Thermal Springs and Cold Mineral Springs in Korea

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1. Introduction

A mineral spring is one whose water contains mineralized matter, gases, radioactive substances, etc. A thermal spring is not always a mineral spring. The name "mineral spring" is given to a spring in which 1 kg of water contains more than 1 g of solid matter; others are called a simple spring. According to this definition, almost none of the thermal springs in Korea may be referred to as mineral springs, but are simple springs.

As to the classification of thermal and cold springs, KOMADA[8] treated springs less than 20°C in maximum temperature as cold springs, and springs 20°C or higher in maximum temperature as thermal springs. He divided thermal springs into three groups, tepid springs (from 20°C to less than 40°C), warm springs (from 40°C to less than 70°C) and hot springs (over 70°C). According to Tokyo Hygienic Laboratory classification, however, which is widely adopted in Japan, thermal springs are separated from cold springs at 25°C. The author has adopted this classification.

We do not like to bathe in water below human body temperature, however, so from this viewpoint, tepid springs are separated from hot springs. A comfortable temperature for bathing is 40°C–45°C for Japanese. Thus, thermal springs of less than 40°C were dealt with as tepid springs, and those 40°C or higher as hot springs.

In addition, there are many springs, called "Yangsu" (medicine water), "Yŏngch'ŏn" (holy spring), "Naengch'ŏn" (cold spring), "Kamch'ŏn" (sweet spring), "Hamch'ŏn" (salty spring), "Samch'ŏn" (acid spring), "Ch'usu" (spicy water), etc., all over the peninsula. All are used mainly for drinking purpose. Some of those called "Yangsu", "Naengch'ŏn" or "Kamch'ŏn" are not special in quality, and some are mineralized so little that they are sometimes more pure than common groundwater. "Hamch'ŏn" are commonly found near the seashore, so some may contain water intruding from the sea. Some "Yangsu", which are appreciated for their iron oxide content, have their source in pyrite-bearing quartz veins, exposed in abandoned adits. Hence, the total number of cold mineral springs may be reduced if strictly examined. However, all those described as

mineral springs or "Yangsu" in the literature will be treated as cold mineral springs in this paper.

In addition, KOMADA explored the important hot springs in Korea geologically, and even carried out boring at the Tongnae and Haeundae spas. His work contributed very much to the research, enterprise, and management of hot springs in Korea, and the present author owes very much to his work also.

2. Geographical Distribution

There are 46 hot springs, with maximum temperatures above 40°C, 13 tepid springs with maximum temperatures above 25°C and below 40°C, and 30 cold mineral springs with maximum temperatures below 25°C. These are not distributed equally over the peninsula.

Hot springs are most numerous in Hwanghae-do, P'yŏngan-namdo and Hamgyŏng-pukto, while no hot springs are known in Kyŏnggi-do, Kyŏngsang-pukto, Cholla-pukto and Cholla-namdo.

Some tepid springs will be included as hot springs if they might be developed, but tepid springs known at present are most numerous in Kangwŏn-do, followed by Hamgyŏng-pukto. Also, no tepid springs are known in P'yŏngan-namdo, Ch'ungch'ŏng-pukto, Kyŏngsang-namdo, Kyŏngsang-pukto, Chŏlla-namdo and Chŏlla-pukto.

There are many cold mineral springs, named "Yangsu", all over Korea. However, as far as the literature is concerned, no cold mineral springs are known in Kyŏnggi-do, Chŏlla-namdo and Chŏlla-pukto, but many cold mineral springs are found in Hamgyŏng-pukto, P'yŏngan-namdo, Kwangwŏn-do and Kyŏngsang-pukto.

In summary, there are many hot springs and cold mineral springs in Hwanghae-do, P'yŏngan-namdo, Kangwŏn-do and Hamgyŏng-pukto. There is an abundance of hot springs in the western part of Hwanghae-do, among which many are higher than 70°C in maximum temperature. It is noteworthy that all the above provinces are also active in the mining industry.

On the contrary, there are no hot springs, tepid springs or cold mineral springs in Chŏlla-pukto and Chŏlla-namdo. These two provinces rank lowest throughout the peninsula in total number of mines also, and these two provinces are least blessed with underground resources in all of Korea. They are followed by Kyŏnggi-do and Kyŏngsang-pukto, but cold mineral springs are not so few in Kyŏngsang-pukto.

Besides, according to Shigetaro KAWASAKI,[2] there might be more hot springs than are known at present. It may be that some springs were abandoned due to the decay of post-volcanic action itself, some were choked up at their openings and some became cold due to mixing with cold water.

However, it may be interesting to note, from Korean history, that the sources of some springs were blocked artificially. There are many old tales and records

