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TEMPERATURE DISTRIBUTION IN THE CRUST AND UPPER MANTLE OF THE TERRITORY OF UKRAINE

The study aims to build a three-dimensional thermal model of the crust and upper mantle of the territory of Ukraine. Its basis is a scheme of deep processes in the tectonosphere, which, first of all, considers the results of heat and mass transfer during modern activation. They are superimposed on the models of the platform (except for the territory of the East European platform; the Donbass is also included in it), the Alpine geosyncline of the Carpathians, and the Hercynian-Cimmerian geosyncline of the Scythian plate. The incomplete process of modern activation cannot be accurately described by the geological theory used by the authors. Gravity modeling was previously conducted on a system of profiles around the northern hemisphere with a total length of more than 30.000 km, crossing Eurasia, North America, as well as the Atlantic and Pacific oceans to select an adequate scheme of heat and mass transfer. The paper distinguishes the most realistic scheme of the process . It is applied for Ukraine, and the more accurately the activated area is determined. Such a task was solved for the first time. In the south, the model is limited by the Black Sea depression, at a depth of 400 km. Temperatures in the transition zone to the lower mantle were not considered. Test thermal models are compared with geothermometers. The error (50 °C) of calculation and cross-section of isotherms is determined (150 °C for depths from 50 to 400 km, at a depth of 25 km the error is lower, the cross-section of isotherms is 100 °C). Zones of partial melting of the rocks of the crust and upper mantle have been established. They are distributed in the middle part of the crust, in the upper horizons of the mantle (50–100 km). At a depth of about 400 km, partial melting occurs only under the non-activated part of the platform. Differences in the model from the presented one are described. They are associated with possible variations in the age of the process and its peculiarities at different levels of heat and mass transfer. Practical significance. The study emphasizes that mineral deposits are characteristic to thermal anomalies and other environmental parameters.

Key words: modern activation, deep process, tectonosphere, thermal model.

Introduction

The article is written based on the results of the first stage of research. Its purpose is to build a unified model of deep processes in the tectonosphere of Ukraine and the corresponding distribution of the physical properties of the rocks of the crust and upper mantle. The authors have participated in a comprehensive research of these problems over many years. The findings are presented in 7 monographs covering the entire territory of the country, and 5–10 monographs on deep processes and data analysis of individual geophysical methods (namely, geothermal [Gordienko et al., 2002 and others]). The bibliography is presented, in particular, in [Gordienko, 2017 and others]. Together with the study of other regions of the continents and oceans, we managed to formulate a general geological theory [Gordienko, 2022c] and solve a number of problems. They included the origin of deposits of some minerals and the development of methods for their search.

In this case, we are talking about building a thermal model of the tectonosphere. It is calculated on the basis of the scheme of heat and mass transfer during deep processes. And then it is used to create models for the distribution of elastic wave velocity, density, electrical conductivity, viscosity, and energy intensity of rocks. For some of these parameters, independent control is conducted. Calculated values without selection are compared with experimentally established ones and are considered reliable, conditioned by discrepancies due to errors. This order of analysis has been implemented for almost all endogenous regimes on continents and oceans. In certain oceanic areas, there is currently inadequate data to make definitive conclusions. Additionally, in both continental and oceanic regions where modern activation is occurring, the phenomena and fields available for observation may not yet fully reveal the extent of the process.

Thus, for Ukraine, the work should start with a definition of the area of recent activation (*RA*) and the content of the deep process, its combination with others, the construction of thermal models, comparison with observed temperatures (*T*), the actual calculation of the model, the allocation of layers of partial melting within it substances.

Recent activation process

The endogenous regime of modern activation has been known for about 80 years. But its existence is still debatable. Therefore, it is necessary to dwell on the understanding of the content of the term by the authors [Gordienko, 2017 and others]. It is based on the work of Soviet geologists of the 1940–1960s, who saw in this phenomenon a new form of the earth's crust development which follows the platform. This refers to the qualitative restructuring of platforms, expressed in various activation phenomena (tectonic and magmatic), which undoubtedly occurred in the distant geological past. However, in the Mesozoic, these phenomena manifested themselves more strongly than in the Paleozoic, and in the latest stage of the Earth's development, the activation of platforms is especially intense and diverse. Therefore, in tectonic analysis, such areas should be distinguished as special zones within those main structural elements of the earth's crust (geosynclinal regions and platforms), on whose basis they arose.

Let us note the main features of the deep process of modern activation, important for solving the problem. The scheme of heat and mass transfer in the RA tectonosphere contains uncertainties associated with its incompleteness and manifestation in regions with very different ages of previous geosynclines or rifts. The subcrustal superheated area arose about 5–25 million years ago during the rise of matter from an intermediate chamber under the platform or the asthenosphere that existed before the start of activation in the alpides. From this area, a partial melt is carried into the crust. The age was approximately estimated from geothermal data and a few manifestations of magmatism on the Moldavian and Moesian plates, in the Transcarpathian trough, Pannonia, and on the Czech massif. Around the same time period, there were significant surface uplifts in various regions. The Dniester-Prut interfluve experienced rapid uplifts approximately 4 million years ago, while the Folded Carpathians saw uplifts 10–15 million years ago. In different periods, the Ukrainian territory of the East European Platform (EEP) experienced uplifts up to 25 million years ago.Partial melt enters the depth interval of 30–40 km (occupies about half of the volume) and 20–30 km (occupies a quarter of the volume). The average temperature rises here by (500±100) ºC. Eclogitized blocks of basic crustal rocks descend under the crust; upon reaching the asthenosphere, they lower its temperature by about 100 ºC. Heating the crust "unfreezes" the eclogitization reaction. Its rapid course is facilitated by fluids brought by mantle melts and formed during the partial melting of rocks of the amphibolite facies of metamorphism in the crust.

