

Status and Future of Geothermal Resources Development and Utilization along Qinghai-Tibet Railway in Tibet, China

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ABSTRACT

Under the background of China's western development strategy and the operation of Qinghai-Tibet Railway, the area along the Railway in Tibet ushers in a good opportunity for development. Making full use of local superior geothermal resources is an effective way to ease the energy shortage in development process in this area. Thus, efforts are made in this paper in investigation and research. There are nearly 40 geothermal anomaly areas in a straight-line distance of about 240 km, a railway journey of about 450 km, within a range of no more than 55 km far from the Qinghai-Tibet railway from Amdo County, the north end, to Lhasa city, the south end. Among those 44 anomaly areas, 22 were picked out for geological or drilling exploration. Exploration results show that 10 areas such as Yuzhai, Nagqu, Roma, Gulu, Damxung, Ningzhong, Yangbajin, Jiguoda, Yangyi, and Qusang, have good prospects of development due to relatively larger resources potential, better natural environment, and shorter distance from populous towns. More attention was put on these 10 areas. Based on analysis of locations, scales, chemical characteristics, resource potentials, and research levels of these areas along the railway, utilization status and main existing problems are summarized. And furthermore, comments and suggestions are put forwards for future development and utilization.

1. INTRODUCTION

China Tibet is located in Mediterranean – Himalayan geothermal belt, which is one of the three most active geothermal belts in the world. Tibetan area is the most typical geothermal area in China with the largest geothermal resources capacity. Six hundreds of geothermal anomalies were discovered in Tibet, and 342 of them are available for development. Surface springs of the vast majority of those anomalies are over 80 °C, total power generation potential capacity is beyond 100 million kW_e. However, limited by poor geological environment and climate conditions, small population, combined with weak economic foundation and other factors, development and utilization of geothermal resources in Tibet has been in a very backward state.

Things began to change more or less in recent years. With the implementation of the strategy of "western development" in China, especially the traffic operation of the Qinghai-Tibet railway, Tibet's social economy ushers in important opportunity for development. It shows very important practical significance and objective outlook to make further study in order to make reasonable development and utilization of geothermal resources.

The area this paper focuses on is the region along Qinghai-Tibet railway in Tibet (Figure 1). It would play an important role in the social and economic development in Tibet. How to make full and reasonable use of the rich geothermal resources and how to make effective protection of special eco-geological environment in the same time is a key scientific question for preliminary study to solve.

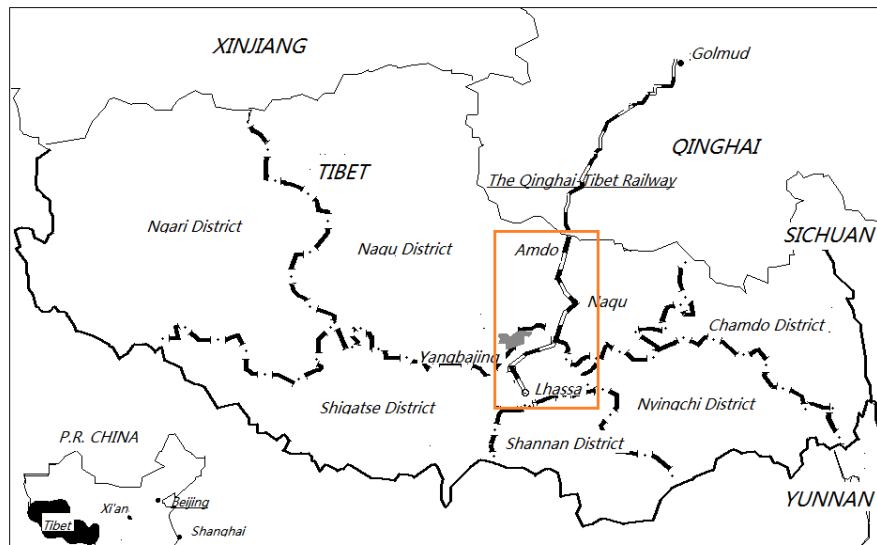


Figure 1: Location of study area

2. GEOLOGICAL BACKGROUND AND GEOTHERMAL ANOMALIES

The Qinghai-Tibet plateau is the youngest and largest plateau in the world. It has very complex geological structures due to several large-scale tectonic movements associated with magmatic intrusion and eruption activities during the long geological history in particular after the Mesozoic era. It shows structure changes of scales. Before Yanshan epoch, the region is relatively stable; there are various types of sedimentary construction and paleontology. Since the Himalayan period, magnificent plateau landscape had formed with the beginning of large-scale uplift and the ending of settlement history. Since Cenozoic era, tectonic activities has become very frequent as the variation of geological stress. The former structure framework with main east-west trending was gradually destroyed, and a series of tensile, shear and torsion active tectonic belt with north-south trending was formed. Among these many active structures, the Dangxiong-Yangbajing-Duoqingcuo belt is the most typical and grand one. The study area of this paper is just in the active tectonic belt.