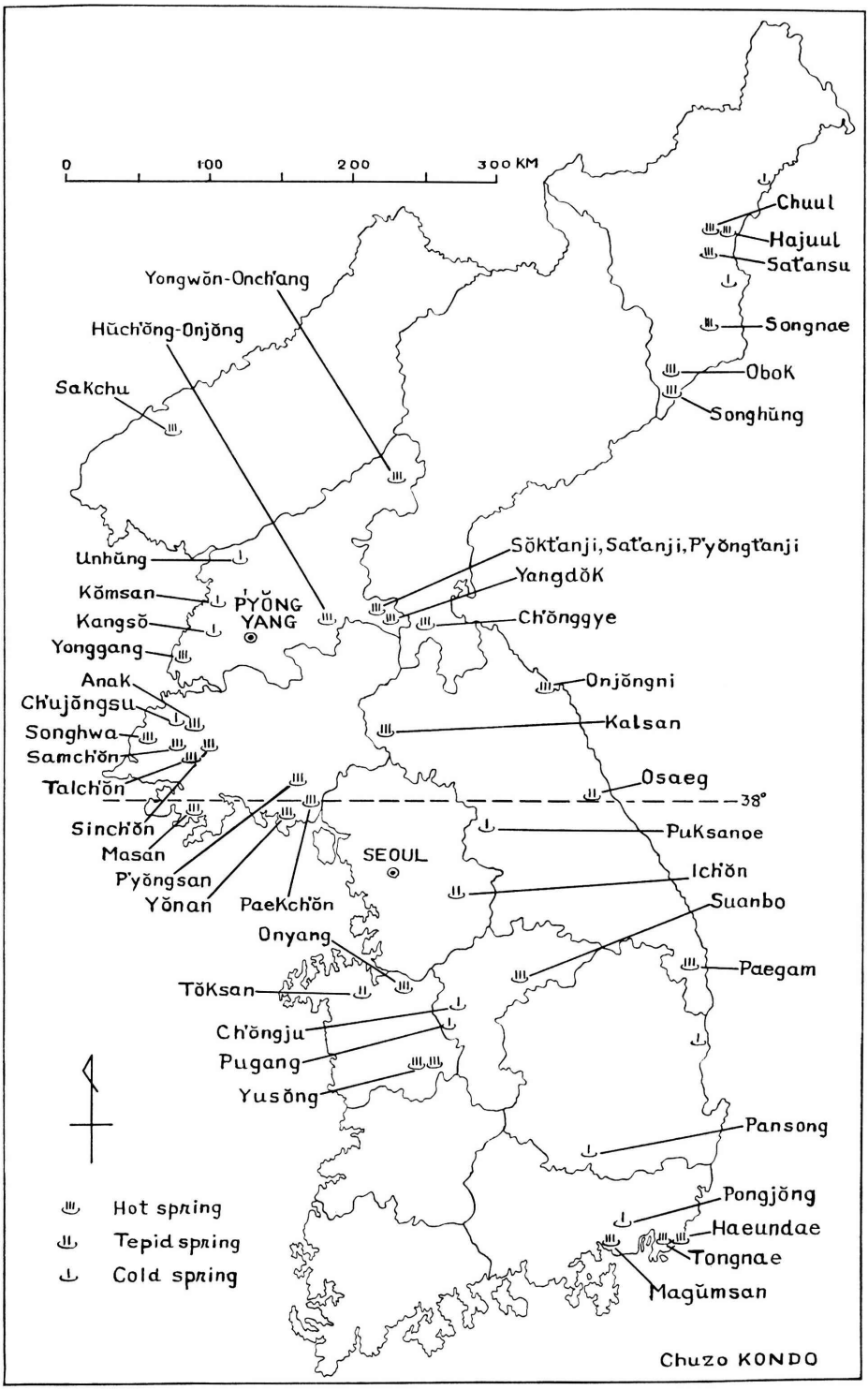

Fig. 1. Distribution of Thermal Springs and Cold Mineral Springs in Korea.

telling of *Yanban,* government officials, who came to the spas too frequently, stole drink and food from inhabitants and pressed young girls into service, so that the complaining inhabitants clogged the sources of the spring. Some records suggest that there might be a hot spring in Pup'yŏng, near Sŏul, which seems to have been clogged by inhabitants because of their complaints against officials.[17] It is also said that the exploitation of the Haeundae hot springs had been prevented for a long time for similar reasons.

3. History of Utilization

It is certain, from old records, that cold mineral springs and thermal springs were used for drinking and bathing. Hot springs of the type called "Onyang" (warm positive), "Onjŏng" (warm well), "Pich'ŏn" (boiling spring), "Tanjŏng" (hot water well), etc., seem to have been used since primitive times, especially for the treatment of pox.[2]

It is said that king of the "Shiragi" (Silla) dynasty (A.D. 500–935) often bathed in the Tongnae hot spring of Kyŏngsang-namdo, so the utilization of hot springs in Korea might have begun about 1,000 years ago. There might have been some accomodation about 400 years ago, and a pleasure resort was established about 200 years ago in Tongnae.[6]

The Onyang spa was already known in the age of "Kudara" (Paekche) (百済) (A.D. 313–663), and the Korean style bath, preserved until today, is said to have been constructed by order of "T'aejo" (太祖), the founder of the I dynasty (李朝), repaired by Prince Taewŏngun (大院君) and was used occasionally by ITaewang (李大王).[7]

All famous spas, such as Yusŏng, Sinch'ŏn, Anak, Yonggang, Onjŏngni and Chuul, seem to have begun 400 or 500 years ago. It is said that "T'aechong" (太宗) of the I dynasty (1401–1419) once bathed in the Yusŏng hot spring,[7] and also tha "Sejo" (世祖), King Hyechang (恵荘) nce ostayed where the Manryukaku hotel is at the t present time.

As already stated, Koreans have a long history of using hot springs, but they do not appreciate bathing itself. Also the people could not enjoy the natural gift of hot springs due to misgovernment.

Most famous spas of today did not have good accomodations before the annexation of Korea (1910). NAKAMURA once stated that the Paegam spa in Kangwŏn-do was installed with a comfortable bathroom and has the best accomodation among Korean style spas.[7] However, Koreans had the custom of drinking the water of thermal springs and cold mineral springs since long ago. For example, the mineral water, "Ch'usu", of Ch'ŏngju in Ch'ungch'ŏng-pukto, the most famous mineral spring in Korea, is drunk and bathed in by many persons, who come a long way, and girls enjoy washing their hair in it. Also, it is said that kings of the I dynasty, such as "Se-jong (世宗)" and "Sejo", visited there.[11]

Immediately after annexation, the Police Affairs Department of the Govern-

ment-General of Chosen began an investigation of mineral springs all over Korea and published the results twice, in 1914 and 1918.[1] Many Japanese went to Korea to advance the development of spas to bring the prosperity of today. Therefore, the majority of important spas were exploited by Japanese from the end of Meiji to the middle of the Taisho period. For instance, the Tongnae spa became such as it is today only since 1916.

