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THE GENERAL LAWS OF GLOBAL BIOGEOCHEMICAL PROCESSES

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- Global strategy of environmental protection is connected not only with the scale of technogenic influence. The task of revealing “vulnerable points” in complex natural systems becomes one of the most important problems for today. Complex natural systems may be destroyed even in case of slight influence on such points. So, the environmental protection needs the knowledge of regularities and evolution of systems’ vital activity. Determination of the biosphere elemental composition and properties is one of the most complex problems. The key point of investigation of the specificity of the biosphere elemental composition formation is determination of patterns of redistribution of elemental average concentrations among various phases, like solid - liquid - gaseous (i.e., the lithosphere – the hydrosphere - the atmosphere), which occurs as a result of a global continuous processing of inert matter by living material.

- Our task here is to investigate this process in the system “lithosphere – hydrosphere” in view of the integrated involvement of living material in it. It is also necessary to take into consideration here that the differences existing between proto-lithospheric and biospheric elemental compositions can be only found if the regularities in the evolution of the biosphere elemental compositions are determined.

- The graphic presentation of the comparisons of stony meteorites – chondrites (proto-planetary material) and the upper lithosphere (biosphere) average elemental compositions as shown in Fig.1 provides determination of the following groups of elements: $C_{chond.} > C_{lith.}$ (contains only 11 elements), $C_{chond.} \sim C_{lith.}$ (18 elements) and $C_{chond.} < C_{lith.}$ (42 elements).

- The correlation coefficient between logarithmically expressed element concentrations for the 71 studied chemical elements in proto-planetary material and in the lithosphere is equal to 0.87. The tangent for the regression line inclination is equal to 0.75. This tangent numerical value is a quantitative estimation of the nonlinearity factor for the elemental composition general evolution within the system “proto-lithosphere - living material - biosphere”.

