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ПОХОДЖЕННЯ, УМОВИ ТА МЕХАНІЗМ ФОРМУВАННЯ АЛЬПІНОТИПНИХ ГІПЕРБАЗИТІВ МАЛОГО КАВКАЗУ

THE ORIGIN, CONDITIONS AND MECHANISM FOR THE FORMATION OF ALPINE-TYPE HYPERBASITES OF THE LESSER CAUCASUS

Проблеми походження гіпербазитів є одним з широко обговорюваних питань геології. Це пов'язано з тим, що вони часто з'являються там, де їх не очікують. Тобто їх розвиток не збігається із загальними закономірностями розвитку геологічних процесів, що є причиною різного роду дискусій щодо їх стратиграфічного положення, походження, умов формування, віку, петрографічного і мінерального складу. Виходячи з позиції концепції динаміки еволюції земної кори (КДЕЗК), це пов'язано з недосконалістю раніше існуючих концепцій. Ця концепція створена на основі природних законів чітко встановлених фактичних даних. Сутність цієї концепції в тому, що при обертанні Землі навколо своєї осі утворюються геодинамічні сили. Останні у надрах Землі поширюються з певними закономірностями. Всі природні процеси, в тому числі і геотектонічні, відбуваються під впливом цих сил. У цілому походження магматичних порід пов'язане з глибинними аномальними процесами, які формувалися під впливом геодинамічних сил, розуцільненням мантійної речовини, що зумовлює катастрофічне зростання об'єму мантійної речовини, а також пов'язаним з цим розвитком вулканоплутонічних процесів. Гіпербазити утворюються як у дивергентних, так і конвергентних зонах земної кори. Головним фактором для їх формування є високий тиск – відсутність сприятливих глибинних термодинамічних умов для повного розчленування магматичних розплавів.

Ключові слова: плюм, гіпербазити, підводний вулканізм, тектоніка, магматизм, дивергенція, колізія, зони напруг.

The problem of hyperbasites origin is one of the widely discussed topics in geology. This is because they often appear when no expected. Their development does not correspond to the general regularities of the geological complexes' development. Therefore, when problematic instances of hyperbasites appear, discussion is inevitable. This is due to the imperfections of existing concepts, which are not without flaws. The essence of this concept lies in the fact that during the rotation of the Earth around its axis, geodynamic forces are formed. The hyperbasites complex by its nature belongs to deep igneous formations formed at the initial stage of development of volcano-plutonic processes, where the composition of magmatic products was not subject to decomposition. In general, the origin of igneous rocks is associated with deep anomalous processes, which were formed under the influence of geodynamic forces, where decompression of mantle matter occurs, causing a catastrophic increase in the volume of mantle matter, as well as the associated development of volcanoplutonic processes. Hyperbasites are formed both in divergent and convergent zones of the Earth's crust. The main factor for their formation is high pressure – deep thermodynamic conditions, where there are no favorable thermodynamic conditions for the complete separation of magmatic melts by composition. The emergence of hypermafic rocks on the surface is associated with geotectonic or denudation processes. Denudation processes can expose only those hypermafic formations that are located at the site of formation. These zones include ancient platforms, sheets, terranes, etc., which were cut by deep erosion processes. As for those hyperbasic formations that are classified as alpinotype hyperbasites, they were moved to the structure of the Alps-Himalayan folded zone from the basement with a collision with subsequent geotectonic processes, where they formed in the bed of the Paleotethys Ocean, both in the process of divergence and convergence. The noted pattern of formation and the mechanism of formation of alpine-type hyperbasites clearly corresponds to the patterns of development of geodynamic forces in the face of the Earth, also with natural laws, which are the main factors in the evolution of the Earth's crust. From the standpoint of KDEZK, the origin, mechanism of formation, as well as the form of distribution of alpinotype hypermafic rocks of the Lesser Caucasus occurred in the Paleotethys bed, under different thermodynamic conditions and at depths. Further, as a result of the collision, it participated in the formation of folded zones of the Lesser Caucasus. Within the Lesser Caucasus, two genetic types of hypermafic rocks are exposed. Some of them correspond to the convergent zone of the Tethys paleocean, while others correspond to divergent zones. In terms of ore content, the most promising are those hypermafic rocks that are genetically related to convergent zones.

Keywords: *plume, hypermafic rocks, submarine volcanism, tectonics, magmatism, divergence, collision, stress zones.*

Introduction

Hyperbasites are among the principal types of igneous rocks. Numerous geological studies have been dedicated to these formations [1–5, 8–38]. Our task is to elucidate the nature of their origin, the conditions of formation, and their connection with global stress zones from the standpoint of the concept of the dynamics of the evolution of the Earth's crust (DEEC). Hyperbasite complexes of rocks are part of ultrabasic rocks of magmatic origin, which constitute the main components of the Earth's crust.

