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Recharge Conditions of the Low Temperature Paratunsky Geothermal Reservoir, Kamchatka, Russia

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Abstract

The Paratunsky geothermal field is a classic example of a low temperature hydrothermal reservoir of meteoric origin. Hydrogeochemical zoning reflects a different intensity of water exchange in the Western and Eastern sites of the field. The hydrogeochemical history of operations 1966-2015 shows the involvement of chloride waters across the field's Eastern boundary. Water recharge to the Paratunsky geothermal field is provided mostly by meteoric waters from elevations above +1150 masl. The most likely area of water recharge to the Paratunsky geothermal fields is the Vilyuchinsky volcano (elevation 2173 m abs.).

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1. Introduction

The Paratunsky geothermal field has been in operation since 1966[5] at a rate of extraction of thermal waters up to 350 kg/s and a temperature of 75-100 °C. The extraction of thermal waters is mainly carried out in the mode of artesian flow and maintains numerous swimming pools with thermal water, district heating of the Paratunka and Termalny villages, greenhouse farming and fish breeding. We consider putting into operation the Upper Paratunsky area and an intensification of thermal production with use of submersible pumps for the growing number of consumers. The Paratunsky geothermal field is a classical low temperature geothermal field of meteoric origin. Its formation is due to infiltration waters penetrating to depth and heated by a regional conductive heat flow and local heat sources associated

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with magmatic feeding systems of extinct volcanoes. Fluid gases (N_2, Ar) are of atmospheric origin, and the proportion of thermogenic methane does not exceed 0.5 – 0.6 %.

2. Hydrogeological stratification and permeability structure

According to the results of exploratory drilling, mainly to the depth of 1000-1500 m, the following hydrogeological stratification was postulated for this field[5]: 1 - alluvial sand and gravel-pebble deposits (host reservoir of a powerful stream of cold groundwater); 2 – Lower Quaternary siltstones interbedded with fine-grained sandstones (caprock of geothermal reservoir) - lie at a depth of 40-180 m, their thickness varies from 10-150 m; 3 – Lower Quaternary conglomerates with interbedded siltstones and tuffstones (form upper aquifer of thermal waters); 4 – Tuffstones, tuff conglomerates and tuffs of the Alneysky series (occur only in the Northern area); 5 - tuffaceous pyroclastic rocks of Paratunsky Formation (characterized by the highest productivity) are the main hydrothermal host rocks; 6 - Intrusive rocks (low productivity, except for some tectonic zones).

The four above-mentioned horizons (3-6) are combined in a single thermal aquifer complex, which is characterized by circulation in mostly fractured host rocks. The presence of the upper caprock (unit 2) provides excess pressure and a barrier to a rising convective flow of thermal water. The thickness of the geothermal productive reservoir is estimated at about 1200 m[1].

3. Chemical composition of thermal waters, as a reflection of the conditions of water recharge in geothermal reservoirs

The chemical composition of well thermal water reflects geological, structural and geofiltrational features of the field. The wells of the Nizhny and Northern sites were characterized by more mineralized thermal waters (M 1.9-2.6 g/l) of chloride-sulfate composition, in contrast to sulfate waters in the Srednyand Mikizhinsky sites of the Paratunsky field. The appearance of sulfate ion, can mostly be explained by a sulfur oxidation process, which is consistent with assumption of a local crater funnel being present at the Sredny site – a manifestation of latent volcanism[7]. The Northern and Nizhny site wells are characterized by anincrease in the chloride ion concentration in thermal water during the 1966-2015 operation, up to 400-500 mg / l and more (wells 57, 64, 502, RE-7, 60, 101) from initial values 100-140 mg / l. The maximum chloride concentration, 597 mg/l, was observed in well 101 at the Northern site. In the Sredny site a chloride concentration increase in production well fluids over time was negligible. The maximum value was observed in well GK-2 (80.9 mg / l). As compared to 1969, in 2014 the shape of the thermal anomaly was unchanged according to the SiO_2 geothermometer, yet silicate geothermometer temperatures increased by 20ºC, which may be associated with the influx of more acidic waters (low pH). The hydrochemical characteristics of the Paratunsky field hydrothermal fluids are linked to the geological structure and dynamics of groundwater. This can be seen in examples from the Western and Eastern field blocks. Low-mineralized hydrothermal fluids of the Western block (the Sredny and Mikizhinsky sites) are characterized by a high rate of water exchange, and their mineralization rarely exceeds 1g /l. In the Eastern submerged block water mineralization increases by 2 and more g/l in accordance with the significant drop in water exchange rate. Variations in water temperature at the well heads during 1966-2015 operation were negligible, no more than 2-3ºC. The mechanism of connection between hydrochemical characteristics and the terms of water recharge are analyzed through TOUGH2-modeling, the results of which are partially presented in the study[4].

4. Use of water isotope data (δD, $\delta^{18}O$) to determine the area of water recharge for the geothermal reservoir and groundwater inflow zones during operation.

In 2014, 45 samples were analyzed, 44 selected from production wells and 1 sample from river Karymshina in a low-water period May 15, 2014. In 2015, 83 samples were analyzed, of which 58 samples were selected from production wells of the Paratunsky field, 5 samples from the wells in the Upper Paratunsky field, 1 sample from well 8 in the Yuzhno-Berezhny field in 08-09.2015 flood period, and 16 samples from the Karymshina, Paratunka and Mikizha rivers and 8 samples from the production well RE7 during the whole of 2015. Determination of the isotopic composition of the water were performed by P.O. Voronin and A.Yu. Polyakov with an LGR IWA 35EP