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A model of the deep structure of the Earth's crust and upper mantle in the area of the Karymshinsky gold-ore cluster according to geophysical data (South Kamchatka)

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Abstract. In the South of Kamchatka, modern geodynamic processes are actively taking place. A deep geological and geophysical model of the structure of the Earth's crust and upper mantle along the regional profile of the Apacha Village-Mutnaya Bay in the zone of Tolmachevsky active magmatic center is presented. The profile passes near the South-Western border of the Karymshinskaya volcano-tectonic structure (VTS) and crosses the Ahomtenskaya VTS. The model created on the basis of integrated interpretation of materials of the earthquake converted-wave method (ECWM), gravity and magnetotelluric sounding (MTS). The thickness of the Earth's crust along the profile varies from 30-33 km at the edges reaching 44-46 km, in its central part. The dominant feature of the model is a high-density formation – a block of the Earth's crust, saturated with intrusions of the main and ultrabasic composition. The formation of the block is associated with a permeable zone between the crust and the upper mantle. In the block correlation of seismic boundaries is disturbed and in a density model the area with massive heterogeneity is allocated. A significant increase in depth to the M-Boundary in the center of the model is explained by the presence of a "bloated" transition layer between bark and mantle in this place. The thickness of the layer is about 10 km, and the density of the mantle reaches 3.4 g/cm^3. It is assumed that this is a site of eklogization of breeds in a zone of paleosubduction of oceanic lithosphere under a continental. The area is favorable for the accumulation of meteor waters, which are in contact with high-temperature environment and postmagmatic solutions of intrusions, which leads to the formation of hydrothermal systems. The genetic connection of Karymshinsky gold-ore cluster with the intrusive array of medium-sour composition, allocated in the zone of the Tolmachevsky active Magmatic Center is shown.

Keywords: crust, upper mantle, transition layer, deep model, heat flow, ECWM, MTS, South Kamchatka

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Introduction

Currently, it is of great interest to solve the problems of the distribution and localization of volcanogenic gold fields in the area of the Nachikinsky (Krutogorovsk-Petropavlovsk) zone of transverse dislocations and on its flanks (Fig. 1). The zone crosses the area of modern volcanism in the south of Kamchatka, where several gold deposits and ore occurrences have been identified. The area of the Porozhisty field and ore occurrences to the east of it is distinguished under the general name "Karymshinsky ore cluster". The site is located in the area of the Tolmachev Active Magmatic Center (TAMC) (Nurmukhamedov, 2017; Nurmukhamedov, Sidorov, 2019), the contours of which are shown in Fig. 1. Two regional geophysical profiles pass through the central part of TAMC: in the northeast direction, the profile of the Opala Mountain-Vakhil River and in the north-west direction, Apacha Village-Mutnaya Bay.

Along the profiles from 1987 to 1993 the Elizovsky geophysical expedition of Production Geological Association Kamchatgeologiya conducted in-depth studies using the earthquake converted-wave method and magnetotelluric sounding. The results are presented in scientific publications (Moroz et al., 1995; Mishin, 1996, 1997). However, much later analysis of the earthquake converted-wave method showed that on the western fragments of regional profiles a systematic overestimation of the depths to the Moho boundary and other boundaries in the Earth's crust was allowed. Therefore, reinterpretation of the earthquake converted-

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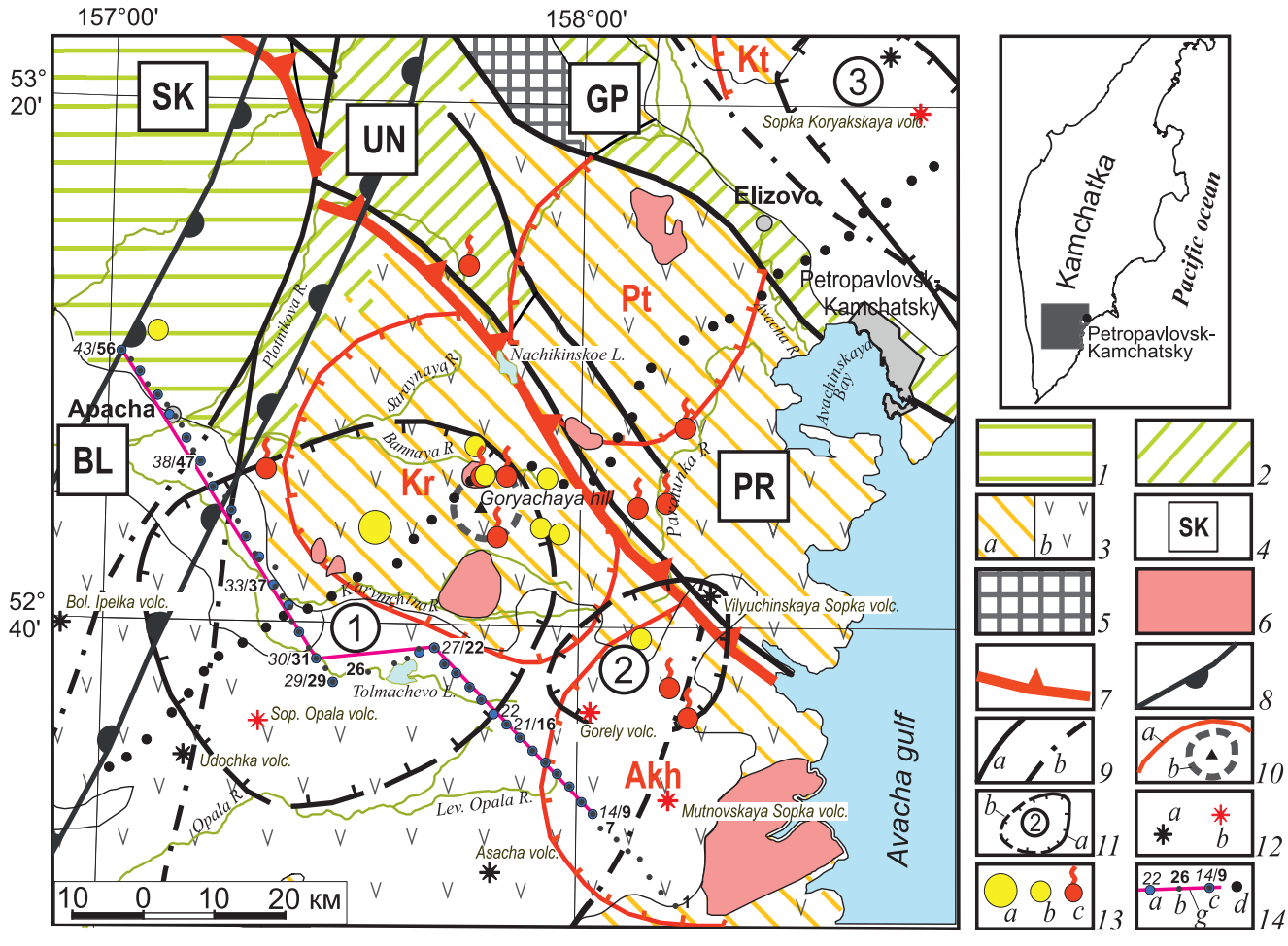