It is worth noting that hyperbasites are essential constituents of volcano-plutonic complexes formed under the influence of geodynamic forces [5–11]. In the context of DEEC, geodynamic forces arise from the rotation of the Earth around its axis, serving as the primary driving forces behind all natural processes occurring throughout the Earth's space. Ultrabasic rocks represent extremely basic branches of igneous rock formations, where silica, as the main component of rocks, does not exceed 45%. The silica content is a crucial condition for the classification of rocks (ultrabasic, intermediate, and acidic) [1–38].

The Origin of Hyperbasites

From the perspective of the DEEC (Dynamics of the Evolution of the Earth's Crust), hyperbasites can develop in various geodynamic conditions where complex volcano-plutonic processes occur. It is known that there are primarily three types of volcano-plutonic products in the structure of the Earth [11–38]. These include plutonic (intrusive), effusive (constituting lava and pyroclastic materials), and their transitional magmatic products (various subvolcanic formations). These products are observed in the Earth's crust in highly complex combinations, allowing for an understanding of their nature in a genetic aspect.

The formation of the composition of different complexes of rocks, including hyperbasites, requires a specific thermodynamic environment. The distribution of the thermodynamic environment in the Earth's space, particularly in the Earth's crust, is created under the influence of geodynamic forces. From the perspective of DEEC, geodynamic forces in the Earth's space propagate strictly according to physical-chemical and mechanical laws, which play a crucial role in the evolution of the Earth.

The diversity in the composition of magmatic activity products is determined by the patterns of distribution of geodynamic forces. These forces are generated under the influence of the law of centrifugal forces in the Earth's mantle and primarily develop in three directions: from west to east and from the Earth's poles to its equator. As a result of the interactions of these forces, other tangential forces are created [5–11], which, in the Northern Hemisphere, develop in southeast directions, and in the Southern Hemisphere, in northeast directions. However, the speed of propagation of these forces varies and is determined by the parameters of the Earth (Fig. 1).

In general, both in the evolution of the Earth and in its crust, geodynamic forces are creative forces. They participate in all natural processes, spreading within the Earth and its crust. It is known that the Earth consists of different geospheres, each having various physico-mechanical characteristics. These geospheres react differently to the Earth's rotation [5–11]. Hence, there are mass displacements between them, leading to the formation of plumes, mantle diapirs, sutures, hotspots, and other anomalous phenomena, which essentially serve as sources of volcano-plutonic processes. Plumes, diapirs, sutures are products of the decompression of mantle material. They mainly form between geospheres, where physico-chemical phase transformations occur, associated with a catastrophic increase in the

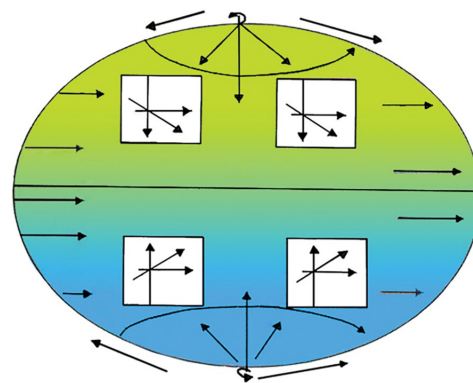


Fig. 1. patterns of geodynamic forces distribution on Earth's surface

volume of mantle material, leading to manifestations of volcano-plutonic processes.

It is worth noting that the accumulation of these anomalous processes between the Earth's crust and upper mantle creates favorable thermodynamic conditions for the formation of the asthenosphere. The formation of the asthenosphere occurs between the upper mantle and the lithosphere, which geologists and geophysicists refer to as the “weakened zone of the Earth's crust”.

Without delving into discussions extensively covered in geological sources [11–38], it is worth mentioning that from the perspective of DEEC, the probability of the absence of these layers in the polar zones of the Earth is very high. Additionally, they may be wedged beneath a thick layer of the Earth's crust. Therefore, the asthenosphere is not considered a complete geosphere in the structure of the Earth.

From the perspective of the DEEC (Dynamics of the Evolution of the Earth's Crust), changes in the thickness of the Earth's crust affect its activity. An increase in crustal thickness reduces its activity, while a decrease in thickness increases activity, aligning well with physico-mechanical laws. The activity of volcanic and seismic processes also correlates strictly with changes in crustal thickness. Thus, crustal thickness is one of the main factors influencing crustal activity. From the DEEC perspective, crustal thickness actively influences even the distribution of geodynamic forces. Geodynamic force velocities on the Earth's surface are unevenly distributed, affecting the activity of volcano-plutonic and seismic processes. Therefore, the movement of lithospheric masses on the surface of the upper mantle occurs under the influence of these forces. The movement of lithospheric masses is a key factor in the distribution of stress zones, which is responsible for the activity of volcano-plutonic and seismic processes.