In both versions of the heat and mass transfer model, there is no indication of a temperature decrease in the region of polymorphic transformations at the base of the upper mantle. Therefore, it is unlikely that a significant portion of the subsided material would transition to a denser olivine phase.Accordingly, there are no significant subsidence of the surface. This fact makes it possible to limit the depth of the lower source of the moving material to 300–400 km.

Calculation method

Thermal models in the depth intervals of maximum overheating in the mantle under the crust are quite close under the platforms and alpides and do not contradict the data of geothermometers. It is obvious that two zones of partial melting should correspond to such models. A fairly thick zone is in the subcrustal part of the mantle (in the depth range from 40–60 to 90–100 km), and a thin zone is in the lower crust at depths slightly more than 20 km. The latter may be absent if the removal of magma into the crust occurred noticeably earlier than those assumed in the calculation of the process age. This zone can serve as a source of material for intracrustal advection, leading to the formation of individual intrusions of acidic and intermediate magmas at depths of up to 5–10 km.

Consideration of the shape of the mantle gravity anomaly in the most studied regions of Ukraine reveals a number of fragments that are noticeably different from the neighboring ones. They are about 50 km wide, which is close to the size of a tectonic action quantum (QTA) [Gordienko, 2017; Gordienko, 2022b]. It can be assumed that, in the space occupied by the process, activation covers relatively narrow bands located close to each other. Seismological data also confirm such structure.

The transfer of matter in the mantle under the platform during RA can occur according to different schemes. In addition to direct removal from the lower reservoir to the upper one, intermediate pockets of partially molten rocks can also form. The gravitational effect will also change. In [Gordienko, 2022a], the magnitude of the anomaly was determined in various regions of the continents and oceans along an almost continuous traverse around the northern hemisphere with a total length of more than 30.000 km. Numerous data on velocity sections along DSS profiles were used [Chulick et al., 2002; International…, 2014; Mooney et al., 2002; Pavlenkova et al., 2006 and others]. They pass through the territories of the RA zones for many thousands of kilometers. And in all cases, the anomalies calculated according to the simplest scheme for the movement of matter (with an intensity of about 30–40 mGl) coincide within the error. It is highly probable that such a process occurs throughout the EEP.

Throughout Ukraine, all DSS profiles known to the authors were used to calculate the mantle gravity anomaly [Baranova et al., 2008, 2011; Grad et al., 2006; Kozlenko et al., 2009; Starostenko et al., 2015; Tripolsky et al., 2004 and others]. Kriging was used to fill in the gaps [Davis, 1986; Demyanov et al., 2010; Olea, 2018]. An error estimate showed that simple kriging is sufficient for the material used. The results are shown in Fig. 1. With real sizes of objects, the RA zone is limited by the value of the mantle anomaly of 20 mGl.

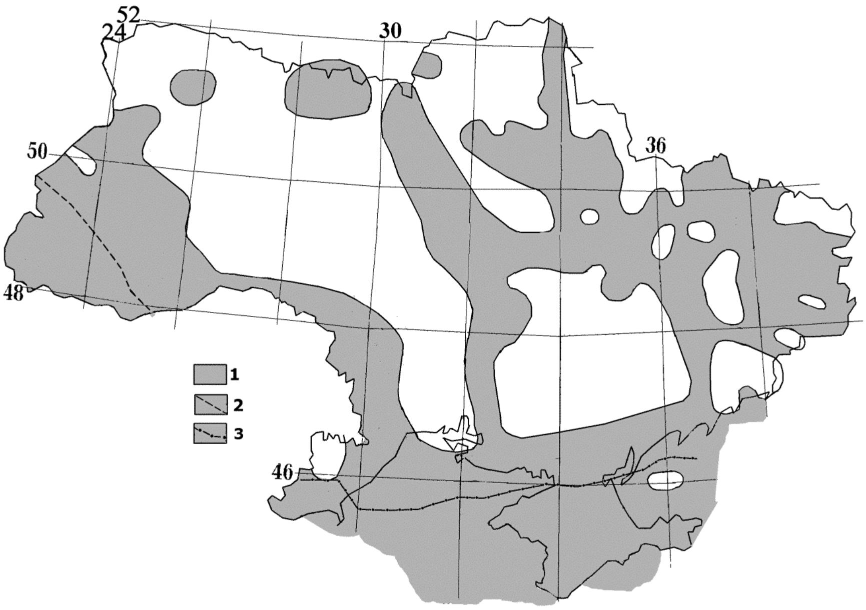

Fig. 1. Borders of the RA on the territory of Ukraine (1)
and borders between the regions: the EEP and the Carpathian (2), the EEP and the Scythian plate (3).

Practical significance

All known manifestations of RA are locatedwithin the limits marked in Fig. 1. They include young surface uplifts [Verkhovtsev, 2006], hydrocarbon deposits (including coal methane), points with an anomalously high content of mantle helium and hydrogen [Bagriy, 2020 and others] in underground gases, heat flow anomalies, practically all seismicity, hydrothermal ore occurrences of the Carpathians, etc. (Fig. 2).

Fig. 2. Comparison of a significant mantle gravity anomaly
with the criteria for identifying zones of recent activation.

1 – area of the mantle gravity anomaly; 2 – hydrocarbon (HC) deposits; 3 – points with anomalous helium isotopes; 4 – points of hydrogen release with a concentration of 1–60 %; 5 – earthquake epicenters.