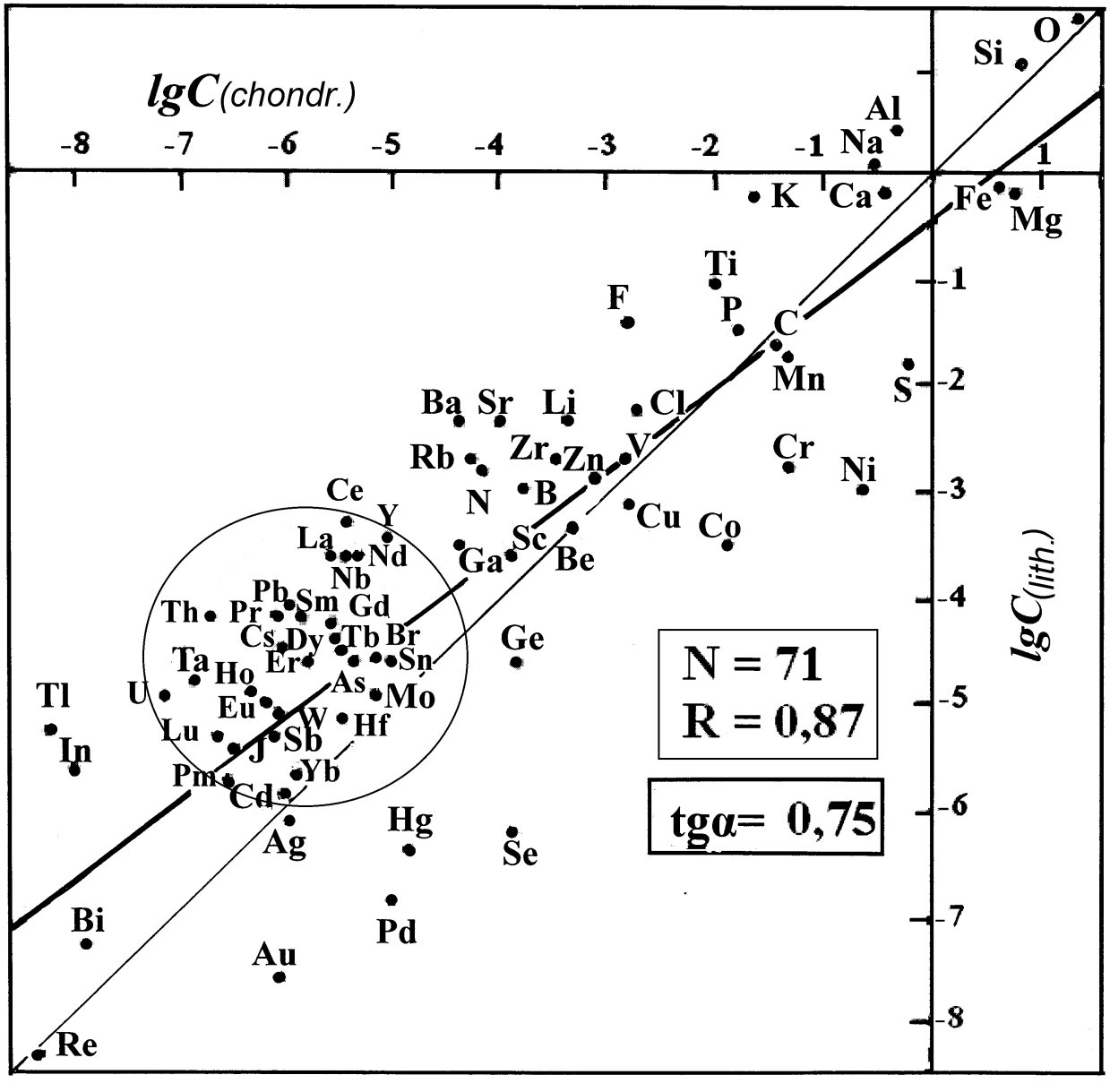

Fig.1. Ratios for element concentrations in chondrites and in the lithosphere

- The established pattern provides quantitative estimations of the trends in processing of inert matter with living materials on the surface of the Earth. This process leads to a general relative raise of chemical element concentrations in the solid phase according as the element prevalence in the environment. Therefore, translation of the chemical elements from more soluble compounds to some less soluble ones is a common & specific reaction of the "living matter" to the deficiency in their concentrations as seen in the habitat.

- When studying specificity of the formation of the hydrosphere elemental composition, we take the same methodology “empirical generalization” as with the lithosphere research. We regard the ocean as a complex system where transformations of the material that is received through a geochemical barrier “river – sea” provide average elemental composition of the ocean.
- The diagram for the dependence of average elemental composition of ocean & river waters is presented in Fig. 2. Assuming the quantity of the studied elements is equal to 64, the correlation coefficient is equal to 0.94. The line corresponding to the equation as obtained by the linear regression method makes up abscissa axis, tg $\alpha = 0.67$. The fact that all the elements are located on one side of the line (or on the line precisely), forming an angle of tangent equal to 0.70 with the abscissa axis, also deserves attention.

