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Satbayev University

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ИЗВЕСТИЯ

НАЦИОНАЛЬНОЙ АКАДЕМИИ НАУК
РЕСПУБЛИКИ КАЗАХСТАН
Satbayev University

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ASTHENOSPHERE AS AN INTERMEDIARY BETWEEN THE PLANET'S ENDOGENOUS ACTIVITY AND THE TECTONIC AND MAGNETIC ACTIVITY OF ITS LITHOSPHERE

Abstract. A critical review of the views of tectonist scientists on the cause-effect relationships of deep and near-surface processes in the Earth's section is being conducted. It is noted that in this issue two groups of tectonists are distinguished: the first group of scientists restricts this relationship at the level of the upper mantle-lithosphere (the earth's crust), while the second group tends to connect endogenous processes in the lithosphere (the Earth's crust) with chemical-physical processes taking their beginning from the level of the nucleus and covering the main (subarachnospheric) incision of the mantle. The author himself refers to the second group of scientists. However, he does not agree with the views of scientists about the calibrated character of the transfer of heat-mass flows of deep origin directly to the lithosphere due to the presence along the route of these flows of the low-viscous layer of the asthenosphere. The author being related the fluidity (low viscosity) of the asthenosphere substance to the thermal nature of this layer, which provides its intermediary role between the endogenous activity of the planet and tectonomagmatic activity of the lithosphere (the crust). This role is expressed not only by the relation to the tectonomagmatic activity of the lithosphere to the permeable zones, but also by the reorientation of activity residues in the subhorizontal direction between these zones. The idea of the continuity of the section of the asthenosphere entirely enveloping the spherical surface of the lower mantle is being asserted, this explains the reasons for the variability in the value of the viscosity of this layer under the platforms and more «permeable areas» within the lithosphere.

Key words: heat and mass flows, convection; submentosphere mantle, tectonosphere, pellitospheric faults, ascending flow.

Introduction. In the context of finding out the nature of relationship between the Earth's endogenous activity and the lithosphere's (Earth's crust) tectonic and magmatic activity, geotectonic hypotheses and ideas can be divided, for convenience's sake, into two groups. Supporters of the first group as a rule limit themselves to the upper mantle and the Earth crust levels, and practically don't aim at finding out the deeper factors of the Earth's activity, nor do they try to establish what impact such factors have on the tectonic and magmatic activity of the planet's upper shells. Supporters of the second group try to look at the problem in its entirety, to look at the whole of the Earth's section in an attempt to find out features of cause-and-effect relations between heat and mass flows in the depth and the formation of this or that types of tectonic structures near the surface.

Probably, a Belgian scientist Haarman was one of the first to realize the necessity of looking at all the processes, taking place in the upper mantle and the Earth crust, in their relationship. This understanding, evidently, was the reason for introducing a relatively new concept called by the sonorous name of "tectogene" into the geological science [1]. In his, as well as his followers', opinion, "tectongenes" are deep-seated zones in which various physical and chemical processes are taking place, that eventually form thermodynamically active geological structures of the Earth crust, rooted in the upper mantle.

A possible relationship between the upper mantle and the Earth crust is considered in greater detail in Van Bemmelen's undation hypothesis and V.V. Belousov's [2] radio migration hypothesis [3, 4]. The authors of these hypotheses believe that the proposed geochemical differentiation of the mantle substances and their density differentiation, taking place by way of forming upward and downward mass flows, should lead to the

Earth crust oscillatory movements, create depressions and elevations, facilitate geosyncline formation, cause orogenic processes etc., i.e., should be the immediate reason of the Earth crust tectonic and magmatic activity.

V.V. Belousov's idea of "the continental crust oceanisation" [2, 5-7], widely discussed in the second half of XX century, is, basically, a variant of the same scientist's radiomigration hypothesis. His description of the oceanisation idea is as follows: "… our idea is that there are no major convections in the mantle at all, that the mantle's molten material goes up vertically (or aslant by a focal channel), inserts itself into the Earth crust, cools down there, turning part of it into heavy metamorphic rock, and then, together with the latter, goes down vertically or aslant by the same focal channel" [5]. So, in his opinion, the Earth crust transformations, including eugeosyncline formation with oceanic type crust, and its further inversion or orogenic elevation are consequences of the matter vertical movements – exchanges between the upper mantle and the crust.

