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Research on Sustainable Utilization of Shallow Geothermal Resources in Beijing, China

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ABSTRACT

The city of Beijing, as China's capital, has more than ten years of history in development and utilization of shallow geothermal energy. The technology of ground source heat pump is an important measure of developing renewable energy in Beijing, which makes use of shallow geothermal energy for building heating and cooling. By the end of 2012, the number of ground source heat pump projects in Beijing has reached 1,217 with the application construction area of 37.59 million square meters. The ground source heat pump makes a significant contribution for optimizing energy structure, reducing consumption of coal and other fossil fuels and promoting energy conservation.

This article describes the occurrence background and status quo of shallow geothermal resources, elaborates the existing problems in the exploitation and utilization of shallow geothermal resources, such as the suitability in different geological conditions, the key technologies restrictions and negative effects on the geological environment. Finally it puts forward the countermeasures and suggestions aimed at these problems on the sustainable exploitation and utilization of shallow geothermal resources in Beijing.

1. INTRODUCTION

Shallow geothermal energy is a renewable energy and local resource which can improve the capital energy resources structure, which generally exists in the different underground geologic body with some characteristics of large volume, safe and reliable, renewable, significant environmental benefits. This kind of energy is controlled by regional geology, hydrogeology conditions.

The utilization of shallow geothermal resources is realized through ground source heat pump system, and is also served for life and production. Ground source heat pump system is mainly use a large amount of energy stored in the underground soil, rock or other media to provide heating or cooling for building space. Unlike the conventional systems, ground source heat pump will no longer use coal / oil / gas or other fossil fuels. It can completely replace the conventional thermal heating system.

There are a hundred years of development history on the utilization and development of shallow geothermal resource used by heat pump technology. In 2000, there were 26 countries use ground source heat pump technology in the whole world. In 2005, the number expanded to 33 countries. By the end of 2010, there were 43 countries in the world make use of the technology. The research on the development and utilization technology of shallow geothermal resources began in 1980s to 1990s.

Since 2004, the annual growth rate of China's ground source heat pump market exceeds more than 30%, which is much higher than the world average growth rate of 20%-22% of the corresponding period. By the end of 2012, the total application area is about 21 million square meters. The projects concentrates in north and northeast areas, and the types of buildings are mainly concentrated in the office building, hotel, hospital, market, school and residential areas. From the energy saving and environmental protection and sustainable development point of view, the shallow geothermal energy has become one of the hot issues of common concern in the ground source heat pump field and geological system.

The development and utilization of shallow geothermal energy gain faster in Beijing, China. A large number of exploratory research works are carried out and a lot of valuable experiences are gained, but there are still some problems need to be solved. The study will lay a firm foundation for the benign application of ground source heat pump technology.

2. CHARACTERISTICS OF SHALLOW GEOTHERMAL RESOURCES IN BEIJING

2.1 Occurrence Background of Shallow Geothermal Resources in Beijing

Shallow geothermal energy is a form of thermal energy and a part of geothermal resources. The distribution of shallow geothermal energy is controlled not only by the geological structure, but also has close relation with the Quaternary strata, lithology and structure of groundwater occurrence characteristics. Figure 1 is a sketch map of geological structure in Beijing.

2.1.1 Control on the Ground Temperature Field by Geological Structure

The ground temperature field distribution and temperature changes have a clear link with geological structure. The tectonic setting structure is well-developed in Beijing area, which undergoes the movement of Indosinian movement, Yanshan movement and many times of tectonic movements, and forms a large number of NW and NE faults. Even some individual fractures still active at present. Crack formation provides a good path for the deep heat source, so that the temperature near fault is higher.

2.1.2 Quaternary Structure and Water Rich Features

The Quaternary sediments in Beijing plain are controlled by bedrock geology tectonic, climate change and fluvial process dominated by Yongding River, Chaobai River, Juma River. It mainly distributes in plain areas and the river valley, piedmont and mountain basin. On the whole, from northwest to Southeast, from mountain to plain, the Quaternary sedimentary increases in thickness and levels, the sediment particles become thinner which can be seen in Figure 2.

