

# OUTLINE OF GEOPHYSICAL RESEARCH STATION, FACULTY OF SCIENCE, KYOTO UNIVERSITY

Bathing in hot springs has always been an important part of natural life There are over 2,000 spas in Japan, which every year are visited by over 100 million people. That is to say, everyone in Japan enjoys hot spring bathing at least once a year. In spite of such an intimate relation between Japanese people and hot springs, there are very few institutes dedicated to research in hot spring sciences. In this regard, the Geophysical Research Station of Kyoto University, Beppu, is unique because of its broad range of scientific studies of geothermal phenomena. These studies include geochemical, geophysical, geological and hydrological research on geothermal systems in their natural and modified states. The Geophysical Research Station has an ideal location on the Beppu geothermal system, which is one of the largest geothermal systems in Japan on the island of Kyushu which is the southernmost of the four main islands of Japan. The surface thermal activity at Beppu varies from hot springs to superheated fumaroles and steaming ground on the volcanoes behind Beppu City. The hot water and steam are used for bathing, domestic heating and small-scale agricultural applications. A 3MW geothermal power plant is also operating at one of the large hotels in the City.

Kyoto University is presently expanding the scope of the Geophysical Research Station to include research on geodynamic and tectono-thermal processes in the earth's crust. Beppu City is situated in a zone of high seismicity at the north-east end of the Philippines-Kyushu volcanic arc. The city has been built on a large fan deposit on lower flanks of the Tsurumi Volcanic Centre. Lavas were last formed about 2,000 years ago. It is intended that future studies take advantage of this unique tectonic setting.

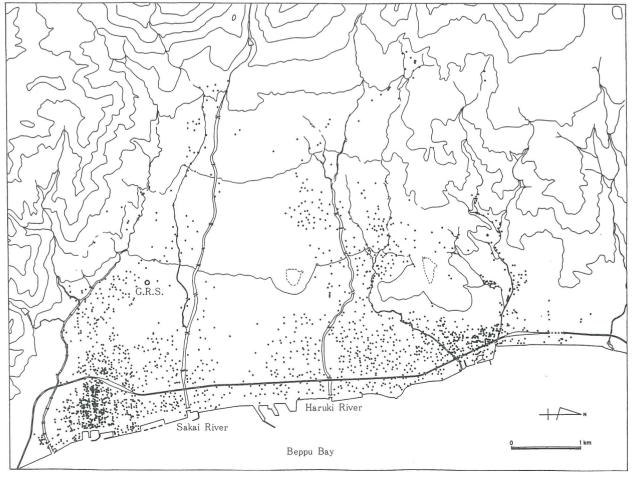


Fig. 1. Distribution of drilled wells in the Beppu geothermal field.

## BRIEF HISTORY

Beppu has a long history as a resort area for its onsen (hot spring bathing) and its jigoku (literally "hell"; fumaroles and steaming ground). In order to enhance the flow of hot water, wells were drilled as early as 1880 using a flexible bamboo technique known as "Kazusa-bori". These may be some of the earliest geothermal wells drilled anywhere in the world. By 1924 over 1000 wells had been drilled. Today there are over 3000 wells in an area of  $5 \text{km}(E-W) \times 8 \text{km}(N-S)$ , and the total flow of hot water and steam is around 600 kg/s. The wells range up to 700m in depth, and the temperature of over  $200\,^{\circ}\text{C}$  has been measured.

In the early 1920s, the Tokyo Electric Light Company made a small experiment to generate 2kW of electricity using geothermal steam from a Beppu well. This was probably only the second time in the world that geothermal electricity was generated (the first occasion was in Italy). Although a 30kW geothermal power generation unit was briefly operated in 1951, it was not until 1979 that a permanent power plant began producing electricity from geothermal steam at Beppu. This is a 3MW unit which provides power for the Suginoi Hotel.