4. Present State of Utilization

(1) Hot springs

Almost all hot springs are being used for bathing, but some are used only by the local inhabitants and do not even have a bath installed. Some are used only for laundry. There are 46 known hot springs in total, but only 30 of these springs are equipped with both bath and lodging houses. However, hot spas such as Tongnae, Haeuudae, Yusŏng, Onyang, Sinch'ŏn, Paekch'ŏn, Yonggang, Onjŏng-ni, Chuul and Hajuul have good accomodations as hot spring resorts and are always crowded with visitors. The Tongnae spa has best accomodations and the Onyang spa follows. Spas, such as those at Onp'ung (Sakchu), Yangdŏk, Anak, Samch'ŏn, Talch'ŏn, Songhwa, P'yŏngsan, Yŏnan, Masan, Ŏbok (Sech'ŏn), Songhŭng, Suanbo and Magŭmsan also have good accomodations and are always crowded with visitors (see Fig. 1).

In Korea, hot springs are used for bathing and drinking almost exclusively, but hot spring waters at Haeundae, Chuul, Sinch'ŏn and Paekch'ŏn are also used for heating purposes and for hot house cultivation and swimming pool facilities at Paekch'ŏn.

For bathing, tubs are usually set in seepage or winze, and framed with well-cribbing, or seepage water is led to bath tubs which are set apart. Usually no artificial means is applied to obtain water, however water is being pumped from drilled wells at Tongnae, Haeundae, Yusŏng, Sinch'ŏn, Onyang and Yonggang.

The first drilling in Korea was attempted by IWANAGA at Haeundae in 1911, and hot water (52°C or so) was found by drilling to a depth of 10 m or so. The first bore in Tongnae was made at about the same time, and at the new Yusŏng spa in 1912, and at Sinch'ŏn in 1921.

Most wells, including drilled wells, vary from 6 to 15 m in depth, and the deepest well in Korea, found at Onyang, is 93.3 m deep. However, most wells in Onyang are only several meters deep. Large scale pumping equipment is found only at Tongnae, Haeundae and Paekch'ŏn.

(2) Tepid springs

All tepid springs are used as sources of drinking water, but tepid spring water, except in the hot season, usually requires heating for bathing purposes. Hence, very few tepid springs are used for bathing, they being found only at Ichŏn in Kyŏnggi-do, Tŏksan in Ch'ungch'ŏng-namdo and Osaek in Kangwŏn-do, and

accomodations are poor except at Ichŏn. Of course, no artificial means are being used to obtain water.

(3) Cold mineral springs

Almost all cold mineral springs are utilised exclusively for drinking purposes, and some are crowded all day with people of all ages, coming great distances to drink the water in summer. The Ch'ŏngju-Ch'usu cold mineral spring in Ch'ungch'ŏng-pukto especially has been exploited by a company since 1919, and bottled water for sale under the commercial name "Crystal" has been gaining public favor since 1921.

Some cold mineral springs are used for bathing. For instance, water from the Pongjŏng mineral spring in Kyŏngsang-namdo is used for bathing after being heated. Water from the Pansong-Yangsu spring in Kyŏngsang-pukto is not only drunk as a cure for diseases of the stomach, but is bathed in as a treatment of skin diseases. Such mineral springs as the "Ch'ujŏngsu" in Sŏha-myŏn, Anak-kun, Hwanghae-do, the Kŏmsan-Yangsu in P'yŏngan-namdo, the new Kangsŏ-Yangsu in P'yŏngan-namdo, "Yangsu" in Hwangim-myŏn, Yonggang-gun, P'yŏngan-namdo and "Yangsu" in Puksanoe-myŏn, Ch'unch'ŏn-gun, Kangwŏn-do are all used for bathing. None of these, however, have good accomodations and the baths resemble a vapour bath.

In addition, water from the Unhŭng-Yangsu spring in Anju-gun, P'yŏngan-namdo is used for treating of eye diseases and worms.

5. Geology

Hot springs of Korea differ strikingly from those of Japan in geologic features, the majority occurring in alluvial plains, and gushing out from alluvial deposits of sand, gravel and mud. Only springs at Masan, Suanbo, Yangdŏk and Chuul form exceptions.

There are many springs where the bedrock is unknown. But bedrocks which yield springs are, in general, composed of acidic intrusive rocks such as granite-gneiss, granite, granite-porphyry, quartz-porphyry, felsophyre, etc.; granite is especially common. For example, the bedrock at the Tongnae spa consists of a batholith of granite crossed by biotite-felsophyre. The Onyang spa is composed of porphyritic biotite-hornblende granite, older than deposits of the Lower Jurassic system. The environs of the new Yusŏng spa is composed of gray two-mica granite, intruded in the Okch'ŏn system and traversed by both quartz-porphyry and biotite granite. The hot spring at Yangdŏk flows out of granite. Most hot springs in the western part of Hwanghae-do gush out from granite or injection-gneiss. Many of the hot springs in Hamgyŏng-pukto are in a granite-gneiss region. In the vicinity of the Haeundae spa, both pyroxene porphyrite of the Silla series and hornblende-biotite granite of the Pulgukksa series (which traverses the former) occurs, but thermal water is obtained only from the dike or neck of granite.

As stated above, the majority of hot springs in Korea occur in granitic rocks, but the bedrock is usually traversed by other acidic rocks, as seen at Tongnae and Yusŏng. In the Tongnae spa, the area of high water temperature appears as an ellipse elongated from north to south, and the portion having an especially high temperature is found near the west boundary between granite and felsophyre, intruded in the former, and the shape roughly follows that of the felsophyre core.[6] The granite in the Onyang spa is traversed by pegmatites, and thermal water gushes out from fissures of both granite and pegmatite. Judging from the underground temperature distribution, the thermal water of the Paekch'ŏn spa is thought to have some relation to pegmatite.[12, 13]

NAKAMURA once pointed out the close connection between hot springs and the presence of tungsten and molybdenum ore.[16] Indeed, there are many tungsten and molybdenum mines in Mt. Kŭmgang near the Onjŏng-ni hot spring. The Santoku (Samdŏk) molybdenum mine was located near the Suanbo spa. Tungsten ore deposits are found north of the Ch'ŏnggye hot spring in Hamgyŏng-namdo, and the Pugang cold mineral spring is in a tungsten ore-producing area.

