Statistic analysis of non-volcanic geothermal resources of northern Japan - based on geothermal resources maps -

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Abstract

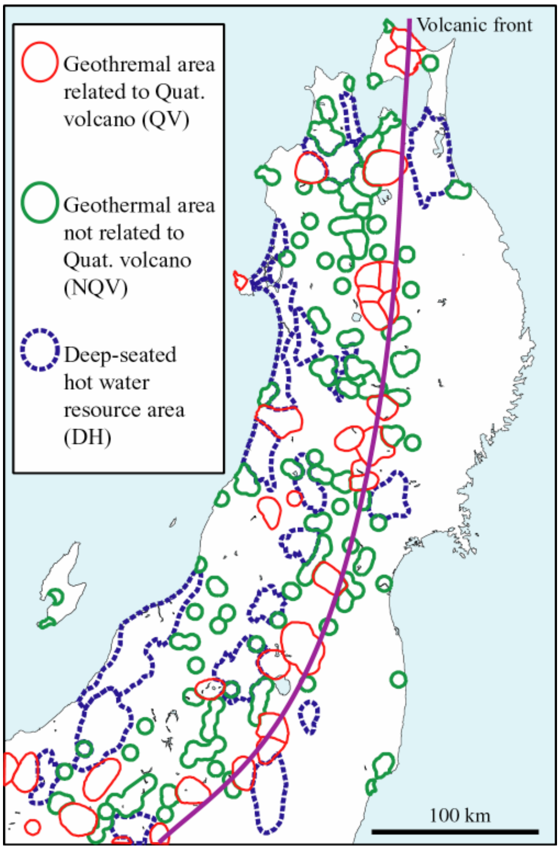
A series of geothermal resources maps were compiled at a 1:500,000 scale in northeast Japan to allow better understanding of characteristics of the geothermal resources and geologic control factors. Geothermal resources are classified into following three types: geothermal resources closely related to young volcanism, deep-seated hot water resources in sedimentary basins, and other resources. Hot springs that belong to the latter two resource types were statistically analyzed based on various parameters. The hot springs with the largest production rate or the highest temperature are selected from each geothermal area as the representative hot springs, and compared each other in terms of chemical characteristics, temperatures, dissolved chemical concentrations and production rates of hot springs. Most hot springs are classified into three types: diluted hot springs, chemically mixed hot springs, and chloride-rich concentrated hot springs. Amount of total dissolved matters increases from diluted hot springs to concentrated hot springs, but temperature and production rate do not show clear correlation with the hot spring types.

Keywords

non-volcanic geothermal resource, deep-seated hot water resource, hot spring, statistics, northern Japan

Introduction

Geological Survey of Japan has bees publishing *Geothermal Resources Maps* to allow better understanding of characteristics of the geothermal resources and geologic control factors. Three *Geothermal Resources Maps* [1, 2, 3] cover the Tohoku volcanic arc in the northern part of Japan, and these maps were complied into a CD-ROM publication [4] that contains GIS vector data sets of the geothermal resources maps. The Tohoku volcanic arc in northern Japan is one of typical trench-volcanic arc systems and contains active volcanoes and vigorous geothermal activities. Besides geothermal systems that are closely related to young Quaternary volcanoes, many non-volcanic geothermal areas are identified (Fig. 1). Generally, these non-volcanic geothermal resources are of lower temperature than volcanic geothermal resources and not suitable for electric power generation. However, these geothermal resources are located close to populated areas and easy to be developed for direct use. Therefore the effect of the development of these resources on environments is large and detailed studies on mechanisms and resources assessment of non-volcanic geothermal resource are necessary. In this paper, we show the results of a basic statistic study on the non-volcanic geothermal resources in Tohoku volcanic arc based on the geothermal resources map data.



Fig, 1 Distribution of geothermal resources areas in the Tohoku volcanic arc, northern Japan.