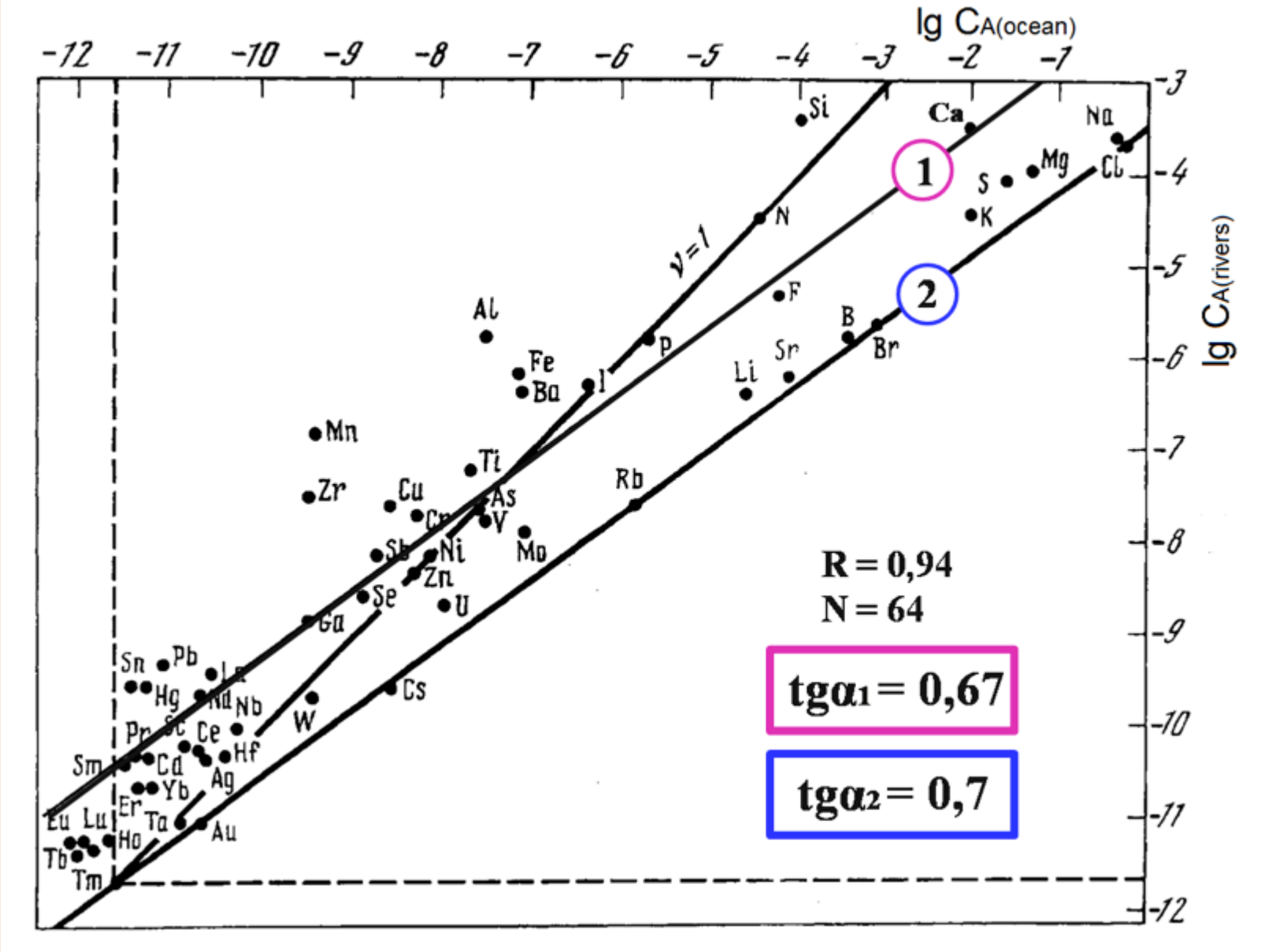

Fig. 2. Ratios of average concentrations for elements in ocean and river flow.

- The line running through Cl, Na, B, Br, Sr, Li, Rb, Cs, Mo, U, W, Tl, Re and Au (marked figure 2) to combine elements that considerably differ in their chemical and physical features through the general pattern of the material transformation & migration on the geochemical barrier “ocean-atmosphere”, the characteristic feature of the elements located on this line being the equilibrium of their flows within the “ocean – atmosphere - continent - ocean” system.

- The actual equality of the tangent for the line inclination angle as obtained by the linear regression method and the tangent ratio for the line reflecting the pattern of material transformation & migration in the barrier “ocean – atmosphere” (Fig. 2), indicates the equality of constants for nonlinearity of the average elemental compositions redistribution processes as occurring between the dissolved and solid phases in absolutely different geochemical barriers “ocean - atmosphere” and “river - sea”. The basic generality of geochemical barriers is that they are the places of "the life condensation". Regression analysis has allowed us to reveal the general tendency of relative increase in microelement concentration indices for the solid phase (and their respective drop in solution) as a result of the inert matter processing by living material both in the lithosphere and in the geochemical barriers like “ocean - atmosphere” and “river - sea”.

