UDC 550.42:577.4(571.1)

THERMAL WATER RESOURCES OF KOLPASHEVO AREA IN TOMSK REGION

M.V. Mishchenko

Tomsk Branch of Institute of Oil-and-Gas Geology and Geophysics of A.A. Trofimuk, Tomsk city
E-mail: mishenkomaria@mail.ru

The possibility of using thermal underground water for thermal-power purposes is shown. The resources of Apt-alb-Senoman, Goteriv-Barrem and Valazhin water-bearing complexes are estimated. The analysis of possible scale in borehole is carried out. Thermal resources of the underground water are calculated.

Introduction

In conditions of hydrocarbonic fuel expensiveness the problem of alternative energy sources use, such as the Sun energy, winds, heat of the Earth, biomass, small rivers, tides of seas and oceans, takes on special significance. One of the most perspective sources is thermal underground waters.

Within the limits of the Tomsk region the most perspective for thermal underground waters use is the Kolpashevo area [1, 2].

As the main classification parameter the temperature of underground waters is used. They are divided on cold (<20 °C), warm (20...50 °C), hot (50...75 °C), very hot (75...100 °C) and overheated (> 100 °C) waters. A.D. Nazarov subdivides thermal waters into high-grade (>100 °C), mid-grade (70...100 °C) and low-grade (<70 °C). Types of utilization: development of the electric power 80...100 °C, heat supply 65 °C, hot water supply 50 °C [3].

Disposition and uniqueness of waters lying on a cut has played a great role in a choice of research territory. The Kolpashevo area is located in the central part of the Tomsk region on transport systems crossroads (motorway, large river arteries and air ways). Within the limits of Kolpashevo territory big stocks of underground waters are concentrated, with temperature allowing placing them into mid-grade category (60...100 °C) waters [4].

It is expedient to use economically special wells (thermowells) for extraction of thermal waters. Walls of such wells are isolated by a heat insulating material, allowing the increase of coefficient of thermal waters heat effective use from 0,5...0,55 up to 0,75, and temperature of extracted waters – on 8...10 °C. Such wells are more technological in service.

Proceeding from temperature conditions, the most perspective is the use of the given thermal underground waters in national economy as a heat supply and hot water supply. Their use as the energy carrier is also possible, as recently there were technological opportunities of mid-grade waters use for electric power development with application of low-boiling substances. In this connection, the question of the given waters resources estimation arises, because the detailed estimation for all water-carrying complexes in territory of the Kolpashevo area has not been done. The estimation of stocks has been done only for the albian-cenomainian water-carrying complex, as their use for bed pressure maintenance (BPM) in oil beds (Bondarenko, Kulikov and others).

Now the program (HydroGeo) has been created allowing hydrodynamical and hydrogeochemical calculations, and also modeling. By means of the given program the basic calculations have been made.

Hydrogeological conditions of the Kolpashevo area

In the top part of a cut overlay cold waters of *Oligocene-quarternary* and *Eocene-upper-chalky water-carrying complexes* (*w.c.c.*), fig. 1. Oligocene-quarternary w.c.c. is the main source of potable water, and Eocene-upper-chalky w.c.c. is the main source of table and medical-table waters. Their capacity accordingly makes 100 and 500 m.

Further, downwards on a cut, underlay warm waters of the *aptian-albian-cenomanian water-carrying complex*. Waters are mainly saltish, sodium chloride with bed temperature from 28 up to 35 °C. The complex is presented by inequigranular weak-cemented sandstones, aleurolites and clays with capacity 600...1000 m. Well debit at self-shedding reaches 300...600 m^3/day , and at water pump extraction increases up to 1000...4000 m^3/day. [5], that allows, in particular, to use them as the main source of bed pressure maintenance in oil beds of the Tomsk area deposits.

Below there lie hot waters of the *goterivian-barremian water-carrying complex*. The complex is presented by non-uniformly layered argillo-arenaceous-aleurolite depositions, with capacity 450...750 m. With mainly saltish and moderately salty, sodium calcium-chloride waters, with bed temperature 75...85 °C, on a mouth at self-shedding 45...50 °C, with lowered (in comparison with the aptian-albian-cenomanian water-carrying complex) water-profuseness. Well debits do not exceed 10...115 m^3/day at recession of level up to 350...875 m.

