GEOPHYSICAL EXPLORATION OF RUSSIAN GEOTHERMAL RESOURCES

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MAP OF RUSSIAN GEOTHERMAL RESOURCES

The geothermal resources of Russia (Fig. 1) are rather well-studied (Atlas of the USSR thermal..., 1983; Boguslavsky et al., 2003; Kononov et al., 2003). Most of them are low temperature ones (Eastern and Western Siberia, Northern Caucasus, Kaliningrad region, Chukotka, Baikal rift zone, Moscow syneclise). They are used depending on temperature, pressure and fluid composition for space heating of apartment houses and industrial buildings, in agriculture (greenhouse heating), cattle breeding and fish-farming, drying of grain, tea, algas, wood, some industrial productions (wool washing, paper production), extraction of valuable dissolved components, improvement of oil-bearing reservoir recovery, thawing of frozen ground, balneological and recreational use (geothermal baths and swimming pools).

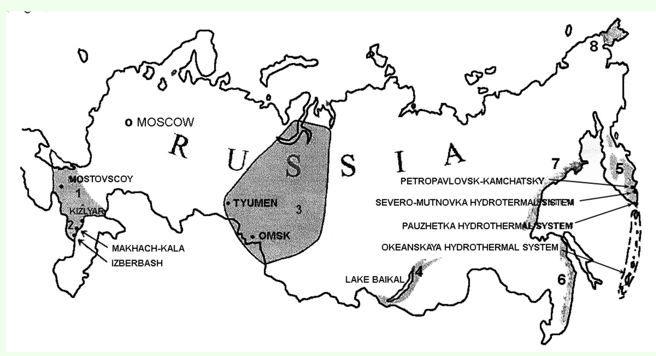

Figure 1. Geothermal resources of Russia (Kononov et al., 2003). (1) Alpine province of the Northern Caucasus, (2) Scythian Plate of the Northern Caucasus, (3) Western Siberia, (4) Baikal region, (5) Kuril-Kamchatka region, (6) Far East region, (7) and (8) Okhotsk-Chukotka volcanic belt.

HIGH-TEMPERATURE GEOTHERMAL RESOURCES OF KAMCHATKA

The high-temperature geothermal resources are located mainly in Kamchatka (Fig. 2). The most developed of them are Mutnovka and Pauzhetka, where heat flow is used for electric power generation (50MW and 12 MW, accordingly) with a north-east-north strike and 60° south-east-south dip. High-temperature liquid (40 kg/s, 1390 kJ/kg) upflows from southeast of the fracture, where a deep 280 °C liquid-dominated zone shows quartz-epidote-chlorite secondary hydrothermal mineralization. In the upper part of the main production zone, ascending fluids encounter two-phase conditions characterized by prehnite-wairakite precipitation. Fracture host rocks are diorites, Miocene-Pliocene sandstones, rhyolites and andesite tuffs and lavas. Shallow steam condensate and a meteoric water mixing zone are characterized by calcite-chlorite-illite mineralization.

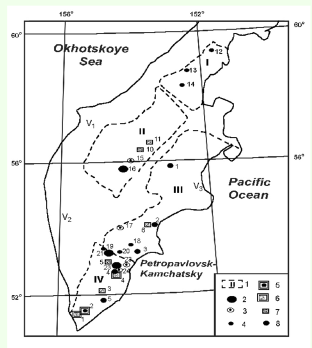

Figure 2. Map of Kamchatka geothermal deposits exploited and recommended for prospecting (Sugrobov, 1995): 1 - geothermal provinces (I - Northerh, II - Median, III - Eastern, IV - Southern, V - province of large structural depressions); 2-4 - low-potential deposits (T< 150°C): 2 - exploited; 3 - prospected; 4 - recommended for prospecting; 5-7 - high-potential deposits: 5 - exploited; 6 - prospected: 7 - recommended for prospecting: 8 - some volcanoes and calderas (1 - Tolbachik, 2 - Little Semyachik, 3 - Avacha, 4 - Gorely, 5 - Ksudach).