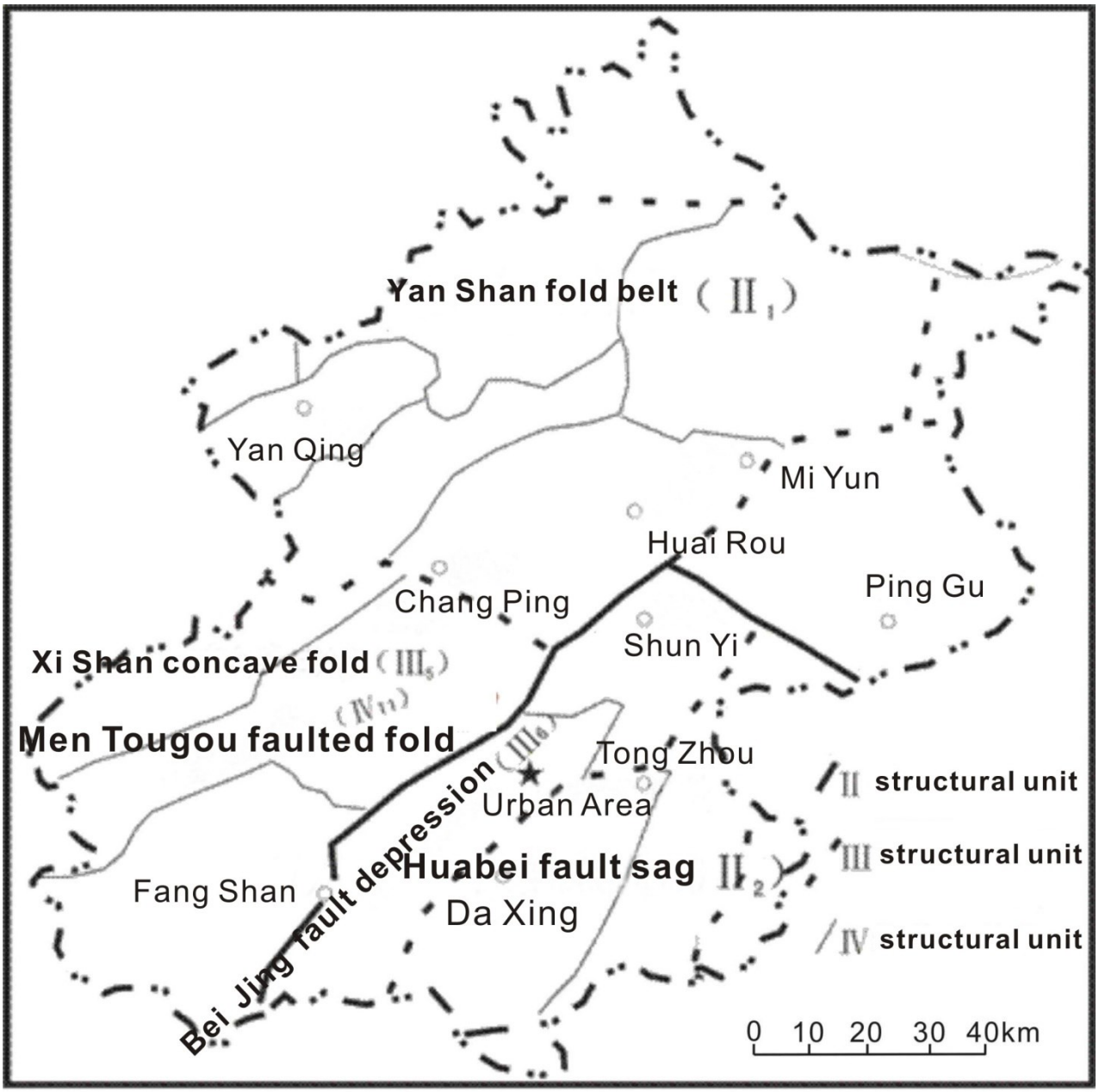

Figure 1: A sketch map of geological structures in Beijing Plain

Quaternary pore water mainly occurs in sand and gravel of river alluvial formation in Beijing plain. Sand and gravel layer have good stratification, and easy to form a continuous aquifer. Different regions have different water rich characteristics. The deposition regular pattern of loose sediment of each river Quaternary is roughly the same. From the top to bottom of alluvial fan and alluvial plains, aquifer particles changes from coarse to fine, the aquifer structure is gradually transits from single layer to multilayer, depth of groundwater is from deep to shallow.

