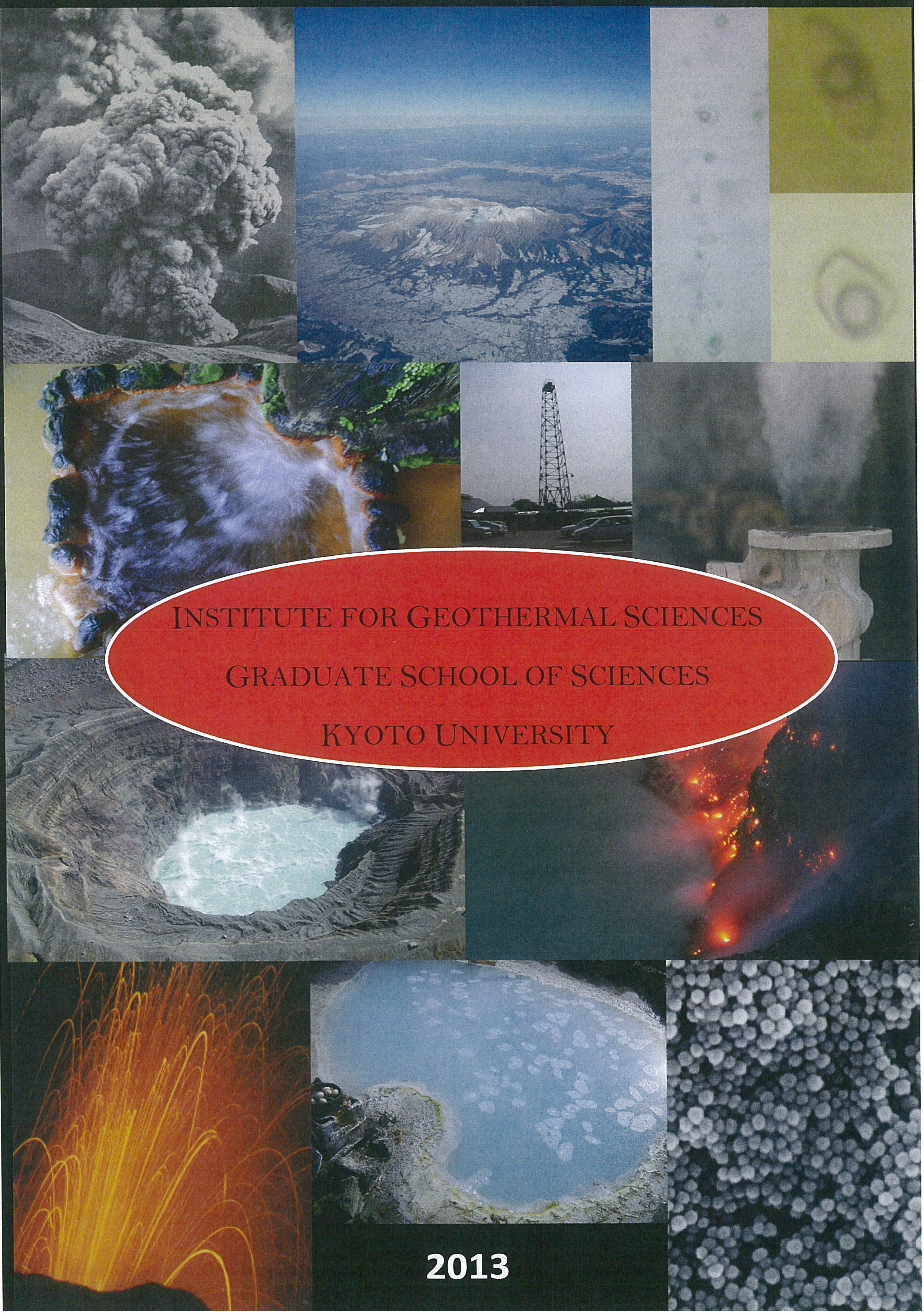


INSTITUTE FOR GEOTHERMAL SCIENCES

GRADUATE SCHOOL OF SCIENCES

KYOTO UNIVERSITY

2013

Scope of the institute

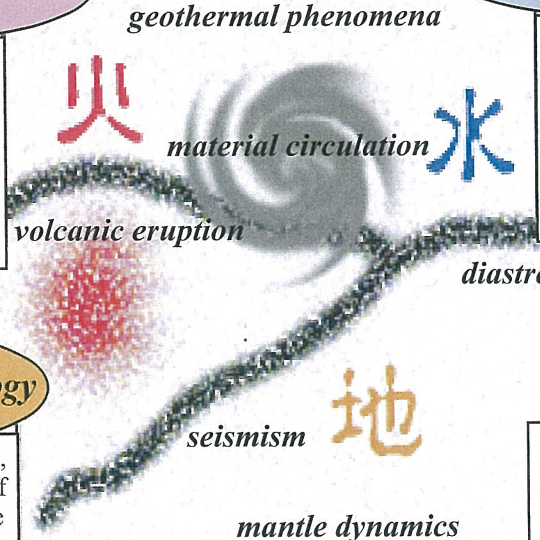
The Earth can be viewed as an active heat engine working to convert its internal thermal energy into surface phenomena such as diastrophism, seismicity, volcanism and hotspring activity. Because of differences in time-scale, superficial features, or practical aspects it has been normal to deal with these phenomena independently. To work towards a comprehensive understanding to the Earth' s evolution and its predictability, we believe that it is indispensable to consider the Earth as a single heat engine by the use of synergistic research techniques.

We regard central Kyushu, one of the largest volcanic and geothermal fields in the world, as a natural experimental facility. The Institute of Geothermal Sciences is promoting a comprehensive approach to geothermal science through fieldwork, laboratory experiments and theoretical modeling. By analyzing the thermal structure and the dynamics of the Earth over scales ranging from the crustal surface to the mantle and the core, we aim to construct the science of geothermics in synergistic manner.

Research sections

We are conducting comprehensive research into volcanism, geothermics and tectonics mainly by fieldwork, laboratory experiments, and theory. The fundamental scope of our research covers the thermal structure and the dynamics of the Earth's interior. A variety of research works can flexibly cooperate within this interdisciplinary Geothermal Science research system. We have the following five sections.