The study area, region along Qinghai-Tibet railway in Tibet, is very rich in geothermal resources. There are nearly 40 geothermal anomaly areas in a straight-line distance of about 240 km, a railway journey of about 450 km, within a range of no more than 55 km far from the Qinghai-Tibet railway from Amdo County, the north end, to Lhasa city, the south end. Among those 44 anomaly areas, 22 were picked out for geological or drilling exploration, such as Cuona, Guozu, Yuzhai, Naqu, Roma, Tuoma, Minquguo, Gulu, Dongweng, Yuela, Qimiduo, Dangxiong, Ningzhong, Congwanong, Laduogang, Gulingqu, Qulongduo, Yangbajing, Gariqiao, Jidaguo, Yangyi, Qusang, and etc. Detailed geological investigation had been made in Yangbajing, Naqu, Laduogang and Yangyi geothermal fields. The results show that Yangbajing and Yangyi geothermal fields are proven high temperature geothermal fields with reservoir temperature of over 150 °C (Figure 1, Tibetan Institute of Geological Survey. 2009).

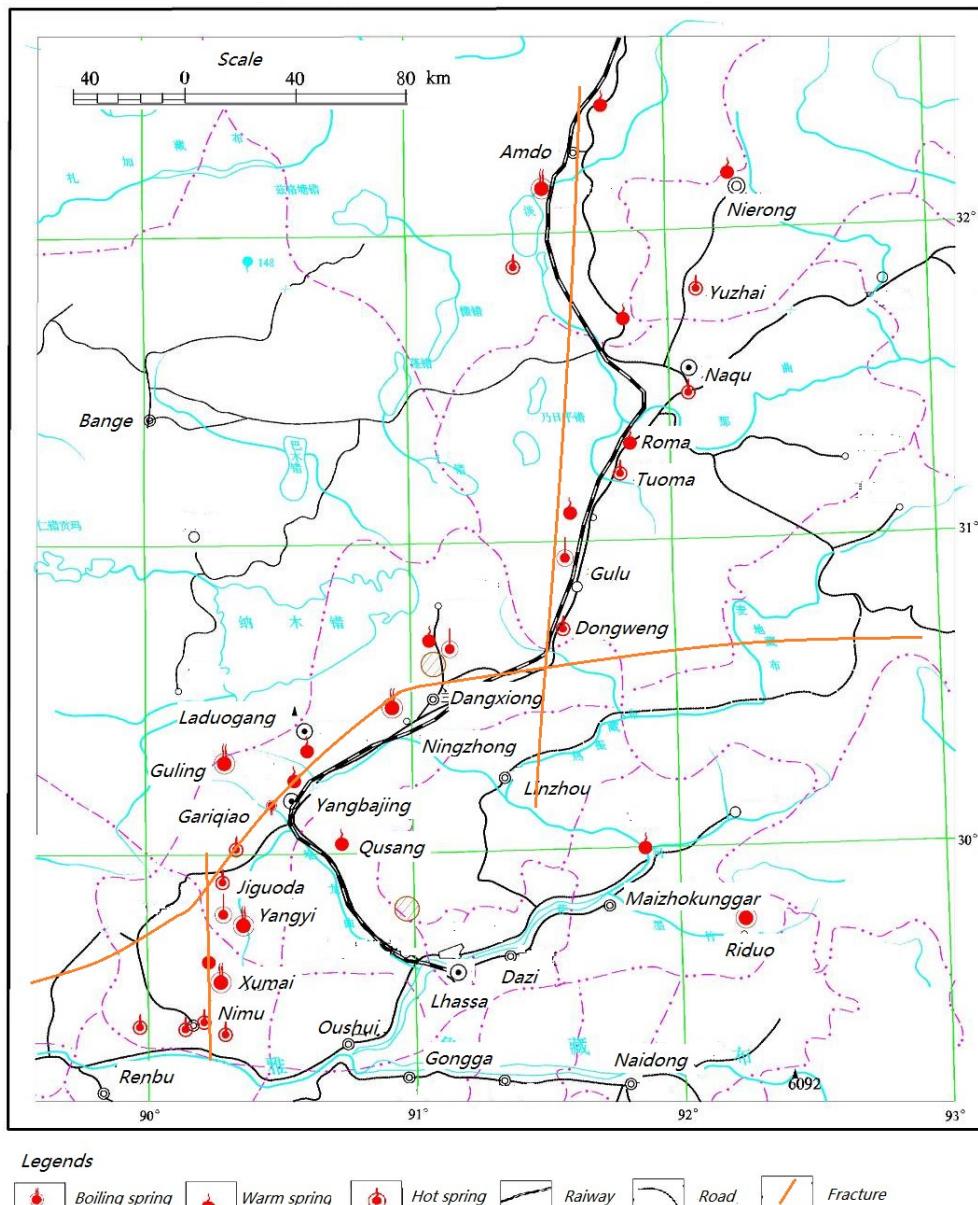


Figure 2: Geothermal anomalies along Qing-Tibet railway in Tibet

Among the 22 explored anomalies, 10 areas such as Yuzhai, Nagqu, Roma, Gulu, Damxung, Ningzhong, Yangbajin, Jiguoda, Yangyi, and Qusang, have good prospects of development due to relatively larger resources potential, better natural environment, and shorter distance to populous towns.

3. STATUS OF GEOTHERMAL DEVELOPMENT AND UTILIZATION

It is since 1980s that Tibet has started to use geothermal resources. The earliest specific study on geothermal in Tibet was done by the Chinese academy of sciences in 1975. The Chinese government put emphasis on that work especially in Yangbajing field. Geothermal resources are used in electricity generation, green house, bathing, space heating and industry use (Table 1, Zhang and Li, 2013).

