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CORRELATIONS AMONG TIDE, DISCHARGE, TEMPERATURE AND CHEMICAL CONTENTS AT KAMEGAWA, BEPPU CITY

By

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Abstract

This research was made simultaneously for the correlations among tide, discharge, spring temperature and chemical contents at Kamegawa, Beppu City, Dec. 26, 1964.

As the result, in the correlations between chlorine ion and sea tide (discharge), 12 wells out of 25 were negative and 6 wells out of 25 were positive and others had no correlation.

These phenomena were explained by former experiments.

1 Introduction

It is well known at present that confined or unconfined underground-water near the sea coast is affected by the sea tide and that temperature, discharge and chemical contents vary with the sea tide in case a thermal spring and an artesian well exist near the sea coast. And there are a large number of data and papers referring to the above phenomena. Reasonable explanations and analysis[1] have been attempted for discharge and temperature changing with the sea tide, but the relation of the change of chemical content with the sea tide has not been illustrated well.

Correlations between the tide and the concentration of chlorine ion were negative in the many of the data and were positive in few of them in some former researches. Former data could not be said general because then were a collection of a few data recorded of one or two wells at different times (seasons). Then, we have made continuous researches of 12 hours or 24 hours from A. M. 8, Dec. 26 th, 1964 in Kamegawa District, Beppu City. Researched district is shown in Figure 1 (Map 1). The area of the researched basin is one square kilometer and those are of the stratified type (alluvium).

2 Results of Research

There have been many researches[2] of the thermal spring and the under-

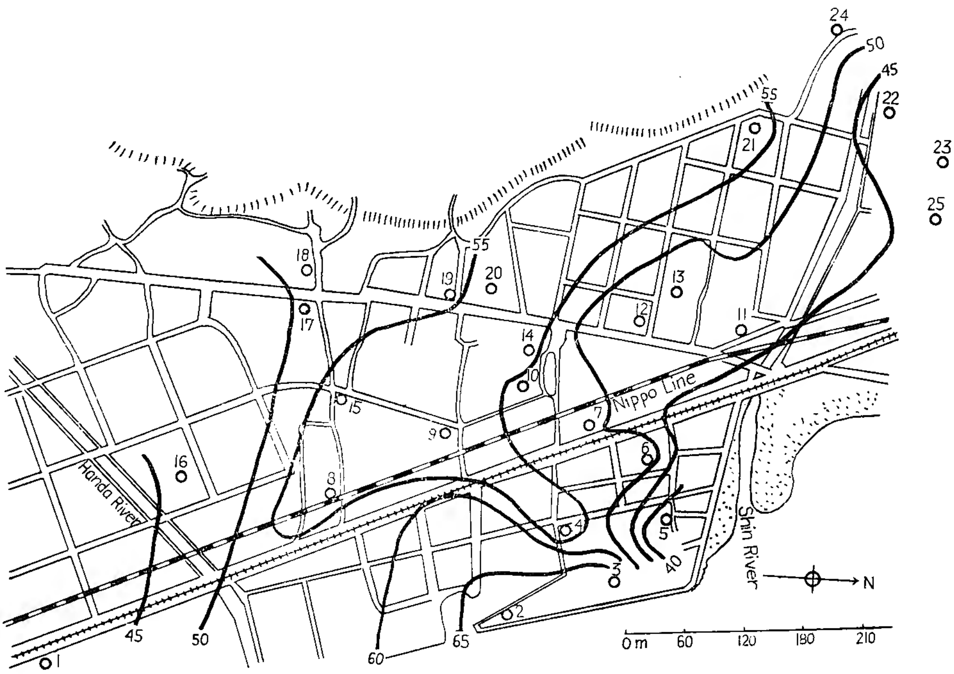

Fig. 1. Map showing temperature of spring water in Kamegawa, Beppu City, December 26, 1964. (in °C)