Institute for Geothermal Sciences



Volcano-dynamics

This section investigates the dynamic aspects of volcanoes by developing techniques of monitoring volcanic activity and of data analysis. It also contributes to research into the prediction of volcanic eruptions.

Geothermal fluid science

This section investigates the origin of chemical substances in geothermal fluids as well as their local and global circulation process and the transport processes of energy and materials through geothermal fluids.

Structual volcanology

This section investigates the dynamic, thermal and hydrological structure of geothermal fields and active volcanoes in central Kyushu such as Aso, Kuju and Tsurumi, and the processes of generation, movement and eruption of magmas.

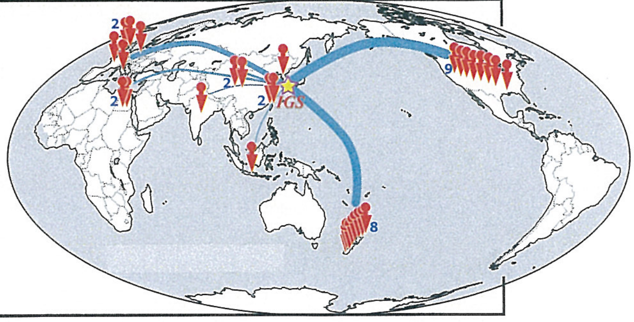
Geothermal Tectonics

This section investigates the relationship between volcanic or geothermal process and tectonics, subduction-zone magmatism and material circulation process through the whole mantle by the use of magmatological approaches.

Geothermal intelligence section (from abroad)

This section exchanges and accumulates interdisciplinary information relevant to geothermal sciences. It also promotes international cooperative work aimed at the development of new techniques in geothermal sciences.

By 2012, we had invited 31 researchers from the region shown in a right map, and we are continuing the collaborative research with them as the important partners.



Publication

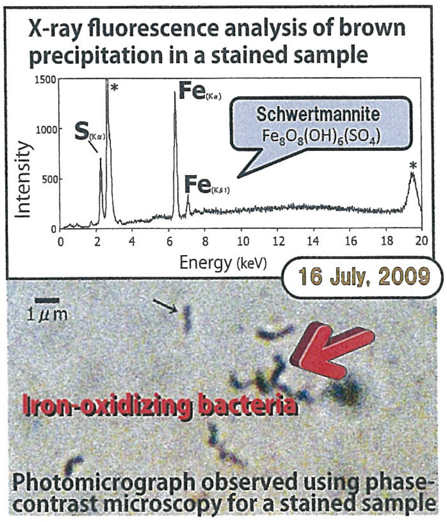
Annual Report of Institute for Geothermal Sciences (1997 ～)

