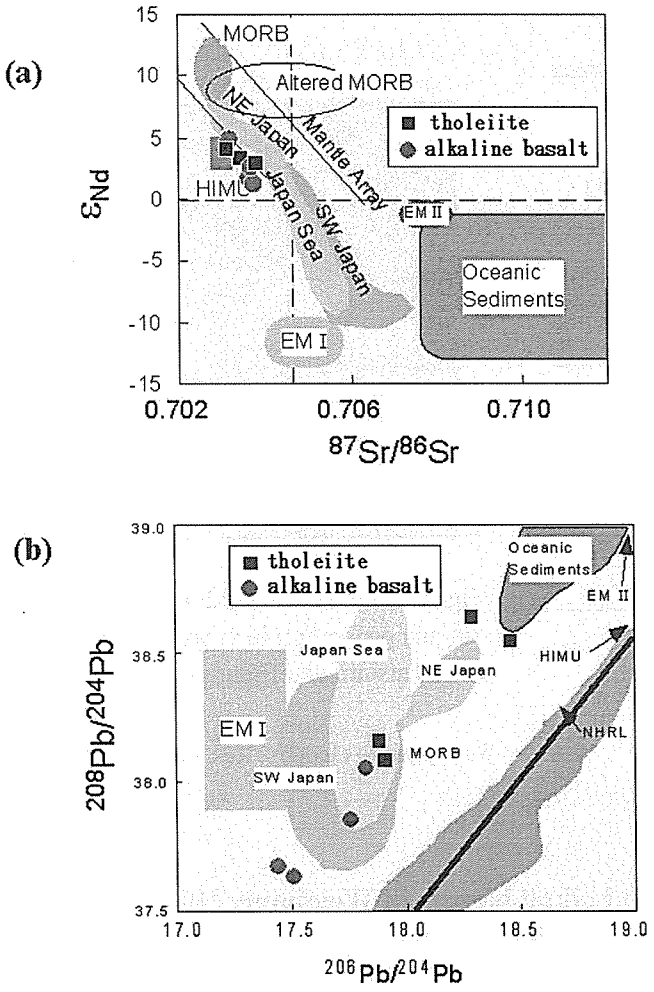


Fig. 1. Sr-Nd-Pb isotopic signatures of Weichang basalts, NE China.

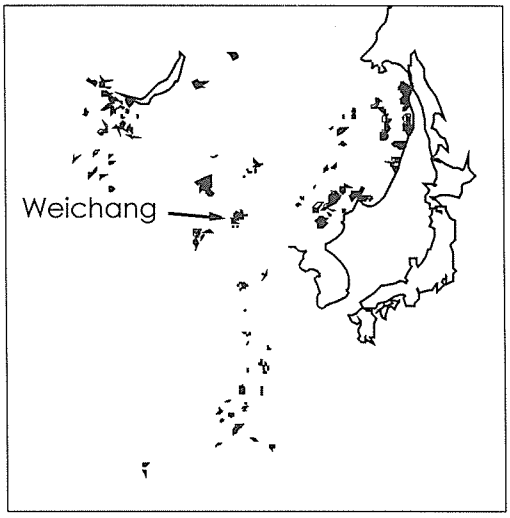


Fig. 2. Distribution of Cenozoic basalts in Eastern China and Russia. Weichang basalt forms plateau of 10,000 km².

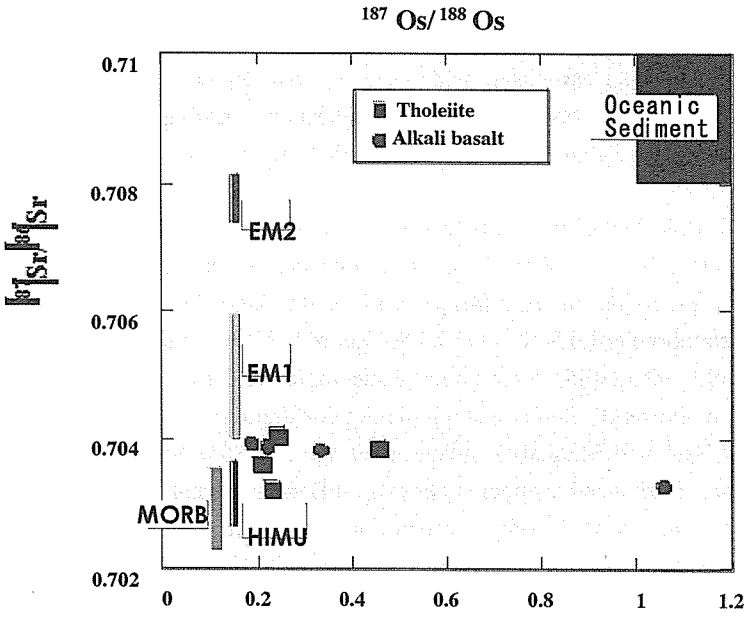


Fig. 3. Os-Sr correlation of Weichang tholeiites and alkali basalts.

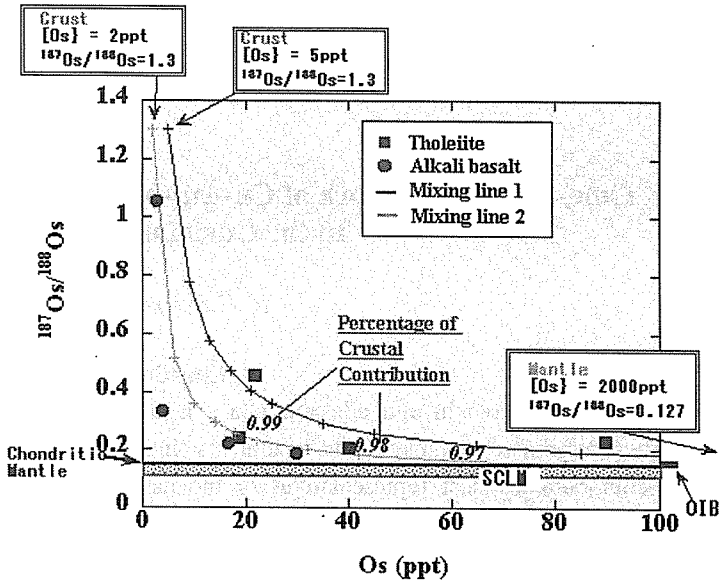


Fig. 4. Mixing calculation using correlation between Os abundance and $^{187}Os/^{188}Os$ ratios.

Proterozoic Cu-Au systems of the Curnamona Province, Australia: geological and stable isotope constraints on timing and origins

R. G. Skirrow, P. M. Ashley, and ***K. Suzuki***

The Curnamona Province in New South Wales and South Australia, including the Broken Hill and Olary Domains, is emerging as a significant Proterozoic Cu-Au as well as Pb-Ag-Zn metallogenic province. Mineralization styles range from shear-hosted magnetite-ironstone associated Cu-Au styles (e.g. Copper Blow deposit), through stratabound vein/replacement Cu-Au(-Mo) mineralization with locally developed Fe-oxides (e.g. Kalkaroo, Portia prospects), to high temperature(?) Au(-Cu-Mo) deposits with very minor Fe-oxides (e.g.

White Dam prospect). Key shared characteristics, in addition to the Cu-Au +/- Mo +/- As +/- REE +/- Ba +/- F signature, include an association with potassic +/- Fe alteration (biotite, K-feldspar +/- magnetite), combined structural - stratigraphic controls, and syn- to late-tectonic timing. The Cu-Au mineralization and alteration overprint regionally extensive pre- or early-tectonic sodic alteration effects in the Willyama Supergroup, although albitization and calcsilicate alteration are also associated with some Cu-Au deposits. A significant proportion of deposits occur near the regional interface between albitic to calcsilicate-bearing and variably magnetic metapsammitic lithologies, and overlying relatively reduced metapelitic rocks with low magnetic susceptibility.

Based on stable isotope and reconnaissance fluid inclusion results, copper - gold at Kalkaroo and Waukaloo were deposited at probable maximum temperatures of ~420-460°C from hypersaline Na-K-Ca-Cl fluids. Oxygen and hydrogen isotope compositions of fluids in equilibrium with sulfide-associated biotite and amphibole overlap with both magmatic and metamorphic fluids ($\delta^{18}O$ = 5.5-8.5 per mil, δD = -44 to -67 per mil), and are distinctly lighter than metamorphic fluids responsible for regional syntectonic Na-Ca-Fe metasomatism at around 1583-1588 Ma. In conjunction with molybdenite Re-Os isotopic dating constraints for Mo and Cu-Au mineralization at the Portia, Kalkaroo, White Dam and Waukaloo prospects (9 ages, ~1632 Ma to ~ 1612 Ma), we infer that Cu-Au mineralization was introduced syntectonically at differing crustal levels during inversion of the Willyama Supergroup basin, and was broadly synchronous with the Olarian Orogeny. Emplacement of granitoids with I-type characteristics may have occurred at ~1630-1640 Ma, although their role in the mineralizing systems remains unknown. The Cu-Au mineralized systems of the Curnamona Province are considered to be variants within the diverse global family of Fe-oxide associated Cu-Au deposits.

(Submitted to Mineral. Dep.)

Time-Space framework of Cu-Au(-Mo) and regional alteration systems In the Curnamona Province

R. G.Skirrow, P. M. Ashley, N. J. McNaughton, and ***K. Suzuki***

Introduction

The Broken Hill Domain and adjacent Olary Domain in the Curnamona Province experienced broadly similar lithostratigraphic, magmatic and tectonic evolution during the Palaeoproterozoic and Mesoproterozoic. Although both domains host representatives of the major mineral deposit styles in the province, the Olary Domain contains the greater share of known Cu-Au(-Mo) mineralization, whereas Pb-Zn-Ag resources discovered to date are localized primarily in the Broken Hill Domain. Robust and predictive exploration models for Cu-Au Bad Pb-Zn-Ag ore systems in the Curnamona Province will build on a framework of quantitative information on the timing of hydrothermal events relative to tectonism and magmatism, the geometry of fluid now pathways, and fluid and host rock physicochemical properties. Here, we present a summary of geochronological, stable isotopic and preliminary fluid inclusion constrains on the timing, character and distribution of fluids responsible for Cu-Au(-Mo) mineralization and regional Na-Ca-Fe alteration, and conclude with comments on the significance of the results for exploration models, Reviews of the Regional geology and metallogenesis of the Olary Domain by Ashley (2000) and Ashley et al. (1998) provide a background to out results.

Conclusions and Exploration Implications

Cu-Au(-Mo) introduction in the epigenetic Fe-oxide associated systems may have commenced during the period -1612-1632 Ma, based on high-precision Re-Os dating. This timing would have overlapped with possibly the earlier stages of the Olarian orogeny as marked by granitoid emplacement (e.g., at 1616 +/- 9 Ma, Fanning et al. 1998). However, improvement in the accuracy of Re-Os dating, and further age dating arid characterization of -1620-1580 Ma S-type and/or I-type and -1630-1640 Ma I-type granitoids (Ashley et al., 1998; Wyborn et al.

1998), are required to fully reconcile results on the temporal relationships between mineralization and magmatism

Regional-scale flow of -450-550°C Na-Ca-Fe metamorphic brines between -1595 Ma and --1583 Ma was controlled principally by D3 structures.

The regional alteration event temporally overlaps with magmatism of the Hiltaba Suite - Gawler Range Volcanics and Cu-U-Au mineralization (Olympic Dam) in the Gawler Craton, and is within error of the age of volcanism on the Benagerie Ridge (Fanning et all, 1998)-

Syntectonic Na-Ca-Fe regional alteration is prominent in the southern, higher metamorphic grade parts of the Olary Domain, whereas Cu-Au(-Mo) mineralization and associated Fe-oxide and potassic alteration arc best developed in the lower metamorphic grade, northern Olary - Benagerie Ridge.

The White Dam Au(Cu-Mo) mineralization may be a high-temperature style associated with quarzofeldspathic veins in a high-grade metamorphic area.

Although the Cu-Au-Mo-As-F-LREE geochemical signature and stable isotope compositions of proximal alteration minerals in the Fe-oxide associated systems are consistent with magmatic fluid input possible 'causative' magmatism has yet to be identified.

(AGSO Record 2000/10, 83-86)

Geochemical modeling of partial melting of subducting sediments and subsequent melt-mantle interaction: generation of high-Mg andesites in the Setouchi volcanic belt, southwest Japan

Y. Tatsumi

A possible mechanism for high-Mg andesite formation, including melting of subducting sediments and subsequent melt-mantle interaction, was examined by geochemical formulation of partial melting and melt-solid reactions. The modeling results demonstrate that a sediment-melt produced at 1050°C and 1.0 GPa changes its composition from rhyolitic to andesitic, as it dissolves olivine and clinopyroxene and crystallizes orthopyroxene. Such a reaction product possesses major and incompatible trace element compositions close to high-Mg andesites in the Setouchi volcanic belt, southwest Japan.