As already stated, the two provinces, Chŏlla-pukto and Chŏlla-namdo, which are least blessed with mineral resources in all Korea, also lack any hot, tepid or cold mineral springs.

Hot springs in Korea are not related to volcanoes, except for one or two in the vicinity of Mt. Paektu. In Hamgyŏng-pukto, younger volcanicr ocks such as basalt and trachyte predominate, nevertheless hot springs are rather more numerous in granite regions than in volcanic rock regions. Hence, most hot springs in Korea are related to magmatic intrusions, and are intimately connected with acidic intrusive rocks. The age of formation is thought to be the pre-Tertiary period. As the surface of the earth becomes more deeply eroded, the possibility of discovering new hot springs will increase.

In most hot springs which flow out on alluvial plains, however, both temperatures and yields usually increase with rainfall. Accordingly, it is certain that rain water feeds the alluvial deposits of thermal water.

The majority of cold mineral springs have not yet been investigated geologically, but the mineral spring of Ch'ŏngju in Ch'ungch'ŏng-pukto gushes out from fissures in both biotite granite and quartz-porphyry. The Pugang mineral spring in Ch'ungch'ŏng-pukto flows from a dike of biotite granite traversing gneiss. The geology of cold mineral springs seems similar to that of hot springs. Therefore, most cold mineral springs may be cooled hot springs.

Sometimes, however, no igneous rock is found in the vicinity of hot springs. For example, the Masan hot spring district is composed of garnet-bearing altered rocks, mica schists and breccia, and thermal water gushes out from the breccia. The Suanbo spa consists of calcareous clayslate and grayish-white limestone in alternation, dark-brown sandstone and dark-brown sandyslate, all belonging to the Okch'ŏn system; thermal water flows out from fissures in the sandstone.

6. Geologic Structure and Horizontal Distribution of Water Temperature

Hot springs are usually related to geologic structures such as faults, fissures, etc., in the district concerned, and hot springs in Korea are generally distributed in the directions, east to west, north to south, or close to these two directions, suggesting their intimate relation to geologic structures. Two predominant tectonic lines are known in the peninsula; one is the Sinian direction, running from ENE to WSW, and the other is the Korean direction, going from NNW to SSE.

First, looking over those in the east-west direction or in a direction close to it, one finds the Yusŏng hot springs and the new Yusŏng hot springs, which run east to west. The isothermal lines of ground water temperature in the new Yusŏng spa extend from east to west, and major fissures predominate in the same direction; the thermal water is thought to gush out from these fissures, or from a dike running east to west. In the Sinch'ŏn spa, thermal water can be obtained by drilling less than 100 m below the surface only within an elliptical area, elongated from ESE to WNW, 360 m in major axis and 75 m in minor axis. The sources of the Chuul spa are located within an area 285 m long from ENE to WSW, and 52 m long from NNW to SSE, and concentrated in the WSW portion. Those of the Suanbo spa are distributed over an area 60 m long from east to west, and 40 m long from north to south.

The other direction, from north to south, on the other hand, is also important. The Tongnae spa is located in a fault valley, running close to the north-south direction, and the isothermal lines of underground temperature at a depth of from 6 to 9 m below the surface form an elliptical shape, elongated from north to south; the area, enclosed by isothermal line of 45°C 118 m in major axis and 94 m in minor axis, is 9,311 m^2. The Masan hot springs occur in an area 20 m east to west and 60 m north to south. In Hamgyŏng-pukto, there is a big fault running from Kyŏngsŏng-gun to Songjin through Myŏngch'ŏn-gun, north to south, and many springs occur in a zone along this fault.

The Onyang hot springs are distributed over an area 100 m long from east to west and 80 m north to south, but two major zones are found within this area. One runs nearly north to south and yields thermal water of 43°C, while the other extends from ESE to WNW and yields thermal water of from 42°C to 50°C. These two zones are probably related to either fault lines or dikes. The Onjŏngni hot springs occur at the junction of two valleys, and are thought to gush out at the intersection of two geotectonic lines; springs are distributed linearly NW to SE for 42 m.

Furthermore, looking over the distribution of thermal springs (see Fig. 1), a major zone, extending NNW-SSE from the western portion of Hwanghae-do to the eastern portion of Kyŏngsang-namdo through the eastern part of Ch'ungch'ŏng-namdo, is thought to exist. The zone involves the very hot springs of Hwanghae-do, hot and tepid springs of Ch'ungch'ŏng-namdo, mineral springs

of Ch'ungch'ŏng-pukto and hot springs of Kyŏngsang-namdo. The existence of such a zone is supported by a depression in the sea east of Kyŏnggi-do

Moreover, two thermal springs zones are thought to exist in a ENE-WSW direction from the southern extremity of Hamgyŏng-namdo to the south-western corner of P'yŏngan-namdo, and from the southern extremity of Kangwŏn-do to the northern part of Ch'ungch'ŏng-namdo.

7. Supply

Almost all hot springs in Korea, which gush out from Quaternary deposits, have a constant supply, which is not active usually. The pressure head of thermal water at the Chuul hot spring is 2 m above the surface, and the thermal water at Sinch'ŏn, Yonggang, etc., flows out above the surface, but most hot springs in Korea are under too low pressure to flow out above ground, so where no pumps are available, baths are usually set 2 to 3 m below the surface.

