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Study on gravel packing completion technology of sandstone geothermal well

Li Hongyan[1],Gao Xiaorong[1],Sun Caixia[1],Lu Xingchen[1],Ren Xiaoqing[1,2],Dong Wenbin[1]

Mailing address：1.Sinopec Lvyuan geothermal energy Development Co., Ltd. Hebei Xiongxian 071800

2.School of Energy Resources, China University of Geosciences，Beijing 100083；

E-mail:dongwb9406.xxsy@sinopec

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ABSTRACT

Nowadays, The sandstone reservoirs in bohai Bay Basin are mainly in Neogene Ng Formation, The stratum depth is between 1300 and 1500m, Sand flow from thermal reservoir is more serious, Seriously affecting the production of geothermal Wells.To solve this problem, The usual method is to put wire wound screen into the sandstone reservoirs for sand control, But in the process of long-term use, Corrosion or wear may occur around the wire, Sand cannot be effectively prevented from entering the wellbore, Sand control effect will be greatly reduced and the life of geothermal Wells is rapidly shortened. In order to improve sand control effect and to drill good geothermal Wells, The gravel pack completion process was used. This paper summarizes the sand outflow from geothermal wells in Bohai Bay Basin in recent years, and combine formation parameters、physical property parameters with formation pressure parameters during production，then determine gravel diameter, screen mesh, and gravel running speed during gravel pack completion,and developing an effective completion program for geothermal Wells finally, and it can provide reliable basis and reference for sand control of sandstone geothermal Wells in Bohai Bay Basin.

In the development process of sandstone geothermal well, the sand control completion method is usually run wire-wrapped screen pipe. This completion method has better sand control effect for the area with better sandstone cementation, while it has poor sand control effect for the area with poor sandstone cementation.Gravel pack completion is a widely used sand control method in unconsolidated sandstone oil and gas reservoirs. Gravel pack layer is used to prevent formation sand from invading the wellbore and maintain a certain permeability to facilitate the smooth flow of oil and gas into the well. Therefore, sand retention performance of gravel layer determines the productivity and comprehensive effect of sand control Wells (Dong Changyin et al.), while there are few gravel pack completion methods in the development of geothermal fields.The sandstone reservoirs in Bohai Bay Basin are mostly Neogene Guantao Formation, which is shallow buried and has poor sandstone cementation performance. The conventional gravel pack completion method cannot achieve the expected sand control effect. Therefore, gravel pack completion method can be applied to the sand control of geothermal Wells. Take Qinghe area of Hebei Province as an example.

1.REGIONAL GEOLOGICAL FEATURES

Qinghe County is located in the southwest of Bohai Bay Basin, the north of Linqing Depression and the middle of Wucheng-Guantao Uplift. The Wucheng-Guantao bulge is distributed in the northeast direction, adjacent to Daying Sag, Qiuxian sag and Deo-Guanxian sag. It is adjacent to Minghua Town bulge in the west, Deo-Guanxian sag in the east, and Dayying Sag in the north.