The overlying complex is replaced by very hot waters of the *valanzhinian water-carrying complex*. The complex is presented by sand-aleurolite depositions of high water-profuseness, with capacity 45...200 m. Waters are salty and strong salty in all parts, sodium chloride and calcium-sodium, with bed temperature 60...90 °C and on a mouth of gushing forth wells 50...66 °C. Debit of self-shedding wells exceeds 70...500 m^3/day.

Waters of the valanzhinian w.c.c. are replaced by very hot and overheated waters of the *valanzhinian-upper-jurassic, lower-upper-jurassic and paleozoic w.c.c.* accordingly.

Valanzhinian-upper-jurassic w.c.c. is presented by clay strata, and is a water-resistant. Capacity of the complex makes 300...400 m.

Lower-upper-jurassic w.c.c. is presented by non-uniformly layered argillo-arenaceous depositions, with capacity from 0 to 600...800 m. It is the main of oil and gas reservoir. Mainly salty and strongly-salty sodium chloride methane waters, with bed temperature 75...100 °C.

Overheated waters of the *paleozoic w.c.c.* with temperature above 100 °C, mainly brine, sodium chloride methane waters. The complex is developed in a zone of tectonic infringements and to erosive-tectonic remnants of granitoid and carbonate rock massifs.

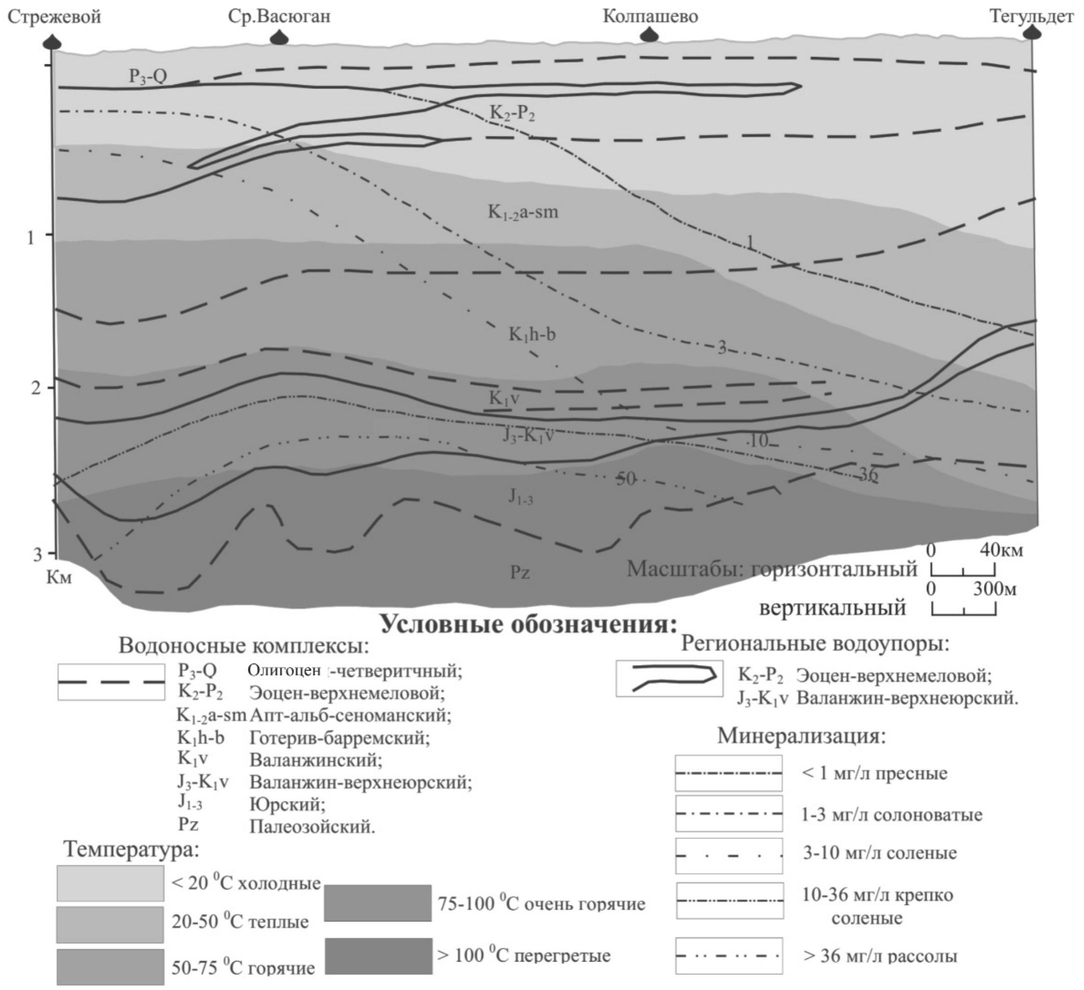

Fig. 1. *Hydro-geological cut on a line of the Strezhevoy – Middle Vasyugan – Kolpashevo – Teguldet [4]*

Стрежевой – Strezhevoy; Ср. Ваюган – Middle Vasyugan; Колпашево – Kolpashevo; Тегульдет – Teguldet

Условные обозначения: – Denotation:

Водоносные комплексы: – Water-bearing complexes:
Олигоцен-четвертичный – Oligocene -quaternary;
Эоцен-верхнемеловой – Eocene-upper-chalky;