(Geology, in press.)

Slab melting: its role in continental crust formation and mantle evolution

Y. Tatsumi

A possible mechanism for continental crust formation, slab-melting and subsequent melt-mantle interaction, was examined by geochemical formulation of partial melting and melt-solid reactions. The modeling results suggest that such a process can reasonably explain the major and trace element compositions of the andesitic bulk continental crust. However, the Sr-Nd-Pb isotopic compositions of melting residues in the subducting slab, which may have foundered and been stored in the deep mantle, do not match those of any proposed geochemical reservoir. This may lead to the conclusion that the slab melting did not play the major role in the continental crust formation during the Archean.

(Geophys. Res. Lett., in press.)

Constraints on Arc Magma Genesis

Y. Tatsumi

Improved understanding of the complex processes associated with subduction zone magmatism requires the identification and explanation of tectonic, petrological, geochemical, and geophysical characteristics common to most subduction zones. These characteristics include: (1) the presence of dual volcanic chains within a single volcanic arc, (2) the constant depths to the surface of the subducting lithosphere beneath trench- and backarc-side volcanic chains, ~110 km and ~170 km, respectively, (3) greater volume of magma production beneath the trench-side volcanic chain (4) selective enrichment of particular incompatible elements, (5) systematic across-arc variations in incompatible element concentrations and isotopic/element ratios, (6) location of a high-temperature (>1350°C) region within the mantle wedge, (7) occurrence of localized high-temperatures (~1300°C) immediately beneath the crust/mantle boundary, (8) location of very low-velocity regions within the mantle wedge. It is suggested here that dehydration processes and associated selective element transport, which take place in both the subducting lithosphere and the downdragged hydrated peridotite layer, and secondary convection within the mantle wedge induced by plate subduction are largely responsible for the observed characteristics of subduction zone magmatism.

(AGU Monograph, in press)

Aeromagnetic survey in Aso Volcano

M. Utsugi, Y. Tanaka, T. Hashimoto and H. Hase

To investigate the magnetic structure of the central cones of Aso Volcano, we conducted the aeromagnetic surveys using helicopter in November of 2000. We measured along 18 parallel N-S lines with 250 m spacing around the center part of the central cone of Aso Volcano (Fig. 1) using portable Overhauser effect magnetometer. The altitude of flight was kept about 200 to 300 m above the terrain.

To determine the distribution of rock magnetization, we divided the crust with a number of cubic blocks (length=250m, width=250m and height=250m) with 3 layers. Using the joint inversion of the observed data and the topography, we determined the intensity of the magnetization of each cubic block. The effect of the topography is corrected from a digital terrain model by integrating analytically in the vertical direction and then numerically in horizontal plane. The distribution of the surface

magnetization around Mt. Nakadake is shown in Fig.2. One of the low magnetized areas is shown in the

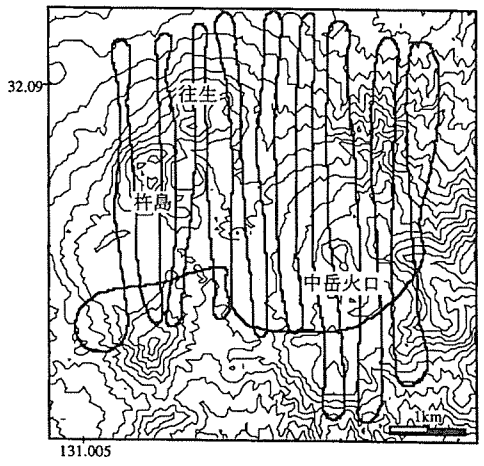


Fig. 1 Flight course of aeromagnetic survey

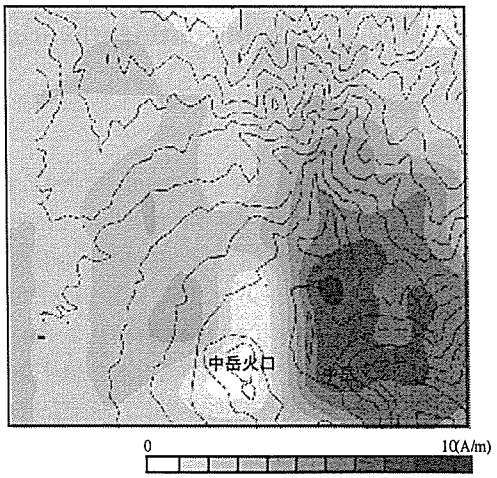


Fig.2 Distribution of the surface magnetization around Mt. Nakadake.

vicinity of the active crater of Mt. Nakadake. This low magnetization may be caused by that the higher temperature under the Nakadake crater reduces the underground rock magnetization.

The Sr, Nd and Pb isotopic ratios of GSJ standard rocks

M. Yoshikawa, T. Shibata, and Y. Tatsumi

The analytical procedure for chemical separation and mass spectrometry basically followed *Yoshikawa and Nakamura* [1993] for Sr isotopic ratio and *Shibata et al.* [1989] for Nd isotopic ratio and Koide et al. [1990] for Pb isotopic ratio. The samples were decomposed by HF + HNO_3 + $HClO_4$ in a 7ml teflon beaker. Sr and Nd were separated with 2.5N HCl using 1ml cation-exchange chromatography in H^+ form (Muromac AG50W-X8 resin). Sr was purified with 0.06M DCTA in 0.5N pyridine, distilled water and HCl using 0.3ml cation-exchange chromatography in pyridinium form. Nd was purified with 0.22M hydroxy-alpha-isobutric acid using 0.3ml cation-exchange chromatography in pyridinium form. Pb was separated with 0.5M HBr and distilled water using 0.1ml anion-exchange chromatography in Br^- form. Pb was purfied using the same column with the same procedure described above.

Mass spectrometry was carried out on a Finnigan MAT 261 and Triton TI instruments. Normalizing factors to correct for isotopic fractionation for Sr and Nd are $^{86}Sr/^{88}Sr = 0.1194$ and $^{146}Nd/^{144}Nd = 0.7219$, respectively. The averaged correction factor is 0.116 % per mass unit (n = 8). Measured ratios for standard materials were $^{87}Sr/^{86}Sr = 0.710279 \pm 0.000028$ (2σ) for NIST SRM987 (n = 5) ,$^{143}Nd/^{144}Nd = 0.511851 \pm 0.000013$ (2σ) for La Jolla (n = 9), $^{208}Pb/^{204}Pb = 36.708 \pm 0.011$ (1σ), $^{207}Pb/^{204}Pb = 15.494 \pm 0.004$ (1σ), and $^{206}Pb/^{204}Pb = 16.938 \pm 0.003$ (1σ) for the NIST SRM951 (n = 8).

Measured Sr, Nd and Pb isotioc ratios of Geological Survey of Japan (GSJ) standard rocks are listed in Table 1.

Table 1. Sr, Nd and Pb isotopic ratios of GSJ rock standards

Sample name	$^{87}Sr/^{86}Sr$	$2\sigma_m$	$^{143}Nd/^{144}Nd$	$2\sigma_m$	$^{208}Pb/^{204}Pb$	2σ	$^{207}Pb/^{204}Pb$	2σ	$^{206}Pb/^{204}Pb$	2σ
JB-1	0.704144	± 0.000005								
JB-1a	0.704136	± 0.000005	0.512750	± 0.000013						
JB-2			0.513097	± 0.000011	38.267	± 0.007	15.565	± 0.003	18.354	± 0.004
JB-3	0.703446	± 0.000006	0.513048	± 0.000009						
JA-1	0.703566	± 0.000007	0.513102	± 0.000018	38.281	± 0.020	15.552	± 0.009	18.328	± 0.010
JA-2	0.706338	± 0.000006	0.512558	± 0.000013	38.694	± 0.017	15.622	± 0.007	18.419	± 0.008
JA-3	0.704183	± 0.000008	0.512859	± 0.000014	38.265	± 0.014	15.551	± 0.006	18.315	± 0.007

Temporal Change of P wave Velocity at Kuju Volcano, Kyushu, Japan

M. Yoshikawa., Y. Sudo., H. Masuda. and S. Yoshikawa.

The northwestern area of Kuju Volcano is one of the most active geothermal fields in Japan, where seismic swarms have been observed. The Vp/Vs ratio changes with time and increases before the seismic swarm.

On the other hand, a temporal change of travel time of P-wave was able to be detected. Travel time of P-wave before April 1996 was slower than after the time (Fig.1, Fig.2). It indicates that P-wave velocity changed with time in this area.

Kuju Volcano in the central Kyushu came to life with a phreatic ash eruption on 11 October 1995. So this change with time of travel time seems to be associated with this eruption and the interaction of geothermal fluids inside the volcano.

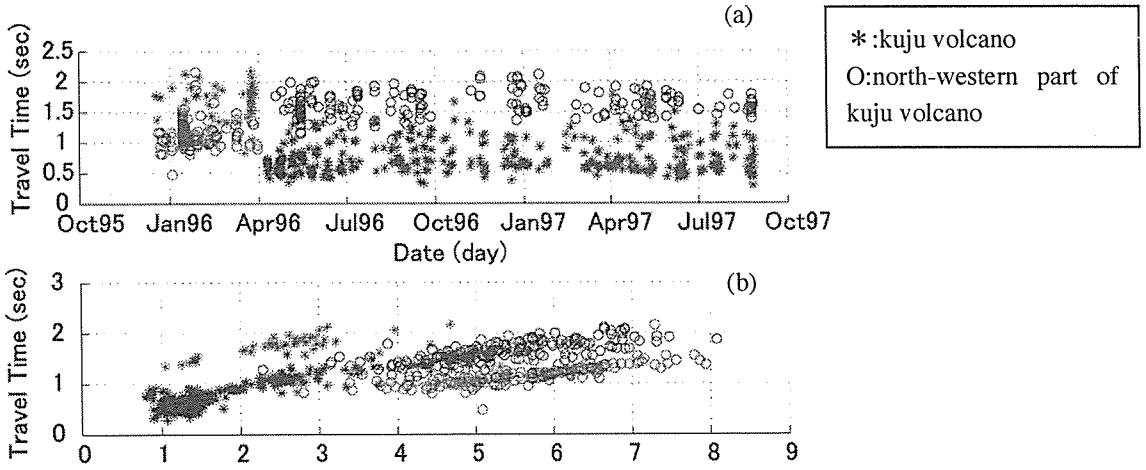


Fig.1(a)Temporal change of P arrival time and (b)Travel time curve at station kj2.

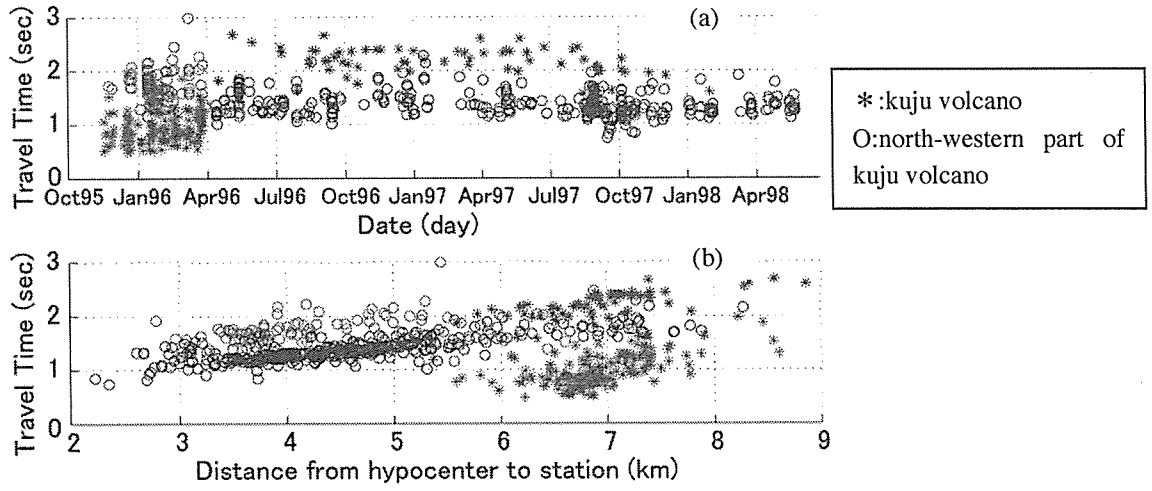


Fig.2(a)Temporal change of P arrival time and (b)Travel time curve at station 1ms

Thermal Springs in Shargaljuut, Bayankhongor Province, Mongolia

Y. Yusa and K. Tagomori

The Shargaljuut Thermal Spring Area is located at the foot (about 2000 meters above the sea level) of the Hangayn Mountains in a distance of about 60 km to the North-East from Bayanhongor City, Mongolia.