Supply, therefore, is usually small and the maximum supply is 10,000 koku per day (330 gallons per min) or so at the Chuul hot springs or the Sinch'ŏn hot spring, where supply is greatest throughout Korea. At the Tongnae hot springs, the maximum yield of one well is only 160 koku per day (5.29 gpm), so the total supply is estimated at 2,500 koku per day (82.7 gpm) or so. At the Onyang spa, some well yields 4,900 koku per day (162 gpm), but the main well yields only 200 koku per day (6.6 gpm). At the Haeundae spa, the supply rarely exceeds 100 koku per day (3.3 gpm) or so, and is usually less than 50 koku per day (1.65 gpm) per well and 320 koku per day (10.6 gpm) in total.

In general, when rainfall is high, yield increases and temperature rises also, and when the atmospheric pressure is low, supply increases. Supply is generally greater in July and August than at other time thoughout the year. According to KOMADA, the pressure head changes about 3 cm or so per 10 mm of atmospheric pressure, and the supply increases as the head rises in the Tongnae spa.

8. Temperatures of Spring Waters

The temperatures of hot springs and cold mineral springs in Korea range from 5°C (cold springs) to 94°C (hot springs).

The hot springs, with maximum temperatures over 40°C, number 46, among which very hot springs, 70°C ormore, number only 10 (Masan (94°C), Paekch'ŏn (89.5°C), Talch'ŏn (80°C), Sat'ansu (80°C), Sŏkt'anji and Sat'anji (80°C), P'yŏngt'anji (76°C), Anak (75°C) P'yŏngsan (75°C), Yŏnan (74°C), and Songnae (70°C)). It is noteworthy that most very hot springs are concentrated in the western half of Hwanghae-do. Those 60°–70°C in temperature number only 10 also, and the majority of hot springs run from 40°C to 60°C. The temperatures of hot springs in Korea are generally not too high then, and most springs belong to the warm spring group of KOMADA.

Most tepid springs run from 35°C to 39°C and 8 out of a total of 13 springs are included in this range.

As for cold mineral springs commonly called "Yangsu", there are many whose temperatures are unknown. However, the temperatures of cold mineral springs generally vary from 10°C to 13°C, although some change with the season. According to observations made at Ch'ongju-Ch'usu from 1912 to 1917, the water temperature varies from 10°C to 16°C, and is controlled by rainfall to some degree, but is hardly affected by the season, and commonly varies from 14°C to 15°C and is always higher than the average air temperature in the district.[10]

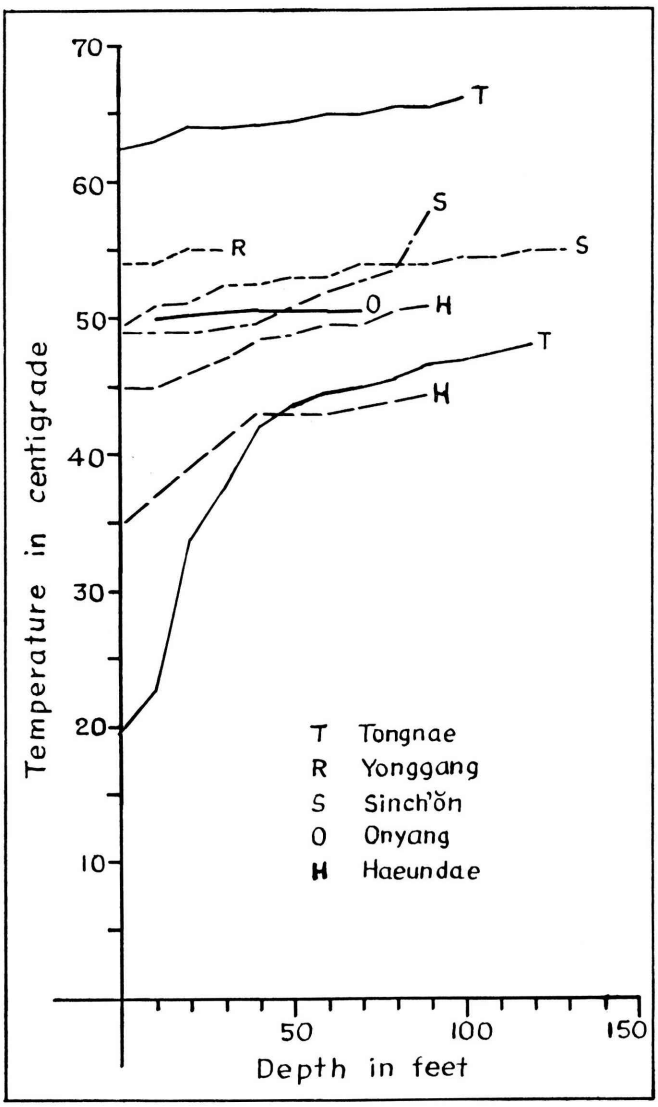

Fig. 2. Geothermal Gradients.

Geothermal gradients in general show no remarkable changes in hot spas in Korea (see Fig. 2). At the Tongnae spa, the underground temperature usually increases from 0.2°C or 0.3°C to several degrees, rarely more than 10°C, at a depth of 3–6 m and rarely 9 m or so below the surface. These depths are equal to the thickness of the Quaternary formation there, which may indicate that the underground temperature is affected by aquifers in the Quaternary formation at these depth. If one bores into the bedrock, the underground temperature increases with depth, but the geothermal gradient is rather small, and even if a bore is sunk very deeply, a remarkable rise in temperature is not expected. This may be due to the fact that the heat source is intrusive material, which are situated far below the surface. Some wells at the Tongnae spa, however, show a decrease in temperature at a depth of from 12 m to 18 m below the surface, and then temperatures decrease with depth. This is due to the fact that the thermal water comes from fissures in the bedrock. There are two groups of hot springs at the Tongnae spa.

The horizontal distribution of underground temperature is as transitive as the vertical distribution is and the change in temperature is generally greater horizontally. In short, hot springs in Korea have the horizontal distribution of temperatures, elliptical or elongated elliptical. However, hot springs sometimes occur in a linear distribution.