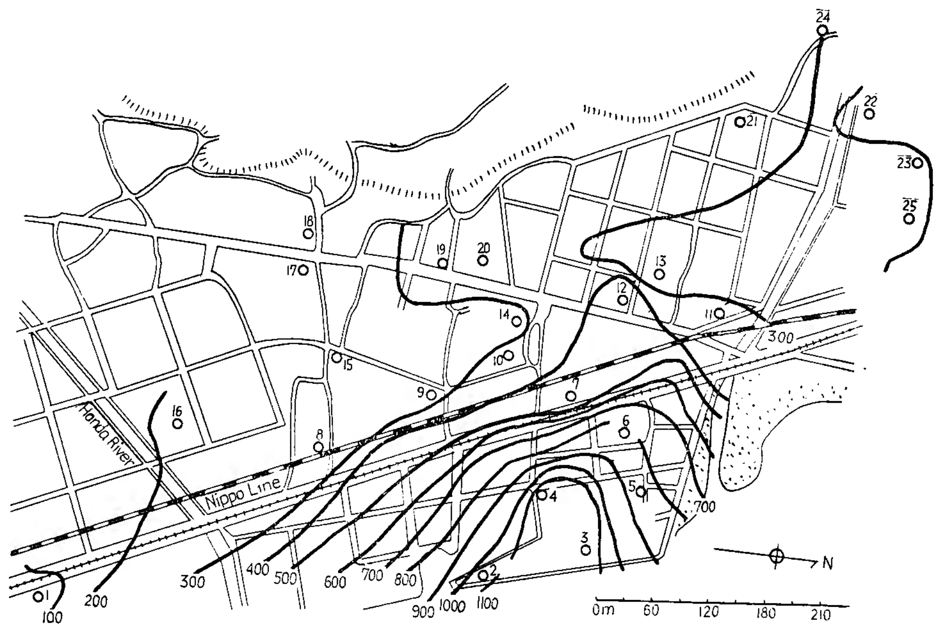

Fig. 2. Map showing distribution of chlorine ion concentration in Kamegawa, Beppu City, December 26, 1964. (in mg/l)

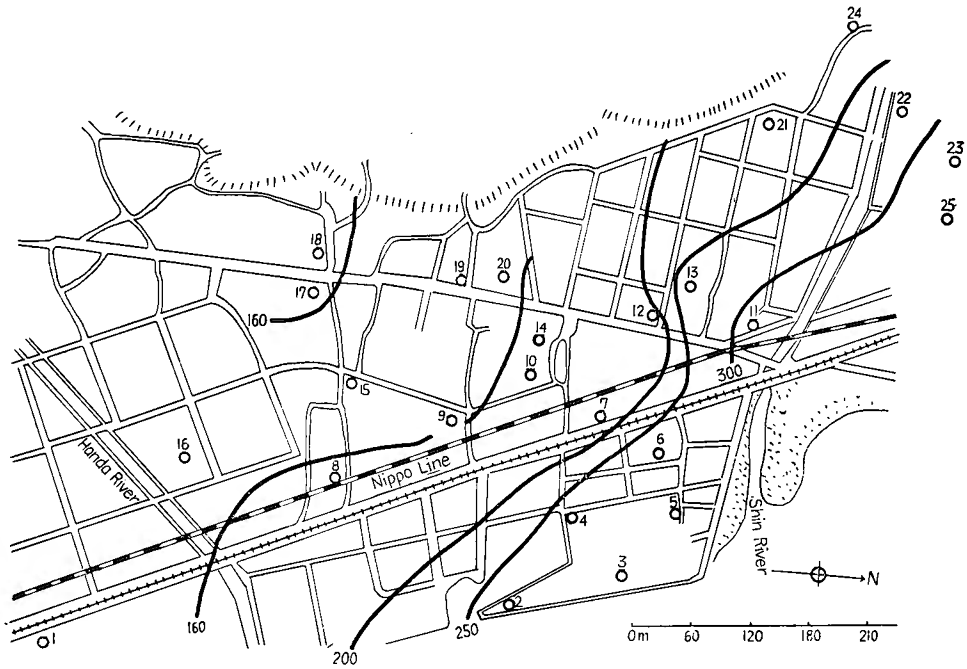

Fig. 3. Map showing distribution of total alkalinity (HCO_3^-) concentration in Kamegawa, Beppuy City, December 26, 1964. (in mg/l)