Discoloration of crater lakes in response to volcanic activity

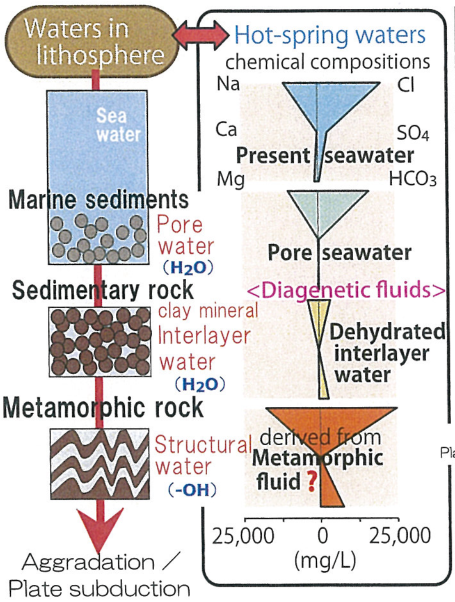
Active crater lakes display various colors resulting from absorption and scattering of sunlight by materials dissolved or suspended in the lake water [e.g., Onda, Ohsawa et al., 2003].

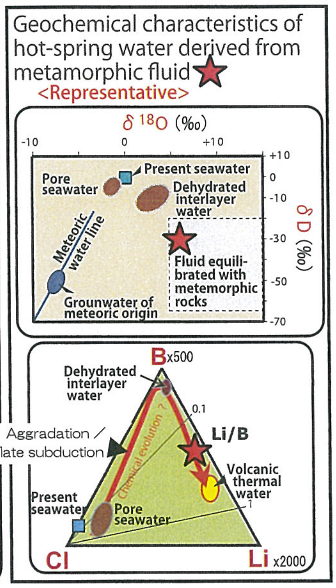
Moreover, convective circulation and chemical precipitation in crater lakes and subaqueous fumarolic activity possibly enhance color changes in the water bodies [e.g.,Ohsawa et al., 2010].

A drastic change in lake water color from blue-green to brown observed in the summit crater lake of Mt. Shinmoe-dake, Kirishima volcano after its 2008 eruption was inferred to have resulted from schwertmannite formation by bacterial oxidation of pyrite supplied by the ash-fall of the eruption. *Submitted to BUVO*



Source fluids of non-volcanic hot-spring waters





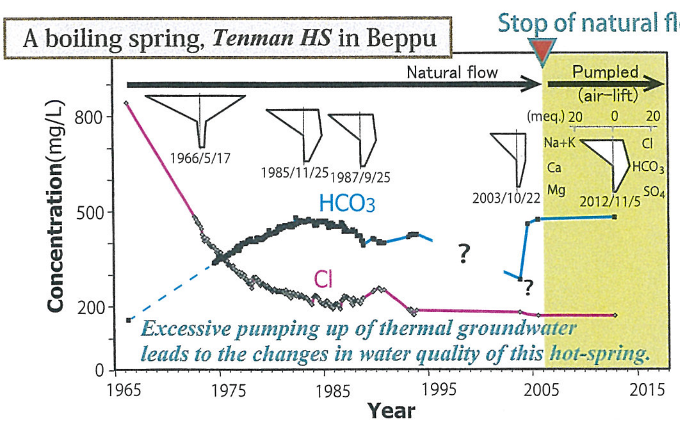
The existence of hot-spring waters of high salinity was known in non-volcanic regions, but its origin had been unknown for a long time.

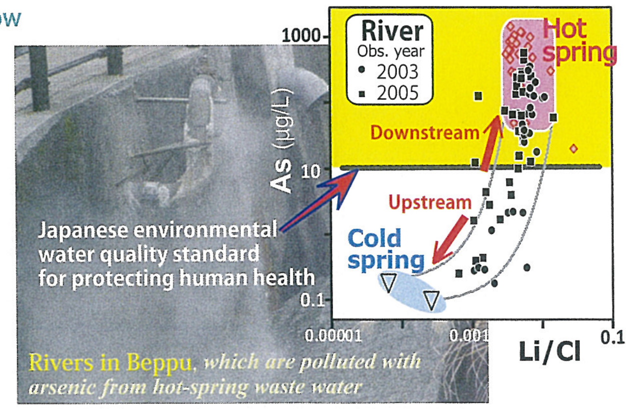
A geochemical study of fluid samples collected from deep hot-spring wells in the Miyazaki plain in the fore-arc region of Kyushu, Japan revealed the deep source fluids of the hot-spring waters will be originated at different stages during the burial diagenesis of marine sediments [Ohsawa et al., 2010].