Апт-альб-сеноманский – Aptian-albian-cenomanian;
Готерив-боремский – Goterivian-barremian;
Валанжинский – Valanzhinian;
Валанжин-верхнеюрский – Valanzhin-upper-Jurassic;
Юрский – Jurassic;
Палеозоиский – Paleozoic

Региональные ресурсы: – Regional resources:
Эоцен-верхнемеловой – Eocene-upper-chalky;
Валанжин-верхнеюрский – Valanzhin-upper-Jurassic

Масштабы – Scales:
горизонтальный – horizontal
вертикальный – vertical

Минерализация: - Mineralization:
< 1 мг\л пресные – < 1 mg/l fresh
3 мг\л солоноватые – 1–3 mg/l slightly salty
3–10 мг\л соленые – 3–10 mg/l salty
10–36 мг\л крепко соленые – 10–36 mg/l highly salty
> 36 мг\л рассолы – > 36 mg/l brines

Температура: - Temperature:
< 20 C холодные – > 20 C cold
20–50 C теплые – 20–50 C warm
50–75 C горячие – 50–75 hot
75–100 C очень горячие – 75–100 C very hot
> 100 C перегретые – > 100 C overheated

Temperatures dot samples at test characterize a cut from quarternary up to lower-chalky depositions inclusive. On character of temperatures distribution in a cut on size of a geothermal gradient it is possible to allocate some characteristic sites, fig. 2.

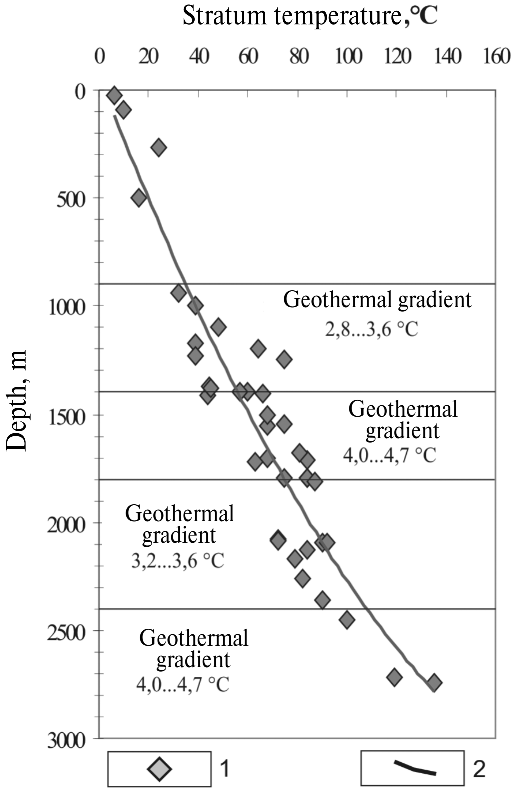

Fig. 2. *Geothermal characteristicof the Kolpashevo area: 1) temperature dot samples; 2) average values on the area*

Infiltrational waters render essential influence on geothermal conditions in the uppermost part of a cut up to depth of 900 m. Reduction of a geothermal gradient on depth of 1800...2400 m is probably connected with a lithologic component, but there is a probability of the temperatures samples discrepancy connected with insufficient period of natural temperature restoration in the well stem.