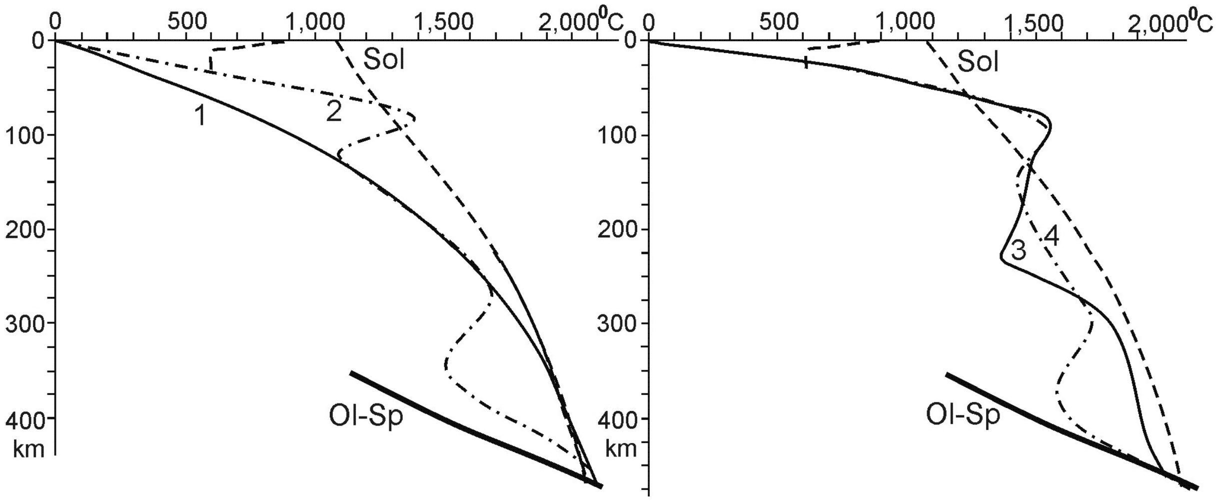

Fig. 3. Thermal models of the tectonosphere of the platform (1) and zones of the RA platform (2), the Carpathian geosyncline (3), and the Scythian plate (4).

Sol is the solidus temperature of mantle rocks and crustal rocks of the amphibolite facies of metamorphism. Ol–Sp is the top of the zone of polymorphic transformation of olivine into spinel.

Varieties of models. Errors

The 4 varieties of endogenous regimes noted above are shown in Fig. 3. They belong to the RA process of middle age, i.e. about 15 million years. Estimates of the influence of variations of this parameter on the calculated temperatures show that the variability is (70±50) ºC in the range of 5–25 Ma at the depths of significant anomalies.

From the south, the model is limited by the area of the emerging Black Sea basin, whose endogenous regime belongs to the type of oceanization. Special calculations indicate the significant influence of deep processes in its tectonosphere on the deep temperatures of the Scythian plate. The boundary, which manifests itself, in particular, in the amplitude and rate of subsidence of the shelf bottom surface, is very sharp. The work [Yanchilina et al., 2017] also provides other signs confirming this opinion.

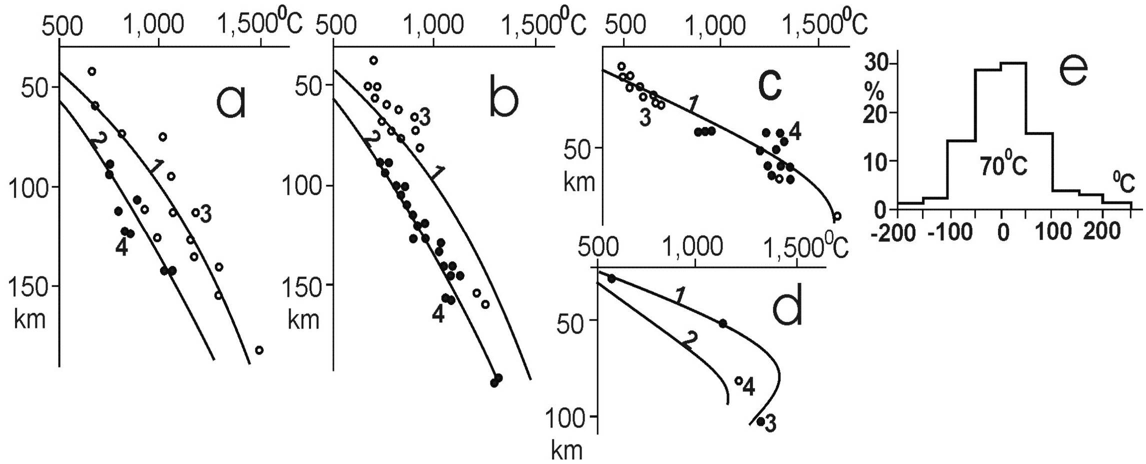

Fig. 4. Distributions of calculated (1, 2) and experimental (3, 4) temperatures in the tectonosphere of some regions:

a – Ukrainian Shield (1, 3 – normal HG; 2, 4 – reduced HG); b – Baltic Shield (1, 3 – normal HG; 2, 4 – reduced HG); c – Carpathians (1, 3) and Apennines (1, 4); d – RA zones of the East European and West European platforms: the Moldavian and Moesian plates (1, 3 – the age of the RA is 2–5 Ma) and the Czech massif (2.4 – the age of the RA is 25 Ma); e – distribution histogram of differences between calculated and experimental T.