From a recent hydrogeochemical investigation of hot-springs along the Median Tectonic Line (MTL) in the forearc region of the southwestern part of Japan, it is likely to find another deep source fluid of hot-spring water derived from the dehydrated metamorphic fluid released from the subducting Philippine-Sea plate. *Submitted to J.Jap.Assoc.Hydrol.Sci.*

Several effects of exploitation of geothermal resource

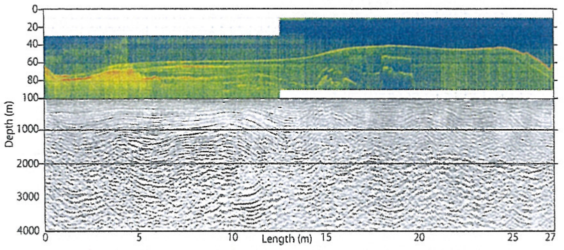
As some contribution to society, this research section has continuously studied on hydrological effects of geothermal and hot-spring exploitations to hot-spring water resource for many years [e.g., Yusa et al., 2000]. For coming ten years, we have a program to perform environmental sutudies dealing with hot-spring at the biggest hot-spring district in Japan, *Beppu*.

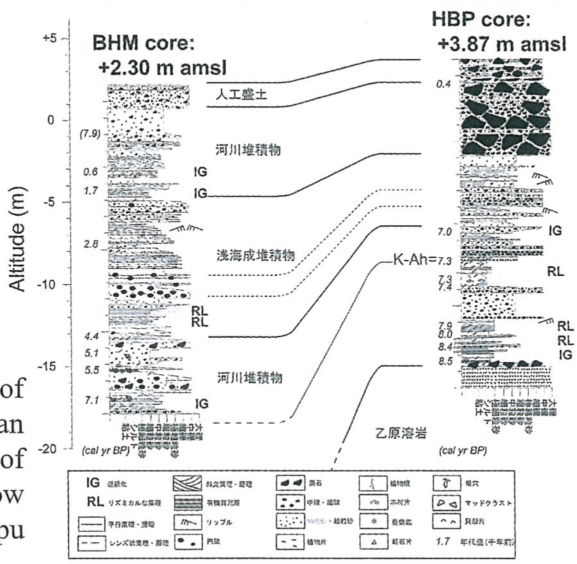




We have researched various kinds of water in lithosphere in addition to those described above (e.g., Aqueous fluid inclusion in metamorphic quatrz [Nishimura et al., 2008], Drip water in limestone cave [Yamada et al., 2008]).

Tectonic basin formation at western end of Median Tectonic Line, and Normal fault movement and volcanic activity

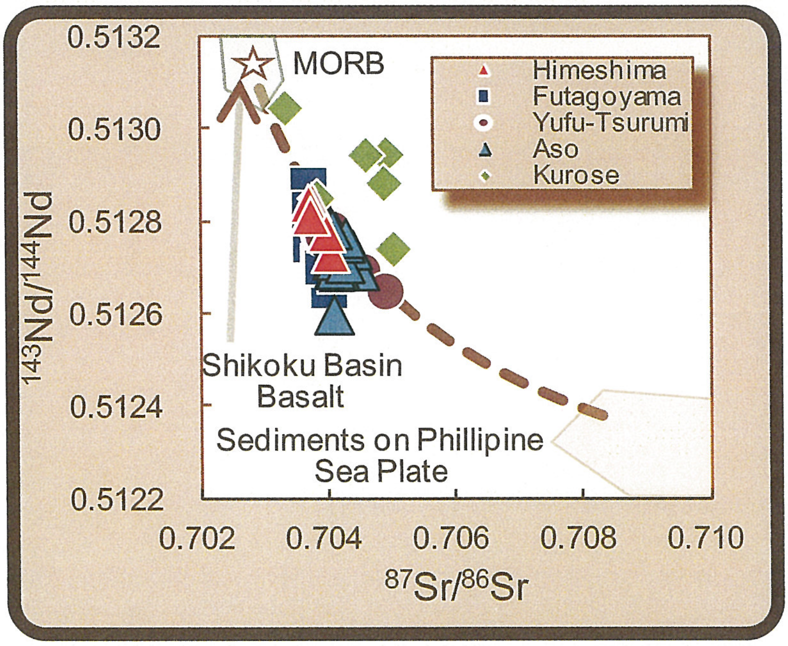




Beppu Bay and Beppu Graben are constructed by the movement of transcurrent and normal faultings at the western end of Median Tectonic Line. Active normal faults with higher displacement of over 1m/thousand years exist at central part of Beppu Bay (shallow seismic data and deep seismic data: Fig.), and southern end of Beppu Graben (Fig. drilling data near Asamigawa fault).

