Plume and spreading basalt assemblages in the global system of the Mid-Ocean Ridges

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The synthesis of published data and our previous investigation [1-5] allow to conclude the discrete character of geodynamic condition of Mid-ocean ridge (MOR) formation that resulted in the coexisting of two independent basalt assemblages.

1) Spreading basalt assemblages (SA) are forming by adiabatic depleted mantle upwelling from the depth less than 200 km and by its low degree of melting at the depth 15-30 km. The low productivity of volcanism is characteristic for this assemblage. SA makes up background of MOR magmatic system.

2) Plume basalt assemblage (PA). The term "plume" means here the associated mantle material and its magmatic products of the limited volume in MOR space. PA is forming due to enriched or depleted mantle upwelling from the depth more than 400 km and high degree of its partial melting at the depth 50–100 km. The high productivity of volcanism is characteristic for this assemblage.

The comparison of Mid-Atlantic ridge (MAR) and East Pacific Rise (EPR) demonstrates the following [5].

- The stable correlation of petrological and geophysical parameters consistent with ridge geodynamic segmentation is normal for slow spreading. This correlation is getting unclear with spreading rate increasing.
- The increasing of spreading rate is accompanied by growth of volcanism productivity, variation of basalt composition and proportion of spreading assemblages relatively plume assemblages.
- Plume formation looks independent relatively spreading process under slow spreading rate. PA and SA are strongly separated each other in space under this condition. Increasing of spreading rate leads to disappearance of boundaries between PA and SA.
- The common limit of magmatism petrological conditions does not depend on spreading rate and geochemical features of basalt mantle source.

PA and SA assemblages have been identified by 20 000 quenched glass microprobe analysis and their location along MOR system has been determined with use of Vernadsky Institute database. It permits to see the followed.

- PA are most representative in the North MAR (Iceland and Azores megaplumes) and make up more than ½ ridge length.
- In South MAR and in EPR PA occupy about 1/3 ridge space.
- In the Indian Ocean and in Antarctic basin SA are dominant. PA locates mainly near triple junctions.

TOR-K - potassium rich basalts (T-type by M. Wilson [6]), which are forming by the mantle upwelling from the maximal depth (700-1000 km) [1], have been identified and their location in MOR system has been plotted on the World map of free air gravity anomaly with 2 arc minute resolution [7,8]. Their location emphasizes well the distribution of PA in MOR space.

This map permits some conclusions and suggestions.

- Under slow spreading condition PA locate mainly on the area of positive bathymetry (high value of free air anomaly). It might be explained that large budget of volcanic products due to high magmatism productivity of PA cannot be compensated by space extension. As the result the positive relief is forming here due to consequent basalt layering within the limited square during long time (Iceland and Azores megaplumes).

- The location of PA in the areas of low free air anomaly value under slow spreading rate can be due to small plume size and short period of their activity in modern time (microplumes near 15° and 25° North MAR).
- Under high spreading rate PA placed in the areas of intermediate free air anomaly value because volcanic products are distributed regularly on the relatively large square and thick layer of basalt is not forming even under high magmatism productivity (Juan de Fuca ridge, EPR).

The data on TOR-K location has been plotted on world tomographic maps of mantle heterogeneities by S-wave along various depth levels as by the old model RG5.5 [9, 10], and by new models NGRAND и S20A [11, 12]. The obtained material permits the following suggestions.

The fields of anomalous mantle (low density mantle) at 100 km depth correspond approximately MOR location. Most of PA are also locate inside anomalous mantle at this depth level. It is well seen for EPR forming under high spreading rate. It is consistent with suggestion about large volume of heated lithosphere around action plume. At the same time PA under slow spreading conditions lie in the areas of various mantle density. It needs to be discussed. For example Iceland and Azores megaplumes disposed in the area of normal or moderate degree of mantle density in spite the development of large volume of anomalous mantle should be expected here by the long time of lithosphere heating.

Similar inconformity suggests the chain of microplume about 1000 km long in the Western part of Africa-Antarctic ridge placed in zone of almost normal mantle density.

The existence of microplumes in cold and dense lithosphere of the equatorial MAR is explained by small plume size and short time of their action (similar to case of free air anomaly low value).

The distribution of the anomalous mantle near MOR orientation is preserved only until 250 km depth. Below this level anomalous mantle is significantly shifted relatively MOR orientation and under Atlantic below 450 km anomalous mantle is almost absent.

If this distribution of anomalous mantle is caused by convection it means the strong vertical uprising of mantle material is impossible. It makes also doubtful the junction of convection and plume for which vertical uprising from the Earth core is suggested.

By the similar reasons genetical relation of plumes and convection in MOR system is also doubtful. In this case it is possible to suggest plume uprising only from 250 km depth of anomalous mantle. At the same time the detailed MAR tomography [10, 13] has traced Iceland megaplume roots up to 800 km depth.

In general the existed data on mantle tomography does not permit to suggest the convection and plume relation.

Our study of well-sampled North MAR suggests also that the direct connection of plume formation and convection is doubtful. The calculations show the formation of SA as the background of PA is accompanied by mantle upwelling under one layer convection model from the depth about 100 km while TOR-K formation is resulted by mantle upwelling from depth 200 km under the same conditions. Under two layered convection model SA is forming by mantle upwelling from 200 km depth while TOR-K is generated by mantle upwelling from 700 km depth and more. [4]. This study exhibits the coexisting PA and SA leads to very contrast distance of mantle upwelling along limited interval of ridge space. This result is not consistent with the traditional presentation of convection cell shape and scale.

We suggest for this case that spreading basalt assemblage is forming due to passive mantle uprising and filling the open space of lithosphere under tension only from the topmost surface of convection cell. Under one layered convection this surface lies at 100 km depth, under two-layered convection – at 200 km depth. Both depths are determined for the constant spreading rate. It is possible the spreading rate increasing accompanies by these depths lowering.

Microplume formation could be resulted by the passive mantle upwelling from the level below convection cell surface due to irregular lithosphere tension or along high penetrable zones (for example triple junctions). Megaplume (Iceland, Azores) should be formed by the active mantle uprising from the depth no more than 1000 km. This process should not depend from lithosphere regular spreading and shape of convection cell.

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