At the Tongnae spa, the supply increases and temperature rises with rainfall. At the Onjŏngni spa, on the other hand, the temperature decreases with rainfall. Variation in temperature is generally greatest in July and August. This may indicate meteoric water to be one source of thermal water. At the Onyang spa, however, the temperature of thermal water seems to be independent of rainfall.

9. Quality of Spring Water

A. Hot springs

The water of hot springs in Korea is colorless, transparent and odorless, but classified into two according to taste, i.e., salty and tasteless. The former includes the majority of hot springs in Korea, and Tongnae, Haeundae, Anak, Yonggang, Onjŏngni and Masan comprise this group; they are neutral at normal temperature but become alkaline if boiled. The latter are weakly alkaline even at normal temperatures, and the alkalinity increases with boiling. This group is comprised of the Yusŏng, Sinch'ŏn, Onjŏngni, Chuul, Hajuul and P'yŏngsan springs. The thermal water of the Onyang hot springs is slightly salty, but belongs to the latter group. Among the above, the thermal water of Sinch'ŏn is the strongest in alkalinity throughout Korea.

We know very little about the chemical composition of thermal water from Korea, but it is known that the total amount of solute contained in 1 kg of thermal water is generally very small, being more than 1 g at only 4 hot springs (Tongnae, Haeundae, Yonggang and Masan). The greatest concentration (26.3417 g) is at the Yonggang hot springs, but the other springs contain 5 g or less (at Tongnae,

only 1.077 g). Excluding the above, most hot springs contain less than 0.5 g of total solid and are not classed as mineral springs, but as simple springs. All hot mineral springs are included in earth-chloride-bearing common salt springs, and there are only 3 quality classifications for hot spring water in Korea.

(1) Earth-chloride-bearing common salt hot springs

These springs contain over 1,000 mg of solid per 1 kg of water, with Cl^- anions and Na^+ cations as the principal constituents which together form common salt. The content of common salt is greater than 5,000 mg but less than 15,000 mg. The water also contains large amounts of Ca^{++} ion which forms $CaCl_2$, $MgCl_2$ and KCl. Only Yonggang belongs to this type.

(2) Earth-chloride-bearing weak common salt hot springs

Springs of this type are similar to the preceding ones, and differ only in their content of common salt, which is less than 5,000 mg. Masan, Tongnae and Haeundae belong to this type. However, the thermal water at Masan is richer in $MgCl_2$ and poorer in $CaSO_4$ than at the Tongnae and Haeundae springs.

(3) Simple hot springs

This type includes those in which the contents of both free carbonic acid and solid are less than 1,000 mg per 1 kg of water, and all remaining springs belong to this group. Simple springs are sub-divided into the following three groups on the basis of their principal ingredients.

a. *Alkaline simple hot springs*: The principal ingredients are hydro-carbonic acid anions and Na^+ cations, which combine to form sodium bicarbonate. The Onyang, Chuul, Onjŏngni, Pyŏngsan, Yusŏng and Suanbo springs belong to this group.

b. *Common-salt-bearing alkaline simple hot springs*: A considerable amount of Cl^- ion is added to the former. Only Sinch'ŏn belongs to this group.

c. *Alkaline common-salt-bearing simple hot springs*: The principal ingredients are Cl^- anions and Na^+ cations, which combine to form common salt, and a remarkable amount of hydrocarbonic acid ion is also contained. Only Anak belongs to this group.

As stated above, highly mineralized hot springs in Korea are included in common salt springs, and dilute hot springs are mostly alkaline simple springs.

In addition the Kalsan hot spring in Kangwŏn-do is said to be a simple alkaline carbonated spring, and there are some hot springs described as sulphuric acid springs or sulphurous springs,[1)] but these are not certain.

B. Tepid springs

The most mineralized of the tepid springs is the Osaeg-Yangsu spring at Koraegok, Sŏ-myŏn, Yangyang-gun, Kangwŏn-do, but the total solid content is only 2,104.0 g per 1 kg of water. Hence, tepid springs in Korea are dilute, too. These are classified into three groups, weakly alkaline carbonated springs, common salt springs and simple springs. Among these three groups, simple springs predominate. There are additional springs, cited as sulphurous springs, but very little is known among them.

C. Cold mineral springs

Cold mineral springs have not yet been investigated thoroughly, but as already stated, many of the "Yangsu" should be included as simple springs. Some, however, are described as carbonated springs, iron springs and vitriol or sulphurous springs. Most of the water from these springs is tasteless and odorless, but the mineral water of the Pongjŏng mineral spring in Kyŏngsang-namdo is brownish yellow, like Japanese "Sake", transparent, strongly acidic and has both an acidic taste and a characteristic stimulating odor. Some are colorless and odorless, but cloudy due to light yellowish-brown colored floating matter. The famous mineral springs, represented by the Ch'ŏngju-Ch'usu spring at Ch'ungch'ŏng-pukto and the Ch'ujŏngsu spring in Sŏha-myŏn, Anak-gun, Hwanghae-do, however, are carbonated springs, and most of them contain iron, and taste bitter to some degree.

The mineralized water of Ch'ŏngju is colorless, transparent and odorless, and its taste is refreshing and stimulating. It is acidic at normal temperatures but becomes alkaline if boiled, and is a simple carbonated spring containing neither iron nor alumina. It is of rare good quality as a refreshing drink.

In addition, the Ch'ongju-Ch'usu spring has a 60 mache Radon content, the greatest throughout Korea. It is followed by the Onjŏngni hot spring, which varies from 40 to 44 mache. These are included as radioactive springs of a low grade, and are followed by the Yusŏng and Haeundae hot springs, which are 28 and 25 mache respectively. Other springs are less than 10 mache in Radon content.