Fig. 1. A fragment of the tectonic diagram of the Koryak-Kamchatka folded region (based on materials (Nurmukhamedov, Sidorov, 2019) with additions). 1 – Koryak-West-Kamchatka folded zone; 2 – East Kamchatka subzone of the Olyutor-East Kamchatka folded zone; 3 – Kuril-South Kamchatka island arc volcanic zone (a), South Kamchatka volcanic belt (b); 4 – structures of folded zones and their designations: BL – Bolsheretsky Uplift, SK – Srednino-Kamchatsky horst-anticlinorium, horsts: UN – Unkanovichy, GP – Ganalsko-Petropavlovsky, PR – Pribrezhny; 5 – late Cretaceous metamorphic complexes; 6 – intrusive formations of predominantly medium and acidic composition; 7 – boundaries of the Nachikinsky zone of transverse dislocations; 8 – borders of the Central Kamchatka deep seam zone; 9 – the main faults extending to the day surface (a) and overlapped by overlying formations (b); 10 – volcanic-tectonic structures: Kr – Karymshinsky, Pt – Plotnikovsky, Kt – Kitkhoysky, Akh – Akhomtensky (a), the contours of the paleovolcano of the Goryachaya hill (b); 11 – boundaries (a – confident, b – assumed) of crustal and coromantium anomalously low-resistance zones, identified according to magnetotelluric sounding and their numbers: 1 – zone of melting and circulation of hydrothermal solutions – Tolmachevsky active magmatic center, 2 – zone of melting in the area of volcanoes Gorely, Mutnovskaya Sopka, Vilyuchinskaya Sopka; 3 – a zone of high fluid saturation in the region of the Avachinsky-Koryak group of volcanoes; 12 – extinct volcanoes (a), active (b); 13 – Porozhisty field (a) and ore occurrences (b) of gold, sources and deposits of thermal mineral waters (c); 14 – points of observations and their numbers on the profile of Apacha Village-Mutnaya Bay: earthquake converted-wave method (ECWM) (a), magnetotelluric sounding (MTS) (b), combined points of ECWM-MTS (c); line of density modeling (g); ECWM points on the profile of Opal M.-Vakhil R. (d).

wave method was carried out (Nurmukhamedov et al., 2016). Subsequently, for the profile of the Opala Mountain-Vakhil River performed geo-density modeling, using a modern software package and based on a set of updated data, a geological and geophysical model of the structure of the Earth's crust and upper mantle was developed (Nurmukhamedov, Sidorov, 2019).

This article presents the results of the interpretation of earthquake converted-wave method, gravimetry, and magnetotelluric sounding obtained along the profile of Apacha Village-Mutnaya Bay in conjunction with geological and geophysical data on the TAMC area. The profile length is about 120 km (Fig. 1).

Brief description of the research area

A review of regional geological and geophysical studies is described in detail in publications (Nurmukhamedov, 2017; Nurmukhamedov, Sidorov, 2019). Profile of Apacha Village-Mutnaya Bay crosses the territory studied by geological, gravimetric and aeromagnetic surveys of the 1: 200,000 scale and its

significant part by the geological and aeromagnetic scale of 1:50,000. Based on these data, structural-formation map of the South Kamchatka (Aprelkov, Olshanskaya, 1986) was constructed and a tectonic diagram of the scale 1: 1,000 000 with elements of the deep structure of the Earth's crust was prepared (Nurmukhamedov, 2013), a fragment of which is shown in Fig. 1.

The profile from north-west to southeast intersects two folded zones: the Koryak-West-Kamchatka zone and the East-Kamchatka subzone of the Olyutor-East-Kamchatka zone. In the west of the area, there is a fragment of the Central Kamchatka deep seam zone – the zone of the joining of island arc blocks (Paleoarc) in the Eocene (Seliverstov, 2009; Shapiro et al., 2009) to the Paleokamchatka. The north-eastern part of the area is occupied by the Nachikinsky zone of transverse dislocations, which is characterized by discontinuous violations of the north-western strike. A significant part of the territory is covered by areal volcanism, spread south of the latitude of the Paratunka and Karymchina rivers (Geological structure..., 1980).