Thermal waters are discharged through about 200 holes/fissures of granitic rocks covering an area of 350×170 meters at the north bank of Shargaljuut River. Water temperatures are in a range of 45 – 90 °C, and high temperature waters are accompanied by bubbles containing mainly nitrogen. Total outflows are 0.05 m^3/s for water and 18.5 MW for heat respectively. Thermal waters are alkaline and in low chemical concentration of Na - $HCO_3 \cdot SO_4$ type. Stable isotope compositions of hydrogen and oxygen in thermal waters indicate that they are originated from meteoric water.

The Shargaljuut Hydrothermal System is interpreted to be that infiltrated meteoric water heated up to about 170 °C by terrestrial heat flow at about 4000 meters depth and given chemical substances by water-rock interaction under a limited CO_2 supply uprises through narrow holes of 0.1 - 1 cm in radius.

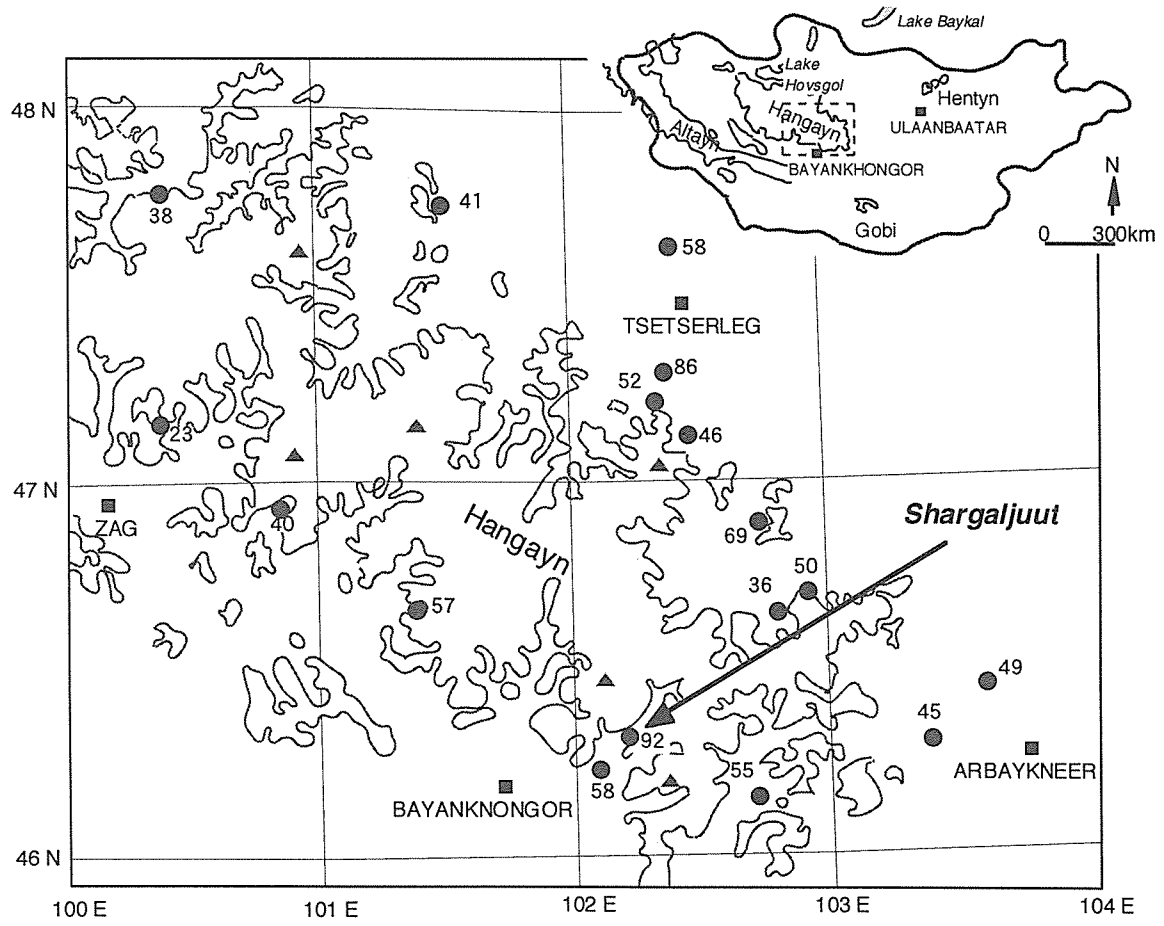


Fig. 1. Location map of thermal springs around Hangayn Mountains. Numerals show discharging temperatures (°C).

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：「雲仙科学掘削計画（自然電位・地磁気)」

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：「ダブルβ壊変 ^{100}Mo-^{100}Ru：ニュートリノの質量」 (広大, 日高・Chi)

：「EXAFS による天然岩石中の白金族元素の存在状態 」(広大，高橋・清水)
田中良和：理化学研究所併任（地震国際フロンティア研究プログラム）
：京都大学防災研究所研究担当
：工業技術院地質調査所地殻物理部併任
：「有珠火山の電磁気観測　7/11-15」
：「秋の宮地域の電磁気調査　9/9-9/11」
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：「口永良部島の空中磁気測量」
：「ロングバレーカルデラの電磁気観測 8/17-8/30」（米国地質調査所）
田中良和・宇津木充・長谷英彰：「岩手火山の電磁気観測　6/30-7/3」
巽好幸：京都大学防災研究所研究担当（姶良カルデラにおける大規模火砕流マグマの成因）
：海洋科学技術センター併任研究員
：岡山大学固体地球研究センター嘱託研究員

国際

橋本武志：「地球電磁気学的手法による火山流体の調査」（Istituto Internazionale di Vulcanologia, Catania, Italy）
大倉敬宏：「フィリピン・マコロード回廊における GPS 観測」（フィリピン火山地震研究所）
：「インドネシア北スラベシにおけるジオダイナミクス」（名古屋大学，高知大学，バンドン工科大学，フィリピン火山地震研究所）
鈴木勝彦：「フィリピン ophiolite の Re-Os 年代と Os 初生同位体比による多段階生成モデル」(フィリピン環境鉱床研究所，Santos, R.A.，東大総合文化，高野，東大海洋研，野崎．宮田)
：「モリブデナイトの超高分解能 Re-Os 直接年代決定法によるオーストラリア Olary-Broken Hill 地域の鉱床生成論 」(オーストラリア地調，Skirrow, R. G.)
：「カナダ Grenville 地域のモリブデナイトの高精度 Re-Os 年代」(カナダ地調，Lentz, D.)
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A brief report on routine observations at AVL

Aso Volcanological Laboratory

Purpose of routine observations

One of the major activities of AVL is geophysical research on structure and dynamics of active volcanoes.

In case of unrest, integrate and intensive observations are necessary in order to have an accurate grasp of volcanic activity and to forecast impending eruption. However, routine observations at an inactive stage of a volcano are also important to establish a baseline for evaluation of possible eruptive activity. In order to obtain simple and general set of laws to predict an eruption, we need comparative studies with other volcanoes which are equipped with basic and common tools, such as seismic monitoring and measurements of ground deformation, gravity and magnetism. Routine observations as well as strategic temporal observations are necessary for hypothesis testing and constructing of a theory. Because the time scales of some volcanic phenomena are long, we need long-term observations and homogeneous data for a better understanding of these phenomena.

AVL has been taking charge of continuous monitoring of Aso volcano since its foundation. Recently, other active volcanoes such as Kuju and Tsurumi have been under monitoring. Exact data and detail description of Aso and Kuju volcanoes are regularly reported to Coordinating Committee for Prediction of Volcanic Eruption. Also they are published in "Report of Coordinating Committee for Prediction of Volcanic Eruption" by JMA. For further information about these two volcanoes, please refer to these publications.

Routine observation crew(#:part time)

<Research Staffs> Yoshikazu TANAKA, Yasuaki SUDO, Hiori ONO, Takahiro OHKURA, Takeshi HASHIMOTO and Mitsuru UTSUGI#

<Technical Staffs> Teruaki HOKA, Mikio SAKO, Shin YOSHIKAWA and Hideharu MASUDA#

<Graduate Students>

Takehiko MORI, Makoto NAKABOH, Hideaki HASE, Miyuki YOSHIKAWA and John Makario LONDONO

Items of routine observations and persons in charge

<Seismology>

A control of the regional network: Y. SUDO

Analysis of data from the regional network: Y. SUDO

A control of the network around the active crater in Aso: H. ONO

Analysis of data from the network around the active crater: H. ONO and T. MORI

A control of the network around Kuju volcano: Y. SUDO

Analysis of data from the Kuju network: Y. SUDO and M. YOSHIKAWA

Maintenance works on instruments: T. HOKA, M. SAKO, S. YOSHIKAWA and H. MASUDA

Maintenance works on seismic stations: T. HOKA, M. SAKO, S. YOSHIKAWA and H. MASUDA

Volcanic tremor accumulator in Aso: Y. SUDO and M. SAKO

<Ground deformation>

Tiltmeters and extensometers in Aso: H. ONO and M. SAKO

Tiltmeters in Kuju: M. SAKO

GPS and EDM in Aso: H. ONO and M. NAKABOH

GPS and EDM in Kuju: H. ONO and M. NAKABOH

Leveling survey in Aso: M. NAKABOH and others

Super Conductivity Gravimeter: Y. SODO, S. YOSHIKAWA and T. MORI

<Geomagnetism>

Fulltime monitoring of total force in Aso: Y. TANAKA , T. HASHIMOTO and M. UTSUGI

Fulltime monitoring of total force in Kuju: Y. TANAKA , T. HASHIMOTO and M. UTSUGI

<Miscellaneous>

Geothermal observation nearby the active crater in Aso: Y. SODO and S. YOSHIKAWA

Volcanic activity and geophysical observations at Aso during the past ten years

T. Hashimoto, Y. Tanaka, Y. Sudo, H. Ono, T. Ohkura, T. Tsutsui, T. Hoka, M.Sako, H. Masuda, S. Yoshikawa, S. Sakanaka, M. Utsugi, and T. Mori

We investigated changes in some geophysical data observed around the active crater of Nakadake, Aso Volcano during the period of 1990-2000 with special attention to the relationship between geomagnetic changes, tremors and superficial activities of the volcano. The followings are suggested.

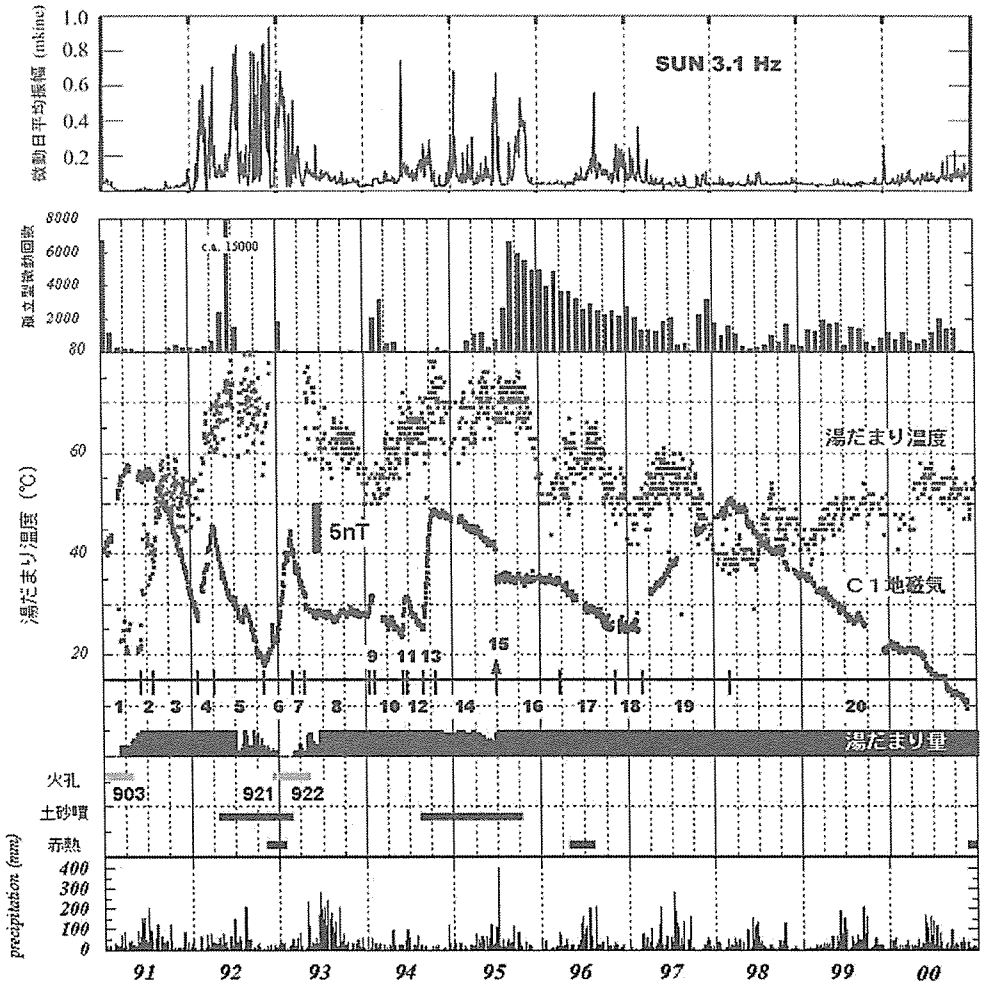


Fig.1 (From top to bottom) Geophysical variations observed at Nakadake, Aso Volcano during the period of 1990-2000. Amplitude variations of tremors (AVL), cumulative number of isolated tremors (JMA), surface temperature of the crater lake (JMA), geomagnetic total force (AVL), water level of the crater (JMA), existence of pit craters, mud flow and incandescent (AVL and JMA), and precipitation (JMA).