Mantle-Crust Recycling

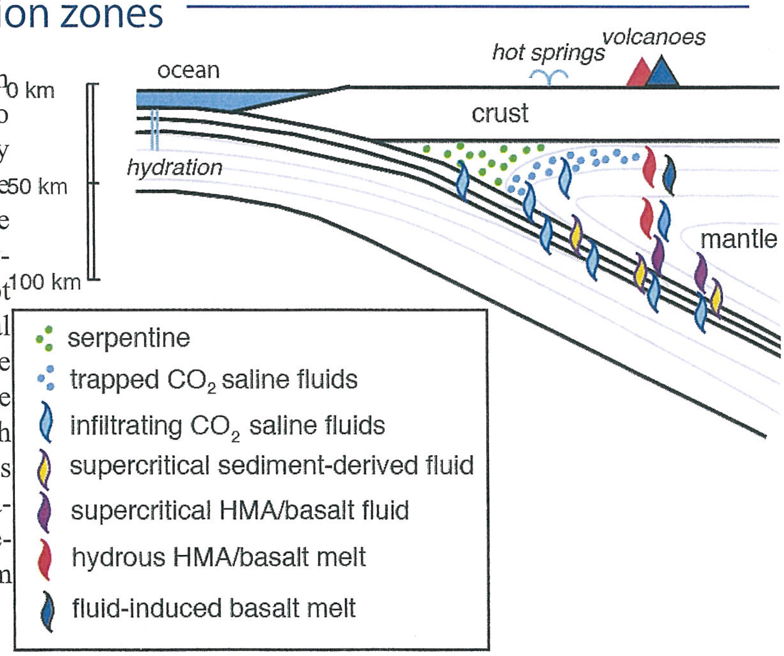
From Geochemistry of Igneous Rocks



Magmatism has been active beneath Kyushu island during last 12 million years. Those magmas are considered as subduction zone and plume type. This complication of magma genesis lead the accumulation of geochemical data of igneouse rocks poor. We have been stdied geochemistry of those rocks, such as major and trace element contents and Sr-Nd-Pb isotope ratios using by X-ray Fluorescence, Inductively Coupled Plasma Mass, and Thermal Ionization Mass Spectrometers. On the basis of above studies, we are investigating magma generating processes, effects of lithospheric and acenospheric mantle to the magmas, material recycling between crust and mantle.

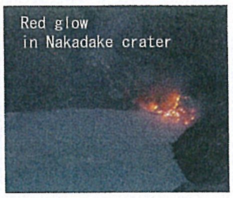
Recycling of seawater in subduction zones

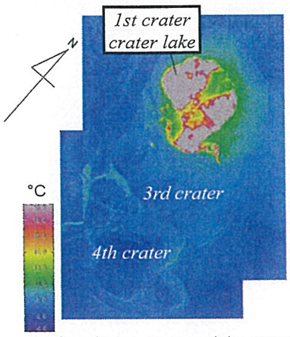
We observe seawater-like fluid inclusions in crystalline mantle rocks from the 1991 Pinatubo eruption. This leads that subducting plates carry seawater into the mantle beneath island arcs like Japan; earthquakes, hot springs, and volcanoes are caused by the seawater. Such saline fluids dehydrated in shallower depths return to salty hot springs. At greater depths, sedimental supercritical fluids are fed to the mantle wedge from the subducting slab, and then they react with mantle peridotite to form HMA supercritical fluids. Such HMA supercritical fluids separate into aqueous fluids and HMA melts during ascent. The separation of slab-derived supercritical fluids into aqueous fluids and melts elucidates double magmatism of mantle-derived andesites and basalts.



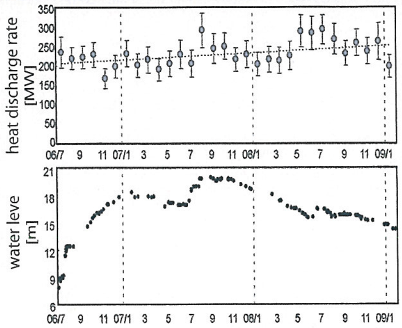
Thermal research in volcanic crater

Aso Volcanic Group has an intense geothermal activity in the 1st crater of Naka-dake, one of the post caldera cones. This crater shows a characteristic cycle of activity that consists of the formation of hot lake, drying-up of the lake water, and finally Strombolian eruptions. We carried out precise and continuous observations of the level and temperature of the lake water, and developed a numerical model of a hot crater lake. The numerical model revealed temporal variations in the mass and enthalpy of the volcanic fluid supplied from the lake bottom.