The profile runs near the southwestern border of the Karymshinsky volcanic-tectonic structure and crosses the Akhomten volcanic-tectonic structure. In the central part of the Karymshinsk volcanic-tectonic structure there is a Pliocene paleovolcano with the center of the Goryachy hill. Thermal mineral springs and the Bolshe-Banny steam-water mixture deposit are located along the perimeter of the paleovolcano. Active hydrothermal activity is observed in a significant part of the territory near the Karymshinsky ore cluster. The described region is characterized by an increase in the thickness of the Earth's crust up to 40-45 km against a background of 32-35 km. The thickening of the crust is explained by an increase in the transition layer thickness between the crust and the upper mantle in the region of active volcanoes and areas of areal volcanism (Balesta, Gontovaya, 1985). Such places (Nurmukhamedov, 2017; Nurmukhamedov, Sidorov, 2019) have high permeability and the presence of a powerful heat flow. The flow is localized closer to the upper layers of the crust, its density increases, which leads to the formation of a focal region of melting (Nurmukhamedov, Smirnov, 1985).

In the south of Kamchatka, modern geodynamic processes are actively proceeding. In 1987-1988 in the TAMC region, a swarm of weak ($M \leq 5$) earthquakes was recorded (Fig. 2), named the Tolmachev Epicentral Zone (TEZ) (Nurmukhamedov, 2017).

In terms of TEZ, it coincides with the site of the maximum density of slag cones and the zone of high permeability. The depth of the earthquake hypocenters is about 8 km. Probably, earthquakes are associated with the advancement of magma (Nurmukhamedov, Sidorov, 2019). Indirectly, this is indicated by the confinement of the TEZ to the proposed melting zone. Miocene

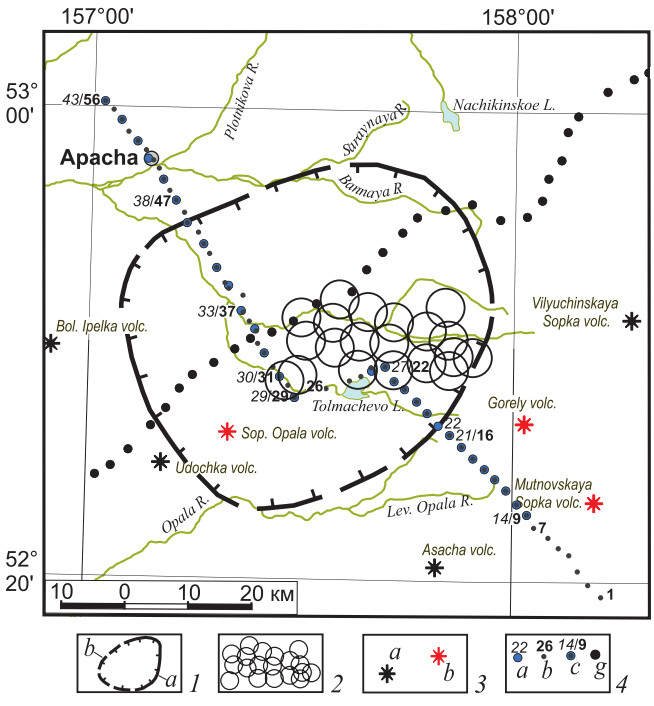

Fig. 2. A swarm of earthquakes in the Tolmachevsky epicenter zone – based on materials (Nurmukhamedov, 2017; Nurmukhamedov, Sidorov, 2019). 1 – TAMC borders: confident (a), alleged (b); 2 – epicenters of local earthquakes (data for 1987-1988); 3 – extinct volcanoes (a), active (b); 4 – observation points and their numbers on the profile of Apacha Village-Mutnaya Bay: ECWM (a), MTS (b), combined points ECWM-MTS (c), points ECWM on the profile of the Opal M.-Vakhil R.(g).

intrusions of medium and acidic compositions (Fig. 1) are associated with a large intrusive array formed in the weakened zone (Nurmukhamedov, 2017).

In the area of TAMC, the magnetotelluric sounding along the profile of the Opala Mountain-Vakhil River, in the depth interval 10-35 km was performed. A contrast anomaly of electrical conductivity (5 Ohm·m against a background of 500-1000 Ohm·m) was revealed. According to the authors (Mishin, 1996; Moroz et al., 1995; Nurmukhamedov, Smirnov, 1985), the anomaly is due to the circulation of hydrothermal solutions in the Earth's crust and the presence of melting zones. In the geological and geophysical model along the profile of the Opala Mountain-Vakhil River (Nurmukhamedov, Sidorov, 2019), a block of the Earth's crust is allocated in the central part of TAMC, saturated with intrusions of the basic and ultrabasic composition. From the east, at a depth of 8-27 km, an intrusive mass of predominantly medium-medium acid composition adjoins it, from which apophyses are introduced into the upper layers along weakened zones (Fig. 1).

Research methodology

Earthquake converted-wave method field observations on the profile of Apacha Village-Mutnaya Bay performed

according to standard methods (Pomerantseva, Mozhenko, 1977). Three-component registration of seismic waves was carried outat 43 points. The distance between points is 2.5-5.0 km. Registration of seismic events is implemented in the "detection" mode. The duration of one parking ranged from 20 to 30 days, which provided the necessary set of information to highlight the boundaries of the exchange. The "Tcherepakha" hardware complex was used in the process of work. The methodology of field work, interpretation and reinterpretation of earthquake converted-wave method data is covered in the article (Nurmukhamedov, Nedyad'ko et al., 2016). The modern version of the earthquake converted-wave method section along the profile of Apacha Village-Mutnaya Bay, combined with the density model, is shown in Fig. 3.