It is widely believed that the top of the transition zone to the lower manthle is at a depth of 410 km and the transition layer is thin. Based on research conducted by Tauzinet et al. (2013) and other experts who utilized an advanced observation system, the density of the network and the multitude of oscillations present have been identified as key factors influencing the results of the section analysis. At a relatively short distance, the roof depth changes by 20 km, the speed jump is from 0.4 to 0.6 km/s, and there are signs of boundary splitting. Such a design (and polymorphic transformation is associated with the appearance of heat sources) can significantly affect the temperature distribution,creating an anomaly of 100–150 ºC [Gordienko, 2017] which has not yet been correctly considered. In addition, in recent years, the idea has emerged that the transition zone is highly hydrated, representing a "graveyard" of water-carrying slabs [Peslier et al., 2017]. Although the same authors write about the complete dehydration of the plate when immersed to about 100 km. If the process is real, the thermal effect of the formation of hydrated minerals in the transition zone will be added to the effects of the formation of wadsleyite and majorite. Real control is possible by determining the jump in the velocity of longitudinal seismic waves at the top of the zone. It gives a negative result. "Velocity data show no evidence that wadsleyite or ringwoodite was globally hydrated by subduction or initial terrestrial conditions" [Houser, 2016, p. 94].

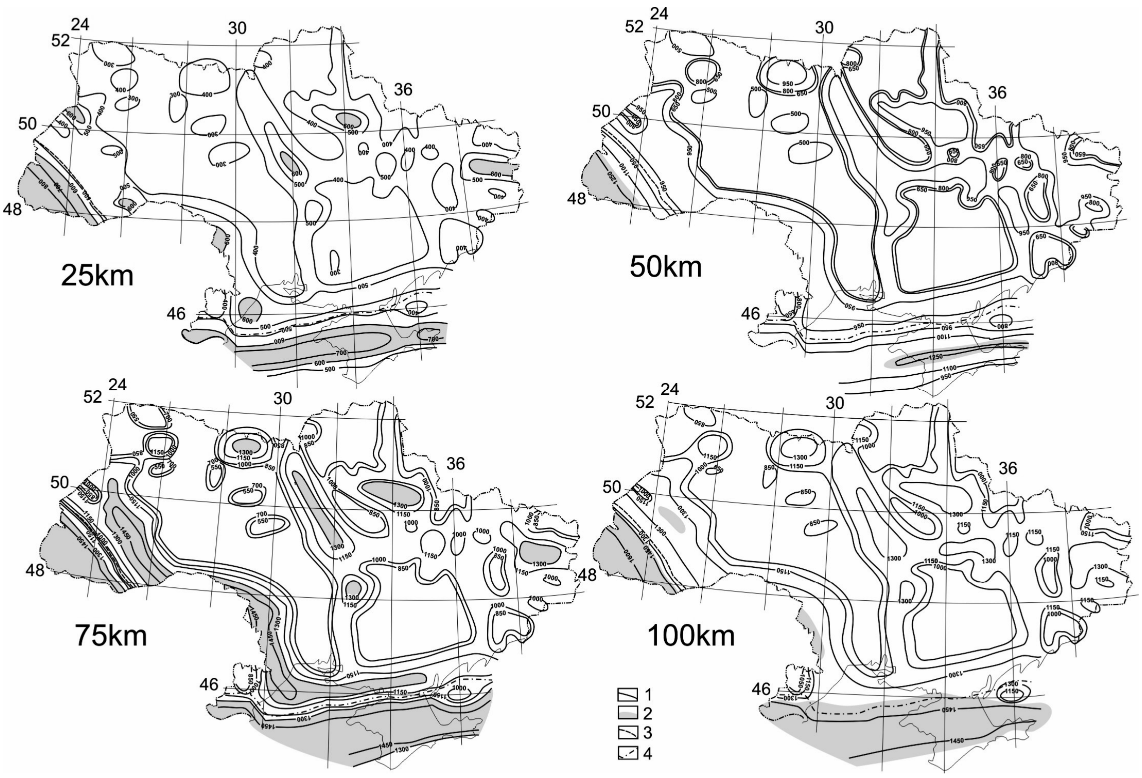

Fig. 5. T distribution at depths of 25–100 km:

1 – isotherms; 2 – boundaries of the zone of partial melting. Other see designations in Fig. 1.

Of course, temperatures change not only at different activation ages, they also depend on the location of the calculation point within the region. In the Carpathians and on the Scythian plate, their values are affected by previous active events in geological history. On the platform, there are noticeable deviations of radiogenic heat generation (HG) in the rocks of the tectonosphere from the averages used in the calculation, which manifest themselves in stationary anomalies of the heat flow.

Data for Ukraine and some well-studied regions of Europe [Gordienko, 2017; and others] are selected for the comparison with the calculated values of *T*. This information is presented in Fig. 4.

The average temperature differences are about 70 ºC. According to the available data, the error in the experimental values of T is determined to be approximately 50 °C [Shcherbakov, 2005; Svetov et al., 2003; and others]. Consequently, the calculated error has the same value. The section of isolines in the created model 150 °C follows from this. In the middle part of the crust, the agreement between the calculated and experimental T is somewhat better; at a depth of 25 km, reliable isotherms with a step of 100 °C can be drawn.

Calculation results obtained for the first time

The constructed model is presented as a sum of slice maps at depths of 25, 50, 75, 100, 150, 200, 300, and 400 km (Fig. 5 and 6). Now it seems premature to spread it to the transition zones from the upper to the lower mantle.

As a starting point in all sections, the temperature under the platform was used during normal heat generation of the rocks of the crust and upper mantle (Table and Fig. 3).