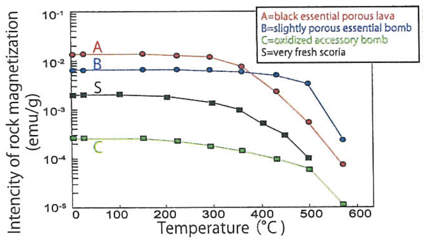




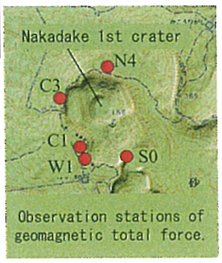
Infrared imagery around the craters.



Temporal change of heat discharge rate (upper) and water levelof the crater lake (lower) from 2006 to 2009.

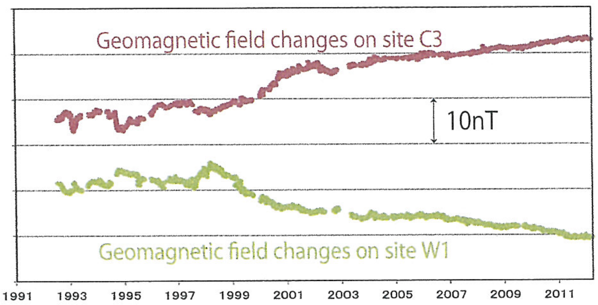


Thermal remanent magnetization curves for rocks of Nakadake crater(Tanaka, 1993)



Thermal state below the active crater of Aso deduced from geomagnetic changes

Magnetization of volcanic rocks tends tends to decrease as their temperature gets higher. Hence we can infer the thermal state of a shallow subsurface region by geomagnetic observation around Nakadake 1st crater. In a typical case, magnetization beneath Aso crater increases as a vent opens with the heat being discharged. In contrast, it tends to decrease after the vent is plugged as a result of the appearance of a crater lake. The geomagnetic response to the change of surface activity is rapid and implies the efficient heat transfer by geothermal fluids.

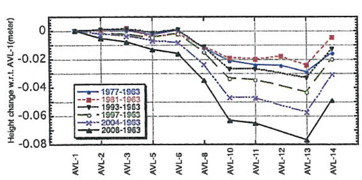


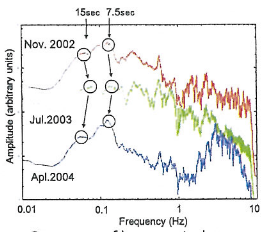
Geomagnetic changes in the vicinity of the active crater of Aso. We can deduce the thermal state from compensative variations at the northerm (upper) and southern (lower) stations

Subsurface structure of the Aso volcano inferred from long-period tremors

From the seismic observation around the Aso volcano, it is clarified, long-period tremors (LPTs) is continually emitted from Aso volcano. To constrain the source of this tremors, we conducted a dense broadband seismic network in 1997. Most of these stations are located within 1.5 km from the crater including the fumarolic vent which continuously emits the volcanic gases. Our analysis using the spatial pattern of the observed LPTs amplitudes reveals that the source of LPTs consists of an isotropic expansion (contraction) and an inflation (deflation) of an inclined tensile crack. The detected crack is almost parallel to the chain of craters and the extension of the crack plane meets the active fumarole at the surface. The occurrence of LPTs are often correlated with the occurrence of another type of volcanic tremor with a shorter period (yamamoto et al., 1999). From the recent studies, it becomes clear that the period of the LTPs has changed according to the components and the temperature of the volcanic fluid.

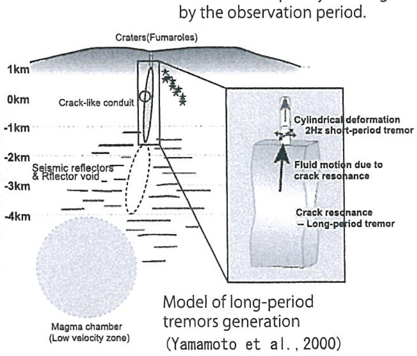
Result of crustal deformation obtained from leveling (1963 -)





Spectrum of long-period tremors. Dominant frequency is changed by the observation period.