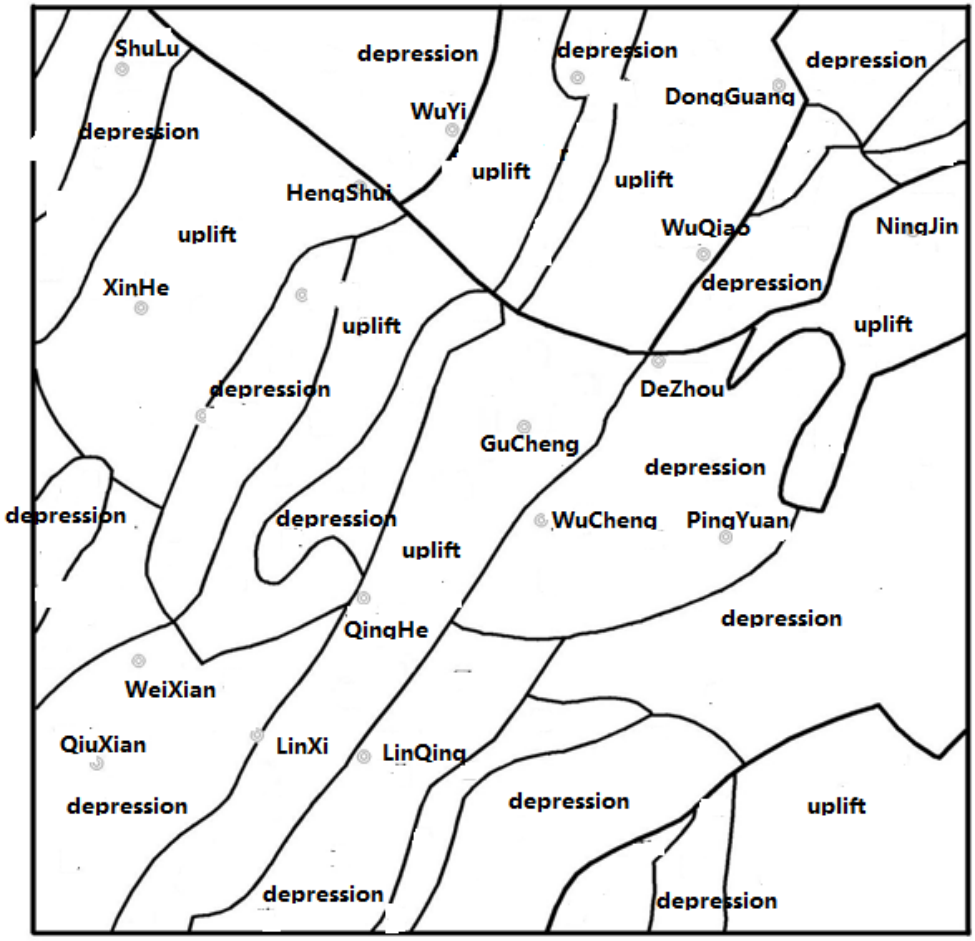

Fig.1-1 Tectonic location map of Qinghe area

Taodong fault and Guanxian fault are the east and west boundaries of Wucheng-Guantao uplift, respectively. The overall structure strikes NNE and is saddle-shaped. There is no Paleogene deposit in the southern part of the uplift, and the Neogene directly overlays the Mesozoic strata.

Taodong fault: Located in the eastern part of this area, it is a hidden fault in the area and a normal fault of mesozoic-Cenozoic inheriting activities. It mainly struck NNE and inclined SE, with a cumulative vertical fault distance of nearly 4000m, and it is the boundary fault between Gucheng-Guantao uplift and Guanxian depression.

Guanxian fault: Located in the western part of this area, the fault struck NNE and tilted NW. This fault is a controlled sedimentary fault controlling the deposition of the middle and Cenozoic strata in the western depression. It has a large vertical fault distance and its main active period is the Middle and Cenozoic period.

From the distribution characteristics of the Wucheng-Guantao uplift, the Neogene Guantao Formation is high in the south and low in the north, thick in the south and thin in the north. The Guantao Formation in Gucheng County in the north is 1150 ~ 1350m deep and about 200m thick, while the Guantao Formation in Qinghe County in the south is 1050 ~ 1500m deep and about 450m thick. The Guantao Formation in Qinghe County is about 100 m shallower than that in Gucheng County and about twice as thick.The stratigraphic trend of the underlying Paleozoic Ordovician is opposite to that of the overlying Cenozoic, with the overall characteristics of high in the north and low in the south. In Gucheng area, the top of the Ordovician is buried about 2100m, and the buried depth of the Mesozoic Triassic in Well Guanguu 2, 10km south of Qinghe County, is 1527-2520m (unpenetrated). Combined with the previous understanding of the Mesozoic strata in this area, It is estimated that the top buried depth of the Ordovician system in Qinghe County is about 2800 ~ 3000m.

2. STRATIGRAPHIC CHARACTERISTICS

Combined with geothermal well data and geological research data of the Linqing depression in the early period, it is concluded that the drilled strata in this area are respectively Quaternary Pingyuan Formation, Neogene Minghuazhen Formation, Guantao Formation, Dongying Formation, Mesozoic Triassic and Paleozoic Ordovician from new to old.

2.1 The Quaternary Plain Formation(Q)

It is composed of grayish yellow, brownish-yellow, yellowish-brown, brownish-red sub-sandy soil, sub-clay, clay and grayish yellow, grayish-white medium sand, fine sand, silty sand, etc. The formation structure is loose, and clay is easy to make slurry. The sedimentary thickness is generally 200 ~ 550m, which is integrated with the underlying Minghuazhen Formation.