(1) An onset of magnetization (cooling) period frequently coincides with a burst of continuous tremor, mud eruption, or opening of a vent. Such events seem to be strongly related to heat and material transport from the shallow part to the ground surface. Inversely, it is frequently observed that the burst of continuous tremor does not coincide with geomagnetic change.
(2) Increase of the cumulative number of isolated tremors does not seem to coincide with an onset of magnetization (cooling) but that of demagnetization (heating).
(3) Condition of the crater bottom severely affects the heat-transfer system at shallow part.

Seismicity in the Beppu graben in 2000

Y. Furukawa, H. Mawatari, and K. Takemura

In the Beppu graben we have observed seismic activity (See the section "Observation of seismic activity in the Beppu graben" in this issue). In 2000 we have located 228 events; the hypocenter and vertical sections in the E-W and N-S directions are shown in Fig. 1. In 2000 we have three major seismic swarms in this graben. The first swarm activity began in January 1999 in the area between the Kannawa and the Asamigawa faults, which occurred just after a large swarm in December 1999. The second one was occurred in April 2000 in the area between the Beppu-Kita and the Kannawa faults. The last one was occurred in May just after the duration of the second one in the area ~2 km north of the area of the second one.

In the areas of the swarms in Dec. 1999 and 2000 swarm-like seismic activity has been observed; the maximum magnitude of these swarms is less than ~3.0. The swarms from Dec. 1999 till May 2000 have several events with magnitude of >3.0, and the number of events was one order of magnitude larger than that of the previous year.

In Fig. 2 the maximum depth of focus become deeper with the distance from the volcanoes, which is considered to simulate the temperature of the brittle-ductile transition in the crust (See the section "Seismic Activity in the Beppu graben, Kyushu, Japan: implications for earthquakes triggered by magmatic fluids" in this issue). In a area in the Beppu bay near the northern swarm area, a dome structure was detected by reflection studies, which is considered to be magmatic intrusion. The swarm areas, the volcanoes, and the magmatic dome structure are approximately on a line, and the deeper swarm activity could be related with magmatic intrusion.

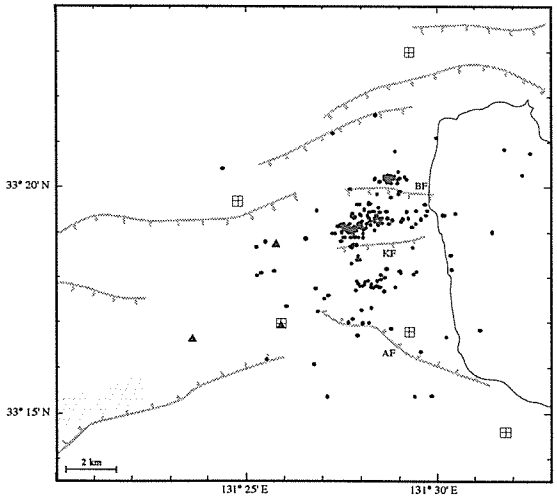


Fig. 1 Epicenter distribution located in the period from April 1993 to Dec. 1999 for events with magnitude greater than 1.0. The shaded oval represents the location of the estimated high electric conductivity body. Fault structures estimated from gravity survey are also shown as shaded straight lines. Open rectangles and filled triangles denote seismic stations and volcanoes, respectively. BF, KF, and AF represent the Beppu-kita, Kannawa, and Asamigawa faults.

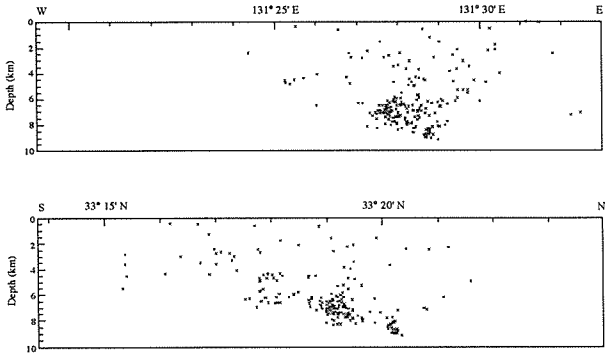


Fig. 2 Vertical cross sections of focal distribution in the N-S and E-W directions.

Volcanic earthquakes near Mt. Naka-dake, Aso Volcano in 2000

H. Ono

The first crater of Mt. Naka-dake, Aso Volcano has been covered with hot water pool since 1993. The incandscent state was appeared at the south part of the first crater on October in 2000 and continued through the year.

Volcanic earthquake activity was calm near the active crater of Mt. Naka-dake in 2000.

The foci of volcanic earthquake distributed under the first crater as yet. The source location and daily number histogram of volcanic earthquakes were shown in Fig. 1 and Fig. 2.

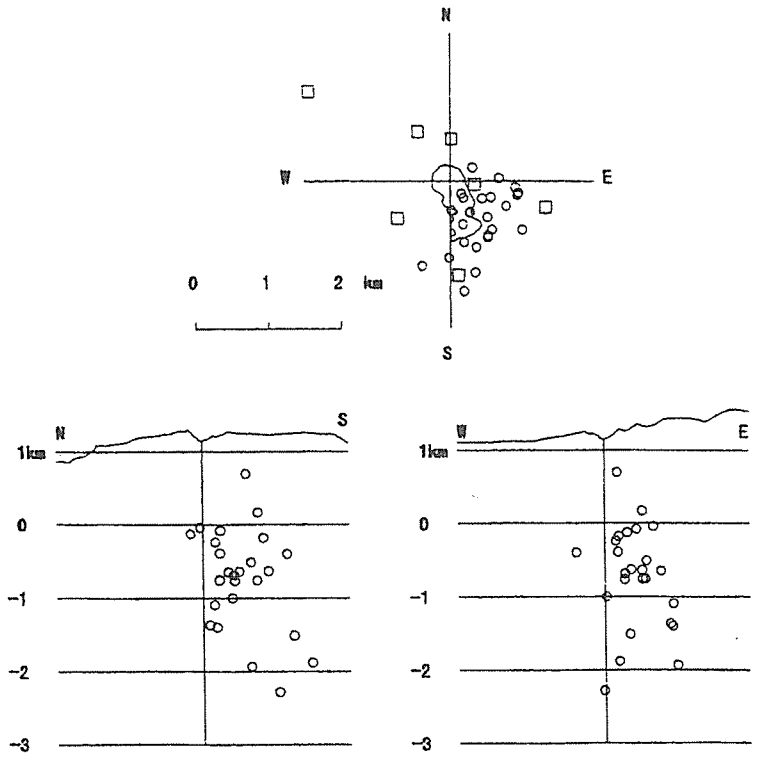


Figure 1. Source distribution of volcanic earthquakes near Naka-dake in 1999.
○ : location of volcanic earthquake, □ : seismic station.

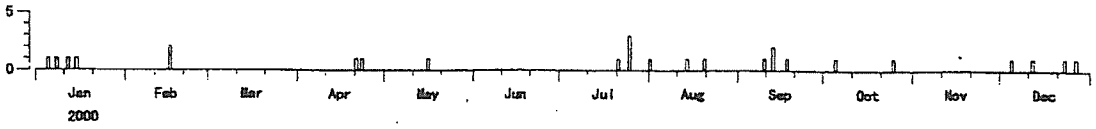


Figure 2. Daily number histogram of volcanic earthquakes in 1999.

Ground deformation observation in 2000

H. Ono

The tunnel for ground deformation observation locates in 30m underground at about 1km south-west from the first crater of Mt. Naka-dake and consists of horizontal tunnels forming equilateral right-angled triangle. Watertube tiltmeters of 25m span (WT1 and WT2) and extensometers of 20m span (E1 and E2) and 25m span (E3) have been installed.

The ground deformation observed by tiltmeters and extensometers in 2000 is shown in Fig. 2 with precipitation by Aso-san Weather Station, JMA.

Extensometers recorded annual variation with strain amplitude of 10^{-6} order.

The northwest uplift of 5 μradian was observed by tiltmeters for the later 5 months in 2000. It is doubtful whether this uplift will progress to volcanic eruption, because the uplift direction is perpendicular to the active crater.

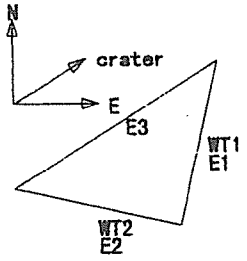


Figure 1. Tunnel and setting of watertube tiltmeters (WT1, WT2) and extesometers (E1, E2, E3).

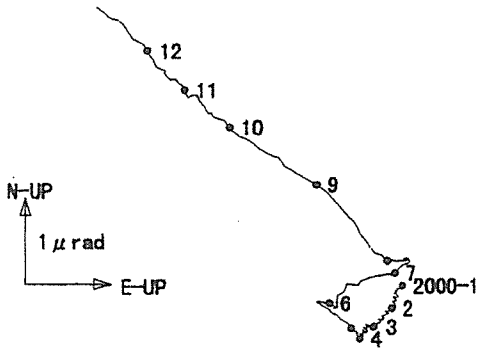


Figure 3. Upward vector from watertube tiltmeter observation. Attached numbers show months (1st day).

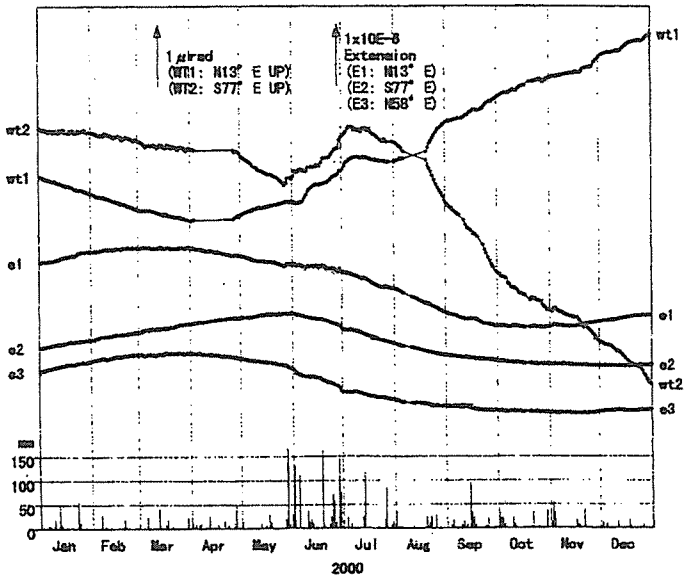
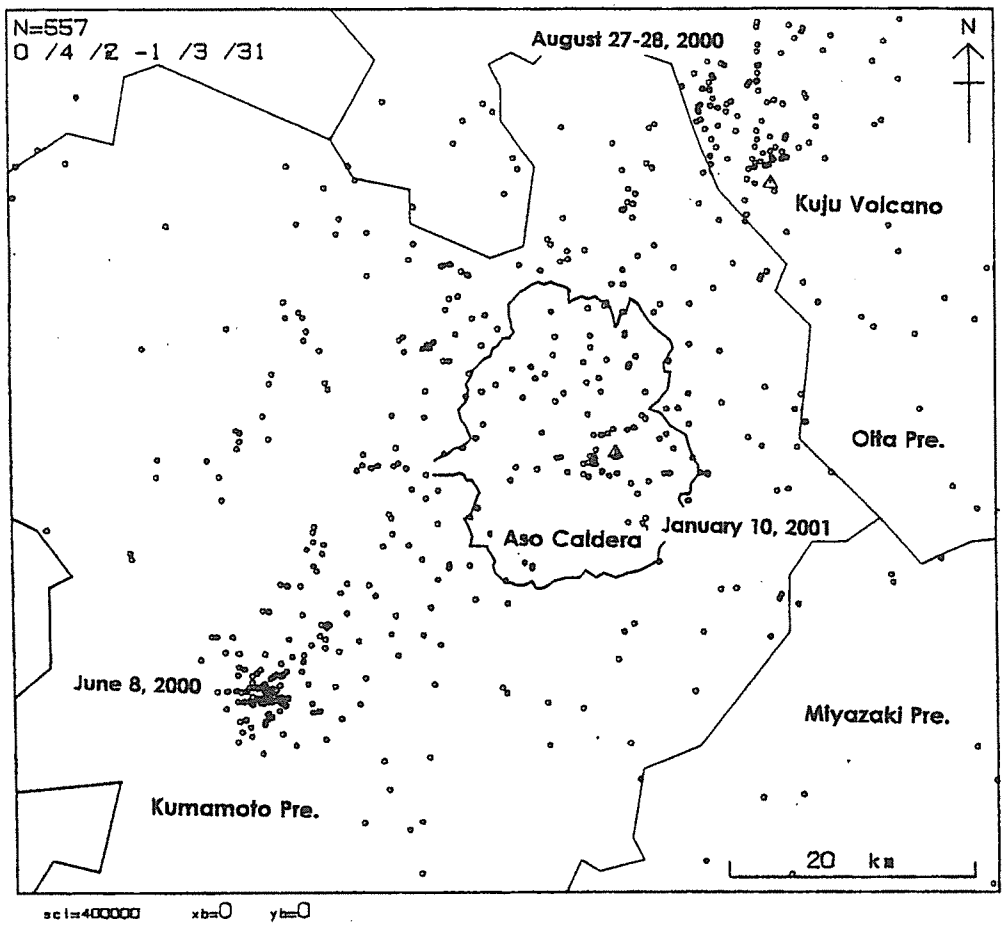