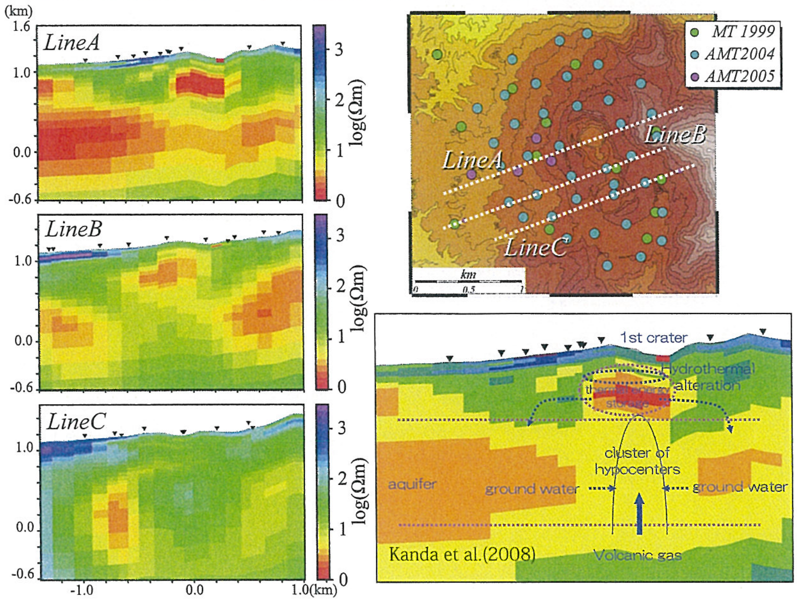
The leveling in Aso volcano (September 2012)



Model of long-period tremors generation (Yamamoto et al., 2000)

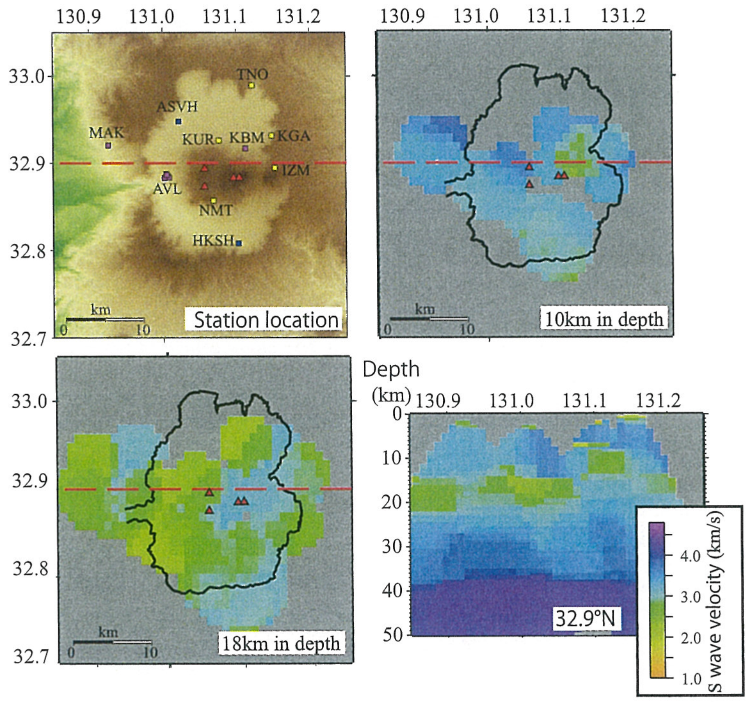
Resistivity structure beneath Nakadake 1st crater

The 1st crater of Naka-dake, Aso volcano, is one of the most active craters in Japan. We carried out dense AMT (Audio frequency Magneto-Telluric) surveys around the Nakadake craters of Aso volcano. Results of two-dimensional inversions for several sections across the craters revealed that there exists extremely low resistive zone at a few hundreds meter depth beneath the 1st crater. We propose that the upper part of the conductor identified beneath the 1st crater is mainly composed of hydrothermally altered zone that acts both as a cap to upwelling fluids supplied from deep-level magma and as a floor to infiltrating fluid from the crater lake. The lower part of this resistive zone probably indicate the existence thermal energy storage [Kanda et al., 2008].