The Geophysical Research Station was established at the present site of Beppu City in January 1924 aiming at conducting comprehensive studies of volcanic and geothermal phenomena on the intensive efforts of the late Professor T. Shida with special support from  $\overline{0}$ ita Prefecture and Beppu City. After this beginning, systematic measurements of the Beppu geothermal system In succession, the Aso Volcanological Laboratory was also established in March 1928 near the active central volcano within the Aso Caldera located about 60km southwest of Beppu in order to promote geophysical studies on volcanic activities. With the mutual collaboration of institutions, the Geophysical Research Station carries out these two geothermal research by selecting the Beppu system as its main research area. In addition, in order to measure geothermal activities, the Handa Observatory attached to the Geophysical Research Station was established in 1934 at Kuju half way between Beppu and Aso, is also one of the largest geothermal systems in Japan. Since then, over 250 scientific papers have been written by the research workers of the Geophysical Research Station.

In April 1987, the Geophysical Research Station was reorganized to expand its research areas by setting up three sections.

# FIELDS OF STUDY IN BEPPU

## 1. Geology (Fig. 2)

Beppu at the northeastern part of Kyushu, is geologically located in the Ryoke belt north of the Median Tectonic Line. The zone here is characterized by the existence of Pre-Neogene basement with structure trend of NE-SW direction, the graben structure of ENE-WSW trend and the volcanic front with NNE-SSW direction. The latter two were emplaced in Quaternary.

The NE-SW zonal structure of the basement rocks of central Kyushu is in general continuous with that of Southwest Japan. The Matsuyama-Yatsushiro Line running along the northern foot of the mountains of Saganoseki Peninsula corresponds to the Median Tectonic Line, which divides the Inner and the Outer zones of Southwest Japan. Within the peninsula, the Sanbagawa metamorphic rocks are exposed immediately south of the Matsuyama-Yatsushiro Line, which also occupies the northernmost belt of the Outer zone in Southwest Japan.

To the south, the Sanbagawa belt is separated by the Usuki-Yatsushiro

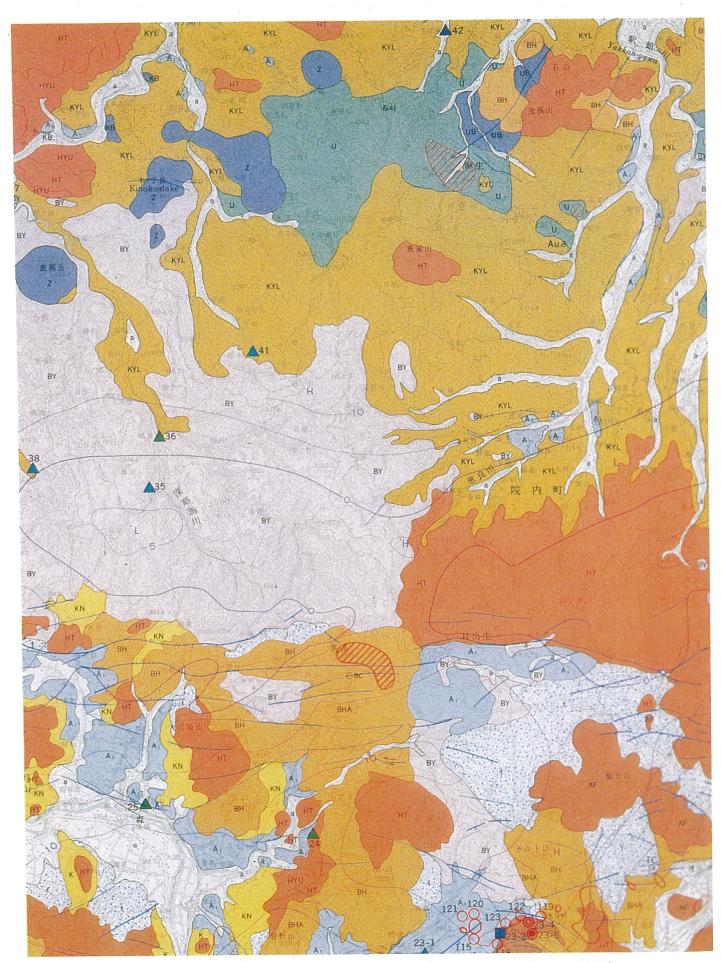
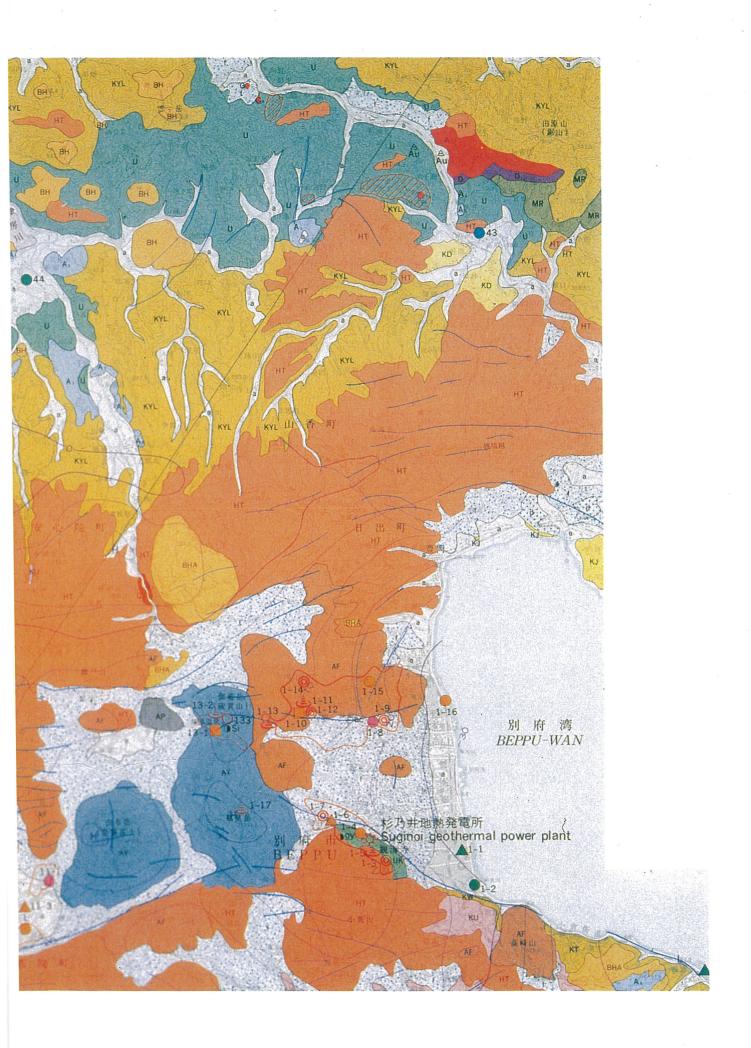