Field observations using the magnetotelluric sounding method were carried out according to the standard method (Moroz et al., 1995; Nurmukhamedov, Moroz, 2008, 2009) using the DEpS-2 digital electric prospecting station. A total of 56 sounding points were completed, of which 4 components (Ex, Ey, Hx, Hy) of the magnetotelluric field (MT field) were recorded in half the points in a period range of 0.1-100 s. At every second magnetotelluric sounding point combined

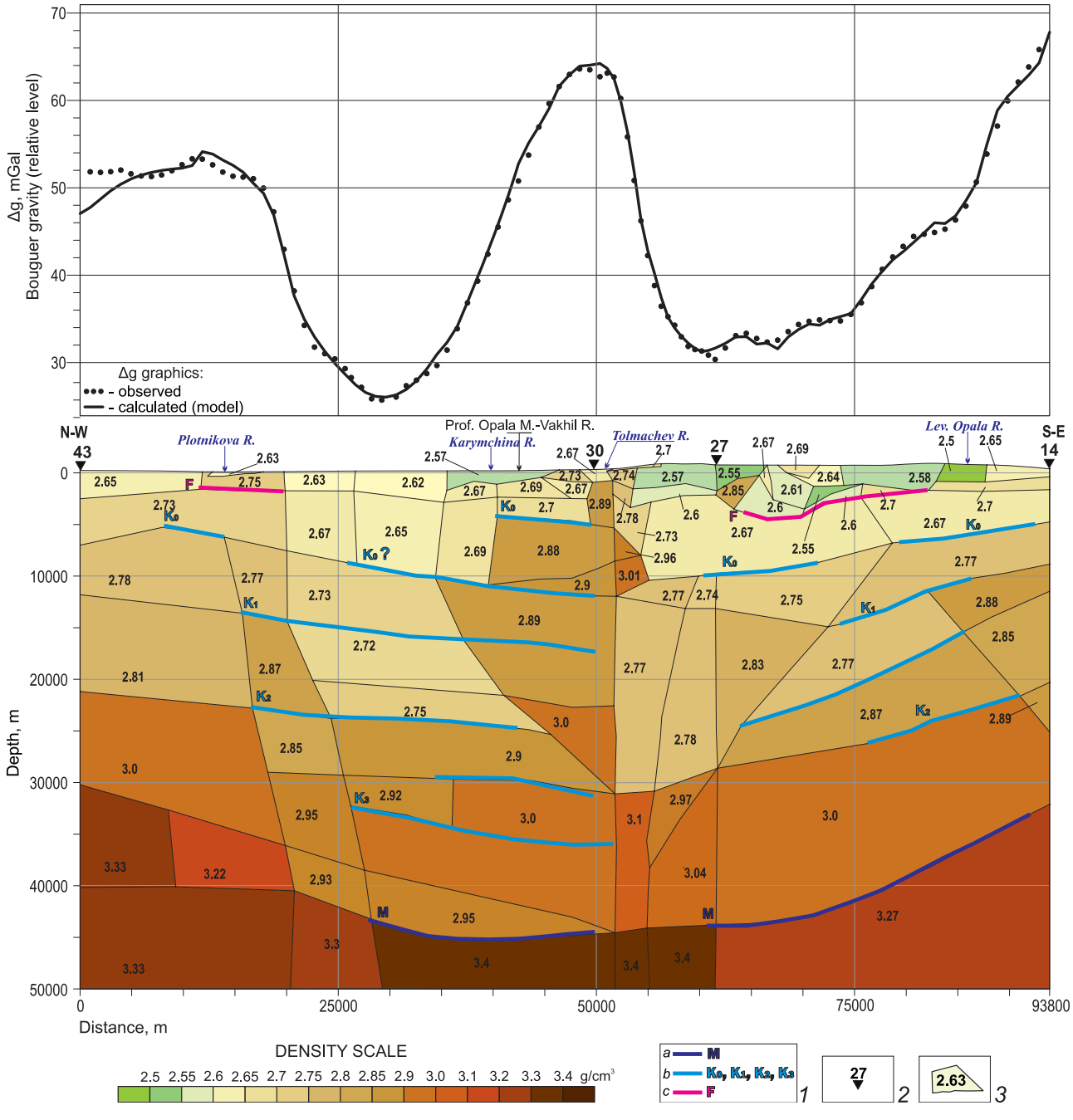

Fig. 3. A deep density model along the profile of Apacha Village-Mutnaya Bay. 1 – seismic boundaries according to the earthquake converted-wave method (a – the boundary of Mokhorovicic; b, c – other seismic boundaries identified in the Earth's crust); 2 – earthquake converted-wave method points and their numbers; 3 – the boundaries of the blocks and the average density value (g/cm³) for them.

with the earthquake converted-wave method point, registration of the fifth component (Hz) was added. At combined points, the range of variations of the MT field is expanded to 1000 s. Primary processing of magnetotelluric sounding data was carried out in the Computing Center of the Production Geological Association Kamchatgeology. The inverse problem was solved using two-dimensional numerical simulation of the MT field (Yudin, Kazantsev, 1977) at the Laboratory of Geophysical Fields of the Institute of Volcanological Geology and Geochemistry FEB RAS.

In the modeling process, we used regional-longitudinal curves, since they are practically free of the induction effect formed in the Sea of Okhotsk and the Pacific Ocean (Moroz, Moroz, 2011). Before the modeling procedure according to the profile of Apacha Village-Mutnaya Bay identified 6 zones, characterized by conformal, but different in terms of resistance, magnetotelluric sounding curves. A different level indicates lateral heterogeneity of the upper part of the section, which leads to the emergence of strong galvanic near-surface effects. The average curves for each zone were calculatedin order to suppress them. For the formation of a starting model according to the profile of Apacha Village-Mutnaya Bay we used the previously developed normal deep model of South Kamchatka (Moroz et al., 1995).

During iterative selection of model elements, a satisfactory convergence was achieved between the average experimental and calculated magnetotelluric sounding curves (Fig. 4) for each zone of the geoelectric model (Fig. 5). The model shows the distribution of electrical conductivity in the Earth's crust and upper mantle and is consistent with the geoelectric model along the profile of the Opala Mountain-Vakhil River (Moroz et al., 1995; Mishin, 1996) in the zone of their intersection.