This clearly indicates that diverse thermodynamic conditions are necessary for the manifestation of volcano-plutonic processes, including hyperbasites, and these conditions are crucial for the formation of various magmatic formations. To identify the conditions for the formation of each type of rock, the nature of the development of geotectonic processes must be taken into account. Global geotectonic processes participate in the formation of facies-formational features of each genetic type of rocks, as well as in the extraction of useful components [15–38].

Focusing on the facies-formational characteristics of hyperbasites, they are characterized by compositional uniformity and belong to ultrabasic formations. They are absent or less significant in their effusive analogs. This suggests that hyperbasites correspond to conditions where magma cannot rise to the upper zone of the lithosphere, where favorable thermodynamic condi-

tions exist for the differentiation and crystallization of the magmatic melt. It is important to consider that magma is a product of decompression and tends to rise to the upper zone of the lithosphere. Under changing thermodynamic conditions, it transitions to the volcano-plutonic stage of magmatism development. Naturally, under these conditions, magma undergoes cooling, differentiation, and other transformative processes typical of the volcano-plutonic stage of the evolution of magmatic formations.

From the perspective of the DEEC (Dynamics of the Evolution of the Earth's Crust), as noted above, the origin and formation of hyperbasites correspond to the initial stages of the development of volcano-plutonic processes. In these stages, the thermodynamic conditions necessary for the differentiation of newly formed magmatic melts are absent. According to DEEC, such zones may include not only deep zones of the Earth's crust but also deep water bodies (oceans), basins with a divergent development character. In these conditions, magmatic melts cannot differentiate in terms of composition due to the powerful hydraulic pressures exerted by the oceanic water bodies, which is entirely logical. These zones mainly include deep-seated oceanic spreading zones in mid-ocean ridges (Fig. 2).

Formation conditions of hyperbasites

Hyperbasites can develop in all age groups of rock complexes. They are often exposed both in platforms and in eugeosynclinal areas of the Earth's crust. The term "exposed" is used here intentionally because hyperbasites form at great depths, and their exposure in the upper zone of the Earth's crust is associated with global geotectonic processes, such as orogenic or collisional processes, at different geological stages in the Earth's evolution. In other cases, they may be exposed by prolonged erosion processes [33–38]. These areas can include the peripheries of continents. They may manifest within ancient continent platforms consisting of accumulations of ancient shields, terrains, and so on. From the perspective of the DEEC, continents as a whole, regardless of their location, formed as a result of volcano-plutonic processes in the initial stages of the Earth's crust development. There is ample evidence for this, often in the form of volcanic eruptions, which essentially constitute the primary forms of continent formation. An illustrative example is terrestrial volcanic eruptions occurring in seismically active zones of the Earth's crust, serving as one of the modes of continent formation.

Regarding the hyperbasites, which are widely developed in mountain-folded zones, including collisional zones of the Earth's crust, this is not coincidental. Each orogenic process occurs based on previously forming geological formations. An example can be formations within the Alpine-Himalayan mountain-folded zone. In these collisional zones of the Earth's crust, during the collisional stage of crustal development, the paleo-Tethys ocean was located, exhibiting all the typical features inherent to modern oceanic basins. The ocean was complex, with active divergent and convergent zones where active volcano-plutonic processes took

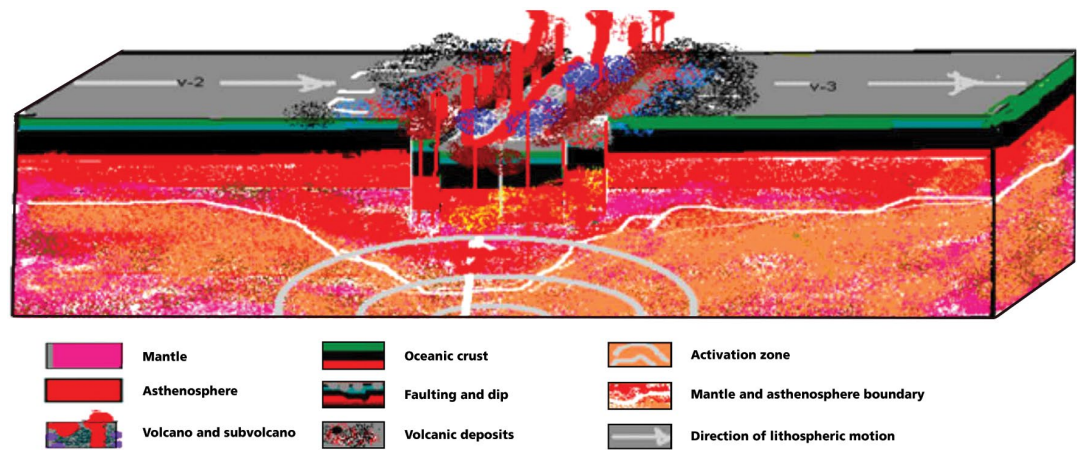


Fig. 2. Scheme of spreading formation

place, covering extensive periods of time – from the Paleozoic to the Mesozoic and partially the early Cenozoic. The internal structure of the collisional zones was formed based on these processes [5–11]. This complexity explains the geological structure of the Alpine-Himalayan mountain-folded structure.