Figure 2. Ground deformation records in 2000. Lower is daily precipitation by Aso-san Weather Station, JMA.

Seismic Activity around Aso Caldera and Kuju Volcano during the period from April in 2000 to March in 2001

Y. Sudo

A telemetrically seismic network around Aso Caldera and Kuju Volcano is composed of 17 stations. Several earthquake swarms have occurred at the southwestern region of Aso Caldera and the northwestern side area of Kuju Volcano. In June 2000, at the southwestern region of Aso Caldera the big swarms occurred, some vents were felt. The largest event occurred at 09:32 on 8 June, its magnitude was 4.8. In Aso Caldera, on 10th January, 2001, the felt event (mag=4.0) occurred at the southeastern side near Takamori Town. This seismic event was very interest, because it had a few aftershocks (only three events) and at its hypocentral region no earthquake has occurred recently. The mechanism of this event indicates the reverse fault. At Kuju Volcano, many earthquakes occurred during this period. The swarm-like events occurred on August 27 and 28, 2000. The mechanisms of their events indicate a combination of both normal and right lateral strike-slip type faults. The tension axis maintains a horizontal north-south orientation.



A new system for sound velocity measurements under high P-T conditions

Y. Aizawa and K. Ito

Using a piston cylinder type high pressure and temperature apparatus in this institute we can carry out runs at 1 ~ 1.5 GPa, room temperature ~ 1200 ℃, which is suitable for investigation of the crust and the upper mantle. We have constructed a system for measurements of sound velocity under the crustal and the upper mantle conditions.

We used a piston-cylinder with 24 mm inner diameter and 80 mm thickness. The cell assembly is shown in Fig. 1. A sample with 6 mm diameter and 6 mm length was put between two platinum rods with with 6 mm diameter and 18 mm length. Two $LiNbO_3$ transducers (6 mm diameter, 0.5 mm thickness, and 36° Y-cut) were attached at the far side of the platinum rods. These rods are indispensable especially for wave-pattern observation under high temperatures to keep the temperature of transducers low enough to prevent the breakdown of the transducers.

Figure 2 illustrates the paths of the ultrasonic pulses. We can observe the pulse that goes through the rods and the sample without reflection (path I) and one that is reflected at the interfaces between the sample and the rods (path II). The travel time is obtained from the measurement of the delay time between these echoes, which gives us the precise travel time in the sample [Birch, 1961; Fujisawa et al., 1974]. A difference of acoustic impedance between the platinum rods and the sample is large, and platinum is stable under temperatures >1000 °C. For these reasons we used platinum as the buffer rods. In our experiments, the uncertainty of the temperature was estimated to be ±20°C at 1000°C.

We measured the travel time of a quartz glass sample at 1 GPa, room temperature ~ 1185°C. Error of the travel time measurements is less than ±0.4 %. Error of usual methods is ~±1% and this method is considered to be useful for measurements of sound velocity under conditions of the crust and the upper mantle.

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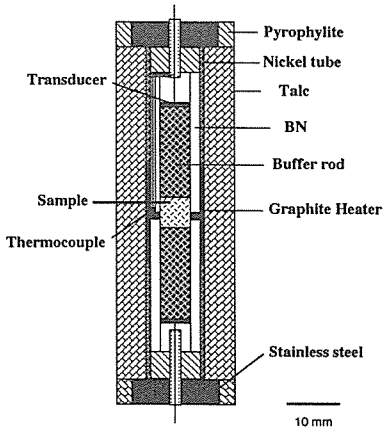

Fig. 1　Sample assembly.

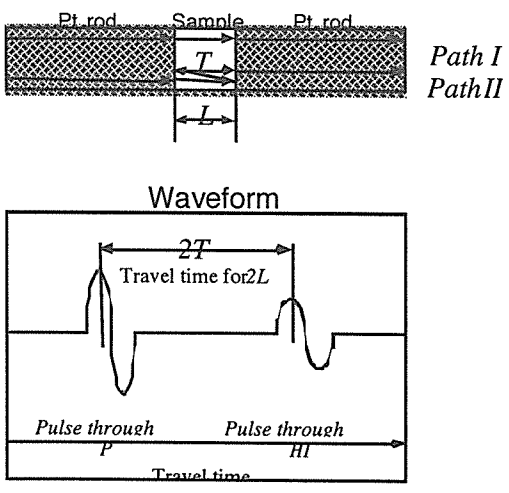

Fig. 2　Paths of the pulses and an observed waveform.

Observation of seismic activity in the Beppu graben

Y. Furukawa and H. Mawatari

We have installed four seismic stations at the Institute for Geothermal Sciences, Kyoto University (IGS), Mt. Karaki (KRK), Mt. Tsurumi (TRM), and Mt. Takasaki (TKS) in March 1993, and one station at Amama (AMA) in October 1993; these stations are located in and around the Beppu graben. The location of the seismic stations is shown in Fig. 1. We have used the earthquake observation system: MICROSEIS-100 of Japex Geoscience Institute, Inc. A 3-component 1 Hz geophone was installed at each seismic station; the data is digitized at a sampling rate of 200 Hz, and is telemetered from each station to the host part of this system installed at the IGS station.

Earthquake is automatically detected by the host system when the amplitude of the vertical signal of three or more stations becomes larger than a threshold value set for each station. The first arrivals have been manually picked, and detected earthquakes have been located using a maximum-likelihood method [Hirata and Matsu'ura, 1987]. The crustal velocity structure used in this study is based on those estimated from refraction seismic studies in the Beppu graben and reflection seismic studies in the central and the southern Kyushu [Ono et al., 1978; Kubotera et al., 1982]. Uncertainty of epicenter location is estimated to be less than 0.5 km in the area between the KF and the AF, but larger than 2 km in the west of 131° 23' E, and error of focal depth will increase with depth and is estimated to be less than 2 km in depths shallower than ~10 km [Hirata and Matsu'ura, 1987].

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Ono, K. et al. (1978) Explosion seismic studies in south Kyushu especially around the Sakurajima volcano. J. Phys. Earth, 26: S309-S319.

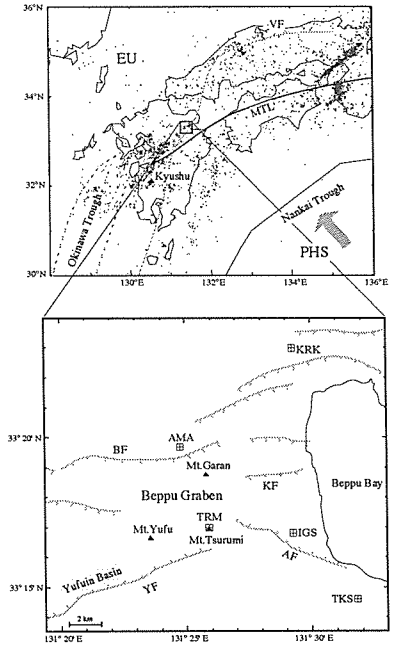


Fig. 1 Schematic tectonic map of the Beppu graben. Top: EU and PHS denote the Eurasian plate and the Philippine Sea plate, respectively. The Median Tectonic Line (MTL) and the volcanic front (VF) are also shown. The Beppu-Shimabara rift zone is shown as hatched zone. The hatched arrow indicates the convergence direction of the PHS. Epicenter of shallow earthquakes (<20 km) located by JMA from Jan. 1993 to July 1996 is also shown. Bottom: the rectangles and the solid triangles indicate the seismic stations (KRK: Mt.Karaki; AMA: Amama; IGS: Institute for Geothermal Sciences; TRM: Mt.Tsurumi; TKS: Mt.Takasaki) and the Quaternary volcanoes. The shaded

Experimental geochemistry laboratory

T. Kawamoto

In Beppu, you can conduct the following two types of experiments:

1 **Quench experiments.** Using piston cylinder type high pressure and temperature apparatus you can carry out runs at 1～1.5 GPa、room temperature ～1700 °C. A typical capsule size is less than 3.9 mm outer diameter and 5 mm height.

2 **In-situ observation under high pressure and high temperature.** By the use of Bassett's type hydrothermal diamond anvil cell (DAC), you can conduct in-situ observation of materials of your interest up to 1050 °C in a range from 0.1 GPa to about 5 GPa. Pressure at high temperature can be estimated by luminescence of $SrB_4O_7:Sm^{2+}$ or an equation of state of H_2O at lower pressures than 2 GPa. You can use an optical microscope, FT-IR microscope (2000 - 10000 cm^{-1}), and Raman microscope (532 nm excited) with a combination of DAC.

Magma characterization system

FT-Infrared microscope (JASCO Micro-20 and FTIR 610)

Abundance of total H_2O and speciation of molecular H_2O and OH ion in melts, glasses, and crystals. W and globar light sources, CaF_2 beam splitter, InSb detector, 25 mm plus 25 mm working distance and x10 Cassegrainian mirror system are used for 2000 ~ 10000 cm^{-1} analysis.

Raman microscope (Kaiser HoloLab 5000)

Information of structure of crystals, glasses and melts. Total H_2O abundances in glasses and melts. 532 nm YAG laser, 21 mm working distance and x20 objective lens are used for 100 ~ 4500 cm^{-1} Raman shift analysis.

Chemical analysis of run products

Electron microprobe analyser (JEOL superprobe), SEM-EDS (JEOL) .

High temperature and pressure apparatus

Diamond anvil cell (Bassett type)

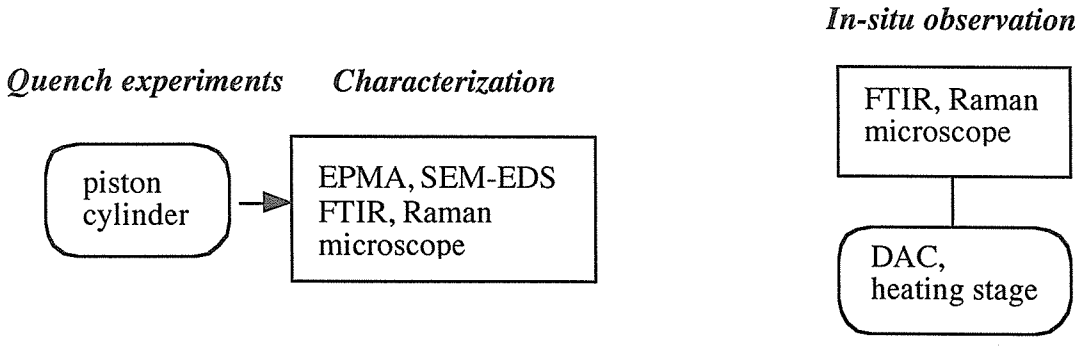
Direct observation of melts and crystals under the conditions up to 1050 °C and 5 GPa.

Piston cylinder apparatus (Senyo)

Phase equilibrium experiments up to 1700 °C and 1.5 GPa.