Table 1: Statistic information of key geothermal fields along Qinghai-Tibet railway in Tibet

Fields	Area / km ²	Spring temperature / °C	Spring types	Reservoir temperature / °C	Utilization
Yuzhai	3	30-52	Warm spring, hot spring	56-67 (upper) 143-158 (lower)	Bathing
Naqu	5.2	<45	Warm spring	67 (upper) 139 (lower)	Green house, Electricity generation, space heating
Roma	0.7	<45	Warm spring	—	Bathing
Gulu	1	37-86	Hot spring, boiling spring	160 (upper) 195 (lower)	undeveloped
Dangxiong	—	—	—	—	Space heating
Ningzhong	0.2	37-88	Hot spring, boiling spring	130 (upper) 160 (lower)	Bathing
Yangbajing	14	40-86	Hot spring, boiling spring	157 (upper) 247 (lower)	Electricity generation, bathing, green house, space heating, industry utilization
Jiguoda	0.15	45-64	Warm spring, hot spring	86 (upper) 146 (lower)	undeveloped
Yangyi	10.76	—	—	<80 (upper) >200 (lower)	Electricity generation
Qusang	0.2	<60	Warm spring, hot spring	—	Bathing

3.1 Electricity generation

Three fields have been used for power generation in the study area such Yangbajing, Naqu and Yangyi. Yangbajing high temperature field is the most famous and largest in China.

3.3.1 Yangbajing power station:

The Yangbajin hot springs field is at an altitude of 4290–4500 m which makes it the highest altitude set of hot springs in China, and possibly the world. The geothermal field belongs to non-volcanic geothermal fields. The hydrothermal system of the field consists of two reservoirs occurred at different depth, namely shallow reservoir and deep reservoir (Liu, 2008). The temperature inside the drilling hole in shallow reservoir is 150-170 °C while that in deep reservoir is 250 °C-329.4 °C(Geological Investigation Institute of Henan Province, 2011).

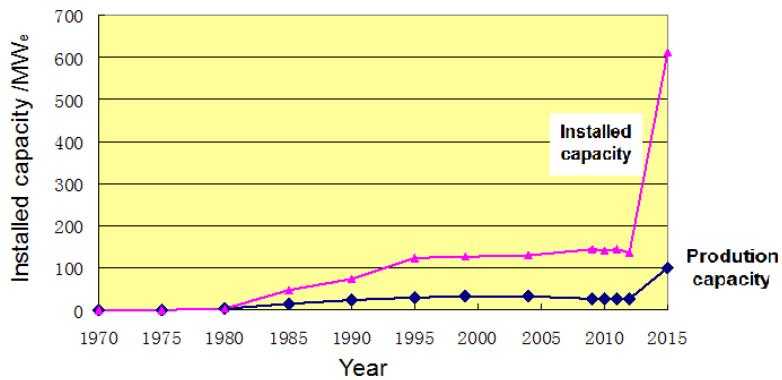


Figure 3: Installed and production capacity of Yangbajing geothermal power station