2.1.3 Effect of Groundwater Runoff on the Ground Temperature Field

Shallow groundwater effects not only on the vertical temperature, but also has very obvious influence in the horizontal direction. The overall trend of groundwater flow is from the mountainous area to the plain, from North West to South East in Beijing plain. The foreland has good runoff conditions with the hydraulic gradient of 0.5 ‰ - 1.8 ‰; from the alluvial top to the central part, aquifer hydraulic gradient decreases gradually with the hydraulic gradient of 0.25 ‰ - 0.5 ‰; the groundwater runoff conditions in the lower part of the alluvial fan gets worse with the hydraulic gradient of 0.1 ‰ - 0.2 ‰.

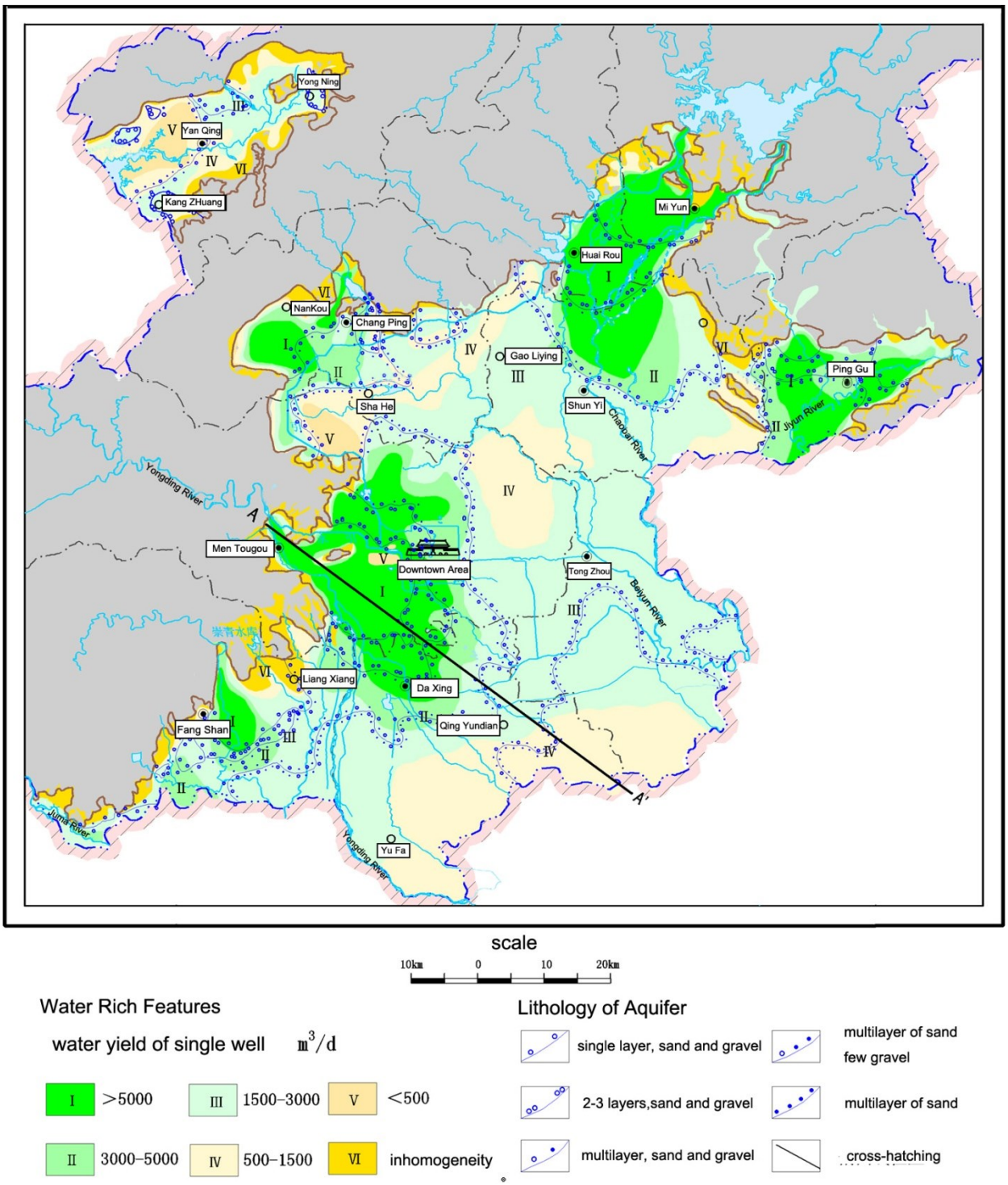

Figure 2: Aquifer Structure of Loose Rock Pore Water and Rich Water Partition Map in Beijing Plain

2.1.4 Distribution of Aquifer and Burial Conditions

From northwest to southeast, the aquifer particles change from coarse to fine in Beijing plain, the aquifer gradually varies from single sand pebble layer to multilayer sand and gravel, and the water permeability and water yield property are getting strong to weak. Beijing plain is an alluvial plain which forms by fluvial process. It has great thickness of Quaternary, coarse grain in aquifer, and well water yield property. Capacity of single well is between 500 - 5000 cubic meters per day.

2.2 Development Status of Shallow Geothermal Resources in Beijing

As the capital of China, Beijing has for more than ten years of history on the development and utilization of shallow geothermal energy. Ground source heat pump technology utilizes shallow geothermal energy for heating or cooling for buildings, is an important measure of developing renewable energy in Beijing. According to statistics, by the end of 2012, the number of ground source heat pump projects has reached 1,217 with construction area of 37,590,000 square meters. It makes a significant contribution

to optimizing the energy structure, reducing the coal and other fossil energy consumption, and promoting energy saving and emission reduction.

3. PROBLEMS IN THE PROCESS OF DEVELOPMENT AND UTILIZATION OF SHALLOW GEOTHERMAL RESOURCES

With the scale of ground source heat pump projects expands rapidly, it faces more and more problems, especially the impact of geological environment is gain more attention by people.