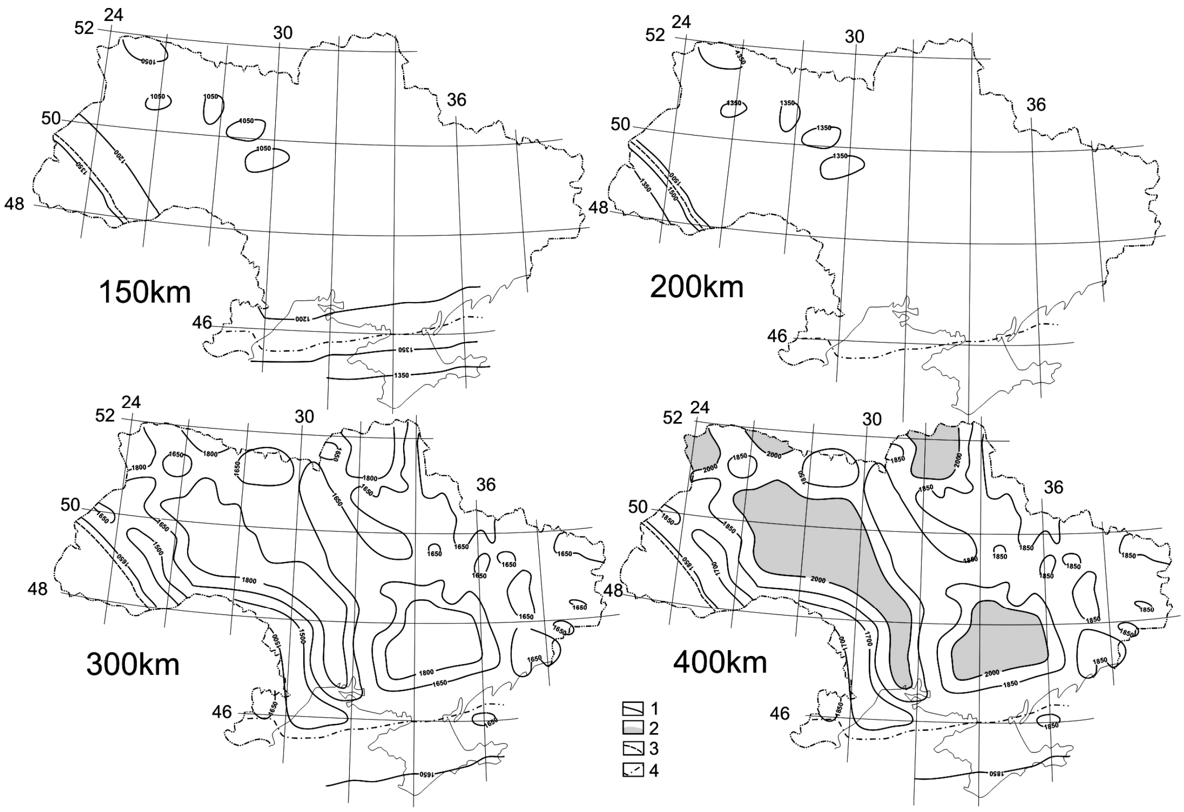

Fig. 6. T distribution at depths of 150–400 km.
Conv. see symbols in Figs 1 and 5.

Platform temperatures and rock solidus temperatures at the depths of the crust and upper mantle

H, km	T, ºC	Sol, ºC
25	310	600,1.140
50	520	1.200
100	940	1.370
150	1.220	1.510
200	1.460	1.650
250	1.660	1.760
300	1.820	1.850
350	1.920	1.930
400	2.000	1.980

The complexity of temperature distribution is different, depending on depth. It is maximum in areas with positive and negative anomalies resulting from heat and mass transfer during recent activity. However, it is minimal in the upper mantle's middle section, even in regions like the Carpathians and Scythian plate, where the effects of the Alpine and Hercynian-Cimmerian processes are evident.

Significant differences between real T and those shown in Fig. 5 may be associated with the age of RA. The above corresponding variations in the case of young heat sources lead to the appearance of additional objects of partial melting in the central parts of the RA platform zones at depths of 25, 50–100 km. The age of manifestations of hydrocarbons and ore mineralization in the Carpathian region indicates a high probability of such a development of events. The solidus of rocks is not exceeded, most likely in the lower part of the earth's crust with predominant granulite metamorphism.

However, it does not follow from the remarks made that the positive thermal anomalies in the upper mantle horizons are necessarily close in age to those of the crust. After all, it is temperature-induced changes in rock density for an activation age of about 15 Ma that make it possible (together with the crustal effect) to agree on the calculated and observed gravitational fields. The indicated time intervals for the occurrence of ore and hydrocarbon satellites of the RA characterize the secondary intracrustal advection (see above). It occurs not directly during the crust–mantle exchange, but at a later stage, after the serpentinization of the lower crustal ultramafic rocks, fluidization of the overlying interval, etc.

In the middle part of the upper mantle (at depths of 150–300 km), noticeable differences in T from platform ones are associated only with previous processes in the Carpathian geosyncline. In the lower tectonosphere (300–450 km), intense negative anomalies are present in all regions, except for the non-activated platform. In the latter case, the prolonged absence of convective heat transfer manifests itself in the excess of the solidus temperature at these depths. Actually, the realization of the energy accumulated in this way leads to RA. It is expected that the zone of partial melting would spread considerably at the depths being considered. This is because the localized decreases in temperature mentioned earlier are likely to be smoothed throughout the upper mantle due to the individual decreases in heat generation [(Gordienko, 2017 and others)].