Materials and methods. An original nature of relationship between the upper mantle and the Earth crust is proposed by a group of Ukrainian geophysicists [8, 9], which is part of their own "polymorphic-advection hypothesis" of the upper mantle and the Earth crust matter convection movement. By "advection" the authors mean that the process is not closed, is interrupted in time, and in that it is different from the usual "convection" term, the latter is to form closed cells and harmonics, functioning continuously. According to the authors [8-10], advection essentially is a pulsating "mixing" of the crust and the mantle material, which is caused by the time required for heating up to high temperatures the allegedly newly arrived from the Earth crust into the mantle "cold and dense material", and in particular – eclogites. The hypothesis is based on the idea of a possible compression and decompression of the matter during its polymorphic transformations, though neither the energy basis for compressing the crust material, nor the mechanism of its sinking into the mantle, are not clarified.

It should be acknowledged that the polymorphous-advection hypothesis is one of the few that are trying to explain individual lithosphere blocks mobility (including lateral mobility) with the help of convection, covering only the upper mantle section (advection is a type of convection), thus denying the existence of large-scale convection rotations in the planet's sub-asthenosphere mantle. But, by this hypothesis, not only the asthenosphere and its rejected material (asthenolithes) are taking part in this advection mixing, but the whole of the upper mantle and the Earth crust, with crust material taking part in forming the downflows, which, as mentioned above, is difficult to imaging due to differences in the crust and mantle density and temperature, that are separating the two layers. That's why the hypothesis is difficult to accept, and, though using the term "convection" as the principle driving force of plate tectonics, essentially this hypothesis tends more towards fixism than to mobilism.

Judging by some published studies, there also exist ideas that exclude any connection between geological processes going on deep inside the planet and those close to the surface [11]. But most of lithosphere plate tectonics supporters belong to the second group of scientists, who are trying to find direct links between the activities of the mantle as a whole, or even the planet's core, and the lithosphere tectonic activity (including the Earth crust) [12-18]. E.g., according to O.G. Sorokhtin's theoretical estimates [15], the geotectonic cycles, that he has identified in the Earth crust (all in all he has identified 26 cycles, we are now allegedly living in cycle 20), fully "…coincide with mantle's convection cycles" (meaning the lower mantle, N.S.). Moreover, in his opinion, there is a direct relationship between the Earth's core formation and tectonic processes close to its surface".

Denying the existence of effective thermal convection in the sub-asthenosphere mantle in one of E.V. Artyushkov papers [14], in another nevertheless draws a picture of this convection [13]. Obviously, he needs it for proposing the existence of "tectonopheres" (or "stationary channels" by Yu.M. Sheinmann [19]) on the junction between rising branches of two neighbouring convection cells, by which – according to E.V. Artyushkov [14] – light differentiates of the separating material of the lower mantle are to "rush upwards" forming large drops and streams. It is by such stream-like flow of the light lower mantle differentiates, formed on the boundary between the core and the mantle, and penetrating the whole of the mantle, that E.V. Artyushkov is inclined to explain the linear nature of tectonically active areas on the planet's surface, thus directly linking the Earth crust tectonic-magmatic activity with processes, taking place on the boundary between the core and the mantle. Unfortunately, his reasoning is inconsistent and contradictory – e.g., in a different place of his paper [14], he denies the direct relation between the lower mantle and the lithosphere, yet underlying the "intermediary role" of the asthenosphere.