- The general nonlinear character of the dependence of average elemental compositions redistribution processes between the dissolved and solid fractions in the matter that is received through barriers “lithosphere – living material – hydrosphere”, “river – living material – sea” and “ocean – living material – atmosphere” on their initial concentrations which we have found suggests the following important conclusion. Biogeochemical behaviour of elements existing in microconcentrations in the nature does not generally repeat their behaviour of their chemical analogues that are present in the lithosphere and the hydrosphere in macroconcentrations. It is especially significant to consider when solving any environmental problems and also when radioactive isotope behaivour in the biosphere is investigated.
- Thus, the general patterns of average elemental compositions redistribution in the biosphere between solid and liquid phases (i.e., “lithosphere - hydrosphere”) have been determined for the first time. This process is most active in biogeochemical barriers, i.e. in places of "the life condensation" and runs under a nonlinear regularity that has been unknown before.

- It is established that this process results in a general relative increase in concentrations of chemical elements in the solid phase in proportion as their prevalence in the environment is reduced. This process running in various natural systems has practically the same parameter of nonlinearity (v) approximately equal to 0.7 (for protolithosphere - living material - sedimentaries system v = 0.75, for river – living material – ocean system v = 0.67 and for ocean – living material - atmosphere v = 0.7). For the contemporary factual awareness level these estimations of nonlinearity indices are practically negligible. Hence, it is for the first time that the existence of a universal constant of nonlinearity of elemental composition evolution in the biosphere has been proved and its quantitative evaluation has been made.

It was found that the correlation between elemental compositions of the lithosphere and the ocean is relatively weak (r = 0.68) while elemental compositions of river water and oceanic water has a strong correlation (r = 0.94).

The constancy of the chemical elemental composition of oceanic water is of fundamental importance and is a constant for our planet. Detailed studies are revealed the constancy of distribution pattern of separate chemical elements in the ocean. Three types of element distribution in the ocean are determined:

1) Conservative: concentration normalized to salinity is constant in space and time;

2) Nutrient-type: element concentration in surface waters decreases due to their consumption by “living matter”;

3) Litho-generative: complex character of distribution of elements, which enter the ocean with the river runoff are scavenged almost entirely in sediments.