Classification of geothermal resources

On the geothermal resources maps, geothermal resource area are defined as an area which bears geothermal fluid of 42 degree C or higher. Geothermal resources are classified into following three types (Fig. 2):

(1) Geothermal resource related to Quaternary volcano (QV): The resource area of this type is defined as volcanic edifice of Middle Pleistocene to Holocene and surrounding area by five kilometers.

(2) Deep-seated hot water resource (DH): This resource type is hot water stored in late Neogene to Quaternary sedimentary basins. Resource areas area figured out based on geology and low gravity anomalies.

(3) Geothermal resource not related to Quaternary volcano (NQV): This type contains all other geothermal resources than the former two types. Therefore this type is expected to contain resources of various origins.

The latter two types, DH and NQV, are treated as non-volcanic geothermal resources in this study. Non-volcanic geothermal areas are recognized broadly west (back-arc side) and near east of the volcanic front of the Tohoku volcanic arc, whereas only a few areas are located on the fore-arc side (east) of the volcanic front (Fig. 1). The DH-type resources are located in major coastal plains and mountain basins. The NQV-type resources are located in mountain and hilly areas and the size of individual resource area is smaller than QV-type and

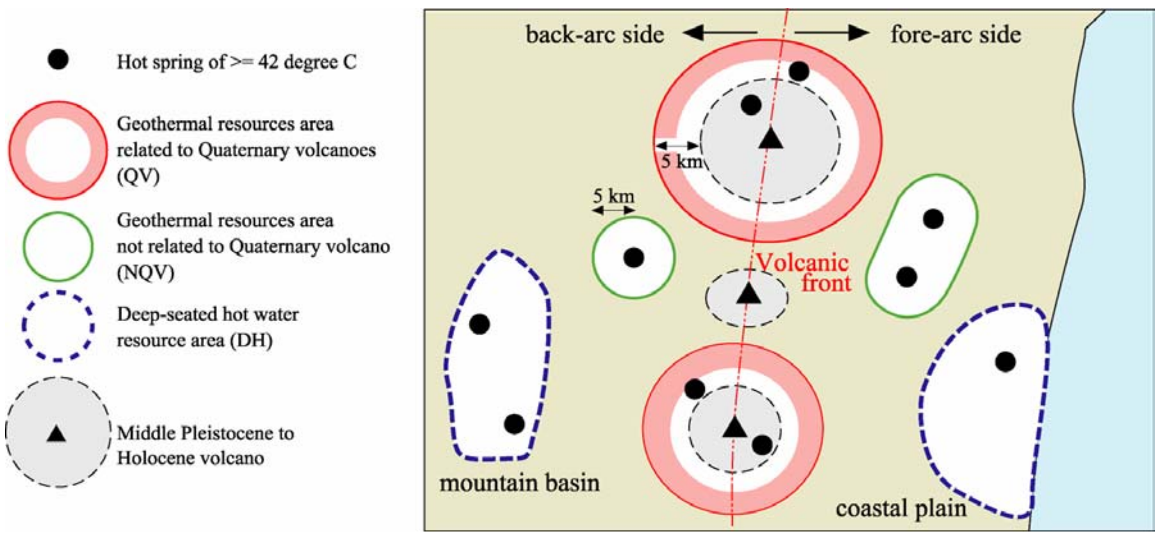


Fig. 2 Schematic drawing showing definition and geographical situation of geothermal resources areas.

DH-type. The smaller size indicates that the heat source of NQV-type resource is smaller and/or less intense and that the extent of the reservoir is rather restricted.

Statistic overview of non-volcanic geothermal resources

In the study area, 33 Quaternary volcano-related (QV) geothermal areas, 20 deep-seated hot water (DH) geothermal areas, and 89 not Quaternary volcano-related geothermal areas. The total number of hot springs is about 1780. Because there is a wide range in data quality among the hot spring data, we made a preliminary study with selected hot spring data. The hot springs with the largest production rate or the highest temperature area selected from each geothermal area as the representative hot springs, and compared each other in terms of chemical characteristics, temperatures, dissolved chemical components, and production rates of the hot springs. Because there is no hot spring with available data in one DH-type area, 108 hot spring data sets were studied. Among them five areas lack production rate data.