2.2 The Neogene Minghuazhen Formation(Nm)

The Minghuazhen Formation is composed of sandy mudstone interbedded with medium fine and medium coarse sandstone of unequal thickness. The upper part of the sandy mudstone is light brown and brown, the middle part is dark brown and gray-green, and the lower part is brownish red and gray-green. The sandstone is light gray and gray, mainly composed of quartz and flint, and is subround. The bottom is the conglomerate, which is distributed in the area. The deposition thickness is about 500 ~ 600m, and the buried depth of the bottom is 1030 ~ 1130m.

2.3 Neogene Guantao Formation(Ng）

The upper part of the stratigraphic lithology is brown red sandy mudstone with light gray and white medium fine sandstone, and the middle part is light gray and white medium fine sandstone with dark brown and purple red sandy mudstone with different thickness interbedded. The lower part is light gray and gray sandstone with deep brown and purple sandy mudstone. The sedimentary thickness is about 280 ~ 500m, and the buried depth of the bottom boundary is 1370 ~ 1630m.

2.4 The Paleogene Dongying Formation（Ed）

In the sedimentary period of Dongying Formation of Late Paleogene, there were volcanic intrusive rocks in Qinghe County, and the lithology was mainly gray-green diorite porphyrite with porphyritic structure in shallow diagenesis, and the phenocrysts were mainly plagioclase and dark minerals.

3. STUDY ON SAND PRODUCTION OF GEOTHERMAL WELL

Sand production is a phenomenon that the formation near the bottom of the well is damaged due to geological reasons and careless operation during operation, which leads to the spalling formation sand entering the wellbore with open water and adversely affects the production and operation of the geothermal well.

3.1 The hazards of sand production

(1) Production reduction or suspension of operations

Sand production in geothermal well is most likely to lead to sand burial in thermal reservoir, sand blocking in casing and sand accumulation in surface pipe, thus reducing the production and recharge of geothermal well. Therefore, the pump is often forced to remove sand buried, clean up the ground manifold, and this problem is difficult to cure. Soon after the resumption of production, the operation had to be restarted.

(2) Ground and underground equipment wear

The formation sand of Neozoic Guantao formation is mainly composed of silica (quartz), which has high hardness and is a very destructive abrasive. It can wear the filter pipe around the wire and make it lose the filtering function. It can wear the ground pipeline and reduce the service life of the ground pipeline.

(3) Casing was damaged and the geothermal well was abandoned

The most serious situation of sand production in geothermal well is that with the continuous increase of sand production, the formation holes outside the casing become larger and larger, which will lead to sudden formation collapse to a certain extent. The casing is deformed or damaged by the impact of the sandstone mass of the collapsed formation, resulting in the abandonment of the geothermal well.

3.2 reason analysis

The reasons for sand production in geothermal Wells can be attributed to two aspects, namely geological factors and technological factors. Among them, the geological factors are mainly internal factors, including the influence of rock cementation and formation permeability, while the technological factors are external factors, including the influence of the number of filter pipes and improper operation mode.

(1) The cementing state of rock

There are three types of cementation in sandstone stratum, and the contact cementation is the main type in the reservoir which is easy to produce sand, and the number of cementation is small, and there are more clay cements in it.

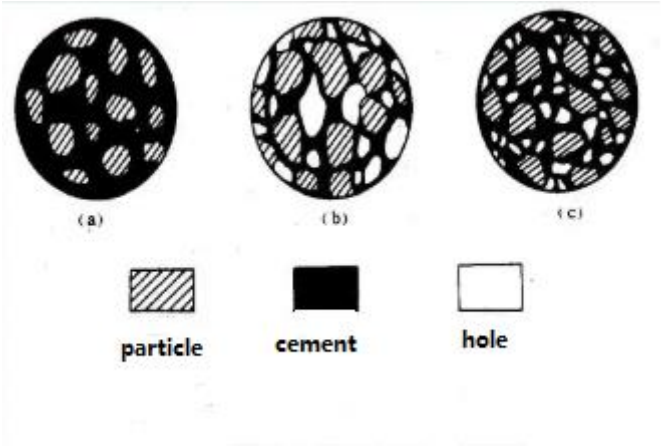

Fig.3-1 Rock cementation type of sandstone formation

(2) Influence of permeability

The experiment and production practice show that when other conditions are the same, the higher the permeability of the thermal reservoir, the lower the cementation strength, the easier the thermal reservoir sand production.