Results and discussion. Sometimes the desire of some of the scientists to directly connect processes, taking place deep inside the Earth and those in the crust, go beyond reasonable limits. Thus, in one of the latest papers on oil geology [20], it is conceived possible that the geodynamic evolution of not only the

Earth crust continental folded structures, but also the Earth's sedimentary basins allegedly "originate" from the core-mantle boundary level, which is around 2900 km deep. Unfortunately, V.N. Larin [21, 22] has also failed to escape recognizing a traced connection between the large-scale phenomena taking place across the whole of the mantle, and the geological processes taking place in the Earth crust. That's why he introduces "swallow up zones" within the sub-asthenosphere mantle acting as a kind of feeding mechanism for all geological (geotectonic) processes in the Earth crust. To admit the possible existence of such swallow up zones within the lower mantle, in which, allegedly, the rising and the descending matter flows are alternately formed, radically contradicts V.N. Larin's principle idea of the Earth's one-way evolution in time, determined by dehydridization and movement of released hydrogen atoms from the planet's inner core surface – for such processes must involve the decompaction of the Earth's primordial geospheres matter in time, and consequently, they would be characterized only the rising flows of the planet's matter.

The above review of the ideas of both the fixism and the mobilism supporters indicates that they are united in their interpretations of the nature of tectonic and magmatic activity of the Earth lithosphere (crust) mobile belts. Their shared conclusion can be worded as follows: the Earth's crust tectonic and magmatic processes' intensiveness is traced from, and their locations are projected by the Earth's endogenous activities, originating from the mantle or even from the core level of the planet. We, too, believe that there is an immediate relation between the deep levels of the planet's section and its tectonosphere (tectonosphere is asthenosphere + lithosphere). But, in our opinion, such relation has two distinctive features. First of all, flows of heat and mass on the Earth's sub-asthenosphere level only go upwards, while descending matter and heat flows within this section of the planet cannot be formed because of the Earth's density and the geothermal gradients and the lack of the energy basis for such flows. Secondly, the structure, properties and composition of the present-day Earth mantle on the whole are such as to exclude a possible traced connection between the planet's endogenous activity and its lithosphere's (the Earth crust) tectonic and magmatic activity at its current stage. The reason for this is the presence of a specific layer, called asthenosphere, "on the heat and mass flows travel line" from the depths towards the lithosphere (Earth crust). In our opinion, the asthenosphere acts as a kind of "accumulator" of the Earth's internal heat and matter, and due to that it has relatively low viscosity compared with the lower mantle levels and the overlying lithosphere. Two circumstances, probably, contribute to the "low viscosity" state of the asthenosphere material:

there is a "permanent heat and matter feed" of this layer from the Earth's core level;

low heat conductivity of the overlying lithosphere, consisting of a variety of hard and rigid rocks, which prevents "quick discharge" of the Earth's internal heat, accumulated in the asthenosphere through all endogenous processes and by dispersing it into cosmic space.

With such interpretation, the permanently incoming "from-under the Earth" matter is to enrich only the asthenosphere. The planet's sub-asthenosphere activity should not – but for rare exceptions – be transferred to the lithosphere (Earth crust) in a direct (traced) manner because of low-viscosity properties of this asthenospheric layer material. In other words, the asthenosphere should act as a permanent accumulator and a kind of buffer of the above activities, controlling further tectonic and magmatic processes in the overlying lithosphere. This conclusion is confirmed by the asthenospheric and the lithospheric layers' features, known to the geological science. Let's dwell upon them. The thermal nature of the planet's asthenosphere layer today is beyond any doubts, for the dramatic fall in the speed of transverse seismic waves at this level cannot be explained by anything but the partially molten state of its material. According to E.A. Lyubimova [23] studies "…the supposition that a layer of lower seismic speeds is an effect of thermal origin, appeals by its simplicity and by the fact that it satisfies not only the seismic, but also the thermal data regarding the distribution of the heat sources and thermal conductivity". Two ways of explaining the reasons of the partially molten state of the asthenosphere material are clearly outlined in geological literature.

According to the first of them, the temperature's gradient value on the asthenosphere level can be sufficient for a partial melting of the material on this level, which could basically explain the separation of this specific layer within the mantle [14, 24]. But this concept is equivalent to ignoring the Earth's inner activity, expressed by sub-asthenosphere flows of heat and matter; it limits this activity to the asthenosphere-lithosphere level only. But from this standpoint it's difficult to understand the nature of horizontal heterogeneities, expressed by the presence of different-viscosity separations on the same level (depth) inside the Earth, which in their turn are a function of temperature and pressure inside the asthenosphere itself. In our opinion, both the nature of horizontal heterogeneities and the specific features of the asthenosphere layer as a whole are best explained by the second concept, that of recognizing the existence of sub-asthenosphere matter flows to asthenosphere level, which all the time feed the latter with abnormal heat of a deep-level origin.