In the structure of the Alpine-Himalayan mountain-folded formation, hyperbasites (often referred to as ophiolites, serpentinites, ultrabasics) occupy a special place in the construction of mountain formations [35–38] because genetically (in the classical sense), hyperbasites are considered intrusive formations. They formed in deep-sea conditions within the Paleotethys and often represented spreading zones of the Tethys Ocean, which were involved in collision. This viewpoint contradicts the position of classical geology, leading to lively debates that continue to the present day. However, from the perspective of plate tectonics, clarification of many issues related to hyperbasites, including the nature of ophiolites and their occurrence forms, as well as the dynamics of development in the lithosphere, is significantly facilitated. From the perspective of the DEEC, volcano-plutonic processes are among the orderly phenomena governed by natural laws that reflect the laws of physics, mechanics, chemistry, biology, and others. It is essential to note that natural laws exist independently of us, and ignoring them is not advisable. This includes geodynamic forces, the role of which is of immense importance in the evolution of the Earth's crust. Before the establishment of the DEEC, the nature of many problematic geological issues, including the genetic problems of hyperbasites, was not adequately clarified.

Many geological processes participate in the evolution of the Earth's crust. However, their development occurs under the influence of geodynamic forces. The reasons for the rotation of the Earth remain unclear to us. From the perspective of the DEEC, the rotation of the Earth is also governed by general natural laws that operate in the space of the Universe.

Concept of Earth's Crust Evolutionary Dynamics is dedicated to elucidating the geological stage of Earth's evolution, i.e., after the formation of Earth as a planet. According to the physical-mechanical law, the formation of geodynamic forces is associated with the rotation of the Earth, and this is undisputed. Such a viewpoint aligns with the laws of nature.

As for the formation of the Earth's internal structure, it also occurs under the influence of natural laws. Here, gravity is the primary factor. Based on the law of gravity, the internal structure of the Earth is formed, consisting of distinctive geospheres (core, mantle, lithosphere, atmosphere). Subsequently, geolo-

gical stages of Earth's development begin, which are developed based on these geospheres. These geospheres, both in terms of the depth of material composition and other parameters, sharply differ from each other and are formed based on physical-mechanical laws.

Further on, in all zones of the Earth, both internal and external, all physical-mechanical movements of substances occur under the influence of geodynamic forces. The main movements are those of lithospheric masses, which occur on the surface of the mantle and are genetically linked to all geotectonic processes, such as the formation of global tensional zones, etc. Among them, the most pronounced are: orogenic processes; collisional processes; divergent and convergent processes; transform processes; the formation of active and passive margins; the formation of marginal seas; the formation of island-arc systems; the formation of continents and oceans; the formation of stable and active zones; the formation of global fault networks; the formation of flexural structures, and others. All these processes, collectively, operate in the external zones of the Earth, the nature of which is explained from the perspective of the DEEC.

There are also other global processes that form in the internal zones of the Earth. These processes include the formation of plumes, diapirs, sutures, hotspots, and others; volcanoplutonic processes; the formation of weakened zones (asthenospheric layers); convection processes, and more. The influence of geodynamic forces is undeniable in the formation of these processes. Previously, all the listed issues were subjects of discussions.

Now let's present the main characteristics of these global processes from the perspective of the Concept of the Dynamics of Earth's Crust Evolution (CDCE), which can be useful for understanding the nature of many mysterious phenomena occurring in both the internal and external spheres of the Earth. Understanding the true nature of these processes has significant scientific and practical value. Global geotectonic processes are interconnected processes. They exist in all spheres of the Earth and can be conditionally divided into two groups: internal and external. From the perspective of the CDCE, all natural processes, without exception, occur under the influence of geodynamic forces that dominate throughout the space of the Earth.

Inside the Earth, where physico-chemical processes take place, the evolution of the Earth's crust plays an important role. These include the formation of plumes (asthenosphere), diapirs, sutures, hotspots, convective currents, etc., which are associated with the formation of volcanoplutonic processes. They participate in the transformation of the Earth's crust from the perspective of the CDCE, built on the basis of the Earth's rotation. The essence (significance) of the concept lies in the fact that the rotation of the Earth around its axis generates geodynamic forces. These forces have a predetermining significance in the evolution of the Earth. The point is that different geospheres participate in the structure of the Earth. These geospheres react differently to the rotation of the Earth. Therefore, in the zones of contact between geospheres, mass displacements occur, which are responsible for the unloading of mantle material. These unloading phenomena are expressed in the formation of plumes, diapirs, sutures, and others. Essentially, they are sources of volcanoplutonic processes.