Fig. 2. Geological map of Hohi geothermal area. (Geol. Surv. Japan 1982)



第 | 表 地質層序表

						第   表 地	質層序表			
Age			Geology		地 層 名					
Quaternary	Holocene		Alluvium		a					
			Fan and talus deposits, and air-fall ash		6					
			Terrace deposits							
			Younger Volcanics	Late	由布·鶴見火山群	九重火	(山群 AP	阿蘇中央火口丘群	阿蘇火砕流	九重火砕流
				Early	福方山溶岩など AF	鹿伏岳溶岩など AB	湧蓋山溶岩など AW	千町無田火山群 AS	花牟札火山群	
			Bungo Volcanics		方牵描溶岩 ΒΗΑ	自向神溶岩 BH	<b>但</b> 石山溶岩 BK	飛竜野流紋岩 BR	長湯熊群山流紋岩 BN	岩 耶馬溪溶結凝灰岩 BY
	Pleistocene		Hōhi Volcanics and its correlatives		筑紫溶岩 鹿 15.7 15.7 15.7 15.7 15.7 15.7 15.7 15.7	會·庄司·冠山東·時山安山 旧\$	<del>,</del>	今市火砕流 H		田中礫層
			Intrusive Rocks		玄武岩・安山岩など	ž.				
			Kusu Group and its correlatives		含珪藻凝灰質砂岩 KD 町田溶岩 KM 耶馬溪層下部層	E LA	· · · · · · · · · · · · · · · · · · ·	野上泥層 KN 中村火砕流	日田層 KH 由布川火砕流 KU	凝灰質砂岩及び泥岩 TC  古期安山岩  KO
Tertiary	Neogene		Intrusive Ro	ocks	第三紀花崗岩類	玢岩 Po				1
		Pliocene-Miocene	Old Black Andesites		木/子岳安山岩など	Ź 旧期黑色安山岩		星原層 UH 玄武岩質安山岩	粘土化带 UZC	
			Usa Group		宇佐層群	宮園式安山岩 UM	鯛生層群 UT	石場礫岩 —UC—	観海寺火山岩 UK	
			Sekinan Group and its correlatives		積南層群 S	大野火山岩類				
	Paleo- gene		Paleogene System		鉾ヶ甲層など P					
Mesozoic			Onogawa Group		c					
			Intrusive Rocks		玉名花崗岩 :	北九州古期花崗岩	領家花崗岩及び朝地深成	岩	and the same	
Paleozoic		2	Metamorphic Rocks		三郡変成岩 MS	朝地変成岩	領家変成岩	未区分变成岩	蛇紋岩	