Heating stage (Linkam 1500)

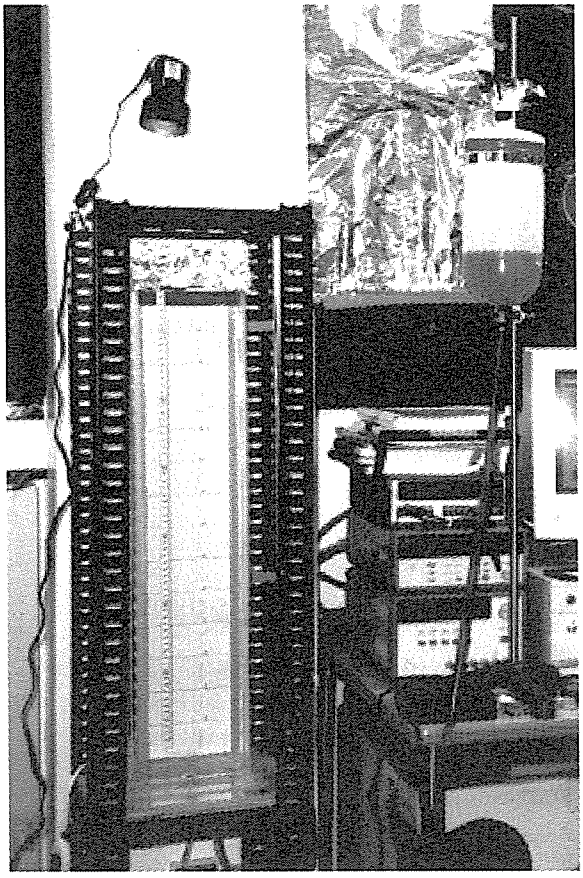
Heating stage under microscope up to 1500 °C at atmospheric pressure.



The fluid dynamics laboratory

I. Kumagai

The fluid dynamics laboratory is equipped with instruments for the measurement of fluid properties and the study of fluid motions. Facilities include a built in kitchen unit, a multi-meter, a dc power supply, a water circulator, gravimeters, a viscometer, a refractometer, heaters, pumps, acryl glass tanks, a 3-channel CCD video camera, tracers for flow visualization and laboratory computer systems for the recording and analysis of data and for digital image analysis, etc.



Experimental apparatus for laminar plumes

Analytical Procedure of Osmium and Rhenium

K. Suzuki

The analytical procedure used here is based on the Carius tube digestion (Shirey and Walker, 1995) combined with bromine-extraction of Os (Birck et al., 1997) or carbon tetroxide extraction (Cohen and Waters, 1996; Pearson and Woodland, 2000) with some modifications. The Carius tube method (Shirey and Walker, 1995) is an effective decomposition technique for achieving complete isotopic equilibration of sample-derived Os with the enriched spike in a wide range of geological materials, although the possibility of accidental sample loss by explosion exists. 2.5 to 5 g of the reference rocks were weighed and added with Re (typically 0.1 – 0.5 ml) and ^{190}Os spike solutions (0.1 – 0.5 ml) and heated in inverse aqua regia in a sealed Carius tube at 220 °C for

at least 24 hours. After cooling, the tube was opened carefully. In case of bromine extraction, the solution was transferred into a 60 ml PFA vessel, into which 2 ml of liquid bromine and 0.5 ml of a 40 % CrO_3 solution in 8N HNO_3 were added. The closed vessel was then placed on a hotplate and heated to approximately 60 °C. Bromine boiling under the aqueous phase scavenged volatile OsO_4 at the top of the vessel and flowed back to the bottom (Birck et al., 1997). After three hours of bromine extraction, the vessel was cooled in a freezer. The Os-bearing liquid bromine at the bottom was then pipetted into another container with 1 ml water. The water in the vial was discarded and HBr (0.5 ml) was added to the bromine containing separated Os, which was then gently evaporated.

As for CCl_4 extraction, we followed the methods developed by Cohen and Waters (1996) and Pearson and Woodland (2000). The solution and sample residue is transferred to 30ml PFA vessel and added with 4 ml of chilled carbon tetrachloride. This mixture is allowed to warm and shaken for 2 min. The organic fraction is then filtered by solvent extraction filter paper. The filtrate organic phase containing Os extracted. Organic extraction of the aqua regia fraction is performed twice more to ensure consistent Os recovery, which was added with 9N HBr. Then, the mixture was tightly capped in a Teflon vessel, allowed to warm to room temperature and then shaken for 2 min and kept under a heat lamp for 1 h. On cooling, the Os-bearing HBr was pipetted from the organic phase and dried. In both bromine and carbon tetroxide extraction, the residue was further purified by microdistillation (Roy-Barman, 1993) and ready for mass spectrometry. After extraction of Os described here, the aqueous phase was added with ethanol to reduce CrO_3 to Cr^{3+}. Rhenium was separated from the aqueous phase left behind the Br_2-extraction of Os, using Muromac AG 1X8 anion exchange resin. Both Re and Os were corrected for blanks. Total procedural blanks for Os and Re are 6.318 pg with $^{187}Os/^{188}Os$ =0.1744 +/- 0.0070 and 20 pg, respectively.

All measurements presented here were performed on a Finnigan MAT^R 262 mass spectrometer in a negative ion detection mode (Creaser et al., 1991; Volkening et al., 1991) equipped with a gas leak valve and an ion counting multiplier. A high purity Pt filament (99.999 %, 0.5 mm x 0.025 mm, H. Cross Co. or 99.99 %, 1 mm x 0.025 mm, Tanaka Precious Metal Co.) was baked in air to a bright red temperature for more than three minutes. Osmium loaded on the Pt filament was covered with 10 μg Ba and 2 μg Na. Custom-made 10,000 ppm $Ba(NO_3)_2$ solution (SPEX) was used. Both Re and Os blanks in the solution used were less than 0.01 pg. The filament was then heated in air until the loaded material started to melt and then quickly cooled, which reduces the organic interferences at masses 233-235 in Os isotopic measurements (Birck et al., 1997). This step was omitted in the Re isotopic measurements. Osmium and Re isotopic compositions were measured in the static multiple Faraday collector mode or in the pulse counting electron multiplier mode. Instrumental mass fractionation of Os was corrected by normalizing the $^{192}Os/^{188}Os$ ratio to 3.08271 (Nier, 1937). The subtraction of oxygen contributions for Os and Re was conducted using the ratios of $^{17}O/^{16}O$ = 0.00037 and $^{18}O/^{16}O$ = 0.002047 (Nier, 1950).

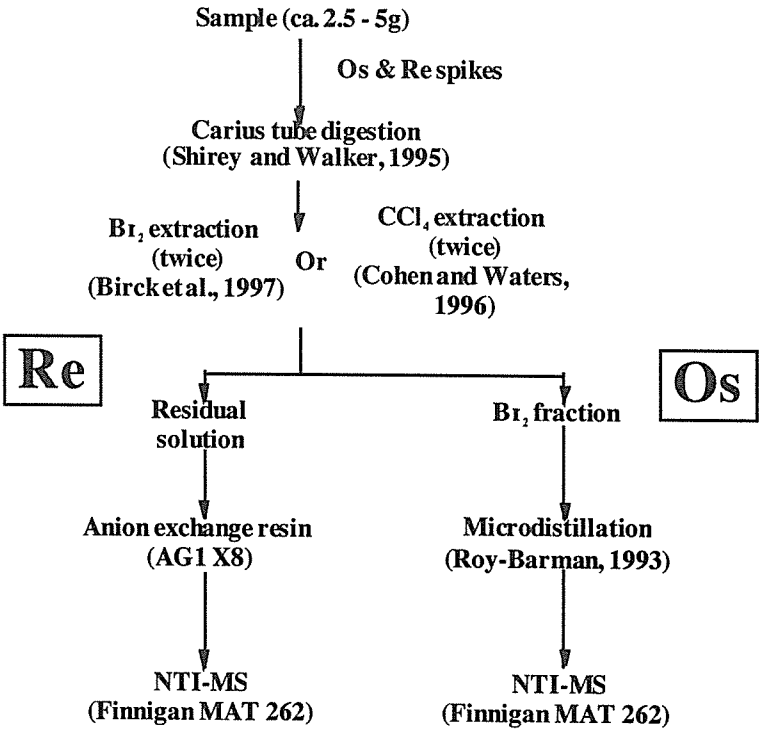


Fig. 1. Analytical procedure.

A high blank of Re in mass spectrometer would cause serious troubles for isotopic measurements of low-level Re (e.g., Shen et al., 1996; Birck et al., 1997). We found the major source of high Re blank in mass spectrometry is the sample magazine,

which supports filament holders. When the magazine was employed which had been used for Pb and Nd measurements on Re filaments, at first high Re loading blank of 10 – 15 pg was observed. Rhenium emitted from Re filaments is possibly attached on the surface of the sample magazine and may be ionized at high temperature caused by following filament heating. The Re blank was reduced to 0.3 pg after 12 months operation of the TIMS without Re filaments.

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(After Suzuki and Tatsumi, 2001, Geochem. J., in press)

An analysing system of Sr, Nd and Pb isotopes from rock and mineral samples

M. Yoshikawa and T. Shibata

1) Rock samples are crushed and then rock chips are pelverized to powder or minerals are separated by isodynamic separator (Franz) at the Rock Crushing and Mineral Separation room.
2) Chemical preparations for Sr, Nd and Pb isotope analyses (e.g. acid leaching, decomposition, ion chromatography) are carried out in the class 100 clean room at BGRL.
3) The isolated elements are analyzed by thermal ionization mass spectrometer (Finnigan MAT 262). The reproducibility of Sr (100 ng), Nd (150 ng) and Pb (100 ng) isotope measurements were 0.002%, 0.0013% and 0.029% (relative standard deviation: RSD%) , respectively.

教育活動 Education

学位・授業 Academics

学位審査

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須藤靖明
（主査）　森健彦（博士　京都大学大学院理学研究科）
（審査員）　森真陽（修士　京都大学大学院理学研究科）
田中良和
（審査員）　森健彦（博士　京都大学大学院理学研究科）
由佐悠紀
（審査員）　筒井和男（修士　京都大学大学院理学研究科）
北川大祐（修士　京都大学大学院理学研究科）
斎藤隆志（博士　京都大学大学院理学研究科）

講義・ゼミナール

科目	担当教官
学部	
地熱学	田中良和,巽好幸,由佐悠紀,須藤靖明,大沢信二,古川善紹
陸水物理学	由佐悠紀,*諏訪浩*[1]
火山物理学	田中良和,須藤靖明
陸水物理学	由佐悠紀（分担）
地球惑星科学Ⅰ	巽好幸（分担）
地球科学実験B	大倉敬宏（分担）
大学院（修士課程）	
水圏地球物理学Ⅱ	由佐悠紀,大沢信二,*奥西一夫*[1],*諏訪浩*[1]
地球熱学・地熱流体学Ⅰ	由佐悠紀,田中良和,大沢信二
地球熱学・地熱流体学Ⅱ	巽好幸,須藤靖明,古川善紹,*竹村恵二*[2]
応用地球電磁気学	田中良和,*大志万直人*[1]
環境地球科学Ⅱ	巽好幸,*井口正人*[1],*石原和弘*[1]
大学院（修士・博士課程）	
水圏地球物理学ゼミナールⅢ	由佐悠紀,大沢信二,*奥西一夫*[1],*諏訪浩*[1],*斉藤隆志*[1]
地球熱学・地熱流体学ゼミナールⅠ	由佐悠紀,田中良和,大沢信二,川本竜彦,鈴木勝彦
地球熱学・地熱流体学ゼミナールⅡ	巽好幸,須藤靖明,古川善紹,小野博尉,橋本武志,*竹村恵二*[2]
応用地球電磁気学ゼミナール	田中良和,橋本武志,*大志万直人*[1],*神田径*[1]
環境地球科学ゼミナールⅡ	巽好幸,*井口正人*[1],*石原和弘*[1],*山本圭吾*[1],*西潔*[1],*神田径*[1]
固体地球物理学ゼミナールⅣ	大倉敬宏,*尾池和夫*[2],*中西一郎*[2]

([1] 防災研究所,[2] 地球物理学教室)

野外実習

地熱学野外実習（7月31日～8月3日）
別府：温泉井の温度検層，水質測定
阿蘇：阿蘇火山巡検，水準測量
地球電磁気学3回生野外実習（7月31日～8月5日）

阿蘇火山自然電位測定
阿蘇火山地磁気測定
地磁気３成分絶対値測定
阿蘇火山ＡＭＴ比抵抗測定

講議（他大学）ほか

大倉敬宏　非常勤講師：神戸学院大学
大沢信二　非常勤講師：大分大学（教育福祉科学部後期「温泉学」）
小野博尉　九州東海大学非常勤講師（農学部後半期「地学」）
巽好幸　集中講義：大阪府立大学，放送大学
由佐悠紀　集中講義：九州大学工学部