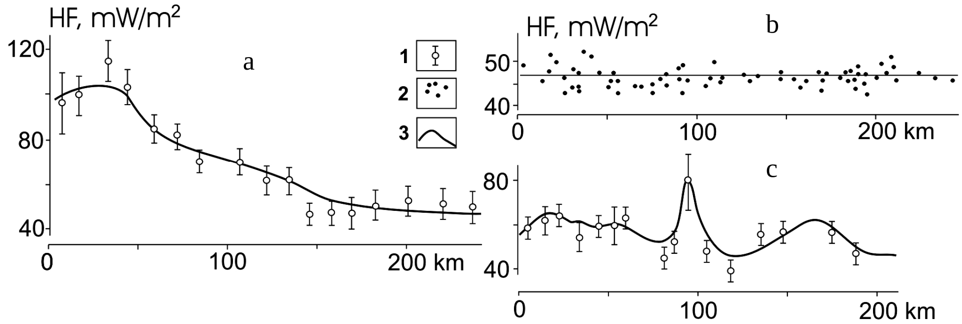

Fig. 7. Observed and calculated values of heat flow in some regions of Ukraine [Gordienko, 2002]:

a – Carpathians; b – slope of the Ukrainian shield, Dnieper-Donetsk depression, slope of the Voronezh massif; c – Donbass; 1, 2 – observed HF (2 – single determinations; 1 – averaged values); 3 – calculated HF.

It should be noted that part of the temperature anomalies at a depth of 25 km in Fig. 5 is shown in more detail than the general model allows. And yet, the figure does not reflect the entire complexity of the thermal field in the middle part of the crust, and even in the upper part. A lot of observed heat flow (HF) anomalies are associated with elements of heat release or propagation, much less tectonic action quanta [Gordienko, 2017, 2022c; and others]. Its movement is the content of deep mantle processes. They are associated with intracrustal advection cells. There, the ascending branch can be represented by the movement of fluids along a local fault. In the latter case, the convective heat transfer overtakes the conductive heat front over the "larger in rank" heat source.

A similar situation is illustrated in Fig. 7. In the Carpathians, the distribution of the heat flow reflects a long-term thermal structure, the influence of which has spread to the very surface. The calculated field, which reflects the main elements of the depth model, is consistent with the observed one. In the RA zone of the slope of the Ukrainian Shield, the Dnieper-Donetsk basin, and the slope of the Voronezh massif, the crustal thermal object was formed relatively recently. Its conductive influence did not reach the surface. Everywhere, the heat flow corresponds to the platform's endogenous regime. There are only individual "outliers" of HF that differ from such a background by more than a triple observational error. In fact, anomalies with an intensity of up to 20 mW/m^2 occur in the region. They were not reflected in the Heat Flow Map due to their small area with a width of a few kilometers. In the Donbass, there are more such disturbances, so the distribution of HF in the same zone of modern activation looks different.

Findings

The work carried out made it possible to build the temperature distribution in the tectonosphere on the territory of Ukraine, which takes into account the main factors of heat release and transfer during geological history. Comparison of the calculation results with independently determined values of T in the crust and upper mantle reveals agreement between the values of the parameter, which corresponds to the real errors of both methods. In this sense, the goal has been achieved. However, there are obvious temperature variations that are not reflected by the model. They do not go beyond the agreed limits, although, they can be considered significant. First of all, we are talking about two blocks of information: zones of partial melting and the formation of mineral deposits.

In the first case, the greatest uncertainty is associated with the age of superheated objects in the upper mantle horizons at depths of up to 100 km, located under the EEP and Donbass. At the achieved level of knowledge, it seems promising to study the distribution of electrical conductivity in the indicated depth interval in more detail, to refine the magnitude of the mantle gravity anomaly and young surface uplifts. It is rational to test this complex outside the areas of noticeable influence of the processes of formation of the Black Sea depression, which may be subject to displacements of the surface of the South Ukrainian monocline. By implementing the approach described, it becomes possible to examine the correlation between the ages of mantle objects and those of crustal ones, whose age is determined by other indicators.In one of the regions (on the Volyn-Podolsk Plate) there are already quite complete indications of the beginning of activation about 3–5 Ma ago after a rest period [Palienko et al., 2013; Pokatilov et al., 1976]. If we apply this representation to the entire RA zone on the platform, the model for the 75 km slice will be enhanced by the 1.450 °C isotherm and the region that undergoes partial melting in the central parts of the zones. In the second scenario, the connection between mantle thermal anomalies and near-surface activity indicators (such as mineral deposits) appears to be even more indirect.Huge reserves of geothermal energy suitable for profitable use in Ukraineare directly determined by the distribution of HF and thermal conductivity of rocks at depths of up to 6 km. They are 100 times greater than the total reserves of all fossil fuels on its territory. It was noted above that (Fig. 7) the heat flux through the surface is significantly different with the simultaneous heating of the subcrustal asthenosphere in the zone of modern activation.. It is not uncommon for areas where there are no profitable geothermal energy reserves. And they appear only with a sufficiently “well-functioning” method of transporting heat at near-surface depths.

The same conditions are necessary for the formation of hydrocarbon deposits, but their appearance is also due to conditions not related to heat and mass transfer [Gordienko, 2017; and others]. Fluids rising above the layer of partial melting and serpentinization of ultramafic rocks in the lower part of the crust carry hydrogen to the surface. According to the authors, this is where its main source is located; an insignificant part of hydrogen and hydrocarbons comes from the mantle. Significant hydrocarbon deposits arise only if sufficient carbon is encountered in the path of hydrogen under suitable PT conditions. Otherwise, hydrogen escapes into the atmosphere; its high permeability does not contribute to the accumulation of this gas to the size of deposits. Relatively high concentrations are likely in the discharge areas approaching the surface of the faults.