GEOPHYSICAL EXPLORATION OF MUTNOVSKY GEOTHERMAL FIELD

Geophysical exploration of the Mutnovsky geothermal region was carried out using seismic, gravimetric (Fig. 3), direct current (Fig. 4), transient electromagnetics (Figs. 5-14) and magnetotelluric (Figs. 15-19) methods. It has revealed the systems of tectonic disturbances elongated in the north-east and meridional directions. Electroprospecting has detected here two large resistivity anomalies (less than 5 Ohm.m): one in the north-east (3x5 km) and another in the south-west (3x3 km) of the area. Inside these anomalies even less resistive zones were found with resistivity 2.5 Ohm.m. Magnetotelluric sounding of this region has revealed low resistivity zones (deepening up to the depths 5-6 km) interpreted as fluid conductors of the heat carrier.

REFERENCES

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Kononov, V.I., Polyak, B.G., and Khutorskoy, M.D., 2003. Hydrogeothermal resources of Russia. Proc. Int. Geothermal seminar, Sochi, Russia.

Schwarz, Y., Nurmukhamedov, A.G., 2002. Rep. on re-interpretation of geophysical data collected in Mutnovsky geothermal field. Elizovo, 78pp. (in Russian).

Sugrobov V.M., 1995. Utilization of geothennal resources of Kamchatka, prognostic assessment and future development. Proc. World Geothermal Congress, Florence, 3, 1549-1554.

GRAVITY DATA

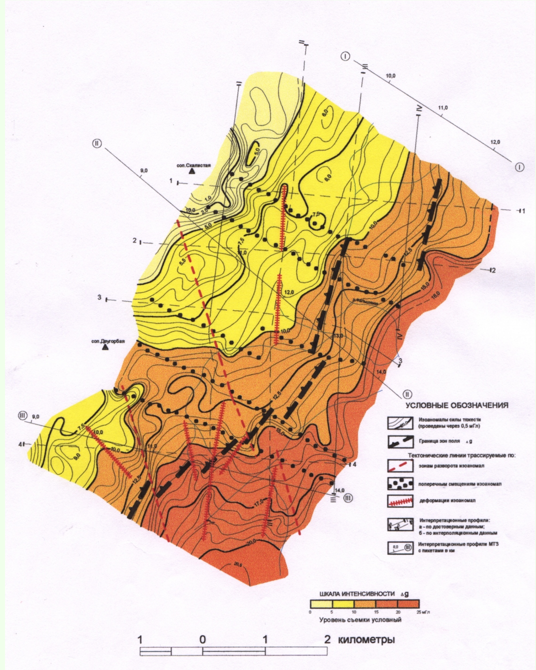

Figure 3. Contour map of gravity data corrected for 2.35 g/sm³

DIRECT CURRENT METHOD

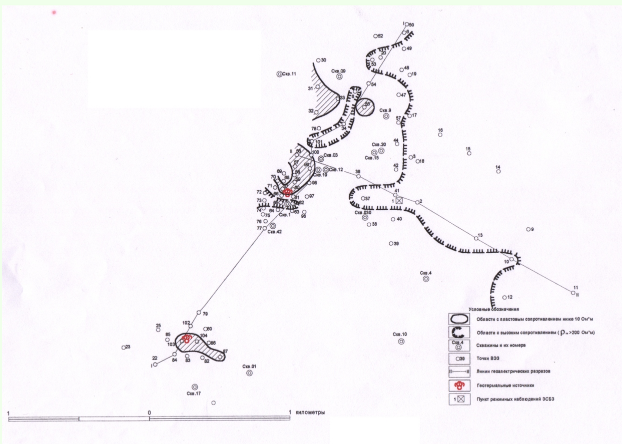

Figure 4. Schematic map of a bed resistivity at a depth of 250 km revealed from DC data