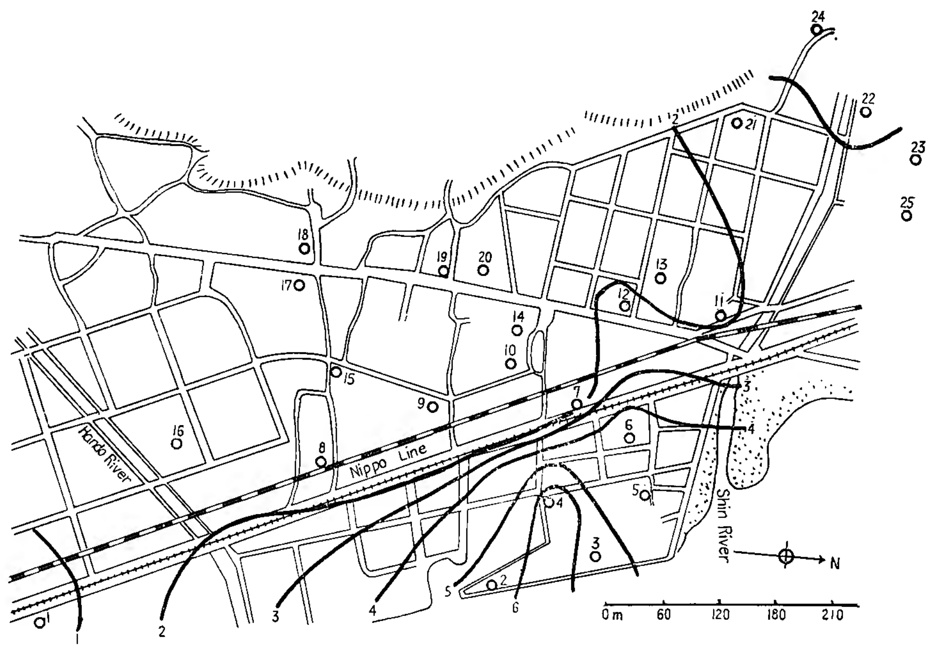

Fig. 4. Map showing distribution of calcium+magnesium concentration in Kamegawa, Beppu City, December 26, 1964. (in mm/l)

ground-water in Kamegawa District, Beppu City by this time. There were many maps of distribution for the temperature, the depth and the chemical contents in details. New maps of distribution of the above matters from this research are shown in Figures 1, 2, 3 and 4.

The temperature of thermal springs is high in northern region near the sea coast and low in southern region, but over the district still south in this map the temperature of thermal springs is eighty degrees (°C) or more. The concentration of chlorine ion involved in Nos. 2, 3 and 4 of the thermal springs near the sea coast is about one gram per litre and this concentration decreases with the distance from the coast. This distribution of the concentration of chlorine ion has the same tendency as the distribution of total concentration of calcium and magnesium ion. The distribution of concentration of BCG-alkalinity is high in northern region and low in southern region.

What matters when we make distribution maps of temperature, discharge and chemical contents of thermal springs, are that we know whether all the springs of the resarched basin belong to the same one vein of spring's strata, the maps of distribution of temperature, dischareg and concentration of chemical contents of springs would not be valuable. But still a mapping of the above data is a valuable work for several reson. It is convenient to us to find out the boundary of spring's vein and singular regions.