The presence of anomalous phenomena in the Earth's space is a fact established by geophysical methods. In the structure of the Earth, they are expressed as weakened zones. Moreover, during their propagation in the Earth's space, a certain regularity is

observed. Typically, they develop between different geospheres. The development of these processes, according to the laws of nature, clearly correlates with the regularities of the spread of geodynamic forces. The intensity of the development of geodynamic forces depends on changes in Earth's parameters. Therefore, the intensity (or activity) of geotectonic processes from the Earth's core to its surface consistently increases with the increase in the Earth's radius. This is strictly consistent with the laws of physics and mechanics.

All of the above indicates that complex physico-chemical processes occur within the Earth, which are governed by the laws of nature. Naturally, volcanoplutonic processes also occur under the influence of these laws. The formation of magmatic rocks, including hyperbasites, is associated with the activity of volcanoplutonic processes. These rocks constitute the main parts of the Earth's crust. Therefore, when studying the characteristics of each geological body, especially their genetic features, origin, formation mechanisms, as well as the regularities of distribution, etc., they are clarified against the background of considering the general laws of the evolution of the Earth's crust. Without this, it is difficult to establish the true nature of geological formations, including hyperbasites. Often, hyperbasites are found in such incredible geotectonic situations that it is difficult to explain their nature and location in relation to surrounding geological bodies [12–38].

It is known that hyperbasites, like other magmatic complexes of rocks, are formed as a result of the activity of volcanoplutonic processes. They constitute a single series within the composition of rocks, which are conditionally classified by chemical composition. They, in all likelihood, were formed at great depths, where favorable conditions for their differentiation by composition were absent. Ultrabasic rocks are formed at the initial stages of volcanoplutonic processes, where the corresponding common thermodynamic conditions prevailed, i.e., conditions suitable for the formation of intrusive rocks. From the perspective of the Concept of the Dynamics of Earth's Crust Evolution (CDCE), these zones may be near equatorial latitudes, where divergent and convergent zones dominate, or zones of their articulation with transform faults, where morphostructural elements of the flexural type are widely developed, creating a favorable geotectonic environment for the manifestation of volcanoplutonic processes [5–11, 31–38].

This gives grounds to say that hyperbasites are formed in deep thermodynamic conditions, which, after the establishment of plutonic formations, move to the upper sections of the Earth's crust and can subsequently be exposed during denudation processes.

From the perspective of the CDCE, the occurrences of hyperbasites in the Earth's structure are diverse. In some places, they emerge on the Earth's surface, which is exposed by denudation processes. This includes rocks that formed in the early stages of the geological development of the Earth. As for the appearance of hyperbasites observed on the daytime surface, they can be formed as a result of orogenic processes, which have two types of appearance forms. One of them was formed between previously formed and autonomously developing platforms, which have a development of a local type. Others can move due to collision processes and have a global character of development. These include all types of collisions developed in ocean basins, as well as global subduction zones, active margins of continents, regional convergent zones located in ocean basins, i.e., essentially consisting of alternations of

divergent and convergent zones [5] (Fig. 3). Similar stress zone arrangements exist within supercontinents.

Certainly, the Earth's crust as a whole consists of alternating stress zones that develop latitudinally and essentially form zones of divergence and convergence located in sub-meridional directions [5].

As for the processes that operate in the external zones of the Earth, they include those processes genetically linked to the formation of the structural-morphological appearance of the Earth's crust, namely: collisional, convergent-divergent, transform fault zones, flexural structures, and others. In aggregate, they are part of global fault networks involved in segmenting the Earth's crust into stable and active zones.

The mentioned stress zones are essentially tectonically active zones where the formation of marginal seas, island-arc systems, and changes in continental and ocean boundaries occur. These processes, collectively, operate in the external zones of the Earth's crust, the nature of which is explained from the perspective of the Concept of the Dynamics of Earth's Crust Evolution (CDCE).

Mountain-building processes. Mountainous structures are one of the prominent morphostructural elements of the Earth's crust, developed both in continental and oceanic basins. Investigating

their nature has always been relevant, particularly studying their origin, formation mechanism, structure, manifestation forms, material composition, distribution patterns, and many other features. Fundamental works by renowned scientists [11–38], representatives of various geological and geographical scientific directions, have addressed various discussions related to genetic problems of mountainous structures.

It should be noted that the origin and formation mechanism of mountainous structures are associated with the movement of lithospheric masses occurring under the influence of geodynamic forces. The movement of lithospheric masses creates a complex stress framework. The main causes of creating these stresses are related to the different thickness of the Earth's crust. The thick Earth's crust on the surface of the upper mantle moves more slowly than its thin part. For this reason, in accordance with the laws of the spread of geodynamic forces in the Earth's space, including its crust, various stresses are created. These stress zones in the Earth's crust are expressed as divergent and convergent zones, alternating in latitudinal directions and developed in sub-meridional directions (see Fig. 2).