特別講義

西田泰典（北海道大学理学研究科教授）「火山における熱的及び電磁気的研究」（9月26～28日）
平　朝彦（東京大学海洋研究所教授）「白亜紀の温暖地球」（10月30日）

セミナー　Seminars

BGRLセミナー

8月　3日　真島英壽（九大・理）
10月 13日　Gary Thompson "The petrogenesis of Rarotonga, South Pacific: A maverick ocean island"
11月 20日　川本竜彦「コマチアイトマグマはどうやって出来たと考えるか」
岡元正久（広大・理）「西オーストラリア Pilbara 地域の先カンブリア紀 komatiite, banded chert の Re-Os 及び Sm-Nd 同位体システマティクス」
11月 27日　丸山誠史（岡山大学固体地球研究センター）「紫外レーザー掘削型同位体比質量分析法(UV-laser IRMS)による酸素同位体比局所分析法の開発と太陽系形成過程の解明」
12月 22日　柴田知之「東北日本第四紀火山岩の微量元素・同位体組成の島弧横断方向の変化傾向からみた島弧マグマの起源」
1月 19日　服部雄次(広大・理)「チベットの土壌の地球化学的特徴」
篠塚一典(海洋科学技術センター)「コンドライト中の希土類元素存在度大気中トリチウムについて」
2月　8日　相澤義高「高温高圧下における岩石・鉱物のP波速度の決定」
2月 15日　熊谷一郎「Anatomy of mantle plumes－マーブルケーキとレイヤーケーキ，あなたはどちらがお好き？－」
3月　1日　芳川雅子「幌満マントルかんらん岩体の化学的進化過程」

電磁気学セミナー

4月　7日　網田和宏「透水係数を変化させて，2次元流動計算を行う場合の計算方法」
橋本武志「論文英語作成の注意点について（1）」
長谷英彰「Matlab 言語で書かれた電場計算コードのＣ言語化」
5月 17日　網田和宏「2 次元領域内で透水係数を変化させる場合のレイリー数の取り扱いについて」
宇津木充「1/R の関数の畳み込み無限2重積分を暗算で解く方法」
橋本武志「論文作成のための英語に関する Tips　(2)」「論文紹介　地殻深部を水はどう流れるか　クラックの役割，中島善人・鳥海光弘　岩波科学　Vol.66, No.12, 1996」
長谷英彰「電場計算コードのＣ言語化（2）」
6月　8日　網田和宏「書籍紹介　Modeling Density-Driven Flow in Porous Media, Ekkehard Holzbecher,

Springer, 1998, 3. Analytical Description」
宇津木充「食い違い弾性理論についての考察」
橋本武志「書籍紹介　Modeling Density-Driven Flow in Porous Media, Ekkehard Holzbecher, Springer, 1998」
長谷英彰「電場計算コードのＣ言語化（3)」

7月 21日　網田和宏「Holtzbecher 式を用いた透水係数変化の試み（1)」
宇津木充「雲仙の全磁力観測」
橋本武志「論文紹介 "The heat source of Ruapehu Lake ; deductions from the energy and mass balances", A.W.Hurst, H.M.Bibby, B.J.Scott and M.J.McGuinness, J.V.G.R, 46, 1-20, 1991.
長谷英彰「電場計算コードのＣ言語化（4)」

8月 31日　網田和宏「Holtzbecher 式を用いた透水係数変化の試み（2)」
橋本武志「電磁気学ゼミ，これまでの整理と今後の方針」
長谷英彰「電場計算コードのＣ言語化（5)」

9月 29日　網田和宏「Holtzbecher 式を用いた透水係数変化の試み（3)」
宇津木充「雲仙の全磁力観測（続報)」
長谷英彰「電場計算プログラムの GUI 化」

12月 26日　網田和宏「Holtzbecher 式を用いた透水係数変化の試み（4)」
宇津木充「阿蘇山における空中磁気測量」
橋本武志「界面動電現象に伴う電場・磁場計算（レビュー)」
長谷英彰「電場計算プログラムの GUI 化 (2)」

2月　2日　網田和宏「Holtzbecher 式を用いた透水係数変化の試み（5)」
橋本武志「2 次元流動計算コードの円筒座標系化」
長谷英彰「電場計算プログラムの GUI 化 (3)」

3月 30日　網田和宏「計算領域内で透水係数が変化する場合の流動について」
宇津木充「地形効果を考慮した自然電位場計算の方法について」
橋本武志「阿蘇の地磁気変化と火口湖からの熱放出量の関係について」
長谷英彰「地形効果を考慮にいれた場合の 3 次元電場計算について」

他機関等

12月 13日　橋本武志「地殻活動電磁気学」（京大防災研究所地震予知研究センター)
11月　8日　橋本武志 "Electromagnetic study in Aso Volcano, Japan"（ウルビノ大学,イタリア)

学 会 活 動　Activities in Scientific Societies

巽好幸
- 編集委員長：The Island Arc
- 編集委員：G-Cubed
- 評議員：日本火山学会・日本地質学会
- 学会賞選考委員：日本岩石鉱物鉱床学会

田中良和
- 運営委員：地球電磁気・地球惑星圏学会
- 委員：地磁気観測作業委員会

由佐悠紀
- 会長・編集委員：日本温泉科学会
- 学会賞選考委員：日本陸水学会，日本地熱学会
- 評議員：日本温泉科学会，日本地熱学会
- 運営委員長：陸水物理研究会

社 会 活 動　Public Relations

大沢信二
- 大分県温泉地保全検討委員（大分県生活環境部）
- 新エネルギー財団地化学技術検討会委員
- 大分県温泉調査研究会理事

小野博尉
- 阿蘇町町史編集委員
- 長陽村立長陽西部小学校３・４年学級「ふるさとじまん」講師(2000 年 11 月)

須藤靖明
- 火山噴火予知連絡会委員
- 阿蘇火山ガス安全対策専門委員会委員
- くじゅう山系（硫黄山）防災協議会委員
- 九重山系硫黄山土石流発生基準雨量検討委員会委員
- 熊本県議会災害対策委員会講師「熊本県内の地震活動状況について」(6 月 12 日)
- 第５回エネルギー業界「ガス情報サロン」講師「阿蘇火山とエネルギー」(7 月 7 日)
- 日本キリスト教保育所同盟第４２回夏期大学講師「阿蘇火山について」(8 月 24 日)

巽好幸
- ODP 国内研究連絡会委員
- IODP 国内連絡委員会委員
- OD21 科学計画策定 WG 長
- OD21 陸上施設検討 WG 委員
- IODP Scientific Planning Working Group 委員
- 大分県環境保全審議会委員

由佐悠紀
- 資源エネルギー庁環境審査顧問
- 地熱開発促進調査委員会委員
- 大分県環境審議会委員
- 大分県自然環境保全審議会委員（温泉部会長）
- 大分県土地利用審査会委員
- 大分県温泉地保全検討委員会委員長
- 大分県温泉調査研究会会長
- 大分県温泉管理検討懇話会座長
- 地熱発電所環境保全実証調査委員会委員
- 地熱構造モデル構築スタンダード作成調査検討委員会委員長
- 温泉影響予測手法導入調査検討委員会委員長
- 日本温泉協会学術部委員
- 別府子供たちセミナー「温泉と火山のはなし」講師（2000 年４～６月）
- 日本電機工業会地熱セミナー講師（5 月）
- 歴史と自然を学ぶ会土曜講座講師（9 月）
- 大分合同新聞「21 世紀への遺産」（大分の温泉）執筆者（10 月）
- インターネット博覧会「温泉の科学」監修（12 月）
- 韓国子供たち科学ツアー講演講師（12 月）
- 平成 12 年度地熱開発管理者研修会講師（１月）

装置・設備　Instruments and Facilities

装置　Instruments

【別府】

ＩＣＰ発光分光分析装置
波長分散型電子プローブマイクロアナライザー
エネルギー分散型電子プローブマイクロアナライザ
波長分散型蛍光Ｘ線分析装置
エネルギー分散型蛍光Ｘ線分析装置
粉末Ｘ線回折装置
液体シンチレーションシステム
イオンクロマトグラフ
ガスクロマトグラフ
自動滴定装置
全自動微小地震観測システム
ピストンシリンダー型高圧発生装置
ICP-MS 用レーザーアブレーション装置
四重極型 ICP-MS 装置
表面電離型質量分析装置
外熱式ダイアモンドアンビル
フーリエ変換型近赤外分光光度計
赤外顕微鏡
加熱ステージ

【阿蘇】

阿蘇，九重火山連続地震観測システム
地殻変動観測坑道
孔中温度観測システム
ビデオ映像監視システム
プロトン磁力計
フラックスゲート磁力計
地磁気絶対測定システム
傾斜計
可搬型地震計（広帯域，短周期）
人工震源車
重力計
超伝導重力計
地磁気地電流法測定装置(広帯域型 ULF, ELF,VLF 型)
光波測距儀
水準測量システム（自動読み）

[Beppu]

ICP emission spectrometer
Wavelength dispersive electron microprobe
Energy dispersive electron microprobe analyzer
Wavelength dispersion type X-ray fluorescence analyzer
Energy dispersion type X-ray fluorescence analyzer
Powder X-ray diffractometer
Liquid scintillation system
Ion chromatography
Gas chromatography
Automatic titration system
Full-automated micro-earthquake monitoring system
Piston cylinder type high pressure apparatus
Laser ablation system
Inductively coupled plasma mass spectrometer (ICP-MS)
Thermal ionization mass spectrometer (TIMS)
Externally heated diamond anvil cell
FT-NIR spectrometer
IR microscope
Heating stage

[Aso]

Continuous seismic monitoring system for Aso and Kuju Volcanoes
Observation tunnel for ground deformation
Borehole temperature monitoring system for Aso
Video monitoring system of Aso and Kuju Volcanoes
Proton and fluxgate magnetometers
Geomagnetic absolute measurement system
Tiltmeters
Portable seismometers [broadband short-period]
Car-mounted seismicsource
Gravimeters
Super-Conducting Gravimeter
Magneto-Telluric measurement system (broad-band type, ULF, ELF, VLF-band)
Electronic distance measurement system
Leveling survey system (automatic reading)

設備　Facilities

岩石粉砕・鉱物分離室

パックミル・ディスクミルによる岩石粉砕やアイソダイナミックセパレータによる鉱物分離を行う.

器具洗浄室

実験に用いる器具の洗浄を行う．ドラフト２台・イオン交換筒・Milli-Q が設置されている.

クリーンルーム

HEPA フィルターを設置し極力金属使用を控えた設計で，クラス 100 のクリーン度を達成している．Sr・Nd・Pb 同位体比分析のための化学処理（試料の分解・イオン交換クロマトグラフィーによる目的元素の抽出）を行っている.

地下観測坑道（阿蘇火山地殻変動観測坑道）

阿蘇中岳第一火口から南西１ｋｍの，地下３０ｍに設けられた，直角三角形の水平坑道で，１９８７年度に竣工した．現在は，水管傾斜計（２５ｍ），伸縮計（２０，２５ｍ），短周期地震計，長周期地震計，広帯域地震計，強震計,超伝導重力計が設置されている.

新規導入

ラマン顕微鏡(Raman microscope)

Kaiser optical systems, HoloLab series 5000

カイザー社製のラマン顕微鏡はオリンパスのＢＸ６０金属顕微鏡と分光検出器で構成される．励起波長は YAG の倍波である 532ｎｍで，出力 50mW，通常 188ｃｍ－１（上付き）～4500ｃｍ－１までの波数範囲のラマン散乱光を測定する．検出器を物理的に移動させることで，下はスーパーノッチプラスフィルターの限界（100ｃｍ－１位か），上は 4600ｃｍ－１以上（限界未決定）測定することが可能である．顕微鏡には作動距離２１ｍｍの２０倍の超作動対物レンズが装着されている他，作動距離が特に長い作動距離が必要ない場合は，５０倍，１００倍のレンズを用いて空間分解能３ミクロンのラマン分析が可能である．シングルモノクロであることと，透過型の回折システムで
あるため，ラマン顕微鏡としては，現在，最も明るい特長を持つ.

外熱式ダイアモンドアンビルセル　Externally heated diamond anvil cell

Foxwood 社製　106

コーネル大学バセット教授が開発制作したこのダイアモンドアンビルセルは，常温から 1050℃までの温度範囲で使用できる．圧力は現在のところ 5GPa 程度であれば達成できる．H2O を圧力媒体として使用し，H2O の状態方程式を用いて圧力を測定する場合，2.5GPa までの圧力範囲で使用することが出来る．それ以上の圧力範囲では SrB4O7:Sm2+などの蛍光物質を試料とともに封入しラマン顕微鏡で波長測定を行い圧力を計算する.
高温度での圧力決定については，圧力マーカーの蛍光線の波長測定よりも，X 線を用いて標準物質の格子定数を求める方法が望ましいが，設備はない.