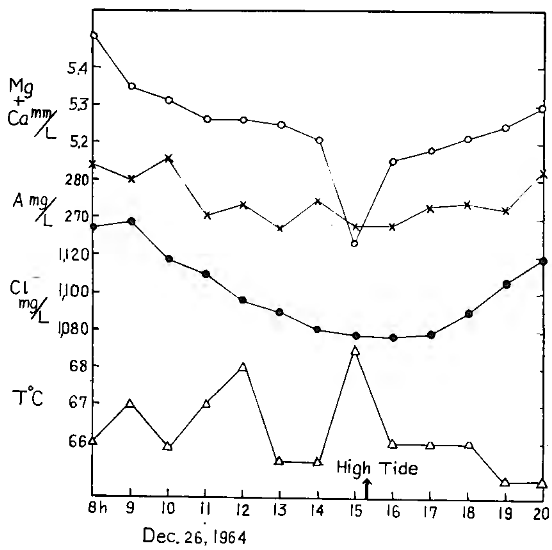

Fig. 5. Graph showing time change of chemical contents in spring water of No. 3 in Kamegawa, Beppu City, December 26. 1964,
(T : temperature in °C, Cl^- : chlorine ion concentration in mg/l, A : total alkalinity (HCO_3^-) in mg/l, Mg+Ca : magnesium ion+calcium ion in mm/l).

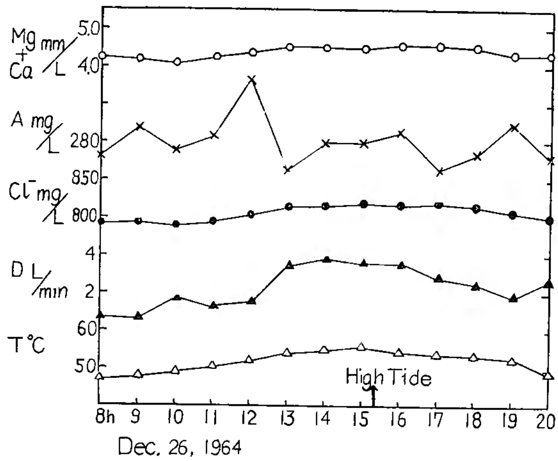

Fig. 6. Graph showing time change of chemical contents in spring water of No. 6 in Kamegawa, Beppu City, December 26, 1964.
(T, Cl^-, etc. See Fig. 5. D : discharge in l/min)

Some parts of this observations are illustrated by Figures 5 and 6. The results show that chemical contents and others very with the sea tide and it is uncertain to decide a chemical content at a well only by one sampring of the spring water. Values of chemical contents shown in Figures 1~4 are, then, taken by mean values of 12 or 24 hours observations.

In the correlations between chlorine ion and sea tide in this research, 12 out of 25 are negative and 6 out of 25 are positive and others have no correlation. The variations of total concentration of magnesium and calcium ions have the same tendency to the sea tide as chlorin ion.

Figures 5 and 6 (well numbers 3 and 6) show typical graphs of positive and negative correlation between chemical contents and sea tide.

3 Consideration of Results

It is reasonable to expect that the source of chlorine ion in this basin is sea water ratehr than fossil water confined in the ground at ancient times or volcanic water[3], though spring water may be partly mixed with both waters.

It is well known that when the sea water encroaches in the confined underground-water or the vein of spring water[4], the salt water from the sea encroaches wedge wise into the lower part of waterbearing stratum from the mouth opening to the sea. In this case, it must be discussed how the salt water mixes into discharge water from the spring in relation with the sea tide present, there are many explanations about the above phenomena, but each is wanting in universality.

Each of the explanation is shown in outline as follows. As the discharged volume from a spring is small at low tide, the stagnant time of spring water in a spring vein is long, so that the spring water dissolves a comparatively large amount of dissolvable substance and inversely when the discharged volume is larger at flood tide, the total value of dissolvable matter in all discharged volume is larger, but dissolvable matter in a unit volume of spring is less, that is, dissolving rate of dissolvable matter decreases at flood tide and high tide. This explanation[5] is not hard to understand, but in this research the correlation between sea tide and chemical contents is not always negative, but there are some positive correlations, too. And it is difficults to say the spring which shows negative or positive correlation are divided by a distance from the sea coast. To some extent the element of locality is recongnized in the distribution of the above correlations, but not the distance from the sea coast.

