GEOTHERMAL EXPLORATION ON THE BASIS OF VARIABILITY OF EXOGENE FIELD STUDIES

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ABSTRACT. New physico-mathematical models of natural geothermal objects, connected with anomalous effects of exogene field on structures and faults in the near aurface and effects endogene field in the zones of secondary postsedimentary changes of deep buried horizontal are based on. Methods of thermal zonding of geological medium in connection with the filtration of pressure waters and with lateral variability of lithology and physic properties of sedimentary rocks, are described. The example of application of geothermal exploration while projecting a renewed system of geothermal heat supply.

I. NEW TYPES OF GEOTHERMAL OBJECTS

One of the new natural geothermal features is connected with anomal effects of exogene field on local through anticlinal (-type) structurs and fault lines of hydrogeology structurs. Sedimentary folds and faults contain subvertical local Zone of higher permeability with contrasting thermal rock properties with intensive fluid filtration. That's why the Zone of higher permealibity plays of a role of thermal heterogencity in the field of temperature perturbations with the Earth surface in the upper horisones and serves as an anomalous feature. By means of modelling it is stated that the totality of perturbations of the exogene field in the geology time scale to momentary form in the limits of local structures and faults vertical zones of unstationary anomalous effects - a constituent of the geothermal field, the depth and intensity of which are determined by contrast of parameters of permeable Zones and duration of thermal impulses on the surface.

On the basis of fragmentary models of geothermal features, containing zones of higher permeability with the lateral and verticale filtration of pressurized waters and lateral veriability of thermal properties, for a multilayer medium and infiltrate - elision water bearing systems we obtained thermalconductivity solutions with conductive-convective mechanism of heat bearing, given in (Boykov, I992a). The simplest of these solutions for a semispace equation of thermalconductivity (when v = const) is given below

$$\frac{\partial^2 t}{\partial z^2} - \frac{c_0 \rho_0 v}{\lambda}\frac{\partial t}{\partial z} - \frac{1}{k}\frac{\partial t}{\partial \tau} = 0, \qquad (1)$$

with a condition on the surface of semispace as a stepped function of temperature in time

$$t(0,\tau) = \sum_{i=1}^{n} \Delta t_i(\tau) = \xi(\tau) \qquad (2)$$

and the initial condition

$$t(z,0) = \theta = const \qquad (3)$$

The Laplace transformations solution is obtained by (Boykov, I992a):

$$t(z,\tau) = \theta + \frac{1}{2}(\xi - \theta)\exp\left(z\frac{c_0\rho_0 v}{2\lambda}\right)\left[\exp\left(-z\frac{c_0\rho_0 v}{2\lambda}\right) \times \mathrm{erfc}\left(\frac{z}{2\sqrt{k\tau}} - \frac{c_0\rho_0 v}{2\lambda}\sqrt{k\tau}\right) + \exp\left(z\frac{c_0\rho_0 v}{2\lambda}\right) \times \mathrm{erfc}\left(z\frac{c_0\rho_0 v}{2\lambda}\right)\mathrm{erfc}\left(\frac{z}{2\sqrt{k\tau}} + \frac{c_0\rho_0 v}{2\lambda}\sqrt{k\tau}\right)\right] \qquad (4)$$

where t = temperature, z = distance on a vertical axis, τ = time, $c_0\rho_0$ = volumetric heat of the fluid, k, λ = heat conductivity and thermalconductivity of geological medium v = velocity of vertical filtration of the fluid.

On the basis of the obtained solutions of the tasks of thermalconductivity the modelling of anomalous effects of the exogene field near the surface (Δt_a) for the totality of boundary coditions on the surface approximated the strongest perturbations of temperature of the Earth surface for the Caspian region is done (Boykov, I992a). Among them: various momentary and long termed ($\Delta t_{a_{max}}$=0,8-2,0°C; z =0,3-3,0 m), transgresstion-regresstione fluctuations ($\Delta t_{a_{max}}$=0,I-I,3°C; z =50-200 m), climatic fluctuations of temperature of the water in the sea in the history time scale ($\Delta t_{a_{max}}$=0,004-0,0I°C; z =2-7 m), climatic fluctuations of the Earth surface in the geology time scale ($\Delta t_{a_{max}}$=0,2-I,6°C; z =50-I80 m). It has been stated that only annual, transgresstion-regresstione and fluctuations during the period of golozen-pleystozene form in the limit of 3-I50 meters from the surface a significant anomalous effects with intensity of the first dozens degrees of Celsius. Anomaly of the exogene field,which according to principal of superposition is summed with anomalous temperature of going to the surface permeable development zone of thermal waters reflects abyssal geothermal object which serves as an exploratory property for geothermal exploration.This type of geothermal objects in nonvolcanic zones can be used for low potential energy sets with submersive pump at the depth of dozens of metres in the limits of permeable zones or for high potential with the selection of geothermal fluid from the deep horisones and so on.