cf. Fig. 2.

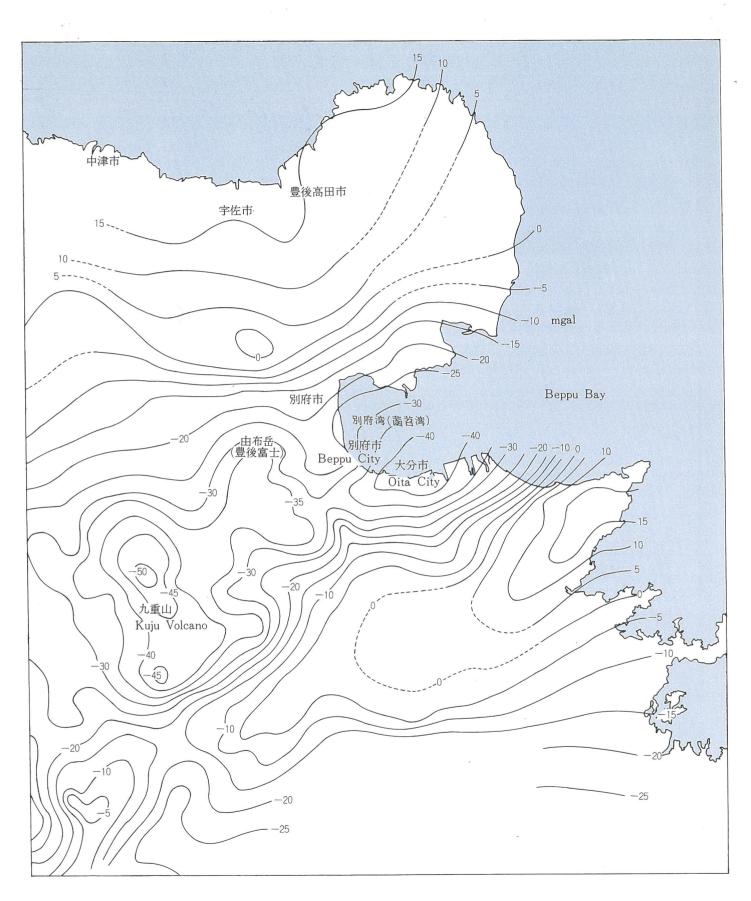


Fig. 3. Bouguer Anomaly in Beppu –  $\overline{0}$ ita Area. (Kubotera et al. 1969)