This concept has some attractive points. Firstly, a permanent heat flow from beneath, combined with the temperature gradient value for this level, keeps maintaining a rather high asthenosphere temperature, since it's difficult to transfer this abnormal heat into the hydrosphere and atmosphere quick enough due to low conductivity of the overlying lithosphere. "Presence of a surface layer with low thermal conductivity, – according to E.A. Lyubimova [23], – is a strong inhibitor to heat loss, even if we assume extremely high heat transfer within the Earth". Secondly, accumulation of high thermal energy concentrations in the asthenosphere, probably reaching liquidus level of its pyrolitic component, facilitates partial melting of the latter and reduces its viscosity to at least the asthenosphere background values of 1020 to 1022 poise [25]. Thirdly, widely varying viscosity values within asthenosphere as a whole and of its asthenolites, which determine the horizontal asthenosphere heterogeneities, easily caught by geophysical methods, are consequences of varying permeability of lithosphere areas associated with the former [26]. In high permeability areas (e.g., mobile belts and zones), where the lithosphere is cut by a wide grid of deep faults going down through the whole of the lithosphere depth, litho-static pressure on the asthenosphere surface level, underlying such area, falls sharply. Material in such asthenosphere areas is more molten [25, 27] and, consequently, is characterized by lower viscosity, sometimes no more than 1017 to 1014 poise [14]. Under lower permeability areas (under platforms) with fewer deep faults going down through the lithosphere, the asthenosphere layer can preserve background or even higher values of viscosity, which can reach those of full-crystal solid (rigid) bodies. Fourthly, regional variability of the asthenosphere material in space in its turn determines regional tectonic and magmatic lithosphere activity, divided into certain belts and zones, since low viscosity and high mobility of asthenosphere areas is the principal reason of tectonic and magmatic activity in their exclusively interrelated lithosphere areas. Hence, it's not surprising that high tectonic and magmatic activity is usually confined to divergent and convergent borders of lithosphere plates, while such plates' inner areas usually feature low activity.

The above considerations show that our understanding of the asthenosphere nature and its interaction with the overlying lithosphere basically satisfies the physical data on tectonosphere features, even though one circumstance still should be clarified. In the "Geological Dictionary" asthenosphere is separated into a continuous layer, covering the whole of the Earth's sphere, underlying the lithosphere all over the globe, with the average thickness of up to 500 km under the oceans and several dozen kilometers under the continents [30]. But there are quite a few published studies, which question the continuous nature of asthenosphere, suggesting that this layer doesn't exist under platforms [8, 9, 27-29], though the asthenosphere separations under oceans and tectonically active continental zones (island arcs, intercontinental rifts, tectonic and magmatic activity zones, orogenic belts etc.) are not questioned. These concepts contradict our understanding of the asthenosphere nature, since, if asthenosphere really is a derivative of heat and mass flows from the Earth's depths originating from the boundary between the core and the mantle, then irrespective of the lithosphere features above it, it must cover all the surface of the mantle's transitional layer at a certain depth, and underlie all of the lithosphere, as described in the "Geological Dictionary" [30].

The reason of the above doubts of some scientists regarding the asthenospheric layer under platforms, in our view, lies in some discrepancy between the terms "asthenospheric material" as such, and "rheological state of the asthenosphere material". Asthenosphere's specific features are determined first of all by rheological features of its material, so that it is accepted in geological science to judge whether it is present of not in this or that area of the globe only based on the specific viscosity value (seismic waves speed) of material at the asthenosphere level of the planet. E.g., assuming that the maximum viscosity value of the asthenospheric material is 1022 poise, as suggested by many authors [8, 9, 13-15, 23], viscosity under platforms might not be at this level, since as we have been saying before, the relatively weak permeability of the platform areas, with few deep faults going down through the whole of lithosphere, doesn't let the asthenosphere level material partially melt to a state with 1022 poise viscosity values. But that doesn't mean that there is no asthenospheric layer (material), so much the more abnormally high temperatures, characteristic of asthenosphere, under the platforms. Probably both are there under the platforms, but there the abnormally high temperatures are likely to be "countervailed" by respectively high litho-static pressure, which makes it difficult to find asthenosphere, as we understand it, in these areas.