Experts in water resources and electricity generation first discovered the rich geothermal resource in Yangbajing in 1975, and concluded that the hot energy could be tapped 300 meters underground. Then an exploration team from the Chinese Academy of Sciences dug the first well and successfully generated electricity. Since 1977, a number of Chinese and foreign geothermal experts have come to Yangbajing and installed more powerful generators. The United Nations Development Programme (UNDP) and the Italian government sent technicians and financial resources to Yangbajing power station since July 1982, and with their help, the

station was equipped with power generators with installed capacity of 10 MW_e in total in 1985. The Chinese central government has also invested 230 million RMB into Yangbajing until 1990, building it into a station that provides as much as one third of electricity that Lhasa needs. Lhasa relies on the Yangbajing geothermal station mostly during the winter when hydroelectricity stations don't work. In 2000 the Japan International Cooperation Agency, a government body, also helped fund the power plant and worked out a plan to exploit geothermal energy deeper into the earth, which enables the power station to work for another 30 years. Today, Yangbajing is still the largest geothermal power station in China with the installed capacity of 24,180 kWe, and in 2015, its capacity will be enlarged as 4 times as today (Figure 3).

3.3.2 Naqu power station:

Naqu power station was constructed in Naqu geothermal field at 1993 and started to generate electricity at 1994 with installed capacity of 1 MW_e (Zheng, 2009). However, it was obliged to shut down because of serious scaling and clogging in 1999 (Figure 4).

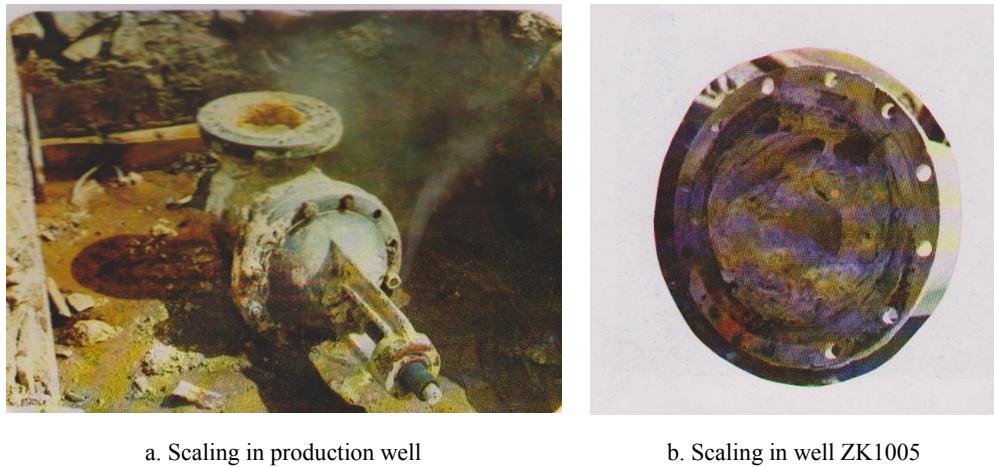


Figure 4: Serious scaling in Naqu geothermal field

3.3.3 Yangyi power station:

The Yangyi field, located 72 km northwest to Lhasa city is a geothermal system with very high reservoir temperature. The highest measured well temperature in borehole 208 is up to 207.2 °C. In the late 1980s, the drilling works were done in Yangyi, and 15 boreholes had been completed. Among these boreholes, only four boreholes (200, 203, 208, and 403) were considered to have the potential for electricity generation. One of these wells, well 208, had the total water and steam production up to 400 t/h. The electricity generation potential of this well can reach to 10 MW_e. The total electricity generation potential of the Yangyi geothermal field had been estimated up to 30 MW_e (Liu, 2008). The power station is now under construction with installed capacity of 20 MW_e for the first stage.

3.2 Green house

There are three reasons for Naqu field to make full use of geothermal resources and they are quite logical:

- a. It is very near to the city of Naqu, which is a very important city in North Tibet.
- b. Energy is too short in the city to support the city's social and economic development.
- c. This area is rich in geothermal resources.



Figure 5: Geothermal green houses in Naqu geothermal field

Under the circumstances, people in Naqu field couldn't wait to use geothermal resources even before preliminary study was absolutely finished. And this is the main reason that caused the last two painful failures in both electricity generation and space

heating mentioned above. Even so, people never stopped trying to use geothermal. In this century, they tried to use geothermal in green house, and it seems much better and shows exciting prospect this time (Figure 5).

3.3 Bathing

Bathing is the main utilization direction for geothermal resources in the study area. 5 of the 10 key fields have been used for bathing more or less, such as Yuzhai, Roma, Ningzhong, Qusang, and Yangbajing.