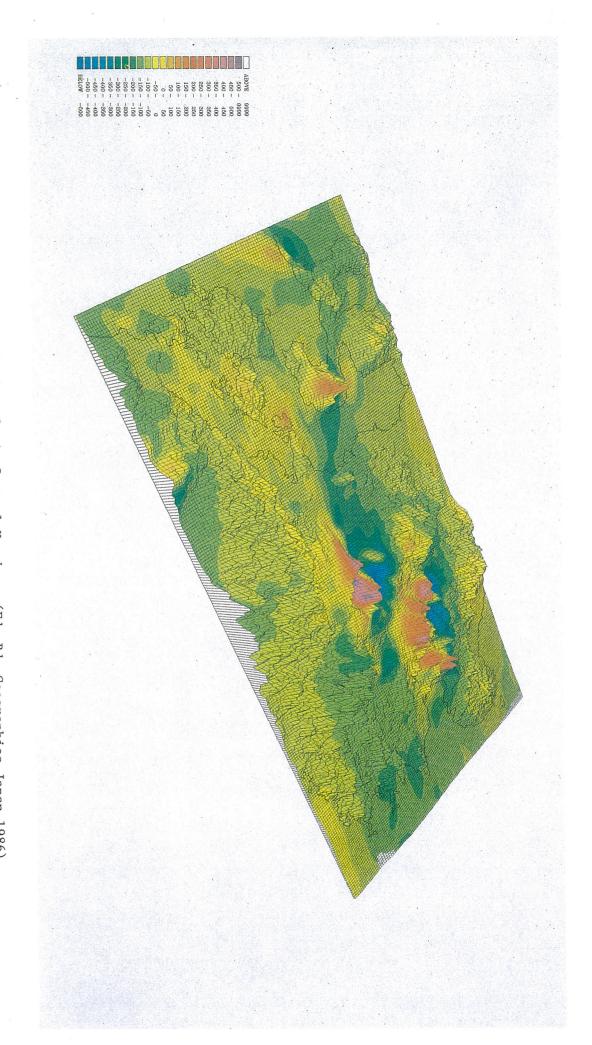


Fig. 4. Magnetic Anomaly in Central Kyushu. (Ed. Bd. Geographics Japan 1986)

Line from the Chichibu belt consisting of the Triassic and Jurassic, i.e., Mesozoic sediments. However, to the southwest, the both Lines converge with each other, where the Sanbagawa belt is lacking. In the north of the Matsuyama-Yatsushiro Line, the Ryoke metamorphic rocks and granites are distributed, which are also exposed immediately north of the Median Tectonic Line in Southwest Japan. The Beppu and Ōita area is located within this belt. On the western and southern sides of Saganoseki Peninsula, the thick, presumably forearc basin deposits of the upper Cretaceous age are distributed on both sides of the Matsuyama-Yatsushiro Line.

The existence of the Beppu-Shimabara Graben is inferred, based on the finding of the lower gravity anomalies and the absence of any outcrop of the Pre-Neogene basement rocks within the inferred graben area. Pleistocene and Holocene volcanics and sediments cover the graben. The graben extends about 150 km in ENE-WSW direction and is about 10 km in width. Beyond the northern and southern sides, there are the Pre-Neogene basements and the Neogene-Ouarternary volcanics and fresh-water sediments.

The city of Beppu is situated within the graben near its east end and near its southern boundary. The western part of the city is located on the fan which extends from Mt. Tsurumidake, which consists of hornblende andesite, and its eastern part on the coastal plain. The Geophysical Research Station is located near the end of the fan.

Beppu Bay is about 10 km wide in the north-south direction. The deepest part of the bay is located in the south of the inner part, which is deeper than -70 m. In the central part of the bay, there are many E-W trend faults being covered by sediments of several meters in thickness. The center of the parallel faults is called the  $\overline{0}$ ita Central Graben.

## 2. Geophysics

In the middle part of Kyushu, we can recognize a low gravity anomaly region between Beppu Bay and the Kuju-Aso district (Fig. 3). The most distinct low gravity zone is located between Beppu Bay and Kuju Volcano suggesting the existence of a volcano-tectonic depression. According to the geophysical analysis on gravity anomaly, the average depth of this depression seems to be 1.5-2 km and the deepest one is 4-5 km.

Magnetic anomalies are shown in Fig. 4. It is a bird-eye view of diagram of the geomorphological relief with overlaying colors indicating magnetic anomalies.

In Beppu, there is high seismic activity at the southern margin of the field, whose epicenters are rather shallow (several kilometres in depth).

#### 3. Geothermals

There are many geothermal fields along the graben, such as Beppu, Yufuin, Kuju, Aso, etc. Natural fumaroles and steaming grounds are also visible in various places (Fig. 5). At present, two geothermal power plants are in operation at the Kuju field (Ōtake 12.5MW and Hatchobaru 55MW: the Kyushu Electric Power Co.Ltd.) and one plant at the Beppu field (Suginoi Hotel 3MW). Furthermore, geothermal prospecting and exploitation are now promoted in the Beppu-Kuju-Aso zone by the Japanese government and private companies.