Another type of natural geothermal feature is connected with focuses of secondary geological changes of the sedimentary rock take place in deep horisontal faults and local postsedimentary structure. The literature data of the analyses of paleotcmperature field, in particular, in the limits of the Dnie-Der-Donets depression on the Ukraine, the Terek-Caspian flexure in Russia and other zones demonstrate deviation on the dozens of per cents cf the modern heat flows and geothermal gradients with paleoflows and gradients in the zones of faults and stepped paleogeothermal deviations in the deep buried horizons, influenced by secondary katagenesis. Reconstruction of the picture of the thermal evolution in the model of the zone of secondary changes of rock made it possible to discover unstationary anomalous effects, significant for the aims of the geothermal. energetic studies (Boykov, I992a, I992b).

For this by method of the integral transformations solution task of unstationary changing is solved in conditions of vertical stationary filtration.

In model of layred medium, discribing in the equation (I) with spasmodic changes of thermal properties of rock in the geology time scale the initial condition is set $t(z,0)=\theta$ and on the inner boundary of the zone discontinuity

$$\lambda \frac{\partial t(0,\tau)}{\partial z} - c_0 \rho_0 v \theta_0 = q, \qquad (5)$$

where θ_0 =const, and q =heat flow of the Earth.

The solution is obtained by the method of the integral transformations (Boykov, I992 a):

$$t(z,\tau) = \theta - (q + c_0\rho_0 v \theta_0) \exp\left(z \frac{c_0\rho_0 v}{2\lambda}\right) \times$$

$$\times \left\{ \frac{c_0\rho_0 v k}{4\lambda^2} \int_0^{\tau} \exp\left(-z\frac{c_0\rho_0 v}{2\lambda}\right) \operatorname{erfc}\left[\frac{z}{2\sqrt{k\tau}} - \right.\right.$$

$$\left. - \frac{c_0\rho_0 v}{2\lambda}\sqrt{k\vartheta}\right] + \exp\left(\frac{c_0\rho_0 v}{2\lambda}\right) \operatorname{erfc}\left[\frac{z}{2\sqrt{k\vartheta}} + \right.$$

$$\left.\left. + \frac{c_0\rho_0 v}{2\lambda}\sqrt{k\vartheta}\right]\right\} d\vartheta + \frac{k}{\lambda}\int_0^{\tau}\left\{\frac{1}{\sqrt{\pi\vartheta}}\left\{\exp\left[-\frac{1}{4}\left(\frac{z}{k\vartheta} + \right.\right.\right.\right.$$

$$\left.\left.\left.\left. + \frac{c_0^2\rho_0^2 v^2 k}{\lambda}\vartheta\right)\right]\right\}\right\} + \frac{c_0\rho_0 v}{4\lambda}\sqrt{k}\left[\exp\left(-z\frac{c_0\rho_0 v}{2\lambda}\right)\times\right.$$

$$\times \operatorname{erfc}\left(\frac{z}{2\sqrt{k\vartheta}} - \frac{c_0\rho_0 v}{2\lambda}\sqrt{k\vartheta}\right) - \exp\left(z\frac{c_0\rho_0 v}{2\lambda}\right)\times$$

$$\left.\left.\times \operatorname{erfc}\left(\frac{z}{2\sqrt{k\vartheta}} + \frac{c_0\rho_0 v}{2\lambda}\sqrt{k\vartheta}\right)\right]\right\} d\vartheta \Big\}. \qquad (6)$$

The changes of thermal properties k and λ and speed of filtration reflect the process of secondary changes in the model.

Modelling demonstrates that appearing in the endogene geothermal field anomalous effects can have the range of the first dosens degrees of Celsius (Boykov, I992a, I992b).That's why focuses of secondary transformations of rocks serve in the sedimentary basins as deep anomalous forming sources of geothermal heat, and going up to the surface along the permeable zones underground waters as energy bearers in geothermal energy sets oriented on high potential parameters while selecting of geothermal fluid from great depths or on low potential with submersive pumps near the surface. For geothermal exploration as exploratory property of this type of geothermal objects serves anomaly of endogene stationary field, reflecting at the surface deep focuse of secondary changes of rock. If above the focuse in the fault permeably zone is created, which goes to the surface, endogene anomaly is summed with anomalous effect of exogene field, which helps to make easy mapping of natural geothermal object.

2. METHODS OF THERMAL ZONDING IN FORMATIONS WITH LATERAL VARIABILITY OF PHYSICAL PROPERTIES AND LITHOLOGY

Modelling demonstrates, that of the character of differs sharply anomalous effects according the velocities of vertical filtration by the surface over the structural local objects of geological medium (Boykov, I992a). If velocity is less than IO^{-7} m/s, contrast of thermal properties is a determinant in the formation of anomalous exogene field by the surface, which correspond both in quality and quantity with effect of conductive heat bearing. With velocities more than IO^{-7} m/s anomalous effect is determined by intensity of filtration. The given regularity has an important practical meaning for the choice of technique of thermal zonding, as the first stage can be used in the technique of anticlinal tectonic structurs reconnaisance, while the second the faults and focuses of submarine phreatic-water discharge.