There's another explanation of the absence of partially molten substance at the asthenosphere level under platforms. Both the abnormal heat and its carriers, represented by high thermal capacity substances, are rather mobile and are tending all the time to thermodynamic stability and so flowing towards all sorts of "vents". If that's the case, then the abnormal heat, accumulated under the platforms, meeting with this "impenetrable armour", could flow to neighbouring tectonically active zones, whose lithosphere is riddled with deep faults

(this process is governed by the law of communicating vessels), thus depriving the sub-platform section of the partially molten substance, characteristic of the asthenosphere as we usually understand it. And by the way, numerous horizontal heterogeneities on its level, as well as the changeability of this level's thickness within the upper shells of our planet, also are an indication of the asthenosphere's material mobility. Also, a stable tendency is taking shape of the asthenosphere's thickness increase under the lithosphere's highly permeable zones and belts. E.g., while the very asthenosphere presence under platforms is questioned, its highest thickness and lowest viscosity, as could have been expected, are found under the oceans [5, 14]. And lastly, one of the main asthenospheric features is that it's capable of maintaining hydrostatic balance, ensuring isostatic ascending and descending of lithosphere blocks, depending on their masses.

Conclusions. Taking the above into account, the idea that there is no asthenosphere under platforms seems doubtful, the 300 m isostatic ascending of Fennoscandinavian and Canadian shields of ancient platforms due to ice cover – 3 to 4 km thick-thawing suggests the presence under platforms of a responsive ductile layer, responding even to insignificant load alleviations (ice's specific weight is 0.9 g/cm3). So, our idea is that the Earth's endogenous activity, consisting of rising heat and mass flows, is first of all accumulated in the asthenosphere, which is the latter's specific feature. This abnormal heat accumulation within asthenosphere is facilitated by low thermal conductivity of the overlying lithosphere, which is characterized by a higher rigidity of its material and is acting as a heat insulator.

Separated as a ductile layer and constantly "absorbing" the Earth's inner geospheres' potential energy, the asthenosphere, probably, is impeding, for rare exceptions (plumes), direct interaction between heat and mass flows, coming from deep inside the Earth, with the lithosphere (the Earth crust), thus acting as an intermediary and transforming the Earth's endogenous activity into tectonic-magmatic activity of its lithosphere. In this case geological events taking place in the lithosphere (the Earth crust), as well as features and scales of tectonic movements, are controlled by the asthenosphere only, and consequently, it is by the asthenospheric evolutionary transformations that general tendencies of the planet's tectogenesis will be ultimately determined.

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АСТЕНОСФЕРА ПЛАНЕТАНЫҢ ЭНДОГЕНДІК БЕЛСЕНДІЛІГІ МЕН ОНЫҢ ЛИТОСФЕРАСЫНЫҢ ТЕКТОНИКАЛЫҚ-МАГМАЛЫҚ БЕЛСЕНДІЛІГІ АРАСЫНДАҒЫ ДЕЛДАЛ РЕТІНДЕ