3.1Suitability in Different Geological Conditions

The development and utilization of shallow geothermal energy requires to account for local geological environment characteristics and the function of groundwater resource. If the Quaternary loose layer is mainly with large thickness of sand gravel, with better groundwater recharge runoff and rich water resource. The groundwater recharge is relatively easy, and it won't produce obvious land subsidence problems. The region is suitable for large area utilization of groundwater source heat pump to developing shallow geothermal energy. If the local hydro-geological conditions are relatively poor with slower groundwater recharge rate, so it is different to recharge groundwater, it can use ground source heat pump system. While the cost of this method is higher and it needs to occupies large underground space.

3.2 Key Technologies Restrictions on Development and Utilization of Shallow Geothermal Resources

The rock-soil thermal parameters are the most important basic data for the investigation and evaluation of development and utilization of shallow geothermal resources. However, currently there are no instruments accredited by national or industry for testing rock-soil thermal parameters in China and no specific provisions and requirements in situ test on rock and soil thermo-physical parameters.

In practical work, the lack of technical standard of rock and soil thermo-physical parameters testing, not only affects the shallow geothermal energy resources evaluation and exploitation zoning and planning, but also restricts the scientific design of ground source heat pump system engineering, it often cause the temperature of rock and soil continue to increase or decrease, influences the efficiency seriously.

In the field of development and utilization of energy, quality of ground source heat pump units is the key factor of energy saving. Like other new things, ground source heat pump technology encounters some difficult technical problems in the marketing process. At present, because of lacking unified national products manufacturing standards on ground source heat pump, the quality of products cannot be guaranteed. Due to the technical level of ground source heat pump industry practitioners is uneven, it results not saving energy in some ground source heat pump projects, or even impossible to run.