Table 1. Table of Hot Springs and Cold Mineral Springs.
Hot Springs

Names	Location			Quality	Maxim. temperature (°C)	Yield (koku/day)
	Myŏn or Ŭp	Gun	Do			
1. Tongnae	Tongnae	Tongnae	Kyŏngsang-namdo	Earth-chloride-bearing weak common salt	51–69	2,500
2. Haeundae	Nam	do.	do.	do.	54–66	320
3. Magŭmsan	Puk	Ch'angwŏn	do.	Common salt-bearing simple	42.5	
4. Onyang	Onyang	Asan	Ch'ungch'ŏng-namdo	Alkaline simple	50.5–54	
5. Yusŏng	Yusŏng	Taejŏn	do.	do.	50–57	
6. Suanbo	Sangmo	Koesan	Ch'ungch'ŏng-pukto	do.	45.5–51	
7. Onjŏng-ni	Sinpuk	Kosŏng	Kangwŏn-do	do.	45	6,700
8. Sangdŏkku	Puk	Ulchin	do.		40	
9. Paegam	Onjŏng	do.	do.	Alkaline simple	46	1,000
10. Kalsan	Pangjang	Ich'ŏn	do.	Alkaline simple carbonated	46	
11. Yŏnan or Kŭmsŏng	Onjŏng	Yŏnbaek	Hwanghae-do	Earth-bearing alkaline	70–74	
12. Paekch'ŏn	Ŭnch'ŏng	do.	do.	Simple sulphurous	89.5	
13. P'yŏngsan	Chŏgam	P'yŏngsan	do.	Alkaline simple	55.0	2,300
14. Masan	Masan	Ongjin	do.	Earth-chloride-bearing weak common salt	94.0	
15. Songhwa	Yŏnjŏng	Songhwa	do.	Alkaline simple	46.0	100
16. Yongch'ŏn	Kunghŭng	Sinch'ŏn	do.	Simple	53	
17. Samch'ŏn	do.	do.	do.	Simple sulphurous	59–62	40

18. Yongch'ŏn	do.	do.	do.		53	
19. Sinch'ŏn	Onch'ŏn	do.	do.	Common salt-bearing simple	58	10,000
20. Talch'ŏn	Ch'ori	do.	do.	Simple sulphurous	53–80	100
21. Anak	Ŭnhong	Anak	do.	Simple	72–75	
22. Yonggang	Haeun	Yonggang	P'yŏngan-namdo	Earth-chloride-bearing common salt	55	1,000
23. Yongt'aek	Yŏngch'ŏn	Sŏngch'ŏn	do.	Simple	46.5	400
24. Yŏngwŏn-Onch'ang	Onhwa	Yŏngwŏn	do.	Sulphurous	60	2,592
25. Sat'anji and Sŏkt'anji	Onch'ŏn	Yangdŏk	do.	Carbonated	80	500
26. P'yŏnt'anji	do.	do.	do.	do.	76	200
27. Yangdŏk	Kuryong	do.	do.	Simple	53–55	
28. Sot'anji	do.	do.	do.	Carbonated	45	100
29. Onjŏng	Sinp'ung	Hŭich'ŏn	P'yŏngan-pukto	Sulphurous	43–50	70
30. Onjŏng or Ch'umogwŏn	Ŭiyon	Unsan	do.	Simple	44–56.5	
31. Onp'ung or Sakchu	Sakchu	Sakchu	do.	Simple	59–61	
32. Onjungdong	Kunnae	do.	do.		56	120
33. Myŏnghwa-dong or Pohye	Pohye	Kapsan	Hamgyŏng-namdo	—	38–41.5	
34. Nokkaktŏng-ni Hamsu	Puk	Changjin	do.	—	65	20
35. Ch'ŏnggye	P'ungha	Tŏgwŏn	do.	Common salt-bearing simple	60	50
36. Yangsup'o	Wiing	Anbyŏn	do.		46	72

37. Chuul	Chuulon	Kyŏngsŏng	Hamgyŏng-pukto		44–56.5	10,000
38. Hajuul or Kaneta	do.	do.	do.		53	300
39. T'angjisu	do.	do.	do.	Alkaline	50	100
40. T'ansu	Chunam	do.	do.	Alkaline saline	60	720
41. Sat'ansu	do.	do.	do.	do.	80	700
42. T'an	do.	do.	do.		60	
43. Songhŭng	Haksang	Sŏngjin	do.	Alkaline	52	1,173
44. Ŏbok or Sech'ŏn	Haksŏ	do.	do.		68	
45. Songnae	Yŏngbuk	Kilchu	do.		70	14
46. Sanggo	Sanggo	Myŏngch'ŏn	do.		Cold water to be added for bathing	150

Tepid Springs

Name of spring	Location			Quality	Temperature (°C)	Yield (koku/day)
	Myŏn	Gun	Do			
1. Ich'ŏn	Ŭmnae	Ich'ŏn	Kyŏnggi-do	Simple	31.5	
2. Tŏksan	Tŏksan	Yesan	Ch'ungch'ŏng-namdo	Common salt-bearing simple	36	
3. Unhang and Songjŏng	Pangjyang	Ich'eon	Kangwŏn-do	—	—	
4. Osaeg-Yangsu	Sŏ	Yangyang	do.	Common salt and alkaline carbonated	35	
5. Kalsan-Yangsu	do.	do.	do.	Carbonated	35	
6. Chogae-Yangsu	do.	do.	do.	do.	35	
7. Yujŏm-sa	do.	Kosŏng	do.	—	26	
8.	Sinam	P'yŏngsan	Hwanghae-do	—	28	
9. Onjŏng or Onhwa	Changdong	Hŭich'ŏn	P'yŏngan-pukto	Sulphurous	39	20
10. Majang	Inhŭng	Yŏnghŭng	Hamgyŏng-namdo	Weak common salt	38	
11.	Oha	Musan	Hamgyŏng-pukto	—	35.6	300
12.	Yongsŏng	Kyŏngsŏng	do.	Alkaline	38	50
13.	Changbaek	Kilchu	do.	—	Less than 35	