To study the density distribution of rocks in the Earth's crust and upper mantle, two-dimensional density modeling was performed (Fig. 3) using materials from the gravimetric survey with a scale of 1: 200,000. Previously, modeling was performed according to the profile of the Opala Mountain-Vakhil River. The results are published in an article (Nurmukhamedov, Sidorov, 2019). The initial frame of the model was the boundaries and faults identified by the reinterpretation of the earthquake converted-wave method data. A priori density values of the upper layers of the section are determined by geological formations overlooking the day surface. For deep layers, density values are taken from published sources. For the Upper Cretaceous deposits, the density value is taken to be 2.67 g/cm^3, for the granite-metamorphic ("granite") layer – 2.64-2.8 g/cm^3, for the lower crust ("basalt" layer) – 2.80-3.07 g/cm^3 and for the upper mantle – 3.30 g/cm^3. The indicated densities are taken as initial data for iterative selection of the model. In the process of modeling, we used the Geosoft software package (GMSYS, Oasis Montaj, Grav/Mag Interpretation, 3D Euler, MAGMAP filtering), where it is possible to take into account the terrain and approximate body sections with contours of complex configuration. The modeling technique is described in the articles (Sidorov, 2014, 2015).

As a result of a comprehensive interpretation, a deep geological and geophysical model is constructed (Fig. 6), in which the following are distinguished: the Mokhorovicic boundary (M), which separates the Earth's crust from the upper mantle; border K_2, separating the upper cortex from the lower; the roof of the consolidated crust (K_0) – the crystalline basement; the roof of the Upper Cretaceous rock complex (F). In addition, other boundaries in the Earth's crust (K_1, K_3) have been identified. Layers corresponding to (from top to bottom) the Cenozoic volcanic-sedimentary cover, the Mesozoic complex of rocks, the granite-metamorphic ("granite") and granulite-basite ("basalt") layers are located between the boundaries. At the very bottom of the model, the upper mantle layer is highlighted. Crustal and crustal-mantle faults penetrate the entire thickness, dividing the Earth's crust and upper mantle into separate blocks. The fundamental similarity of geological and geophysical models is noted in the zone of intersection of the profiles of the Opala Mountain-Vakhil River (Nurmukhamedov, Sidorov, 2019) and Apacha Village-Mutnaya Bay.

Analysis of the geological and geophysical model, discussion of the results

When starting the model analysis, we emphasize that the authors call the K_2 wave exchange boundary – the boundary dividing the Earth's crust into upper and lower parts (Nurmukhamedov et al., 2016). Given information on the Kola superdeep well (Kola superdeep..., 1998; Sharov, 2017) and other scientific publications, the names of the granite and basalt layers are enclosed in quotation marks, implying a certain convention.

Compared with other regional profiles on the territory of Kamchatka, the profile of Apacha Village-Mutnaya Bay has a small extent. It is difficult to isolate systemic changes in the structure of the Earth's crust and upper mantle in such a short segment. According to the earthquake converted-wave method data, the picture of the deep structure is substantially supplemented by the results of density modeling. So, for example, the boundaries marked along but not tracked over long distances along the earthquake converted-wave method are further extended in the form of contacts between layers and blocks with different densities. An analysis of the obtained data indicates that the results of density modeling do not contradict the prevailing ideas about the density characteristics of the lithosphere layers.

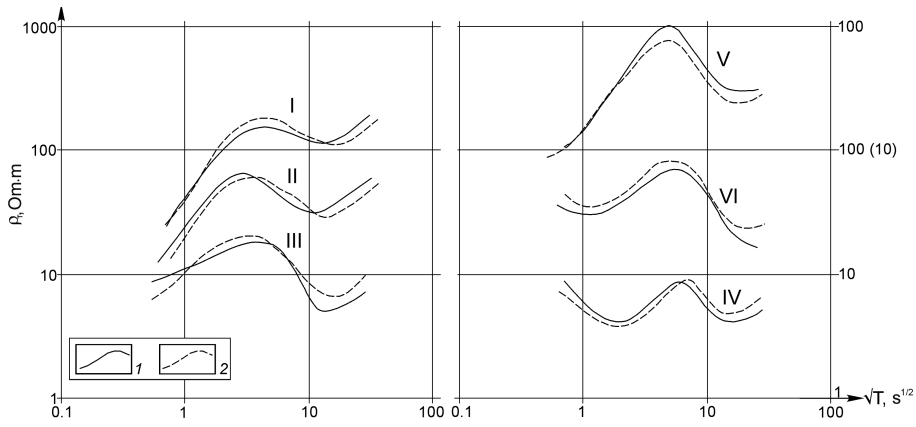

Fig. 4. Comparison of the experimental (1) and calculated (2) curves of magnetotelluric sounding for the geoelectric model shown in Fig. 5