Relation among temperatures, total dissolved matter, and production rates are shown in Fig. 3 as an overview of the non-volcanic geothermal resources in the study area. There is a very weak and positive correlation between temperature and total dissolved matter. Whereas no clear relation is recognized between temperature and production rate, and also between total dissolved matter and production rate.

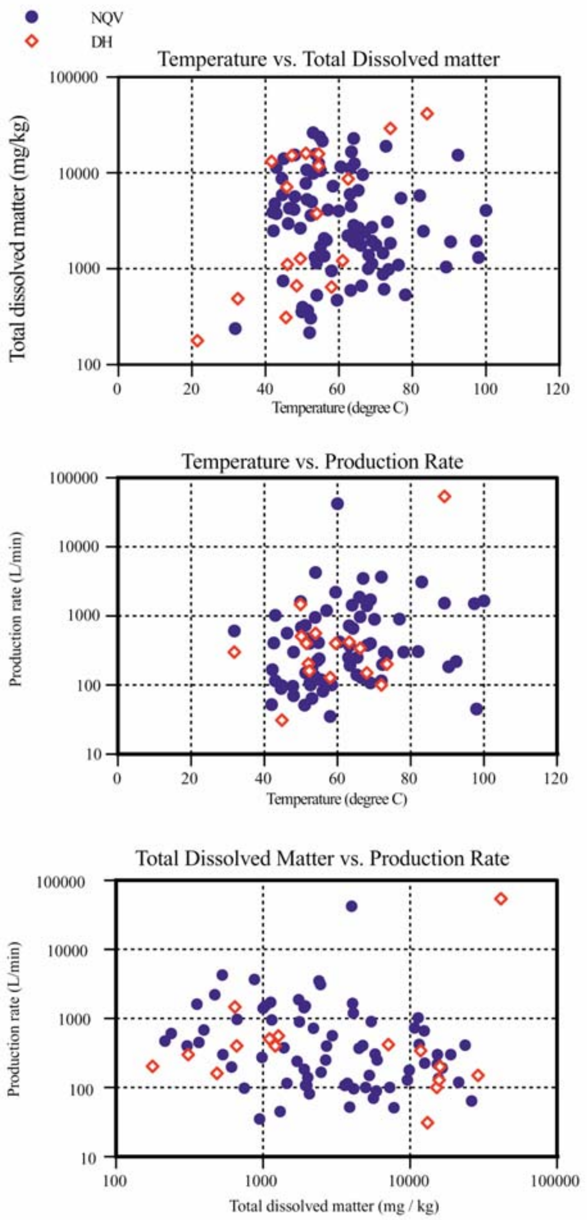


Fig.3 Relation among temperature, total dissolved matter and production rate of the selected hot springs.

Generally, the hot springs selected from NQV-type resource areas are higher in temperature than those from DH-type resource areas. In the other two parameters (total dissolved matter and production rate), there is no significant difference between DH-type and NQV-type.

Chemical characteristics and estimated origins of hot waters

Among anion species, chloride anion is useful to estimate the origins of the hot waters. Amount of chloride shows clear positive correlation with total dissolved matter (TDM). Four