TEM METHOD

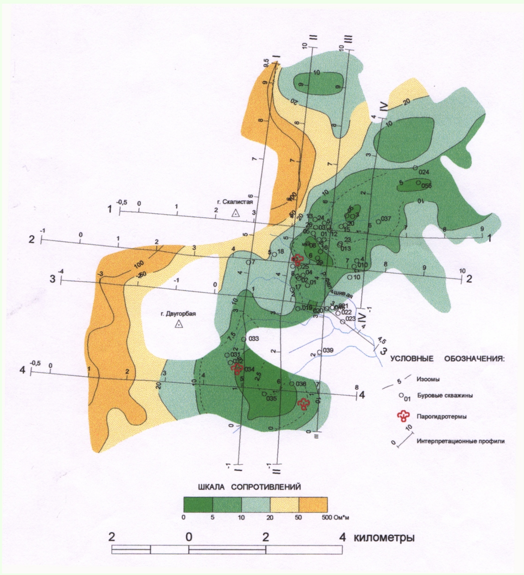

Figure 5. Map of total resistivity of the studied area according to TEM data

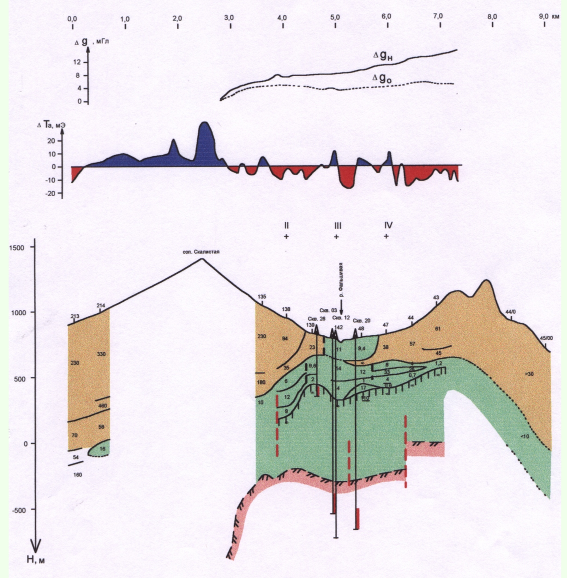

Figure 6. Geoelectric section along profile 1-1. (Δg, ΔT - gravity and magnetic anomalies, correspondingly)