These stress zones are scaled differently. The first rank includes ocean basins and continents. They are also segmented into smaller ranks. This feature is most clearly expressed within ocean basins. Within continents, the signs of these stress zones merged with denudation processes.

The above clearly shows that the origin of mountainous structures and their further development are closely related to global geotectonic processes, such as the movement of lithospheric masses, resulting in various divergent and convergent zones. The latter are essentially the weakest zones of the Earth's crust, where the manifestation of volcanoplutonic processes is observed. They participate in the formation of various genetic types of mountainous structures, including accumulative-type accumulations and fold-type developments.

Divergent and convergent zones can be developed throughout the entire area of the Earth's crust (Fig. 4).

They are usually represented by deep divergent and convergent fractures, located in sub-meridional directions. Linear arrangement of mountainous structures testifies to this. They, in composition, were formed due to the accumulation of products of volcanic eruptions. These mountainous structures include mid-ocean ridges. Such mountainous structures can develop in all zones of the Earth's crust.

As for the formation of mountainous structures of the convergent type, in their structure, along with volcanic material, previously formed products of the Earth's crust may be involved. These include subduction-type mountainous structures, which usually form in the western margins of continents. From the perspective of the CDCE, mountainous structures, based on genetic features, are classified into divergent, convergent, collisional, and transform types, detailed characteristics of which are provided in works [11–38].

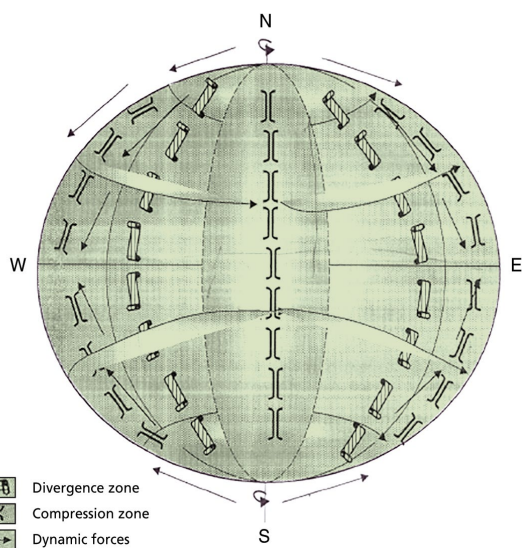


Fig. 3. Scheme of alternation of convergent and divergent zones in the Earth's crust

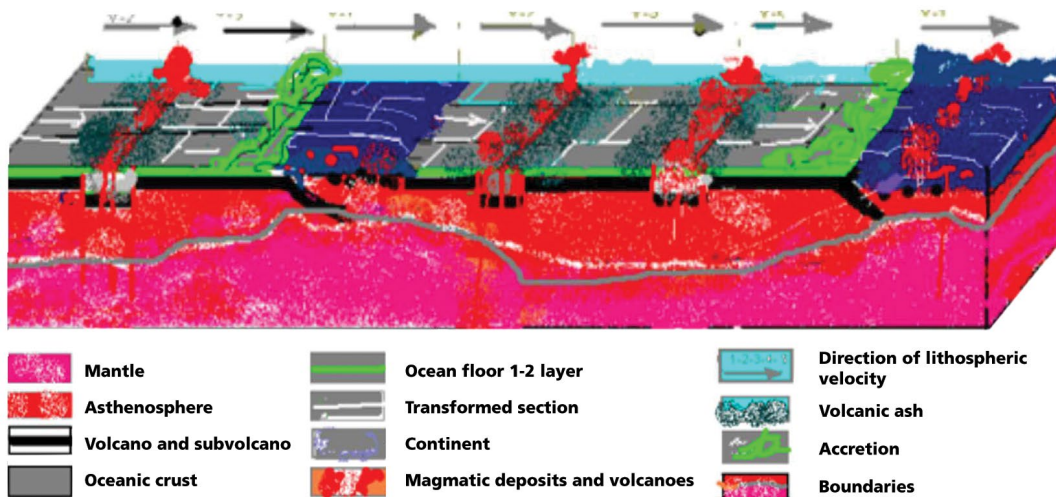


Fig. 4. Scheme of alternation of divergent and convergent zones

Active and passive margins of marginal seas and island-arc systems. The main causes of mountainous structure formation, as noted above, are associated with the development of stress zones that form during the movement of lithospheric masses. The main ones among them are divergent and convergent zones, with which the largest mountainous structures are associated, located in sub-meridional directions. Apart from these, there are smaller-scale stress zones that form within continental blocks of the Earth's crust between autonomously developing continents (Fig. 5).