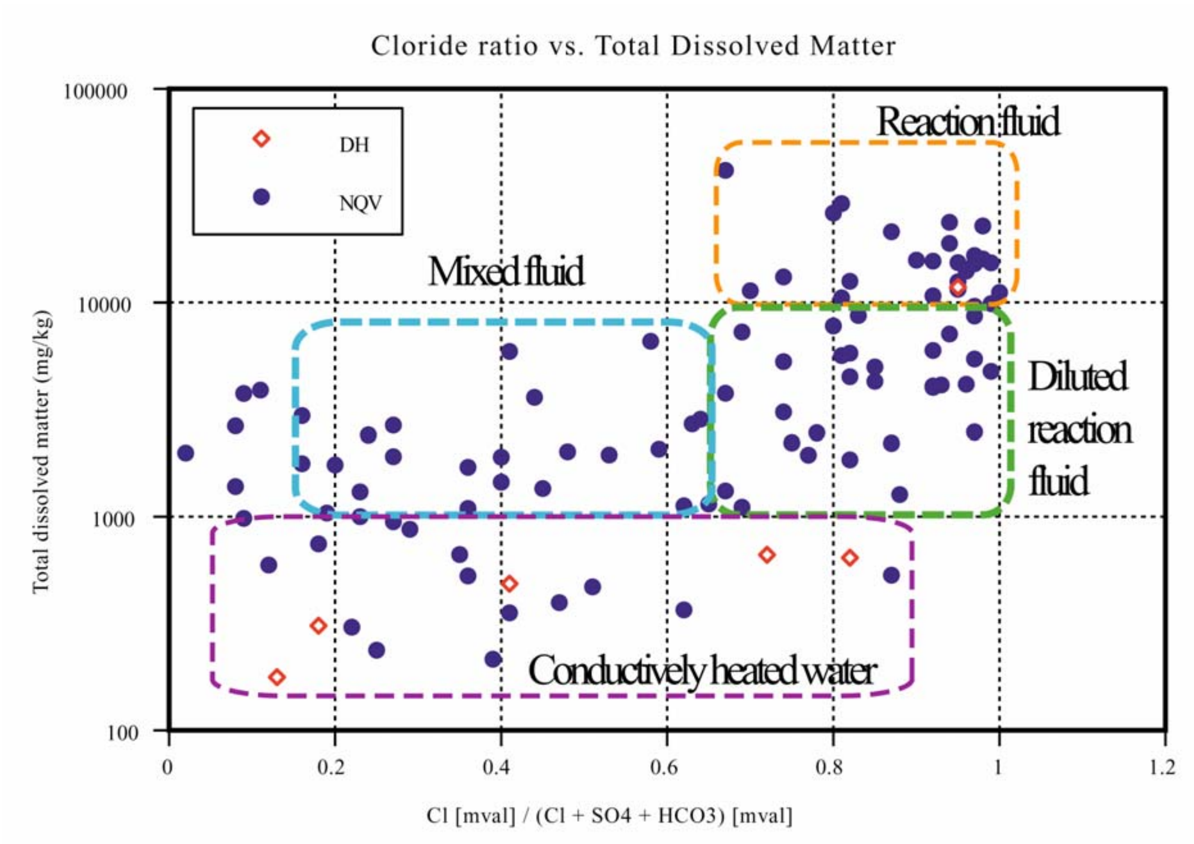


Fig. 4 Relation between chloride ratio and total dissolved matter and estimated origins of hot waters.

groups of different origins of hot waters are estimated based on the chloride-total dissolved matter relation (Fig. 4).

The most chloride-enriched group, of which TDM is more than 10000 mg/kg, must be representing reaction fluid in the depth or in high temperature environment. The group of less TDM but almost the same chloride ratio (more than ca. 0.7) is thought to be diluted reaction fluid. Fluids with less TDM than 1000 mg/kg may be ground water origin and conductively heated without enough reaction or chemical exchange. Fluids with chloride ratio of less than 0.7 and with medium TDM content are thought to be mixtures of fluids of other origins.

Conclusions

Non-volcanic geothermal resources in the Tohoku volcanic arc, northern Japan, are divided into deep-seated hot water resource and geothermal resources not related Quaternary volcano. Representative hot springs that belong to these two types of geothermal resources were statistically analyzed. Most hot springs are classified into three types: diluted hot springs, chemically mixed hot springs, and chloride-rich concentrated hot springs. Amount of total dissolved matters increases from diluted hot springs to concentrated hot springs, but temperature and production rate do not show clear correlation with the hot spring types.

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* in Japanese with English abstract