For the occurrence of ore hydrothermal deposits of material (including metals and silicate filling of veins) in the rocks of the upper part of the crust, as a rule, it turns out to be sufficient. However, suitable fluid chemistry is required. First of all, we are talking about the content of chlorine. Its concentrations are significantly different during platform RA and postgeosynclinal activation. In the second variant, sedimentation during the main process includes the formation of salt deposits in the Alpine geosyncline of the Carpathians and the Hercynian parageosyncline of the Donbass. Subsequent activations are accompanied by deposits of gold-bearing sulfide ores. During the modern activation of the Donbass, salt deposits and ore deposits do not appear. It seems likely that the anomalous chlorine is of mantle origin.

Thus, creating a thermal model for the tectonosphere of Ukraine faces both quantitative limitations and the need to consider various non-thermal factors during its formation to achieve success.

There is no doubt that it is necessary to continue research in the indicated directions.

References

Bagriy, I. D. (2020). Interview to the site “Glavkom”. 08/25/2020 https://glavcom.ua/new_energy/publications/dvichi-pisav-zelenskomu-yak-ukrajinski-vcheni-shukayut-klyuch-do-energetiki-maybutnogo-voden-701046.html.(in Russian)

Baranova, E. P., Egorova, T. P., & Omelchenko, V. D. (2008) Reinterpretation of DSS seismic data and gravity modeling along profiles 25, 28 and 29 in the Black and Azov Seas. *Geof. Journal*, 5, 124–144 (in Russian).

Baranova, E. P., Egorova, T. P., & Omelchenko, V. D. (2011). Detection of a waveguide in the basement of the northwestern shelf of the Black Sea based on the results of reinterpretation of DSS data for profiles 26 and 25. *Geof. Journal*, 6, 15–28 (in Russian). https://doi.org/10.24028/gzh.0203-3100.v33i6.2011.116790

Chulick, G. S., & Mooney, W. D. (2002). Seismic structure of the crust and uppermost mantle of North America and adjacent oceanic basins: A synthesis. *Bulletin of the Seismological Society of America*, 92(6), 2478–2492. SJR 1.347. https://doi.org/10.1785/0120010188

Davis, J. C., & Sampson, R. J. (1986). Statistics and data analysis in geology (Vol. 646). New York: Wiley. https://www.kgs.ku.edu/Mathgeo/Books/Stat/ClarifyEq4-81.pdf

Demyanov, V. V., & Savelyeva, E. A. (2010) Geostatistics: theory and practice. Moscow: Nauka, 327 p. (in Russian).

Gordienko, V. V., Gordienko, I. V., Zavgorod-nyaya, O. V., & Usenko, O. V. (2002). Thermal field of the territory of Ukraine. Kiev: Znaniye, 170 p. (in Russian). https://www.researchgate.net/profile/Vadim-Gordienko/publication/330933823_TEPLOVOE_POLE_TERRITORII_UKRAINY/links/5c5c2f9192851c48a9c164b7/TEPLOVOE-POLE-TERRITORII-UKRAINY.pdf

Gordienko, V. V. (2017) Thermal processes, geodynamics, deposits. 283 p. https10.://ivangord2000.wixsite.com/tectonos

Gordienko, V. (2022a) Density models of the tectonosphere of continents and oceans. *Izvestiya, Atmospheric and Oceanic Physics.* 7, 805–822. https://doi.org/10.1134/S0001433822070040

Gordienko, V. V. (2022b) Mantle gravity anomaly and current activation on the territory of Ukraine. Geology and korisn_ kopalini svitovogo ocean. No. 1, 3–21. (in Ukranian). https://www.researchgate.net/profile/Vadim-Gordienko/publication/330933823_TEPLOVOE_POLE_TERRITORII_UKRAINY/links/5c5c2f9192851c48a9c164b7/TEPLOVOE-POLE-TERRITORII-UKRAINY.pdf

Gordienko, V. V. (2022c). About geological theory. *Geofizicheskiy Zhurnal*, 44(2), 68–92. JCI 0.20. https://doi.org/10.24028/gj.v44i2.256266

Grad, M., Guterch, A., Keller, G. R., Janik, T., Hegedűs, E., Vozár, J., ... & Yliniemi, J. (2006). Lithospheric structure beneath trans-Carpathian transect from Precambrian platform to Pannonian basin: CELEBRATION 2000 seismic profile CEL05. *Journal of Geophysical Research: Solid Earth,* 111(B3). https://doi.org/10.1029/2005JB003647.

Houser, C. (2016). Global seismic data reveal little water in the mantle transition zone. *Earth and Planetary Science Letters,* 448, 94–101. SJR: 2.348. https://doi.org/10.1016/j.epsl.2016.04.018

International Seismological Centre, On-line Bulletin, http://www.isc.ac.uk, Internal. Seismol. Cent., Thatcham, United Kingdom (2014).

Kozlenko, M. V., Kozlenko, Yu. V., Lysynchuk, D. V. (2009) Deep structure of the Earth's crust in the western part of the Black Sea based on the results of a comprehensive reinterpretation of geophysical data along the profile of DSS no. 25, *Geof. Journal*, 31(6), 77–91 (in Russian).

Mooney, W. D., Prodehl, C., & Pavlenkova, N. I. (2002). Seismic velocity structure of the continental lithosphere from controlled source data. *International Geophysics Series*, 81(A), 887–910.