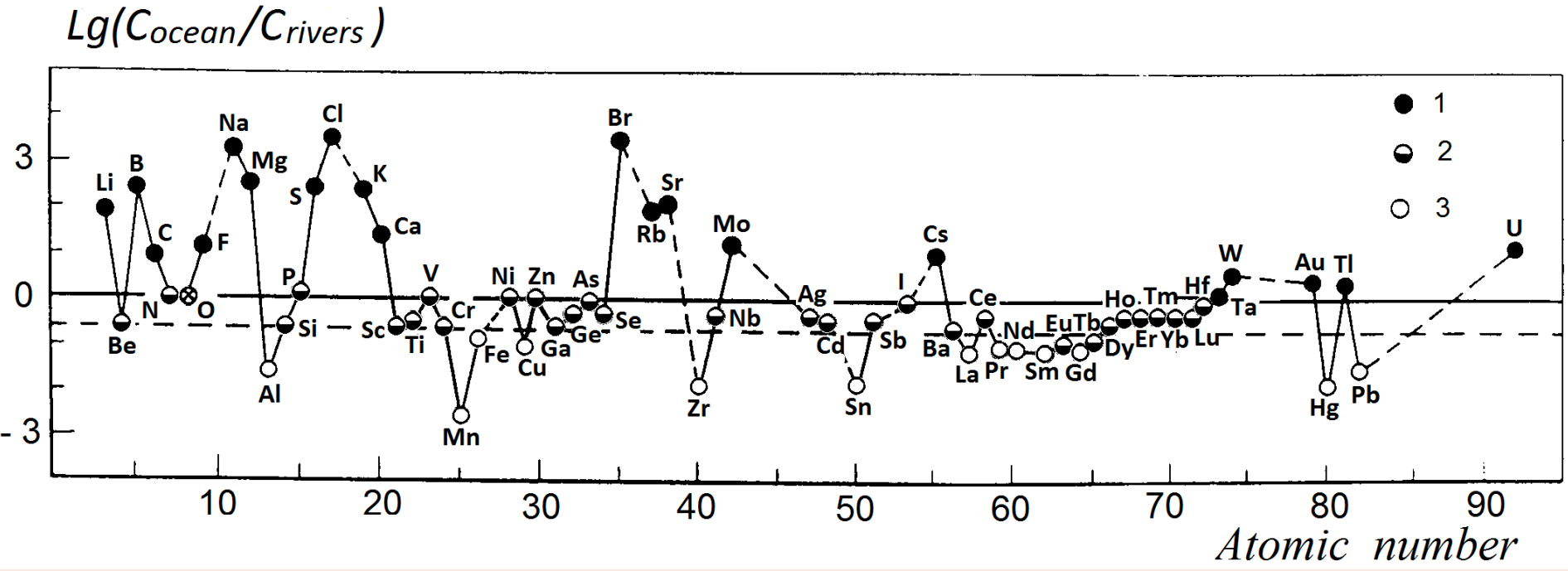

Fig. 3. Concentrations ratios of the chemical elements in the ocean and river waters and types of distribution in ocean:
1) conservative; 2) nutrient-type; 3) litho-generative.

Conservative type of distribution in the ocean - $C_{A(ow)} > C_{A(rw)}$
Nutrient-type of distribution in the ocean - $C_{A(ow)} \sim C_{A(rw)}$
Litho-generative type of distribution in the ocean - $C_{A(ow)} < C_{A(rw)}$

Application of systematic methodology leads to the following generalization: **biogeochemical features of each chemical element determine the originality of the relationship between its average concentration in the ocean and the intensity of its migration through the barrier zones of the hydrosphere**. Graphical presentation of this hypothesis is the most informative one when intensities of global migration and average concentrations in the ocean are drawn in the co-ordinates $\lg C_{ocean} - \lg t_{ocean}$. Main geochemical information on the dissolved forms of elements in hydrosphere is presented in this figure. Lines parallel to the X-axis show concentrations of dissolved forms of elements in the ocean (mole/l). Lines parallel to the Y-axis show a residence time of dissolved forms in the ocean and are the geometrical locus of constant ratios between concentration in oceanic water and concentration in river water. Lines making 45° angles with the both coordinate axes show average concentrations of dissolved elements in the river runoff (mole/l).