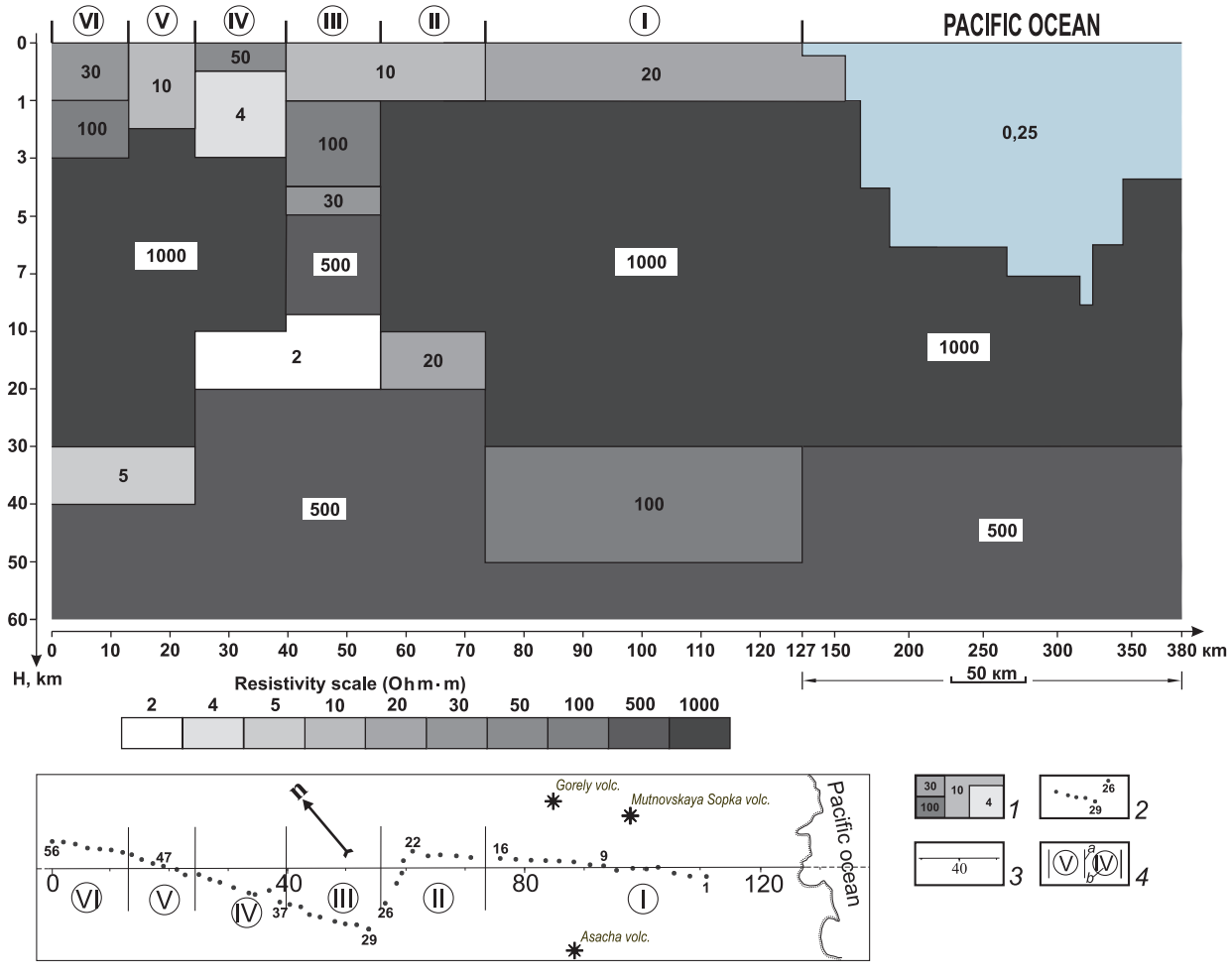

Fig. 5. Two-dimensional geoelectric model of the Earth's crust and upper mantle along the profile of Apacha Village-Mutnaya Bay. 1 – blocks characterized by different levels of resistivity in Ohm·m; 2 – magnetotelluric sounding observation points and their numbers; 3 – modeling line and its marking in kilometers; 4 – boundaries of the modeling zones (a) and their numbers (b).

In the model (Fig. 6), the thickness of the crust along the profile varies from 30-33 km at the edges to 44-46 km, in its central part. The morphology of the K_2 boundary basically repeats the morphology of the M section. Moreover, the thickness of the "granite" layer is stably greater than the "basalt" one. Such a crust belongs to the continental type crust (Kosminskaya, 1958). A significant increase in the depth to the boundary M in the center of the model can be explained by the presence of a "swollen" transitional layer between the crust and the upper mantle at this location. If we take section K_3 as the top of the layer, then its estimated capacity will be about 10 km. As can be seen from the model, in the southeastern direction the layer gradually wedges out, and in the northwest direction its distribution is limited by the Central Kamchatka deep seam zone.