Proceeding from geotemperature conditions, waterprofuseness and deposition depth, the most accessible potential resources of heat-technical and balneological underground thermal waters in the area of research are concentrated in depositions of the aptian-albian-cenomanian water-carrying complex, and for the heat power purposes use of the underground thermal waters concentrated in goterivian-barremian and valanzhinian water-carrying complexes is most perspective.

Estimation of resources

Estimation of operational resources of thermal waters has been done with use of special software [6]. In calculations of filtration-capacitor parameters methods of Teys-Jacob and Horner-Seis are used (with automatic allocation on schedules of quasi-stationary filtrations areas and influences of well stems capacity) and the special analytical technique which is based on numerical integration of inflow curves and pressure restoration on the basis of superpositions principle (imposing of currents).

It has been accepted that given water-carrying complexes are unlimited beds with impenetrable sole and roof, as they have universal distribution in all research territory and are sustained on capacity, and also well isolated from each other by beds of interbanded argillites and aleurolites, and also clays. For calculations of stocks, the equation of Teys-Jacob has been applied for unlimited bed in space. Further, design decrease S_d has been compared with admissible S_{adm}, and at $S_d>S_{adm}$ stocks have been considered provided. Then the additional calculation of the most possible debit at the set admissible decrease has been carried out.

Calculations have been carried out for three water-carrying complexes separately, assuming that their resources can be used independently.

Table 1. *Results of underground thermal waters operational stocks calculation*

Water-carrying complex	Water-conductivity coefficient, m^2/day		Расчетные величины: Piezo-conductivity coefficient, 10^3 m^2/day	Расчетные величины: Level decrease S_d, m	Maximum possible debit at admissible decrease, m^3/day
Aptian-albian-cenomanian	min	125	125	83,909	6555
	max	300	300	36,123	15230
Goterivian-barremian	min	100	100	104	5289
	max	200	200	53,378	10300
Valanzhinian	min	120	120	87,269	6302
	max	470	470	23,437	23470

All calculations (table 1) have been done for a single water-intake with working time of 10000 days, debit 5000 m^3/day, at well filter part radius of 0,1 m and elastic water-feedback 0,001, for admissible decrease of 110 m.

It is obvious from the table that all water-carrying complexes possess the provided stocks of thermal underground waters, as design decreases of waters are lower than admissible ($S_d>S_{adm}$).

In view of the table the estimation of thermal resources, concluded in underground waters, has been done under the formula [7]:

$$G = 10^{-3} Q T \eta_{\text{геот}} C,$$

where G is the thermal resources, GJoule/day; Q is the well debit, m^3/day; T is the temperature of water taken from a well, °C; C is the specific thermal capacity (for water 4,184 kJoule/kg·grad is accepted); η_{geot} is the factor of efficient use of thermal waters' heat, 0,5...0,55.

For the *aptian-albian-cenomanian water-carrying complex* thermal resources at temperature 24 °C and η_{geot}=0,5 will be equal 251,04 GJoule/day. For such well thermal resources will increase up to 533,46 GJoule/day (at temperature 34 °C and η_{geot}=0,75).

For *the goterivian-barremian water-carrying complex* thermal resources at use of the usual well (at temperature 55 °C and η_{geot}=0,5) will make 575,3 GJoule/day. With use of thermowells (at temperature 65 °C and

η_{geot}=0,75) thermal resources will increase up to 1019,85 GJoule/day.

For the *valanzhinian water-carrying complex* thermal resources at temperature 66 °C and η_{geot}=0,5 will be equal to 690,36 GJoule/day. With use of thermowells (at temperature 76 °C and η_{geot}=0,75) thermal resources will reach 1192,44 GJoule/day.

As apparent from calculations, water-carrying complexes possess resources, in quantity sufficient for their practical use.

Forecast of secondary mineral-formation

Use of thermal underground waters leads to infringement of bed conditions, therefore, the forecast of structure and intensity of salts deposition is relevant and has high practical value. In this connection with that system hydrogeochemical modeling has been done in the work.