Cold Mineral Springs

Name of spring	Location			Quality	Temperature (°C)	Yield (koku/day)
	Myŏn	Gun	Do			
1. Ponjŏng	Punae	Changwŏn	Kyŏngsang-namdo	Vitriol		20
2. Pansong-Yangsu	Okp'o	Talsŏng	Kyŏngsang-pukto			17
3. Kilch'on-Hwangsu	Kilch'on	Yŏngch'ŏn	do.	Sulphurous		5
4. Wŏlha-dong Yangsu	Ch'ŏngsŏng	Ch'ŏngsŏng	do.	Alkaline	13	7.8
5. —	Puhae	Yŏngdŏk	do.	Iron		15
6. —	Ch'angsu	do.	do.	do.		5
7. Ch'ŏngju -Ch'usu	Pugil	Ch'ŏngju	Ch'ungch'ŏng -pukto	Carbonated	14–15	
8. Pugang	Puyong	do.	do.	Iron-bearing carbonated		
9. —	Togo	Asan	Ch'ungch'ŏng-namdo			
10. —	Yŏngok	Kangnŭng	Kangwŏn-do		12	0.7
11. —	Puksanoe	Ch'ungch'ŏn	do.		18	
12. —	Inje	Inje	do.			
13. —	Nae	do.	do.			
14. Kappi	Kop'yŏng	Taedong	P'yŏngan-namdo	Iron		
15. Kŏmsan-Yangsu	Kŏmsan	P'yŏngwŏn	do.	Carbonated		
16. Kangsŏ new	Tongjin	Kangsŏ	do.	do.	10	100
17. Kangsŏ old	Kangsŏ	do.	do.	do.	5	

18. —	Sŏngdae	Kangsŏ	do.	do.		
19. Yonggye-ni Yangsu	Sinanju	Anju	do.			0.2
20. Yongyon	Chunae	do.	do.			1.5
21. Unhŭng	Tong	do.	do.			100
22.	Aejŏn	Maengsan	do.	Simple	20	
23.	Hwangim	Yonggang	do.	Common salt		
24. Kungdong iron	Chiun	do.	do.	Vitriol		3
25. Sŏjŏng-ni iron	Samhwa	do.	do.	do.		12
26. Ch'ujongsu	Sŏha	Anak	Hwanghae-do			
27. Sŏgwang-sa	Munsan	Anbyŏn	Hamgyŏng-namdo	Carbonated		1
28. Okp'ok	Hamusan	Puryŏng	Hamgyŏng-pukto		24	
29.	Samchang	do.	do.		22.8	
30.	Pujŏm	do.	do.			

REFRENCES

1) Police Affairs Department, Government-General of Chosen (1914 and 1918.): Outline of springs in Korea. 2 volumes.
2) KAWASAKI, S. (1935). Mineral products from Korea, described in old records. *Report of Mineral Survey of Chosen,* v. 9, Chōsen Geol. Survey.
3) KAWASAKI, S. and KONGO, Y. (1928). Survey report of Masan hot spring in Ongjin-gun, Hwanghae-do. *Chōsen Geol. Surv. Bull.,* v. 8, no. 1.
4) KINOSAKI, Y. (1930). Survey report of Yujŏm-sa hot spring in Kŭmgangsan. *Chōsen Geol. Surv. Bull.,* v. 8, no. 3.
5) —— (1930). Survey report on Sŏgwang-sa Yangsu in Anbyŏn-gun, *Chōsen Geol. Surv. Bull.,* v. 8, no. 3.
6) KOMADA, I. (1924). Survey report on the Tongnae hot springs. *Chōsen Geol. Surv. Bull.,* v. 2.
7) —— (1924). Survey report of Haeundae, Yusŏng (new), Onyang, Sinchŏn, Anak and Yonggang hot springs. *Chōsen Geol. Surv. Bull.,* v. 3.
8) —— (1925). Table of Important hot springs in Korea. *Chōsen Geol. Surv. Bull.,* v. 3.
9) —— (1926). Survey report of Onjŏng-ni, Chuul, Hajuul, P'yŏngsan hot springs. *Chōsen Geol. Surv. Bull.,* v. 7.
10) —— (1926). Survey report on the cold carbonated mineral spring at Ch'ujŏng-ni.
11) —— (1926). Report on an examination of the Tongnae hot springs, 1, 2. *Chōsen Geol. Surv. Bull.,* v. 7.
12) KONDŌ, C. (1943). Uses of prospecting by self-potential method. *Mining Society, Korea Jour.,* v. 26, no. 6.
13) —— (1947). Application of self-potential method to hot springs. *Mineralogy and Geology* v. 1, no. 2.
14) Tōkyō Hygienic Laboratory (1940). Table of chemical composition of mineral springs in Japan.
15) Onsen-Kyōkai (Hot spring Co-operation) (1941). General view of hot springs in Japan.
16) NAKAMURA, S. (1917). Characters of tungsten ore deposits in Korea. *Mining Society, Korea Jour.,* v. 1, no. 4.
17) —— (1924). Hot springs in Korea. *The Globe* (Chikyu), v. 2, no. 1.
18) TATEIWA, I. (1928). Survey report on the Onyang hot spring in Asan-gun, Ch'ungch'ŏng-namdo. *Chōsen Geol. Surv. Bull.,* v. 8, no. 1.
19) —— (1928). Survey report on the Onjŏng-ni hot spring in Unsan-gun, P'yŏngan-pukto. *Chōsen Geol. Surv. Bull.,* v. 8, no. 1.
20) —— (1928). Survey report on the Suanbo hot spring in Koesan-gun, Ch'ungch'ŏng-pukto. *Chōsen Geol. Surv. Bull.,* v. 8, no. 1.