Fig.3-2 Sand production in geothermal well site

4. STUDY ON SAND CONTROL TECHNOLOGY OF GRAVEL PACKING

At present, the conventional sand control method is gravel diameter analysis. On the premise of ensuring the production of geothermal water to meet the heating demand, the number of filter pipe mesh should be appropriately increased to improve the sand control effect in the short term. However, in the long-term use of geothermal Wells, the abrasion degree of quartz sand on the screen pipe gradually intensifies, the sand control effect will be greatly reduced, and the life of geothermal Wells will be shortened accordingly.

4.1 Gravel pack sand control

Gravel pack sand control does not have the above determination. For the formation with loose cementation and serious sand production, gravel pack completion method should be generally adopted. It is to artificially fill a certain size of gravel between the liner and the shaft wall, so as to prevent sand and protect the production zone. In order to adapt to the needs of different formation characteristics, both open hole and perforated completions can be filled with gravel, respectively known as open hole gravel pack and casing gravel pack.

(1) Open hole gravel pack

It is suitable for reservoirs with no gas cap, no bottom water, and no water-bearing interlayer, single thick reservoir or multilayer reservoirs with basically the same pressure and lithology with open hole gravel pack, reservoirs that are not prepared to implement zone separation and selective treatment, and medium, coarse and fine sand reservoirs with loose lithology and serious sand production.

(2) Casing gravel pack

Complex geological conditions, such as gas cap, bottom water, water-bearing interlayer and collapseable interlayer, require the implementation of reservoir casing gravel packing with separated zones. There are differences in pressure and lithology among different layers, so selective treatment of the reservoir is required. Medium, coarse, and fine sand reservoirs with loose lithology and heavy sand production.

(3) Combined well completion

Reservoirs with hard and compact lithology, stable and non-collapsing walls, composite completions with water-free interlayers and collapseable interlayers in open-hole sections, single thick reservoirs, or multilayer reservoirs with basically the same pressure and lithology, and reservoirs that are not ready to be separated and selectively treated.

4.2 Gravel pack design

(1) Selection of filling method

According to the characteristics and design principles of sand control reservoir and geothermal well, the most suitable gravel packing method is selected according to the completion type.

(2) Formation pretreatment design

According to the analysis results of sand samples of thermal storage layers and the specific situation of sand control Wells, the measures such as acid plugging removal and clay stabilization treatment are determined, and the problems such as preventing emulsification and preventing new precipitation are also considered. This step is of great significance to improve the success rate of construction and ensure the production capacity of geothermal Wells.

(3) Design of gravel

Gravel design mainly includes gravel size design, gravel quality control, gravel dosage calculation of three aspects.

Gravel size design:After obtaining the median particle size d50 of sand sample in hot reservoir of sand control well in the sieve analysis laboratory, the required gravel size is obtained according to the calculation formula, that is, the median particle size D50 of gravel. Saucier is the formula in common use.

$$D_{50}=(5\sim6)d_{50}$$

If the formation sand is seriously heterogeneous and the sand particle size is widely distributed, the size range of gravel can be expanded, which can be calculated by the following formula:

$$D50 = (4\sim8)d_{50}$$

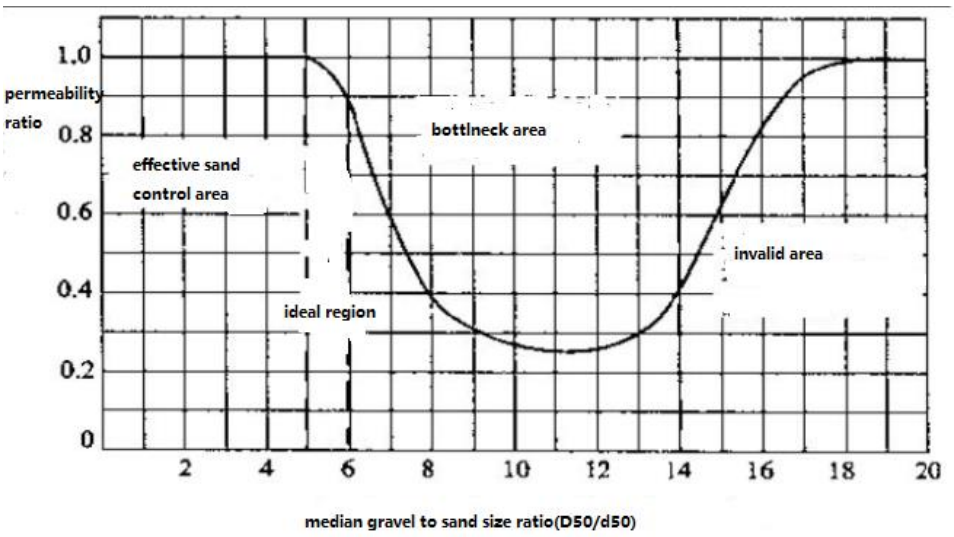

Fig.5-1 The relationship between D50/d50 and gravel permeability

As can be seen from the figure:

When D50/d50 is less than 6, the interface between gravel and thermal reservoir sand is clear, the gravel blocks the thermal reservoir sand, and there is no sand production in geothermal Wells.