Calculation of salt deposition in a well stem has been done with software use [6]. Hydrogeochemical modeling is based on equilibrium physical-chemical modeling principle «on constants of stoichiometric equations of reactions», offered in the late 60's of the last century by V.N. Ozjabkin in Russia and G.K. Helgeson in the USA, but unlike the majority of similar developments, considers non-ideality of a solution by K.S. Pittser's technique. The used technique allows considering density, general mineralization of water, gas-saturation, structure of the water-dissolved gases, thermobaric conditions and other parameters.

During modeling the initial data (the analysis of waters) have been recalculated according to bed conditions, and the solution has been balanced with gas (invasion of CO_2 in water from hypothetical free gas phase containing 0,2 % of CO_2) and rock (by reduction of Gibbs energy of minerals to an equilibrium condition with the solution for what in a program complex a special procedure is stipulated). Then numerical imitation of waters rise on a well stem, down to conditions of the open surface (in conditions of «empty» rock and system closed relatively to CO_2, does not demand maintenance P_{CO_2}=const) has been made. Such modeling corresponds to a hypothesis about *initial equilibrium of system water -carbonate rocks in bed conditions.*

Table 2. *Initial structure of underground waters at temperature 22 °C, pressure 0,1 MPa; concentration of components in mg/l*

Indices	Water-carrying complex		
	Aptian-albian-cenomanian	Goterivian-barremian	Valanzhinian
H^+	4,64483E-6	4,90527E-6	1,60708E-5
Na^+	749,86	1610,04	1967,15
K^+	1,18	15,9	17
Ca^{2+}	18,8	163,9	249,6
Mg^{2+}	1,5	24,31	1,8
OH^-	0,0399508	0,0433115	0,0141174
Cl^-	786,5	2624,5	3312,2
HCO_3^-	337,992	350,576	277,115
SO_4^{2-}	277,5	26,1	26,3
SiO_2	0	2,14821	0
CO_3^{2-}	6,15073	8,8252	2,67124
CO_2	0,255204	0,25269	0,626575
pH	8,4	8,4	7,9
Mineralization, g/l	2,180	4,831	5,854
Density, kg/m³	1001,0	1003,0	1004,0

Salt deposition modeling has been done for three water-carrying complexes which have been described above. The initial design structure of underground waters is resulted in table 2.

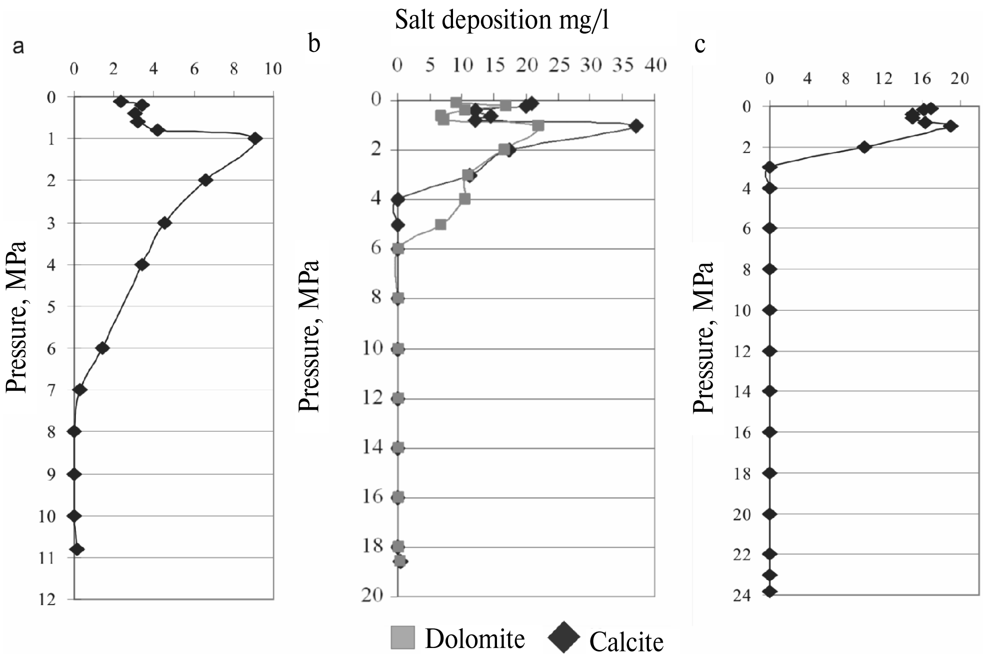

Fig. 3. *Profiles of forecast salt deposition in a well stem at water rising from water-carrying complexes: a) aptian-albian-cenomanian, б) goterivian-barremian, в) valanzhinian*