Qusang geothermal hot spring is quite famous and populous around Lhasa area for its spa and medical value. The chemical type of the spring is $\text{HCO}_3-\text{Ca}\cdot\text{Na}$, PH 6.60. The degree of mineralization is 1634.37mg/L and the hardness is 609.39mg/L (CaCO_3). It is a kind of medical hot mineralized water with HBO_2 content of 123.33mg/L and H_2SiO_3 of 77.44mg/L. In its long utilization history, people go after in a swarm no matter in freezing winter or in warm summer.

Most of the fields use geothermal hot water in quite nature and simple way except that Yangbajing field is using geothermal water in indoor swimming pools.

3.4 Space heating

It is very necessary to use energy for space heating in the freezing plateau of high-elevation. Space heating through geothermal energy has been tried to study and test in the study area since late 20th century. Some work has been done in three fields in geothermal space heating such as Naqu, Dangxiong, and Yangbajing. However, only Yangbajing field succeed in very limited scale. Only the nearby hotel is using thermal waste water from the geothermal power station for space heating. The other two fields both failed by scaling and erosion problems.

3.5 Industry use

Only Yangbajing field is using geothermal for industry use but has not formed scales. Geothermal water is used to build leather factory, borax selection, kaolin production workshop.

4. PROBLEMS AND LIMITATION IN UTILIZATION

The study area is rich in geothermal resources, but the rich geothermal resources are still in a low degree of development. Only a tiny fraction of the resources are being used. Limited by the hard environmental conditions and shortage of preliminary study, it is common to see unreasonable use and incomprehensive utilization in most of the geothermal fields in the study area. Among the 10 referred key fields, 5 are being used such as Yuzhai, Roma, Ningzhong, Yangbajing and Yangyi, 2 were used but now are not being used such as Naqu and Dangxiong, the other 3 and the fields out of the 10 are basically maintained in original states without any development.

Limitation and problems met in utilization can be summarized as follows:

- a. Low degree of development and utilization. Most of the geothermal fields are in original states without utilization. Only small fraction is being used.
- b. Unreasonable development and utilization. Naqu field, the typical field which is located near the cold high-elevation Naqu town, experienced two times of painful failures both in power generation and space heating. The most important reason is lack of preliminary study. Characteristics of scaling and erosion were not absolutely studied before utilization.
- c. Serious resources waste. As the resources are not being used comprehensively, thermal utilization efficiency is quite low. No medium-low hot spring has currently been used for space heating. No geothermal tail water is used for reinjection. Most of it is drained directly to nearby river which is of obvious risk to eco-environment.
- d. Lack of detailed resources evaluation. Large fraction of the fields has not been evaluated in detail and the quantity and quality of the thermal water do not have enough evidence for propaganda and development. According to preliminary analysis, some of them might be medical hot mineral water with high quality.
- e. Wrong location of production wells. Because of the low degree of preliminary study, some fields are not being used in right location. The wrong location of wells leads to poor quality of production efficiency.
- f. Lack of investment. Tibetan area is one of the least underdeveloped areas of China. Lack of funds increased the conditions of lack of energy in some extent. Instant success does not always come without money in geothermal development. Lack of money and demand of energy are the vital reasons which caused painful failures in geothermal utilization in the study area.

5. COMMENTS AND SUGGESTIONS FOR FUTURE

Early achievements have already shown the success of China's western development strategy. The operation of Qinghai-Tibet Railway opened a door for Tibet to get development opportunity and wonderful future, especially for the study area along the railway. Making full use of local superior geothermal resources is an effective way to ease the energy shortage in development process in this area, and more efforts should be made:

- a. Detailed exploration should be done to get more information of the fields and to find out the quantity and distribution of geothermal resources.

b. Reservoir study and resources assessment should be carried on to give reasonable suggestions and plans for utilization and management before development. Besides quantity, medical appraisement and mineral identification should also be made to assess the quality of the resources.

c. Space heating is not only an urgent need but also a sweet dream for habitants in the study area. How to realize this dream is of challenge and significant for engineers to consider. Additionally, spa and bathing use should be improved a lot. Comprehensive use seems to be a way to stop resources waste in most of the fields.

d. Reinjection should be done immediately in Yangbajing field to slow down the process of resources drying in the upper shallow reservoir. New developing methods can also be tried like EGS and HDR (Idaho National Laboratory, 2006), and the north of Yangbajing field seems a good test target.

e. Yangbajing field is one of the most typical non-volcanic geothermal fields on the earth. It should be protected scientifically and open to the world for science purpose. And strengthening international cooperation and communication is good way to promote its reasonable and scientific development.

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