From the perspective of the CDCE, these zones include active and passive margins of Greenland, Australia, Great Britain, Norway, Japan, Madagascar, Kamchatka, Sakhalin, and many other regions of the world, where mountainous structures can also form, and favorable geotectonic conditions may exist for the manifestation of volcanoplutonic processes.

Patterns of Hyperbasite Distribution

The material presented in the previous sections of the article provides a clear understanding of the nature of volcanoplutonic processes, which are organically linked to the formation and subsequent development of hyperbasite complexes of igneous rocks. These rocks, being the main members of the igneous rock series, are formed in the initial stages of volcanoplutonic processes.

As for the patterns of hyperbasite distribution, they were formed under the influence of high thermodynamic conditions where a favorable thermodynamic environment for their differentiation by chemical composition is still absent. They originate from the primary magmatic melt, a product of the decompression of mantle material, where features such as plumes, diapirs, sutures, etc., are formed [11]. In Earth's space, they spread with certain regularities, essentially serving as sources of volcanoplutonic processes.

The zones of hyperbasite distribution are extensive and can emerge at the Earth's surface in all zones of the Earth's crust. However, according to the patterns of distribution of geodynamic forces, they are most intensively developed near the equatorial zones of the Earth and are mainly represented in the divergence zone.

The formation of hyperbasites occurs at great depths (approximately over 1000 m). They can also be formed within deep convergence zones and under other conditions. This leads to the conclusion that all ultrabasic rock complexes are formed in deep thermodynamic conditions, which, through various geological-tectonic processes, move closer to the surface zones of the Earth's crust. The formation of hyperbasites can occur in

different thermodynamic conditions, with high pressure being the main factor for their formation. Such pressure can be created by the thickness of the Earth's crust or the power of bodies of water. In both cases, magmatic melts are in a more or less stationary position where favorable conditions for the growth of mineral individuals characteristic of plutonic formations exist.

As for the formation of alpine-type hyperbasites, they, from the perspective of the CDCC (continental drift collisional zones), were formed in the basins of large water bodies under significant thermodynamic conditions. Subsequently, as a result of collisional processes, they rose into the Earth's crust as mountain structures of collisional origin. It is not coincidental that leading experts worldwide refer to them as alpine-type hyperbasites [11–23, 19–38].

It is necessary to note that hyperbasites observed within the Alpine-Himalayan mountain system are referred to as alpine-type hyperbasites. Apparently, they significantly differ from other ultrabasic rocks. From the perspective of the CDCC (continental drift collisional zones), alpine-type hyperbasites were formed under specific thermodynamic conditions, i.e., under high hydraulic pressure, where magmatic melts cool faster than in other magmatic reservoirs. Therefore, they differ from other genetic types of hyperbasites.

The hyperbasites of the Lesser Caucasus are classified as alpine-type, formed as a result of collision. However, it cannot be claimed that all territories of the Alpine-Himalayan mountain system were formed within the Paleotethys, where various geological transformations occurred, covering large spans of time (Paleozoic, Mesozoic, and Cenozoic), forming thick volcanic-sedimentary deposits in combination with intrusive-subvolcanic formations. It is conceivable that similar geotectonic processes occurred in the Paleotethys basin, as those presently occurring in the basins of the Pacific, Atlantic, and Indian Oceans, where divergent and convergent zones, lithospheric mass movements, active and passive margins, fault systems, island arc systems, etc., are observed. Analyzing the characteristics of these global processes logically leads to the conclusion that similar geotectonic conditions were typical for the development of Paleotethys.

All Alpine-Himalayan mountain fold systems, including the Caucasus fold systems, as collisional zones, were formed based on the sedimentary accumulation of the Paleotethys ocean, which, over a long period (Paleozoic-Mesozoic-Cenozoic), served as the arena for major geological events. Therefore, to better understand the nature of geological events within the Alpine-Himalayan fold

system, it is necessary to consider at least the main features of the tectonic history of Paleotethys. This necessity arises from the fact that the main masses of hyperbasites participating in the structure of the Alpine-Himalayan fold system were formed in the Paleotethys basin and later, as a result of collision, rose to the level of the lithosphere. It is not coincidental that the main products of geotectonic processes, including those of volcanoplutonic processes, contribute to the structure of the Alpine-Himalayan fold structures. Therefore, when foreign (uncharacteristic) products manifest in the structure of collisional formations, it should not be surprising. It is necessary to establish the reasons