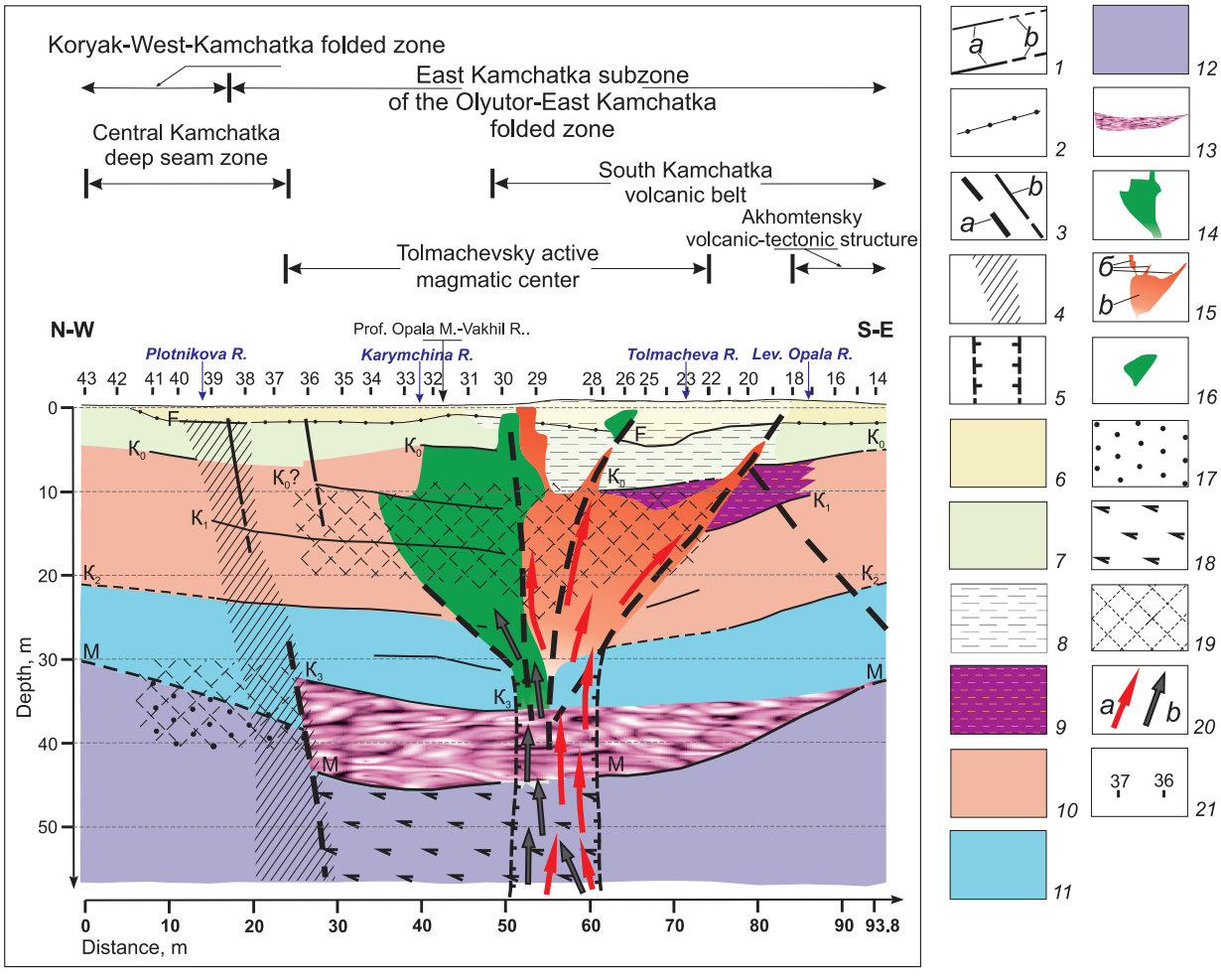

Fig. 6. Geological and geophysical model along the profile of Apacha Village-Mutnaya Bay. 1 – boundaries according to the earthquake converted-wave method data: confident (a), alleged (b), identified with the roof of the Upper Cretaceous rock complex (F), the roof of the consolidated crust (K_0), the boundary between the upper and lower crust (K_2), the Mohorovicic border (M), other boundaries in the Earth's crust (K_1, K_3); 2 – the roof of the Upper Cretaceous complex of rocks, according to magnetotelluric sounding; 3 – discontinuous violations according to the earthquake converted-wave method(a) and geological data (b); 4 – subvertical zone, selected according to the results of density modeling, identified with the axial part of the Central Kamchatka deep seam zone; 5 – zone of absence of exchange boundaries correlation; 6 – Cenozoic volcanic-sedimentary rock complex; 7 – Mesozoic rock complex; 8 – hydrothermally altered Meso-Cenozoic rock complex; 9 – the upper layer of metamorphic complexes mainly in the green shale and epidote-amphibolite facies; 10 – granite-metamorphic ("granite") layer of the upper crust; 11 – granulite-mafic ("basalt") layer of the lower crust; 12 – upper mantle; 13 – the estimated position of the transition layer between the Earth's crust and the upper mantle; 14 – block of the earth's crust, saturated with intrusions of the basic and ultrabasic composition; 15 – intrusive array (a) and its apophyses (b) mainly of medium-medium acid composition; 16 – intrusion of the main structure; 17 – decompression site (3.22 g/cm³ against the background of 3.33 g/cm³) in the upper mantle, coinciding with the anomalously low resistance zone (5 Ohm·m against the background of 500-1000 Ohm·m); 18 – plot of increased density (3.4 g/cm³) in the upper mantle, presumably of peridotite-eclogite composition; 19 – crust and crust-mantle anomalies of electrical conductivity (2-20 and 5 Ohm·m, respectively, against a background of 500-1000 Ohm·m); 20 – direction of the estimated heat flows (a) and magmatic melts (b); 21 – earthquake converted-wave methodobservation points and their numbers.

The density characteristics of the rocks in the transitional zone practically do not differ from the density of the lower part of the "basalt" layer, but a block of low density – 2.95 g/cm³ against a background of 3.0 g/cm³ – is distinguished northwest of its middle. Further, to the northwest at a depth of 30-40 km, a zone with an abnormally low level of resistivity (5 Ohm·m against a background of 500-1000 Ohm·m), which coincides with the local area of decompression in the upper mantle (3.22 g/cm³ against the background of 3.33 g/cm³). It is possible that the anomalous site was formed as a result of the interaction of lithospheric blocks during the joining of island-arc blocks to the Paleokamchatka (Seliverstov, 2009; Shapiro, Soloviev, 2009).

In the lower part of the model, the density of individual fragments (Fig. 3) varies from 3.27 g/cm³ to 3.33 g/cm³, which corresponds to the density of rocks of the upper mantle – peridotites. Where the boundary M

drops to the maximum depth (ECWM 27-36), a block with a high density value of 3.4 g/cm^3 is distinguished, which according to A.E. Ringwood (Ringwood, 1972) corresponds to peridotites and "unchanged eclogites" (3.4-3.65 g/cm^3). It is assumed that the selected site belongs to the site of eclogitization of the upper mantle rocks formed in the paleosubduction zone of the oceanic lithosphere beneath the mainland (Nurmukhamedov, Smirnov, 1985; Nurmukhamedov, Sidorov, 2019). Subduction processes preceded the incorporation in the Eocene of relatively light island-arc blocks to the folded region of Paleokamchatka.