Olea, R. (2018) A practical primer on geostatistics. U.S. *Geological Survey. Open-File Report 2009-1103,* Version 1.4, 348 p. https://pubs.usgs.gov/of/2009/1103/ofr20091103.pdf

Palienko V. P., Spytsa R. O. (2013). Neotectonic geodynamics as a factor of simple-temporal changes in geomorphogenesis. *Ukrainian Geographical Journal,* 4, 21–26. https://ukrgeojournal.org.ua/sites/default/files/UGJ_2013_4_21-25.pdf

Pavlenkova, G. A., & Pavlenkova, N. I. (2006). Upper mantle structure of the Northern Eurasia from peaceful nuclear explosion data. *Tectonophysics*, 416(1–4), 33–52.SJR: 1.545. https://doi.org/10.1016/j.tecto.2005.11.010

Peslier, A., Schonbacher, M., Busenmann, H., & Karato, S. (20170. Water in the Earth’s interior: distribution and origin. Space Science Reviews, 212, 743–810. https://doi.org/10.1007/s11214-017-0387-z SJR: 2.474

Pokatilov V. P., & Bakatchuk P. D. (1976). On the nature of the left-sided asymmetry of the river valleys of the Moldavian Priprutye. *Tectonics and Stratigraphy*, 11, 41–44 (in Russian).

Shcherbakov I. B. (2005). Petrology of the Ukrainian Shield. Lviv: ZuKC. West Ukraine Consulting Center. 366 p (in Russian).

Starostenko, V., Janik, T., Yegorova, T., Farfuliak, L., Czuba, W., Środa, P., ... & Tolkunov, A. (2015). Seismic model of the crust and upper mantle in the Scythian Platform: the DOBRE-5 profile across the north western Black Sea and the Crimean Peninsula. *Geophysical Journal International*, 201(1), 406–428.. SJR: 1.389. https://doi.org/10.1093/gji/ggv018

Svetov, S. A., Smolkin, V. F. (2003). Model PT conditions for the generation of high-magnesian Precambrian magmas of the Fennoscandian shield. *Geochemistry*. 8, 879–892 (in Russian).

Tauzin, B., van Der Hilst, R. D., Wittlinger, G., & Ricard, Y. (2013). Multiple transition zone seismic discontinuities and low velocity layers below western United States. *Journal of Geophysical Research: Solid Earth*, 118(5), 2307–2322. SJR: 1.983. https://doi.org/10.1002/jgrb.50182

Tripolsky, A. A., & Sharov, N. V. (2004). Lithosphere of the Precambrian shields of the northern hemisphere of the Earth according to seismic data. Petrozavodsk: KSC RAS. 159 p (in Russian).

Verkhovtsev, V. (2006). News of the vertical rucks of the earth's cortex of the territory of Ukraine, their relationship with the linear and circular structures. *Energetics of the Earth, її geological and ecological manifestation, scientifically-practical use.* Kiev: KSU, 129–137 (in Ukrainian).

Yanchilina, A. G., Ryan, W. B., McManus, J. F., Dimitrov, P., Dimitrov, D., Slavova, K., & Filipova-Marinova, M. (2017). Compilation of geophysical, geochronological, and geochemical evidence indicates a rapid Mediterranean-derived submergence of the Black Sea's shelf and subsequent substantial salinification in the early Holocene. *Marine Geology*, *383*, 14–34. https://doi.org/10.1016/j.margeo.2016.11.001

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РОЗПОДІЛ ТЕМПЕРАТУРИ В КОРІ ТА ВЕРХНІЙ МАНТІЇ ТЕРИТОРІЇ УКРАЇНИ

Мета – побудова тривимірної теплової моделі кори та верхньої мантії на території України. Її методична основа – схема глибинних процесів у тектоносфері, що враховує, передусім, результати тепломасоперенесення за сучасної активізації. Вони накладаються на моделі платформи (крім території Східно-Європейської платформи, до неї зараховано і Донбас), альпійської геосинкліналі Карпат та герцинсько-кіммерійської геосинкліналі Скіфської плити. Незавершений процес сучасної активізації неможливо точно описати геологічною теорією, яку використали автори. Для вибору варіанта адекватної схеми тепломасоперенесення попередньо виконано гравітаційне моделювання за системою профілів навколо північної півкулі загальною довжиною понад 30000 км, що перетинають Євразію, Північну Америку, Атлантичний та Тихий океани. Виділено схему процесу, найвідповіднішу реальності. Застосувавши її для України, з більшою точністю визначили активізовану площу. Таке завдання вирішено вперше. На півдні модель обмежена западиною Чорного моря, за глибиною – 400 км. Температури у перехідній зоні до нижньої мантії не розглядалися. Тестові теплові моделі зіставлені з геотермометрами, визначено похибку (50 °С) розрахунку та перерізу ізотерм (150 °С для глибин від 50 до 400 км, на глибині 25 км похибка нижче, переріз ізотерм – 100 °С). Встановлено зони часткового плавлення порід кори та верхньої мантії. Вони поширені у середній частині кори, у верхніх горизонтах мантії (50–100 км). На глибині близько 400 км часткове плавлення трапляється лише під неактивізованою частиною платформи. Описано відмінності моделі від представленої, пов’язані з можливими варіаціями віку процесу, його особливостями на різних поверхах тепломасоперенесення. Практична значущість. Простежено розташування родовищ корисних копалин щодо теплових аномалій та інших параметрів середовища.

Ключові слова: сучасна активізація; глибинний процес; тектоносфера; теплова модель.

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