When 6<D50/d50<14, some of the hot reservoir sand intrudes into the gravel pack, resulting in gravel/sand mixing, and the permeability of the gravel zone decreases. Even though the geothermal well does not produce sand, the production decreases.

When D50/d50>14, thermal reservoir sand can freely pass through the gravel pack, and sand control is ineffective.

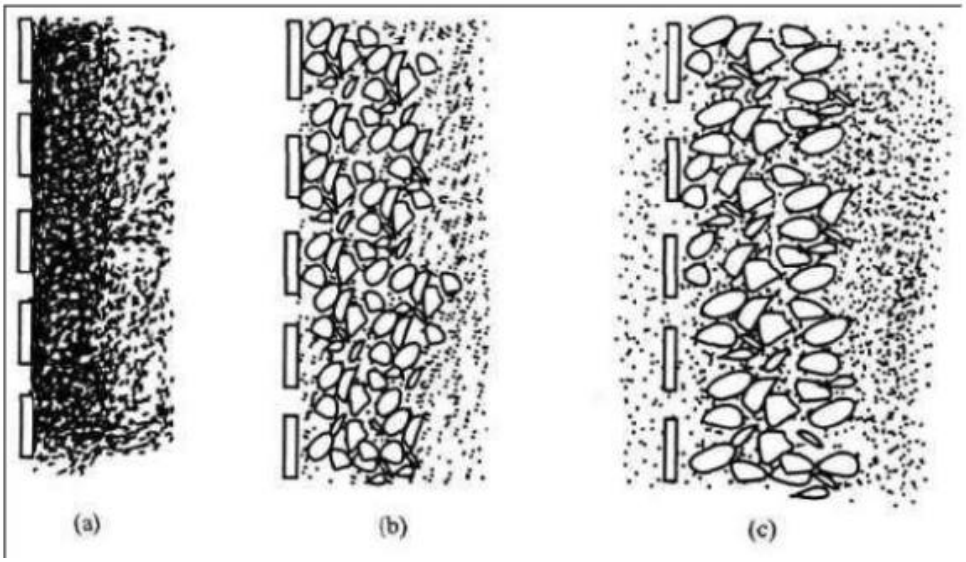

Fig.5-2 Schematic diagram of gravel sand retaining mechanism

Gravel quality control:The main quality requirements of gravel are: uniform gravel particle size; Good roundness and sphericity; The acid solubility in standard soil acid is less than 1%. The water turbidity of gravel sample is not

more than 50 degrees; No two or more granular crystal blocks were found under microscope. Meet the requirements of anti-crushing test.

Calculation of gravel dosage:The amount of gravel used for gravel pack sand control is determined by the volume of the packing site. In order to ensure the construction quality, sufficient additional quantity should be considered in the design of dosage. Generally, it is better to squeeze in more, so as to improve the sand control effect.

In conclusion, according to the formation characteristics of Guantao Formation sandstone in Bohai Bay Basin, the most effective gravel packing process can be selected to improve the sand control effect of geothermal Wells.

5. CONCLUSION

(1) Qinghe County is located in the southwest of Bohai Bay Basin, the north of Linqing Depression and the middle of Wucheng-Guantao Uplift. The Wucheng-Guantao bulge is distributed in the northeast direction, adjacent to Daying Sag, Qiuxian sag and Deo-Guanxian sag. It is adjacent to Minghua Town bulge in the west, Deo-Guanxian sag in the east, and Dayying Sag in the north. The main thermal reservoir is Guantao Formation sandstone reservoir, which is easy to produce sand.

(2) For the sandstone reservoir in Qinghe area, gravel packing can effectively prevent the sand production of geothermal Wells for a long time and extend the service life of geothermal Wells in Qinghe area.

(3) Gravel pack sand control technology can be divided into open hole gravel pack, casing gravel pack and compound well completion according to different formation conditions, so that sand control work is more targeted.

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