フーリエ変換型近赤外分光光度計　FT-NIR spectrometer，IR microscope

日本分光社製　FTIR610+MICRO-20-16

近赤外顕微鏡は，外熱式ダイアモンドアンビルセルを使用できるように，標準よりも長い作動距離と焦点距離（２５＋２５ｍｍ）を有するように改造されている．InSb ディテクターと CaF2 ビームスプリッターの組み合わせることによって，波数 2000cm-1 から 8000cm-1 までの赤外～近赤外領域での測定に最適化されている.

加熱ステージ　Heating stage

リンカム社製　TS1500

性能，1500℃までの温度範囲で，微小な液体包有物や流体包有物の加熱観察を実体顕微鏡下で行うことが可能である．アルゴンと水素の混合気体を用いて還元的な雰囲気で実験を行うことが可能である．

研　究　費　Funding

科学研究費補助金

基盤研究(A) 須藤靖明・橋本武志（分担）「阿蘇山の火口直下に存在する圧力源の実体と噴火活動における役割の解明，代表：川勝均」3,500千円

基盤研究(A) 大倉敬宏（分担）「変動するフィリピン島弧：地球物理および地質学的調査・研究，代表：安藤雅孝」4,800千円

基盤研究(B) 大倉敬宏（分担）「地震発生の制御実験－南アフリカ金鉱山における－，代表：安藤雅孝」　1,600千円

基盤研究(B) 巽好幸・川本竜彦「含水珪酸塩溶融体の高温高圧下におけるその場観察：マントルの融解過程における水の役割の解明」700千円

基盤研究(B) 田中良和（分担）「３次元深部地殻構造電磁探査システムの研究」300千円

基盤研究(C) 大沢信二・由佐悠紀「火山体土壌空隙を介しての火山ガスと大気の相互作用」2,000千円

基盤研究(C) 田中良和・橋本武志「海底電線を用いた九州西部海域の地殻電気抵抗の研究」700千円

奨励研究(A) 大倉敬宏「引き裂かれるフィリピン島弧-マコロード回廊生成プロセスの解明-」1,200千円

奨励研究(A) 川本竜彦「水を含んだマグマの構造の実験的解明」700千円

奨励研究(A) 鈴木勝彦　「白金-オスミウム，レニウム-オスミウム系を用いた海洋プレートの循環を追う試み」1300千円

奨励研究(A) 橋本武志「地下浅部に貫入したマグマの冷却過程の解明」800千円

特別研究促進費 田中良和（分担）「有珠山２０００年噴火と火山防災に関する総合的観測研究」590千円

受託研究

大沢信二「火山体水理構造のマグマ活動への影響の解明」1,923千円

鈴木勝彦「高精度オスミウム同位体測定法の開発と地球化学的方法による白金-190－オスミウム-186壊変系列の壊変定数の決定」1800千円

巽好幸「スーパープリュームの岩石学的研究」16,297千円

奨学寄付金等

川本竜彦，京都大学学術研究奨励金「富士火山の下におけるマグマと熱水の溶解条件の実験的解明」1500千円

川本竜彦，日本原子力研究所平成12年度黎明研究「高温度高圧力条件におけるマグマの分光学」1800千円

鈴木勝彦，日本科学協会「オスミウム同位体を用いた海洋底における有用金属硫化物鉱床の生成過程の研究」550千円

田中良和・須藤靖明・小野博尉・橋本武志，京都大学創造開発研究（在外研究員）「活動的火山における流体流動モニタリングに関する調査研究」1,529千円

共同研究等

田中良和（分担），日米科学協力事業「ロングバレーカルデラの電磁気共同観測」800千円

田中良和，東京大学地震研究所共同研究「伊豆半島における地殻活動電磁気学」248千円

来 訪 者 Visitors

【別府】

4月 1日 岩屋毅（元衆議院議員），中井俊一・折橋（東大地震研）
4日 中城勝喜・寺司昭男（大分県生活環境）
7日 濱崎雅憲（大分地方気象台）
8日 別府子供セミナー（5名），ケーブルテレビジョン別府，伊藤・牧ヶ野（キューバス）
11日 福富・古賀（株・カミナガ）
12日 岡洋一郎（大分モンゴル親善協会）
17日 川畑・野尻・荒巻（富士通）
22日 別府子供セミナー（15名），ケーブルテレビジョン別府，牧ヶ野（キューバス）
26日 太田・御沓（大分県生活環境課）

5月 9日 大分放送取材班一行
16日 山崎芳直（21世紀への遺産）
19日 衛藤良司（大分合同新聞）
22日 青池雄一（共同通信）
23日 花房篤司（朝日新聞）
24日 別府大学学生4名
25日 Ekkehard Holzbecher （元客員助教授，9日間）
26日 豊田研吾（NHK大分放送局）
27日 別府子供セミナー（子供 13 人），ケーブルテレビジョン別府，伊藤・牧ヶ野（キューバス）
29日 Wilfred Elders（元客員教授夫妻），Trevor Hunt（元客員教授夫妻）
30日 太田・木村・天野（京大経理部），西村（京大施設部），北野（理学部司計掛）
31日 Ian Graham（元客員助教授）

6月 12日 太田・御沓（大分県生活環境課）
18日 別府子供セミナー（10名），ケーブルテレビジョン別府，伊藤・牧ヶ野（キューバス）
21日 岡洋一郎・亀山 哲・藤野健治（大分モンゴル親善協会）

7月 3日 堀江正治（名誉教授）
4日 八幡雅彦（別府大学短期大学部）
12日 木崎俊勝（読売新聞）
13日 河野 功・藤川将護（大分県情報企画室），エディ マリカ（2日間）
14日 Jatmiko Prio Atmojo（九大），三浦祥子（ハヌマン）
17日 新名真裕美（北大）
18日 森山・竹中（出光大分地熱）
28日 三浦祥子（ハヌマン），栗原 稔（大分みらい信用金庫）
31日 鑢 嘉紀（朝日新聞），西村嘉晃・石井秀樹・苗村康輔（京大：地熱学実習，3日間）

8月 2日 奥西一夫・Mihaela-Iuliana Constantin（京大，2日間），青板邦之（元京大施設部長）
3日 Christian Schmidt and Michael Husman（ドイツ・ハノーバ大学，28日間）
4日 田中秀雄（大分県文化企画部）
7日 Chi Vinh Ly（広大）
7日 太田・御沓（大分県生活環境課）
21日 鹿園直建（慶応大）

22日　大分大学附属中学校 PTA 一行
27日　新城竜一（琉大，5日間）
27日　渡慶次聡（琉大，4日間）
9月　18日　下池・八田・塩塚（西日本技術開発）
22日　太田・御沓（大分県生活環境課）
24日　西田泰典（北大，26日まで）
25日　岡洋一郎（大分モンゴル親善協会），バヤルマグナイ・ガンフヤグ（モンゴル・バヤンホンゴル県），アルタンツォジュ（大分大学），半田　駿（佐賀大学）
26日　高志徹（鶴見台中学校）
27日　川野哲也（院内町長），衛藤強（院内町振興課）
29日　松本，八田（西日本技術開発）
10月　3日　藤沢康弘（鹿児島大学，4日間），河上哲生（京大，6日間）
4日　清水洋・岡元正久（広大），橋口 智幸（鹿児島大学，5日間）
7日　山崎芳直（21世紀への遺産），小林記之（京大，2日間）
10日　松村絢子（京大，4日間）
11日　大倉敬宏（京大）
13日　徳田建司氏（別府市民）
16日　清田透（大分合同新聞）
18日　西裕季利他2人（NHK 大分放送局）
19日　藤川（大分県情報企画室），高野・百雲（大宣）
23日　太田・御沓（大分県生活環境課），坂本和一・若井ます江（立命館アジア太平洋大学学長・アドミニストレーション・オフィス）
26日　九州大学地熱研修コース一行（12名）
30日　平朝彦（東大），川野田実夫・西垣肇・学生5名（大分大学）
11月　10日　高野・戸田（大宣）
15日　別府市民一行10人，筒井和男（京大）
16日　大野博司（韓国語通訳）
21日　曽我・藤原・米満・梅澤・丸岡・脇野（京大施設部），東辻（理学部施設掛）
25日　田中剛・谷水（名大）・松田准一・松本拓也（阪大）・西尾嘉朗（東大地震研）・平田岳史・服部道成（東工大）・熊谷（海洋科学技術センター）
12月　4日　安藤茂信（湯布院ライオンズクラブ），マレーシア高校生1名，田川豊治（日出町民）
5日　加藤正信（別府市民）
8日　熊谷公生（九重町民）
11日　任鐘元（東工大，19日間）
12日　坂本富男・菅沼秀和・熊谷英憲（海洋科学技術センター）
15日　清英彦（電源開発豊肥地熱事務所），伊藤笙（キューバス）
1月　10日　清英彦・矢口稔明（電源開発豊肥地熱事務所）
13日　岡元正久（広大，7日間）
15日　服部雄次（広大）
18日　巽好幸（海洋科学技術センター，3日間）
22日　浜田亀太郎（地熱），河村建一（末広郵便局）
22日　Chi Vinh Ly（広大）
23日　吉岡正文（瀬戸臨海実験所）
24日　財津・中野（ケーブルテレビジョン別府），
27日　ケーブルテレビジョン別府一行（4名）
30日　三浦祥子（ハヌマン）
31日　堀江正治（名誉教授）
2月　2日　百雲ほか1名（大宣）
5日　Finke（ThermoFinnigan）
14日　佐藤裕之・笹原良宣（大分県別杵速見地方振興局），茅嶋（大宣），伊東和彦（南大阪

大学，3 日間）
16 日　新宮一広（環境衛生科学研究所）藤田洋三（カメラマン）
19 日　鑓嘉紀（朝日新聞）
24 日　巽好幸（海洋科学技術センター，4 日間）
27 日　下岡・浦嶋・奥村・森川（京大経理部），井上・小原（海洋科学技術センター）
28 日　太田・御沓（大分県生活環境課）：広沢・梅木（大分県統計情報課），板井（富士通），和田至誠（大分県議会議員）
3 月　1 日　大分大学附属小学校生徒一行
4 日　別府散策の会一行
12 日　宮田佳樹（東大）
17 日　藤原博・秋吉哲幸（昭和 24 年頃の技術補佐員）
19 日　鍵裕之（東大）
21 日　中川（京大附属図書館宇治分館），島本・木村・浅野（京大宇治地区事務部）
22 日　濱崎・日吉・中尾（大分地方気象台）
26 日　巽好幸ほか 2 名（海洋科学技術センター），東辻（京大理学部施設掛），斉藤博・晃父子（鹿児島県高山町）
27 日　鎌田浩毅・金子克哉・加藤護（京大）他
29 日　テレビ大分取材班一行
30 日　金庫検査；・服部・森田（京大経理部），笹原・田中（京大理学部）

【阿蘇】
4 月　10 日　城森（ネオサイエンス）
5 月　26 日　加茂幸介（名誉教授），平林順一（東工大），長尾年恭（東海大），吉田・西（広島市大）
30 日　宮内（用度掛）
31 日　北野（司計掛長），西村（施設掛），九州財務局
6 月　7 日　金嶋（東工大），山本希（地震研）
13 日　吉田（広島市大，2 日間），松波孝治，重富國宏（防災研，2 日間）
7 月　14 日　吉田（広島市大），立野ダム工事関係者（2 名）
18 日　吉田（白山工業）
8 月　21 日　財務局監査（2 名，3 日間），北野司計掛長他（4 名，3 日間），Christian Schmitt・Michael Hussman（ドイツ・ハノーバ大学，3 日間）
22 日　中山（立野ダム工事事務所）
24 日　吉田・西（広島市大）
29 日　小林・江浦（国際電子工業）
11 月　16 日　長陽村立長陽西部小学校 3，4 年学級（15 名，引率：江口教諭）
30 日　大沢（事務局長他 2 名）
12 月　9 日　坂中伸也（秋田大学）
14 日　石原・井口・為栗（桜島観測所），インドネシア留学生（2 名）
1 月　17 日　宮縁（森林総研）
19 日　大内（西日本技術開発）
3 月　1 日　JICA 研修生（5 名）・早水かほる（日本国際協力センター）・加藤孝志(気象庁)・田所敬一（名古屋大学）・G.M.Besana(PHIVOLCS)
2 日　後藤他 3 名（施設掛）
3 月　27 日　鎌田浩毅・金子克哉・加藤護（京大）他（3 日間），趙國澤夫妻（2 日間）