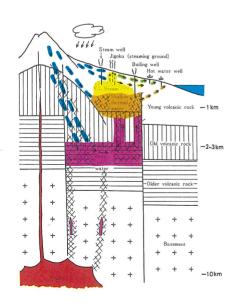


Fig. 5. A schematic model of the geothermal system in Beppu.

Recently, thermal waters have been discovered deep in the sedimentary layers under Oita City Plain south of Beppu.

## 4. Geochemistry and Mineralogy

Various types of geothermal water (chloride rich, sulfate rich, bicarbonate rich and diluted waters) are found in the Beppu-Kuju-Aso zone. Almost all types of geothermal water are distributed especially in the Beppu geothermal field.

The Beppu and adjacent area offers an excellent opportunity for studying rock-hydrothermal fluid interaction. The Res. Station systematically stores drill cores of the area. X-ray powder diffractometry, X-ray fluorecent analysis and solution chemistry of rock-samples can be performed in the Res. Station. The Department of Geology and Mineralogy on the Kyoto campus is pleased to cooperate with the Res. Station researchers in the electron-probe microanalysis, electron microscopy, gravity survey and fission track datings and to give them technical support in preparing thin and polished sections of altered rocks. The electron microprobe operated with energy dispersive system is well calibrated and is capable of analyzing zeolite minerals with far smaller beam current than the conventional wave-dispersive method. It is also equipped with the image analysis system of X-ray and backscattered electron images.

## 5. Hydrology

Mass and heat discharges from geothermal wells in Beppu have been monitored during the past several decades. Meteorological data including those on precipitation have accumulated. Water-level measurements are now being conducted in some shallow phreatic and geothermal wells with automatic-recording systems.

# RESEARCH SECTIONS IN THE GEOPHYSICAL RESEARCH STATION

## 1. Geothermal Fluid Research Section (permanent)

This section succeeds the former organization ("Groundwater Hydrology section") and consists of three members. The main subjects of study undertaken by this section, are physical and hydrological processes of geothermal fluid flows through underground media, such as potential flow, thermal convection, two-phase flow, etc.. This study should be developed incorporating results obtained by the other sections.

## 2. Geothermal Structure Research Section (until 1996)

Two members belong to this section. Its main subjects of study are the characteristics and history of underground geothermal formation based on geologic, petrologic, geophysical and geochemical methods. For this purpose, seismic prospectings and deep drillings will be conducted in and around the Beppu area with the collaboration of the Geothermal Fluid Research Section.

## 3. Geothermal Setting Research Section (until 1996)

This section open to foreign scientists in any disciplines related to geothermal phenomena. Examples of study are comparative stuides between the Beppu-Kuju-Aso area and other geothermal and volcanic fields in the world from various points of view. Each visiting scientist holds a tenure of 3 months to 1 year.

#### 4. Facilities

Observation well for thermal groundwater ( \$\notin 50mm\$, 300m deep: Beppu )
Observation well for shallow groundwater ( \$\notin 38mm\$, 40m deep: Beppu )
Observation well for shallow groundwater ( \$\notin 100mm\$, 50m deep: Beppu )
Observation well for steam ( \$\notin 200mm\$, 100m deep: Handa )
Facility of observation of infiltration (Beppu)
Meteorological observation facilities (Beppu and Handa)

#### 5. Equipments

Wiechert seismograph, Electomagnetic seismograph, Liquid sintilation spectrometer, X-ray diffractometer, Fluorescene X-ray spectrometer, Atomic absorption spectrometer, Thermal analyzer, Digital density meter for fluids, Devices for solution chemistry, Scanning electron microscope, Petrographic microscope, Grain size analyser, Precise rock cutter, Thermister thermometers, Water level recorders, Flow meters, Personal computers etc.

Use of large computer in the nearby universities is possible through telephone network.

Gas chromatographic, Ion chromatographic instruments, and Telemeter systems with seismographs etc. will be installed in the future.

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Edge Enhanced False Colour Image of LANDSAT Thematic Mapper (TM), Northeastern KYUSHU, JAPAN (by courtesy of JAPEX Geoscience Institute)