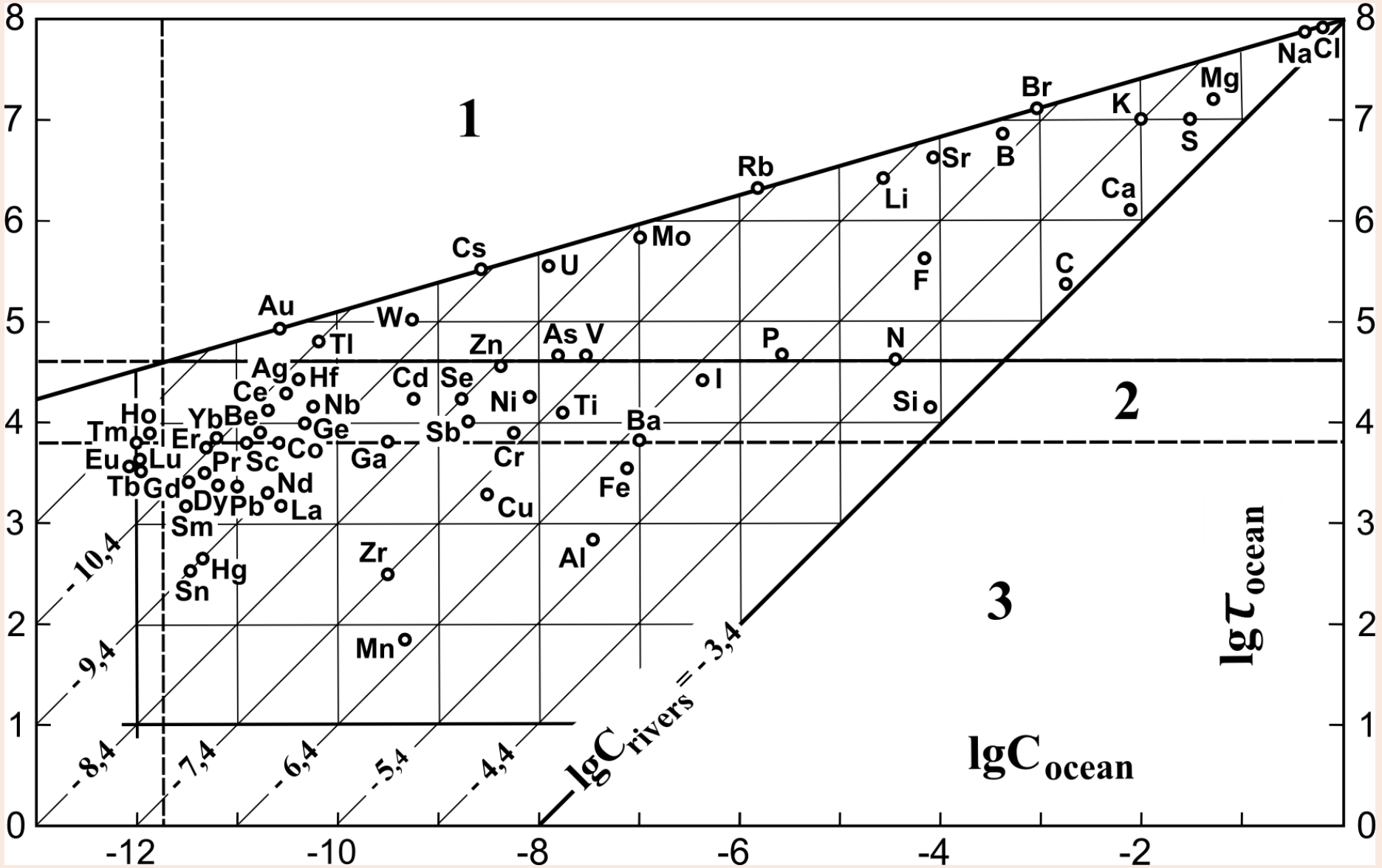

Fig. 4. The system of chemical elements distribution in the hydrosphere.
Types of distribution in the ocean:
1) conservative; 2) nutrient-type; 3) litho-generative.

In this plot elements form groups reflecting the resemblance of their geochemical properties. The line passing parallel to X-axis through t = 40000 years (residence time of water in the ocean) separates conservatively and non-conservatively distributed elements. Elements adjacent to this line have a nutrient-type distribution in the ocean that permits us to reveal the main feature of these elements that is a similarity of their concentrations in oceanic and river water. The geochemical system reveals also so-called litho-generative elements, which are characterized by the loss of the major part of their river input at the river – sea boundary zone. The line connecting Cl, Na, Br, B, Sr, Rb, Mo, U, Cs, W, and Au shows elements, which geochemical fate is determined mainly by the processes of their cyclic migration in the system ocean – atmosphere – continent – ocean.

The System allowed determine the relationship between three main geochemical parameters of the dissolved forms of elements in the hydrosphere:

1) average concentration in the ocean,
2) average concentration in the river runoff and
3) the type of distribution in oceanic water.

Thus, we have gained a possibility to use two these mentioned geochemical parameter for the theoretical prediction of the third parameter.

The System constructed on the base of a new methodology satisfies the criteria of sufficiency and is sufficient for the whole set of chemical elements and for the whole range of observed concentrations (12 orders of magnitude). It has not only interpretational possibilities, but prognostic as well. System allows to predict with a great precision the values of annual river runoff for dissolved Be, C, N, Ge, Tl, Re, to refine such estimates for P, V, Zn, Br, I, and to determine the character of distribution in the ocean for Au and U. The System allowed to obtain theoretically the reliable data on the natural (not affected by anthropogenic influence) average concentrations of many elements in the river runoff. These concentrations have to be used as ecological reference data. The geochemical system gives an insight into the errors in our view of the elemental composition of the hydrosphere. Due to the great response time of the ocean, mean concentrations of elements and patterns of their distribution in the ocean can be used as a main reference data for the determination of natural (unchanged) average concentrations of elements in the river runoff which were not studied before the global degradation of the hydrosphere.

In the future, role the System of chemical elements distribution in the hydrosphere as an ecological reference of natural geochemical state of hydrosphere will increase.

Thanks for your attention