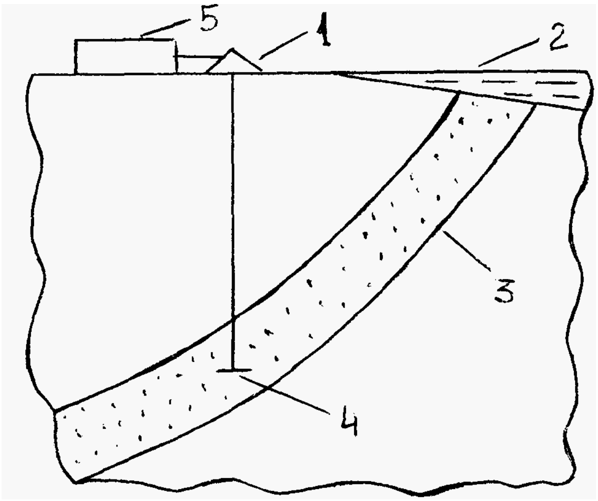
In the range of velocities of vertical filtration less than IC^{-7} m/s, the method of unstationary geothermal prospecting (Boykov, I986) is used. The method is used in conditions of two-layers section and is based on two -level field mapping of temperature in the zone of spread of annual temperature wave near the surface. At the first level with depth and time events have maximum anomalous effect of lateral variability thermal properties of local rock structures of upper section. On second level this unstationary effect becomes minimum up to its disappearance, then in the observed field the anomals determined by the geothermal field of the lower level appear. So the method makes it possible to distinguish geothermal anomalous of various genesis.

In the range of velocities of correlations of filtration more than IO^{-7} m/s the method of multilayer geothermal survey is used. The interpretation of survey results is connected with the groundwater regime of object of reconnaissance. If the object of reconnaissance is deepburied faults then the upwelling of thermal waters doesn't reach the surface and phreatic-water is in deep horizons higher intensive anomalies don't appear. But infiltration of surface waters and atmosphere sediments realises through the zones of higher permeability above the faults. In arid climatic conditions of semi-desert landscape the infiltration regime together with other anomaly forming factors creates on the ground of the annual wave characteristic temperature anomals (Boykov, I992a), which serves as exploratory properties of the subsurface geothermal object. If the reconnaissanse is directed at through going local structures, including geothermal systems, or through going fauls, then the results of the multilayer survey on all its levels of the higher intensive anomalies of the range of several degrees centigrade appeare. While this the geothermal prospecting uses reconnaissance as a direct method, which makes it possible to localize focus or fault lineforms of the surface phreatic-water discharge. In this aspect on the shelf,for instance, the thermal survey has an advantage over the geochemical survey, in which anomalies do not localize at the focuses of phreaticwater discharge (Boykov and Kornienko, I99I).

3. THE PROJECT OF A RENEWED GEOTHERMAL ENERGY SYSTEM IN THE COAST ZONE OF THE SEA

The role of geothermal prospecting in the realization of the project is in the mapping of the temperature anomalies in the limits of the shelf, connected with submarine phreatic-water thermal discharge, coming from the underground reservoir.Such features are usually connected with arches in hydrogeological aspects of the open anticlinal structures, coming to the surface at the bottom of permeable beds, spreading from the deep horizons of the earth to the surface of the faults. The line-focus zones of discharge show themselves in the temperature field of the bottom by means of the contrasting anomalies (Boykov and Kornienko, I99I).

The place for the projecting system of geothermal heat supply (See fig.I) one must choose not far from the coast line where the underground reservoir bed comes to the bottom of the shelf (Magomedov and Boykov, I99I). Pumping out the geothermal fluid from the underground reservoir beds through the waterlifting bore (I) one launches the process of water infiltration from the sea (2) along the permeable bed (3) through the hole botton of the waterlifting bore (4) to the surface. The burassing fluid from the sea during its migration along the bed in the regime of infiltration heats itself up to the temperature of the surrounding rocks and at the moment of its comming to the waterlifting bore becomes a heatbearer of the deep heat for the energy set of the system (5).



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The project is assigned for Duslac area in Dagestan in the coast zone of the Caspian Sea. There are exploitation parameters.

The waterlifting bore 2700 m depth will povide geothermal fluid with $100^{o}C$ temperature to the surface with volume of celection of fluid 20 l/s. This volume of celection pump with consumed thickness of 100 kW can do. Infiltration of seawater will be along the inclined fault with breadth 150 m and with length of road to a bore of 4400 m. For regime of infiltration, seawater it is necessary to keep up overfall of pressures about 60 kgf/cm^2 between the hole bottom, where pressure is 400 kgf/cm^2, and the surface.

4. CONCLUSIONS :

I. There are geological premises and new physico-mathematical foundation of models of two new types of natural geothermal objects, which can be used for aims of the geothermal energetic studies.

2. Model estimations of anomalous effects of exogene field, reflecting such geothermal objects have been done, which can serve as their exploratery properties.

3. Geothermal methods of reconnaissance and exploration of such objects in conditions of vertical filtration of pressure waters with a wide range of velocities of correlations are described.

4. The project of a renewed geothermal energy system in the coast zone of the sea, connected with the geothermal object of the described type is presented.

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