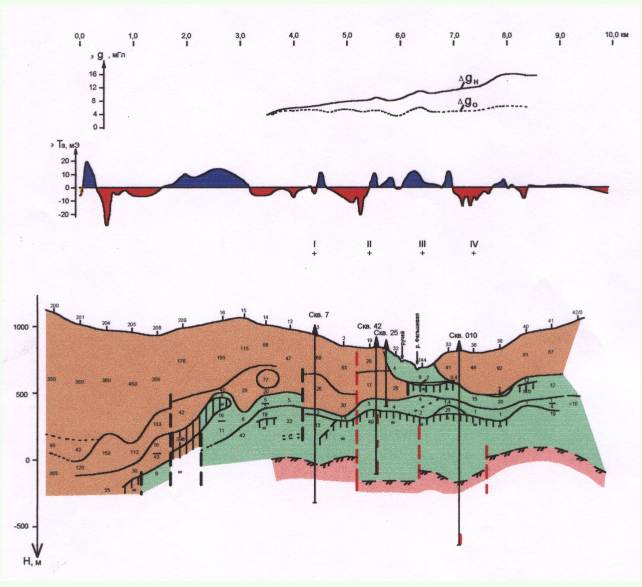

Figure 7. Geoelectric section along profile 2-2

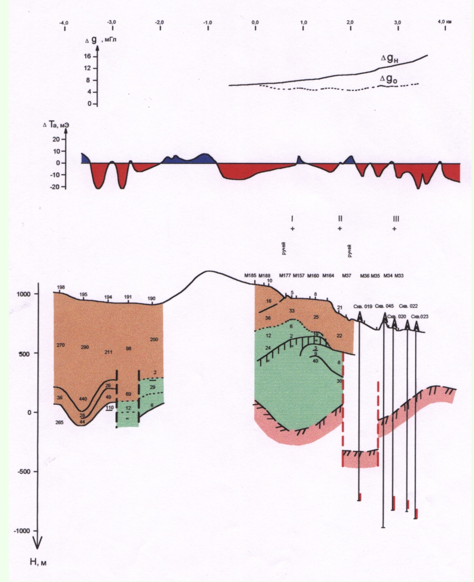

Figure 8. Geoelectric section along profile 3-3

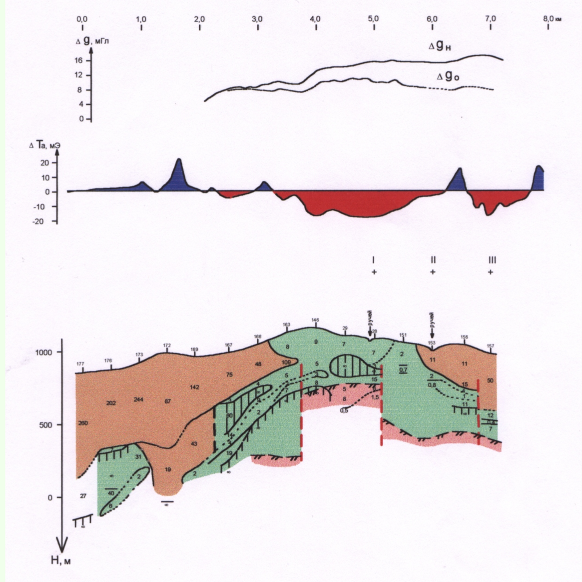

Figure 9. Geoelectric section along profile 4-4

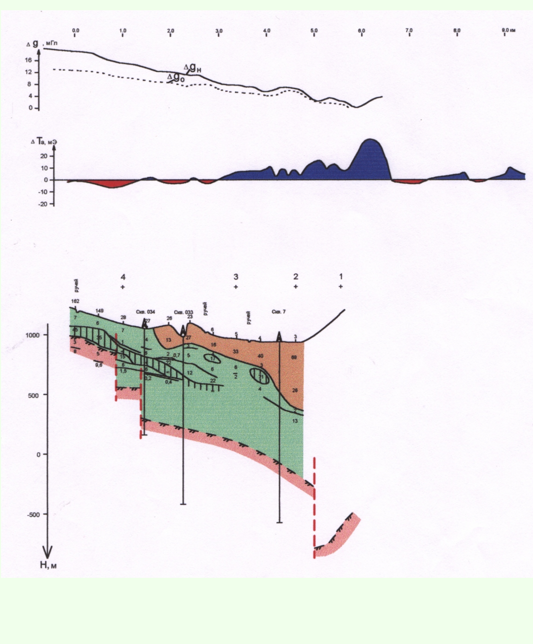

Figure 10. Geoelectric section along profile I-I

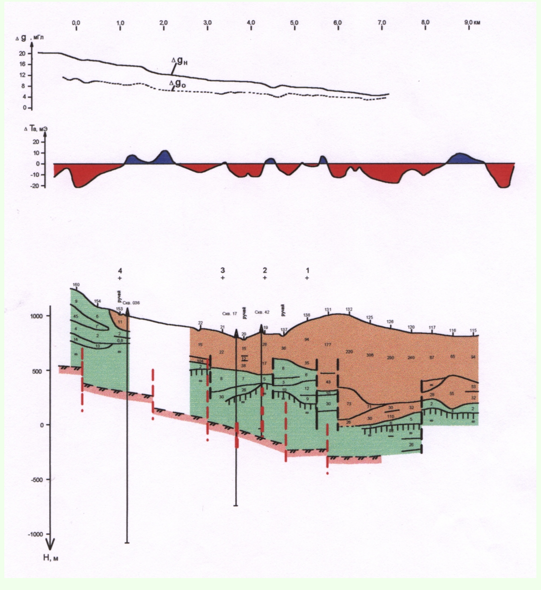

Figure 11. Geoelectric section along profile II-II

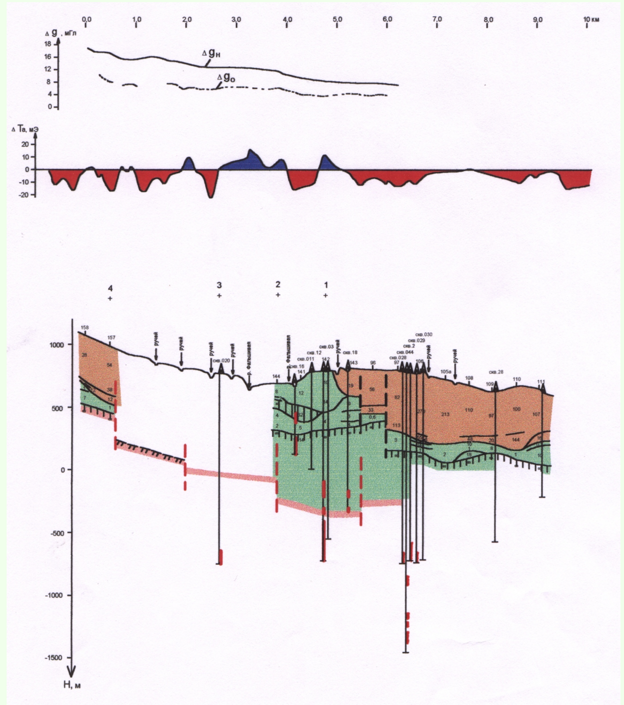

Figure 12. Geoelectric section along profile III-III

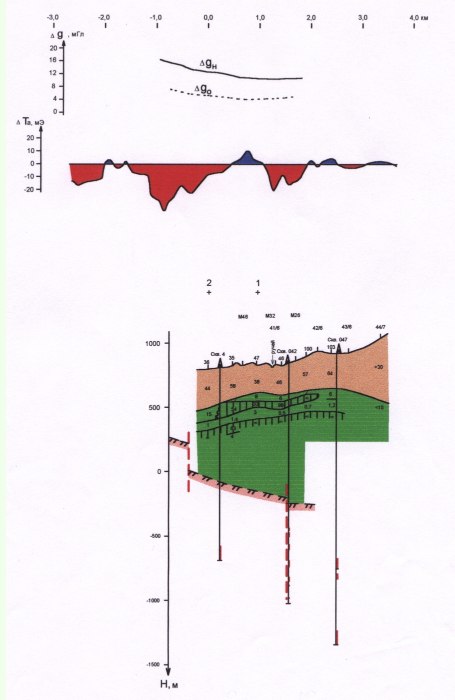

Figure 13. Geoelectric section along profile IV-IV

LEGENDS

- Δg (gravity anomaly) curves a) of the observed field; b) of the residual field
- ΔT_a (total anomalous magnetic field) curves
- First (upper) geoelectric horizon of high resistivity
- Second geoelectric horizon of low resistivity
- Highly resistive layers within the second geoelectric horizon
- The roof of a horizon of increased density
- Tectonic dislocations a) according to electric prospecting data; b) according to gravimetry and seismology data
- Observation sites of electric prospecting measurements using a) TEM methods; b) FS (frequency sounding); c) MT
- Interpretation profiles intersection points
- Boreholes
- Productive zones according to drilling data