As the main potential minerals capable to fallout in a well stem are: SiO_2 – chalcedony, quartz, $CaCO_3$ – calcite, aragonite, $CaMg(CO_3)_2$ – dolomite, $CaSO_4(H_2O)_2$ – plaster. It had been found out during modeling that fallout of mainly calcite and dolomite is possible, fig. 3. Fallout of the given minerals is caused by pressure change, consequence of that is partial decontamination which leads to increase of waters pH and waters nonequilibrium relatively to calcite and dolomite with their subsequent deposition. They do not lead to change of water chemical type whereas a pH parameter and the content of the components participating in fallout of corresponding minerals can change.

Main results of modeling are presented in fig. 3.

By results of modeling it is seen that sedimentation of salts in a well stem occurs non-uniformly, and calcite fallout is observed in all complexes, and only in goterivian-barremian also dolomite fallout. It is possible to point out two peaks: the first is connected with intensive decontamination of underground waters (the maximal sedimentation of salts for all complexes is necessary at the level mark in 100 m); occurrence of the second peak is unknown, and in aptian-albian-cenomanian w.c.c. it is hardly noticeable. Character of dolomite and calcite sedimentation in goterivian-barremian w.c.c. is identical.

Conducted modeling has shown that main causes of salt deposition in extracting wells are water structure and their decontamination.

Conclusions

It has been shown that stocks of aptian-albian-cenomanian, goterivian-barremian and valanzhinian water-carrying complexes of Kolpashevo area of the Tomsk region are provided.

Aptian-albian-cenomanian w.c.c. possesses great resources of thermal, medical-drinking, medical-mineral waters. The Kolpashevo area is rich with resources of thermal underground waters; the greatest interest is caused by valanzhinian w.c.c. exploited now in sanatorium Chazhemto.

Based on calculations results perspective for extraction of underground thermal waters and development of the electric power is valanzhinian w.c.c. Aptian-albian-cenomanian and goterivian-barremian w.c.c. can be used as reserve, with possible further attraction of underground thermal waters of these water-carrying complexes in a turn in geothermal thermal power stations.

All three water-carrying complexes, based on the results of salt deposition modeling, are suitable for use as a source of thermal water. At the same time, in exploitation process the opportunity of fallout in a stem of extracting wells of calcite and dolomite is not excluded. In connection to that, for preventive treatment of well stems, and also the equipment in place actions are necessary for removal of technogenic salt-formation, in particular, treatment by acid solutions, mechanical cleaning and other methods.

REFERENCES

1. Mishchenko M.V. Hydrogeothermal conditions of settlement Chazhemto area // Problems of geology and development of bowels: Works of the VI Intern. conf. after acad. M.A. Usov. – Tomsk, 2002. – P. 154–155.
2. Cadastre of opportunities / A.M. Danchenko, G.O. Zade, A.A. Zemtsov et al. – Tomsk: Publishing house NTL, 2002. – 280 p.
3. Time regulations about the order of carrying out of geology-prospecting works on phases and stages (underground waters). – Moscow: GIDEK, 1998. – 12 p.
4. Nazarov A.D. Oil-and-gas hydrogeochemistry of southeast part of Western-Syberian oil-gas-bearing province. – Moscow: Idea-Press, 2004. – 288 p.
5. Bondarenko S.S., Vartanjan G.S., Kulakov G.V. et al. Methods of studying and estimation of resources of deep underground waters. – Moscow: Nedra, 1986. – 478 p.
6. Bukaty M.B. Software development for solution of hydro-geological problems // Bulletin of the Tomsk Polytechnic University. – 2002. – V. 305. – №6. – P. 348–365.
7. Resources of thermal waters of USSR / Ed. by S.S. Bondarenko. – Moscow: Nauka, 1975. – 240 p.

Arrived on 30.10.2006