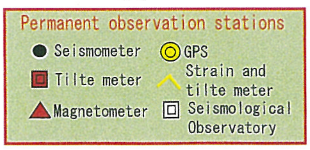
Crustal structure beneth Aso

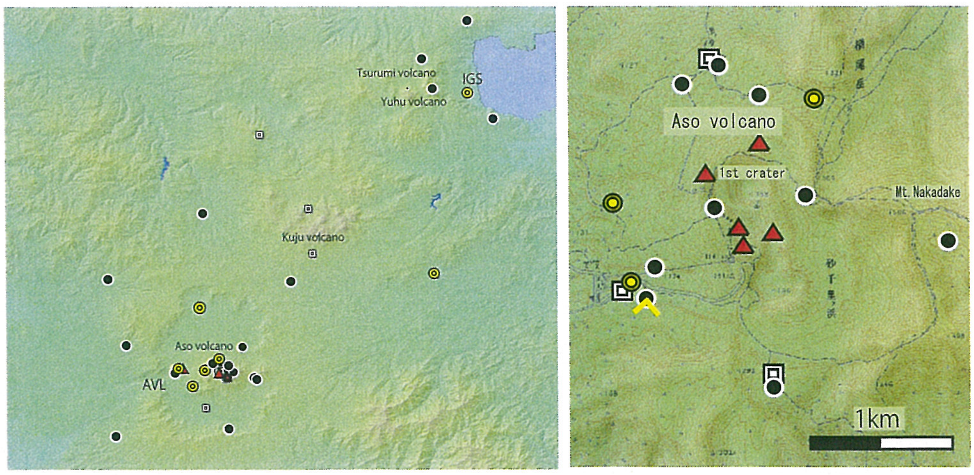
S wave velocity (Vs) discontinuities convert a P wave impinging on them to S waves. Receiver function (RF) detectes such phases in teleseismic P coda. From RFs, we can estimate depth of discontinuities and their Vs contrast beneath a seismometer. Boundary of an area, which contains magma or aqueous fluid, has Vs contrast, because such an area has lower Vs than the surrounding area. Therefore, we can reveal the location of the area, which contains fluid, by detecting such boundaries. We set seismic stations densely, calculated RFs from observed waveforms, and estimated Vs structure with genetic algorithm inversion. We detected a low Vs layer whose Vs is 2.4 km/s at 15-20 km in depth beneath western and northeastern parts of Aso caldera, and at 8-15 km in depth beneath the eastern flank of the central cones. This layer can contain 15% of magma or 30% of aqueous fluid at a maximum, and may correspond to a partially molten region where silicic magmas are generated.



The distribution of permanent and temporary observation stations of GIS.

For the purpose of eruption mechanism elucidation and subsurface structure estimation, we have observation array around volcanoes of Kyushu such as Aso volcano, Aso caldera, Kuju volcano and volcanoes around Beppu.





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Professor

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Shinji Ohsawa (大沢 信二)
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Mitsuru Utsugi (宇津木 充)
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Technical Professionals

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Research Assistant

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Secretaries and Supply Janitor

Kyoto

Yuki Doi (土井 有紀)

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Machiko Imamura (今村 町子)
Sakiyo Yamazaki (山崎 咲代)

Beppu

Ayumi Ichimanda (一万田 歩)
Miho Miyata (宮田 美保)

(Dec. 2013)

Instrumentation in use

【Beppu】

ICP emission Spectrometer
Wavelength dispersive electron microprobe
(lent to JAMSTEC)
Energy dispersive electron microprobe analyzer
Wavelength dispersion type X-ray Fluorescence analyzer
Energy dispersionty type X-ray Fluorescence analyzer
Powder X-ray diffractometer
Liquids scintillation system
Ion chromatography
Gas chromatography
Automatic titration 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 (at Kyoto)
Raman microscope (at Kyoto)
FT-NIR spectrometer
IR microscope
Heatings stage (at Kyoto)

【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
Magneto-Telluric measurement system
(broad -band type, ULF, ELF, VLF-band)
Electronic distance measurement system
Leveling survey system (automatic reading)

Institute for Geothermal Sciences
Graduate School of Sciences,
Kyoto University

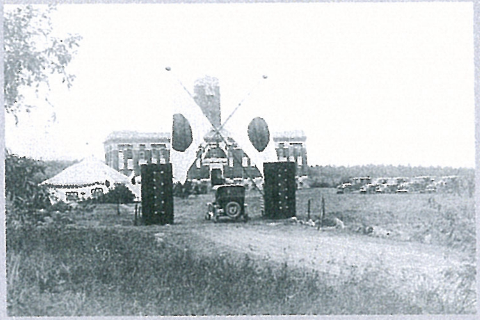

Photo of opening ceremony of Beppu Geothermal Research Lab. (October 28, 1926)

Beppu Geothermal Research Laboratory

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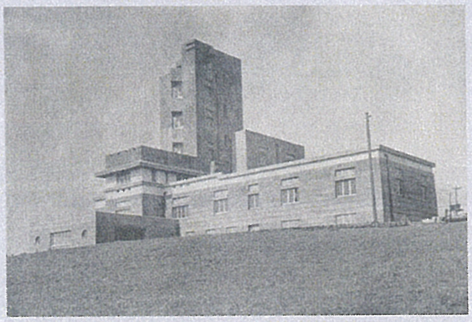

Photo of AVL just after the completion (1929)

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