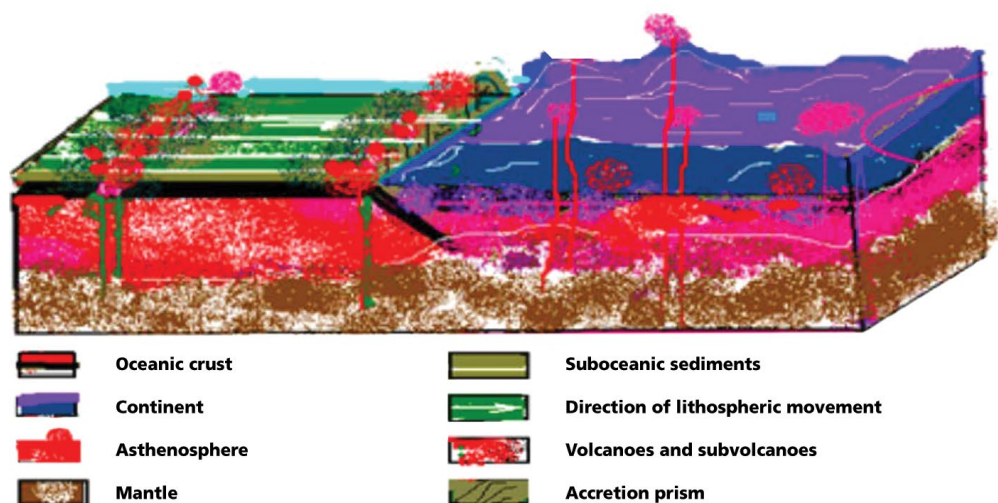


Fig. 5. Scheme of subduction zone formation

for their appearance and understand the mechanism of their formation. Hence, we are entitled to think that alpine-type hyperbasites, currently observed in the structure of the Alpine-Himalayan fold system and formed in the Paleotethys basin before collision, subsequently rose to the lithospheric level as a result of collision. It is essential to note that, from the CDCC perspective, hyperbasites can form under two thermodynamic conditions:

1. The first type of thermodynamic conditions pertains to volcanoplutonic processes that occur within the Earth's crust. In these conditions, primary magmas undergo differentiation under existing thermodynamic conditions. Initially, pyroclastic materials with rich volatile components are separated from the magma. Afterward, a normal thermodynamic environment is established in the magmatic reservoir, where favorable conditions for the differentiation of the primary magma into mineralogical compositions are created. This process leads to the formation of facies-formational types of rocks ranging from ultrabasic to acidic compositions (Bowen's series). It is during this stage of differentiation, under conditions where valuable components are separated, that the formation of ore deposits is associated.

2. The second type of thermodynamic conditions involves hydrothermodynamic conditions where volcanoplutonic processes occur in aquatic environments that cannot be differentiated based on mineralogical composition. Therefore, primary magmas are forced to cool under specific hydrothermodynamic conditions. Possibly, due to this reason, the products of volcanoplutonic processes, as a result of collision, rise to new conditions and undergo a special type of weathering (most likely serpentinization) in these conditions.

The above reasoning finds confirmation in the example of the Lesser Caucasus, where two different genetic types of hyperbasites are observed, formed in two different thermodynamic conditions. Some of them formed in hydrothermodynamic conditions, while others formed in regular thermodynamic conditions within the Earth's crust.

In summary, the differentiation of primary magmas and the formation of hyperbasites can occur in different thermodynamic conditions, either within the Earth's crust or in aquatic environments. The specific conditions determine the mineralogical composition and characteristics of the resulting rocks, and understanding these conditions is crucial for interpreting the geological processes and the formation of hyperbasites in various regions.

Conclusions

1. Nature of Hyperbasite Complex: The hyperbasite complex of rock, by its nature, belongs to deep-seated magmatic formations that were formed in the initial stage of the development of volcanoplutonic processes, where the compositional makeup of magmatic products remained undifferentiated.

2. Overall Origin of Magmatic Rocks: The origin of magmatic rocks, in general, is associated with deep anomalous processes. These processes were influenced by geodynamic forces, leading to the decompression of mantle material and a catastrophic increase in the volume of mantle material, as well as the associated development of volcanoplutonic processes.

3. Formation in Divergent and Convergent Zones: Hyperbasites are formed in both divergent and convergent zones of the Earth's crust. Key factors for their formation include high pressure and deep thermodynamic conditions where a favorable thermodynamic environment for the complete differentiation of magmatic melts into their compositional components is absent.

4. Alpine-Type Hyperbasite Formations: Hyperbasite formations classified as alpine-type, originally formed in the foundation of the Alpine-Himalayan fold system within the Paleotethys

Ocean basin, have been displaced due to collisions in subsequent geotectonic processes involving both divergence and convergence.

5. Correspondence to Geodynamic Force Patterns: The regularities in the formation and the mechanism of alpine-type hyperbasites clearly align with the patterns of development of geodynamic forces on Earth's surface and the natural laws that play a pivotal role in the evolution of the Earth's crust.

These conclusions highlight the deep-seated and complex nature of hyperbasites, emphasizing their formation in diverse geotectonic settings and the fundamental role of geodynamic forces in shaping the evolution of the Earth's crust.

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