3.3 Negative Impact on the Geological Environment

In the process of utilization of shallow geothermal energy, groundwater only plays a role of energy exchange medium. Heat transfer will be through groundwater wells to recharge groundwater recharge aquifers to the original. But in actual operation, there are high technical requirements on the water recharge and it needs to ensure the reinjection water quality. In order to reduce the cost, some operators often violate requirements, it results in waste of groundwater resources and destruction, and even leads to land subsidence and groundwater funnel and other geological disasters, and will cause surface cracks and building inclination and cracking problems. At the same time, because of the influence of no signification of exploration on the hydro-geological conditions and equipment corrosion and other factors, it is easy to cause underground regional water pollution or ground temperature field changes. These negative effects can be avoided or eliminated completely, but if it takes a laissez faire attitude and no effective measures, it will produce certain negative effects on geological environment.

4. COUNTERMEASURES AND SUGGESTIONS

Making use of ground source heat pump technology to develop and utilize shallow geothermal energy is one of the important measures to achieve energy-saving and reducing greenhouse gas emissions.

China's annual new construction area is about 2 billion square meters, and the new residential construction area is expected to achieve 10-15 billion square meters in 2020. The prospect of development and utilization of shallow geothermal energy is very wide. At present, Beijing municipal government joins the promoting of development and utilization of shallow geothermal resources and related planning closely as a specific energy saving measures. To actively promote the sustainable development and utilization of shallow geothermal energy, aiming at the above problems, we propose the following suggestions.

4.1 Further Exploration and Evaluation on the Development of Shallow Geothermal Resources

The development and utilization of shallow geothermal resources are restricted by the local hydro-geological conditions (underground water, stratum structure, the permeability of the aquifer, groundwater quality etc.). Therefore, the development and utilization of shallow geothermal resources in a scientific way must pay more attention to resources investigation and assessment in earlier stage. The work should base on the hydro-geological exploration data and carry out additional exploration work which is necessary to obtain the parameters on rock and soil thermal conductivity and permeability. Investigation on heat pump related soil parameters is the key work. Some research on the relationship between the shallow geothermal resource and groundwater should be carried out. On this basis, draw up the planning on the development and utilization of shallow geothermal resource, carry on the layout rational, determine the appropriate exploitation area, and puts forward the reasonable scale of development and utilization, propose the geological disaster prevention and environmental geological problems.

4.2 Strengthen the Related Technology Research and Development, Improve the Technical Support System

First of all, in the aspect of investigation and evaluation of shallow geothermal resource, the relevant departments should develop technical standards on rock and soil thermo-physical parameters in situ testing as soon as possible and establish strata database of

different thermal properties. Secondly, it needs to vigorously promote technical training and promotion of ground source heat pump to improve professional level and practical ability for practitioners, strengthen the independent research and development, and enhance the R & D and production level of ground source heat pump unit. Finally, a national level R & D platform should be established as soon as possible to realize the sustainable development of resources.

4.3 Establish Long-term Geological Environment Monitoring System, Reduce the Negative Influence

The continuous heat exchange of ground source heat pump system may cause the change of underground temperature field, chemical field and underground water environment. In addition, the water source heat pump system will influence the groundwater oxidation - deoxidation environment, balance of groundwater microorganisms and water quality. Therefore, it needs to establish long-term monitoring system on the ground temperature field, make secular observation on heat wells and surrounding formation temperature, water level, water quality changes, especially recharge ability and temperature recovery of the heat well. Through the long-term monitoring, it can timely grasp the dynamic changes of ground temperature, water-soil quality and ground deformation to prevent problems of geological environment.

CONCLUSIONS

In the broad environment of national leading energy-saving and emission reduction, shallow geothermal resources as a new-born thing will gain more fully development. The ground source heat pump industry as the technical method of development and utilization of shallow geothermal resources will has a very broad prospect. Also the exploitation of shallow geothermal resource will face more opportunities and challenges. In order to achieve rational, efficient, sustainable development and utilization of shallow geothermal energy, it gets very important to combine the basic research with monitoring job in the process of construction of ground source heat pump projects.

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