MODEL REVEALED FROM MT DATA

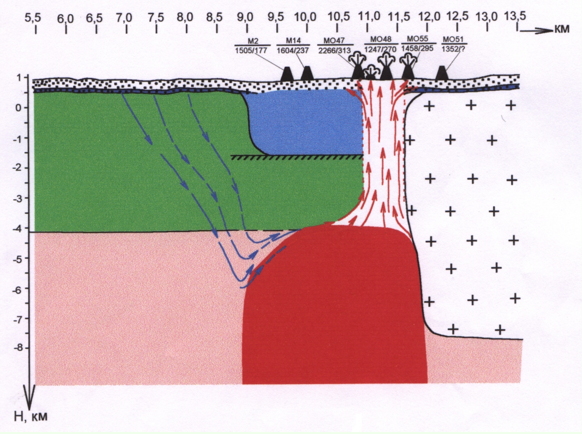

Figure 15. Conceptual model along profile I - I

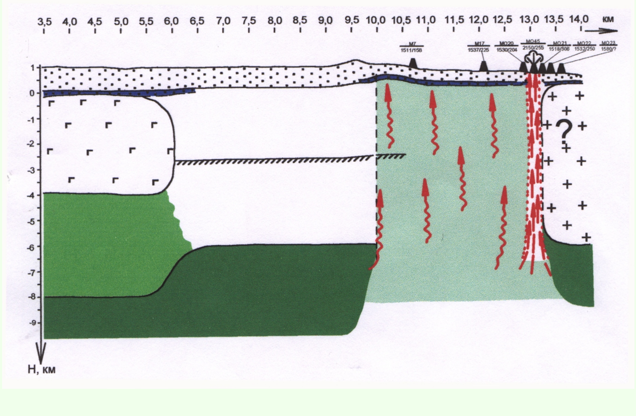

Figure 16. Conceptual model along profile II - II

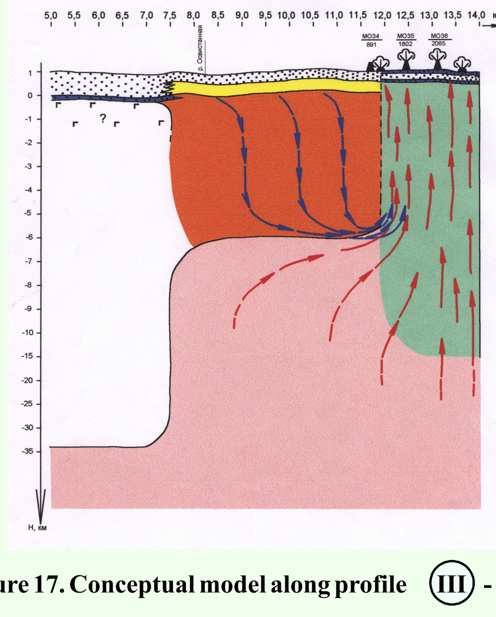

Figure 17. Conceptual model along profile III - III

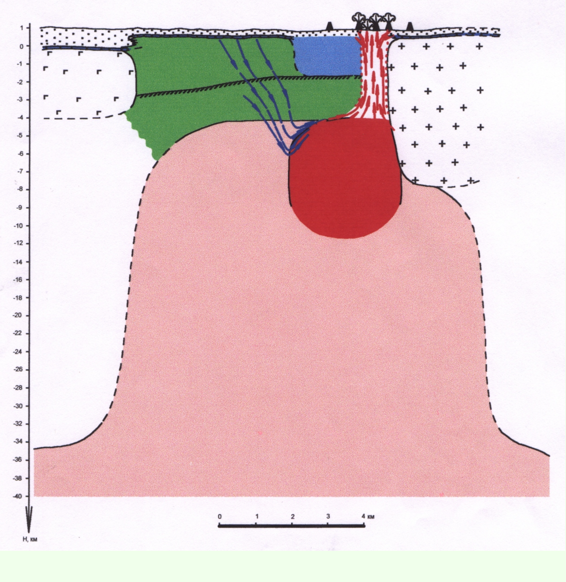

Figure 18. Generalized conceptual model

LEGENDS

- a) volcanogenic sediments (βQ_{iv}); b) lower part of the same horizon saturated with waters of different mineralization and temperatures.
- a) "reservoir" filled with chilled mineralized water and vapor; b) roof of the Upper Cretaceous basement (K_2ir).
- Rocks saturated with highly mineralized fluids.
- Heated granodiorite intrusion (γ-δN_1)
- a) boundaries of subvertical fault (zone of discharge);
- Supposed flows of cool (meteoric) water
- Lower-crust heating seat: a) partial melting zone; b) melting zone
- Natural gas outflow
- Wells: 1) productive; 2) barren; 3) well marking: a) the number of the well; b) face depth; c) maximum temperature
- Interpretation profile sites.