In the upper part of the section, the roof of the consolidated crust (K_0) confidently stands out, which experiences immersion from 4-5 km at the edges of the model to 10 km or more in its central part. Structurally, this site coincides with the Tolmachevsky active magmatic center. In general, the K_0 border repeats the morphology of the K_2 and M sections. Above the section, at a depth of about 4 km (ECWM 30-33), a border is distinguished that is close in its characteristics to the K_0 border. The question remains open of which section these boundaries belong to. At this stage of the research, the authors are inclined to believe that, with the general tendency of the boundary K_0 to sink to the central part of the model, in the TAMC region, a protrusion of the Earth's crust block is saturated with intrusions of the basic and ultrabasic composition (Fig. 6). The roof of this block coincides with the boundary K_0. Above the section, a smooth rise in the boundary of F is noted, which is obviously inherited from the indicated protrusion. It should be noted that in the same place, above the boundary K_0, in the depth interval 4-5 km (Fig. 5), a low-resistance, space-limited object (30 Ohm·m against a background of 100-1000 Ohm·m) was identified, which can be explained the presence of a "heated" intrusion and/or thermal water circulation zone here. Below is the border marked with the index "K_0?". It reflects the waves exchange boundary inside the crystalline basement. The aforesaid is consistent with the geological and geophysical model according to the profile of the Opala Mountain-Vakhil River (Nurmukhamedov, Sidorov, 2019).

The dominant model is the block of the Earth's crust, saturated with intrusions of the basic and ultrabasic composition. In the field of gravity, it is expressed by a contrast increase in Δg values (Fig. 3). It seems to the authors that the penetration of the melts occurred along the weakened zone formed in the crust, at its border with the upper mantle. In the earthquake converted-wave section (Nurmukhamedov, Nedyad'ko et al., 2016), a zone of seismic boundaries correlation absence is fixed in this place, and a region with heterogeneities is identified in the density model. The subvertical zone permeates the horizontally layered crustal medium, and from a depth of 30 km from it faults are spread, which are migration routes to the upper crust of mantle material (magma, high-temperature fluids) and powerful heat flows (Nurmukhamedov, Sidorov, 2019).

To the south-east of the described block (ECWM 20-29) the density of the medium corresponds to rocks of medium and medium acid composition. In the Δg graph, a minimum of the gravity field is observed (Fig. 3), complicated by local low-amplitude maxima. We can assume here a large intrusive mass of diorite-granodiorite composition. Apophyses depart from the array, some of which are exposed on the day surface (Fig. 1). In the section, the array region is characterized by the absence of seismic boundaries correlation with an abnormally low level of electrical resistivity (2-20 Ohm·m against a background of 500-1000 Ohm·m). It is assumed that the formation of the array is associated with a powerful heat flow and the formation of focal melting zones (Nurmukhamedov, Smirnov, 1985; Nurmukhamedov, 2017; Nurmukhamedov, Sidorov, 2019).

The movement of magma into the upper layers of the Earth's crust is accompanied by a swarm of weak earthquakes (Fig. 2), which are probably caused by the local system of stresses characteristic of volcanic earthquakes (Zobin, 1979). However, there are no active volcanoes near the indicated swarm. We can talk about the formation of an eruptive crack, or about the "revival" of an existing one (Zobin, 1979) in the zone of areal volcanism. The swarm is elongated in the latitudinal direction and is located near the Opalinsko-Gorelovsky fault, identified by gravimetric data (Aprelkov et al, 1989).

In the study area, favorable conditions exist for accumulations of underground meteoric waters (Kononov et al., 1964; Kraevoy et al., 1976). These waters through the infiltration zone interact with the high-temperature environment of the melting centers and cooling intrusions, as evidenced by active geothermal activity in the zone of the intrusive array.

Conclusions

1. Density modeling was performed along the profile of Apacha Village-Mutnaya Bay. As the initial data, the results of the reinterpretation of the earthquake converted-wave method materials were used. An analysis of the data shows that the simulation results do not contradict the prevailing ideas about the density characteristics of the lithosphere layers. Based on the earthquake converted-wave method, gravity exploration, magnetotelluric sounding and other data, a geological and geophysical model of the Earth's crust and upper mantle is built along the profile. The model presents the specified position of the main sections of the lithosphere – the bottom of the crust, the border between the granulite-mafic and granite-metamorphic parts of

the consolidated crust, its roof. The Earth's crust along the profile of Apacha Village-Mutnaya Bay corresponds to a continental-type crust. Good convergence of the models at the intersection of the profiles of Apacha Village-Mutnaya Bay and the Opala Mountain-Vakhil River is noted.

2. The dominant model is a high-density formation – a block of the Earth's crust saturated with intrusions of the basic and ultrabasic composition. The formation of the block is associated with the presence of an active permeable zone between the Earth's crust and the upper mantle. From the southeast, an intrusive array of medium-sour composition adjoins the block. The formation of the array is explained by the formation of focal melting sites.

3. A swarm of weak earthquakes from 1987-1988 coincides with the maximum density of slag cones on the surface and the deep zone of high permeability between the Earth's crust and the upper mantle. Perhaps these earthquakes are associated with the advancement of magma in the existing eruptive crack or with the formation of a new one.

4. The area is favorable for the accumulation of meteoric waters that come in contact with a high-temperature environment and post-magmatic solutions of intrusions. Probably, these circumstances contributed to the formation of closed hydrothermal systems and, as a consequence, the formation of ore occurrences of the Karymshinsky ore cluster.

5. Active modern magmatic processes in the south of Kamchatka indicate the relative youth of this part of the peninsula in the system of mountain-folding structures of the entire Kamchatka region. This is clearly observed in geological and geophysical sections along the profiles of the Opala Mountain-Vakhil River and Apacha Village-Mutnaya Bay.

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