There is another which says that at high tide a underground-water having less concentration of chlorine ion mixes with orginal spring water. Such confined and waterbearing strata containing less chlorine ion are more affected by the sea tide than the original spring vein. And the underground of Beppu City is composed of alluvial strata, and therefore impermeable strata among the pervious strata are not perfectly impermeable, and due to some leakage paths through which underground-water mutually come and go and elasticity of strata and the degree of effect by the tide varies according to the kinds of strata[6]. These explanations must be considered with more interest, but also we have not got data to tell whether it's theory is a right interpertation or not.

We assume that a waterbearing stratum is perfected sealed on upper and lower side by impermeable strata. And when in that waterbearing stratum, underground-water (spring water) of different densities is stratified in consequence of the intrusion of the sea water, we with to state in full the fact that the correlation between the discharge (tide) and the concentration of chlorine ion can be either negative or or positive. In the former experimental reports[7] of two-layer's liquids, in case a strainer of the conduit pipe intruded into the upper layer's liquid of an aquifer, a denser liquid of lower layer coned up with the increase of the discharge and the mix rate of lower liquid into the discharge increased. In this case, the correlation between ihe discharge (tide) and the concentration of chlorine ion was positive. Next. when the strainer of the conduit pipe intruded into the lower denser liquid, the absolute discharge per unit time of the lower layer's liquid increased due to the increase of the discharge, but the mix rate of that liquid in the total discharge decreased. This fact shows that the correlation between the discharge (tide) and the concentration of chlorine ion is negative.

The reason why the correlations between the discharge (tide) and the concentration of chlorine ion are often negative, is that, when the artesian well was dug up to some depth, the conduit pipe was put into the water- or oil-bearing stratum and farther into the impermeable stratum such as the clay

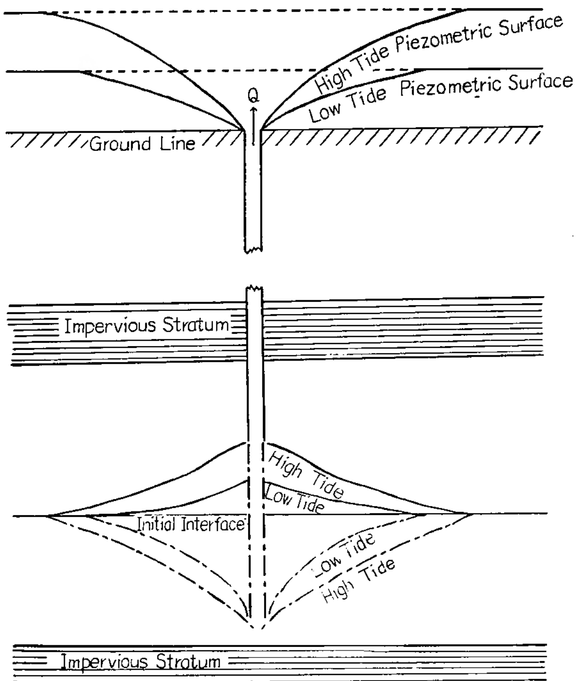

Fig. 7. Model figure of coning up and down of under-layer's liquid of confined underground-water in accordance with end position of condiut pipe.

or rock bed and, the strainer was opened up to the end of the conduit pipe in an ordinary way.

By the above explanation for the ideal waberaring stratum confined top and bottom by the impermeable stratum, the correlation between the discharge and th concentration of chlorine ion in the coastal underground-water is understood roughly. Of coure, the above theory is an explanation from the results of former experiments and it goes without saying the experiments that are not sufficient, so that more experiment will have to be made in future.

It is a question whether the interface between upper and lower layers moves up and down or not with the sea tide and whether at what distance from the sea strand exists, the movement of the interface by the sea tide vanishes. Concerning this questions we will report later.

Acknowledgments

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