Аннотация. Жер қыртысының тереңдіктері мен беткі бөлігінің арасындағы себеп-салдық байланыстар жайлы тектонист ғалымдардың пікірлері сыни тұрғыдан талданған. Бұл орайда тектонистердің екі тобы дараланатындығы айтылған. Ғалымдардың бірінші тобы жоғарыда аталған байланысты жоғарғы мантия–литосфера (жер қыртысы) аралығымен ғана шектесе, екінші топтағы ғалымдар литосферадағы (жер қыртысындағы) эндогендік үдерістерді жер ядросы деңгейінен бастау ала отырып, мантияның негізгі астеносфераасты бөлігін түгел қамтитын химиялық-физикалық үдерістермен байланыстыруға бейім. Мақала авторлары өздерін екінші топқа жатқызады. Алайда ол тереңдіктерден бастау алатын жылу-материя ағымдары осы ағымдар жолында тұтқырлық дәрежесі мейлінше төмен астеносфера қабатында жатуына байланысты литосфераға тікелей әсер етеді деген мазмұндағы ғалымдар пікірімен келіспейді. Астеносфера заттарының аққыштық қасиетін (төмен дәрежелі тұтқырлығын) мақала авторы бұл қабаттың жылулық табиғатымен түсіндіре отырып, оны планетамызға тиесілі эндогендік белсенділік пен литосфераға (жер қыртысына) тиесілі тектоникалық-магмалық белсенділік арасындағы арнаулы делдал ретінде қарастырады. Астеносфераның бұл қызметі литосфераның тектоникалық-магмалық белсенділігінің сол литосферадағы өтімді белдемдерге ғана шоғырлануын қамтамасыз етуімен шектелмей, белсенділіктің қалған бөлігін аталған белдемдер аралығында көлбеу бағытқа бағдарлайтындығы айтылған. Сол сияқты, астеносфера қабаты қимасының тұтас екендігі, яғни бұл қабат мантияның төменгі бөлігінің сфералық бетін түгел көмкеріп жатқандығы аталып көрсетілген, оның платформалар астындағы тұтқырлығы мен литосферадағы «өтімді аймақтар» астындағы тұтқырлығы арасындағы айтарлықтай айырмашылықтардың себебі зерделенген.Жердің эндогендік белсенділігін оның литосферасының тектономагматикалық белсенділігіне айналдыратын

делдал ретінде астеносфера туралы қорытындылар жасалады. Позиция негізделген, оған сәйкес астеносфераның эволюциялық өзгерістері планетаның тектогенезінің негізгі тенденциялары болып табылады.

Түйінді сөздер: жылу-материя ағымдары, конвекция, астеносфераасты мантия, тектоносфера, литосфераны тілгілейін жарылымдар, жоғары бағытталған ағым.

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АСТЕНОСФЕРА КАК ПОСРЕДНИК ЭНДОГЕННОЙ АКТИВНОСТИ ПЛАНЕТЫ И ТЕКТОНОМАГМАТИЧЕСКОЙ АКТИВНОСТИ ЕЕ ЛИТОСФЕРЫ

Аннотация. Производится критический обзор представлений ученых-тектонистов на предмет причинно-следственных связей глубинных и приповерхностных процессов в разрезе Земли. Отмечается, что в данном вопросе выделяются две группы тектонистов: первая группа ученых ограничивает указанную связь на уровне верхняя мантия–литосфера (земная кора), тогда как вторая группа склонна связать эндогенные процессы в литосфере (земной коре) с химико-физическими процессами, берущими свое начало с уровня ядра и охватывающий основной (подастеносферный) разрез мантии. Автор статьи себя относит ко второй группе ученых. Однако он не соглашается с представлениями ученых о калькированном характере передачи тепломассопотоков глубинного происхождения непосредственно к литосфере из-за присутствия по пути следования указанных потоков маловязкого слоя астеносферы. Текучесть (малую вязкость) вещества астеносферы автор статьи связывает с тепловой природой этого слоя, что обеспечивает его посредническую роль между эндогенной активностью планеты и тектономагматической активностью литосферы (земной коры). Указанная роль выражается не только приуроченностью тектономагматической активности литосферы к проницаемым зонам, но и переориентацией остатков активности в субгоризонтальном направлении между этими зонами. Отстаивается так же мысль о беспрерывности разреза астеносферы, целиком обволакивающей сферическую поверхность низов мантии, дается объяснение причины разброса значения вязкости этого слоя под платформами и более «проницаемыми областями» в пределах литосферы. Сделаны выводы об астеносфере как посреднике, трансформирующем эндогенную активность Земли в тектономагматическую активность ее литосферы. Обосновывается позиция, согласно которой эволюционные преобразования астеносферы являются основными тенденциями тектогенеза планеты.

Ключевые слова: тепломассопотоки; конвекция; подастеносферная мантия; тектоносфера; сквозьлитосферные разломы; восходящий поток.

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