Russian Journal of Ecology, Vol. 34, No. 1, 2003, pp. 62–64. Translated from Ekologiya, No. 1, 2003, pp. 66–68.
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SHORT COMMUNICATIONS

Multielement Analysis of Bone Tissue in Grouse (Tetraonidae) from the Middle Urals

V. S. Bezel' and E. A. Bel'skii

Institute of Plant and Animal Ecology, Ural Division, Russian Academy of Sciences, ul. Vos'mogo Marta 202, Yekaterinburg, 620144 Russia

Received August 15, 2001

Key words: microelements, multielement analysis, clarke, lithosphere, Tetraonidae, bone tissue.

Chemical elements distributed in the environmental objects are an important natural phenomenon reflecting the intensity of global and regional biogeochemical cycles. It is known that natural systems and living organisms consist of 15–20 basic chemical elements by more than 99%. The remaining elements, defined by Vernadsky (1954) as dispersed elements, are in small concentrations but have a high geochemical activity, and the extent of their turnover in natural environments is great.

According to the Vernadsky's theory concerning the biosphere function of living matter, there are several levels of biogeochemical cycles. They are based on the pool of elements in the lithosphere, whose spatial and concentration specificity is reflected by clarkes (abundance ratios) of these elements. The involvement of living matter in the biogeochemical cycles begins from the level of producers. Using the term coined by Gol'dshmidt (1938), plants serve as a geochemical pump delivering macro- and microelements from the soil to the biological cycle. Note that the element composition of this level is not analogous to the composition of the soil clarke. There is some "geochemical selection" (Dobrovol'skii, 1983) occurring because of differences in the biological accessibility of various forms of soil chemical compounds, specific features of zonal vegetation, and selective assimilation of chemical elements and their compounds.

Similar selection takes place at the next level, upon the involvement of primary consumers in the biogeochemical cycles. This is why phytophagous organisms have a specific spectrum of chemical elements that does not coincide with soil and plant clarkes. At the same time, the chemical composition of plants and animals is a kind of biogeochemical portrait of individual natural and technogenic ecosystems which reflects their distinctive features in this respect (Lebedeva, 1999). Unlike the basic chemical components of the biota, dispersed elements readily change their concentrations in living organisms in response to environmental changes. Thus, they instantly reflect specific conditions of individual landscapes and anthropogenic load on them, and this phenomenon can be used for monitoring the state of natural ecosystems (Vtorova and Markert, 1995; Lebedeva, 1999).

To date, specialists have accumulated a considerable amount of data on the content of the main physiologically important chemical elements in various types of vegetation (Vtorova and Markert, 1995; Belogolova *et al.*, 2000), whereas data on the accumulation of dispersed elements by consumers is much less abundant (Lebedeva, 1999). The list of the elements studied is far from being exhaustive, so the geochemical portrait of the ecosystem level is incomplete. This motivated us to perform a comprehensive analysis of the element composition of tissues in grouse.

At the first stage of research, we used five birds of the grouse family (Aves: Galliformes, Tetraonidae) caught the Middle Urals in the areas remote from pollution sources. These species have restricted home ranges and, therefore, they adequately reflect the biogeochemical element turnover characteristic of the background areas of the region. The bone tissue was analyzed in the tarsometatarsi of three wood grouse (*Tetrao urogallus*), one black grouse (*Lyrurus tetrix*), and one hazel grouse (*Tetrastes bonasia*). The concentrations of 71 chemical elements (Fig. 1) were measured under conditions of hot plasma (10000°C) using the equipment manufactured by Plasma Quad. V.G. Instrument, at the Institute of Geochemistry of Ore Deposits.

The results of analysis allow us to arbitrarily divide all these elements into several groups (table). The highest concentrations (more than 1000 ppb) are characteristic of 15 elements classified as physiologically important macro- and microelements; 26 elements have minimal concentrations (less than 1 ppb). As a rule, the latter group comprises dispersed elements whose physiological role has not yet been determined. Apparently, there are no mechanisms controlling their input into living organisms. This group is probably the most labile part of the spectrum of chemical elements that most adequately reflects the element composition of the environment. The situation with the contents of the lan-

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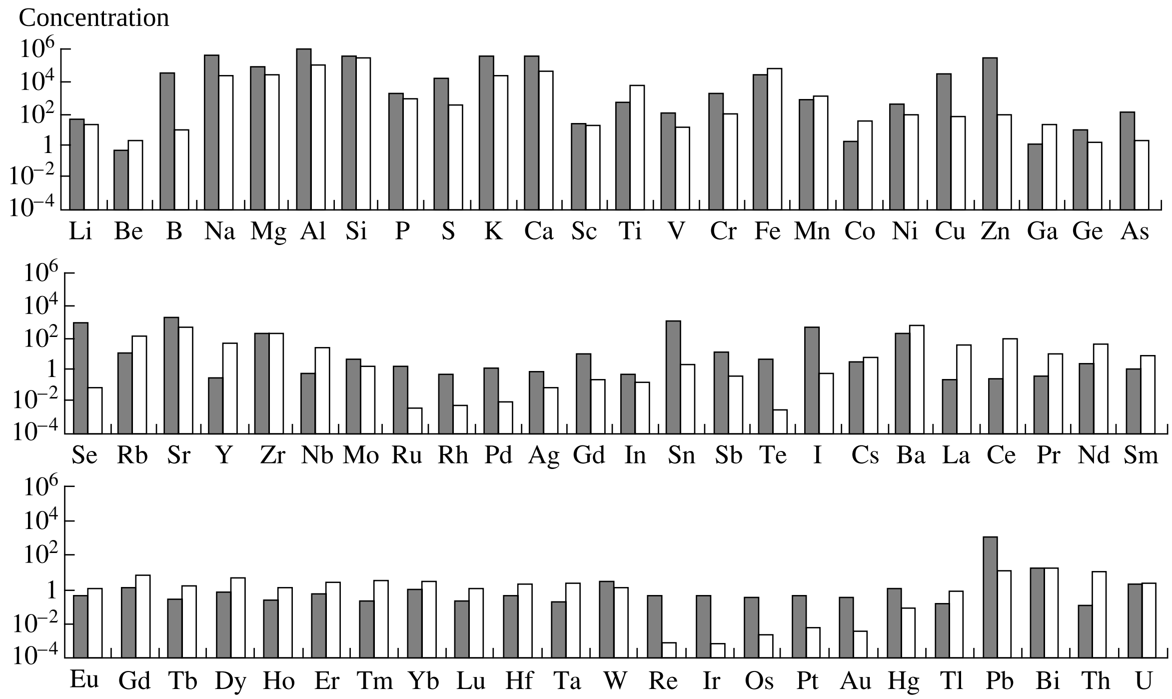

Fig. 1. Concentration of chemical elements in grouse bone tissue (ppb, solid bars) and their clarkes in the Earth's crust according to Ivanov (1994) (ppm, clear bars).

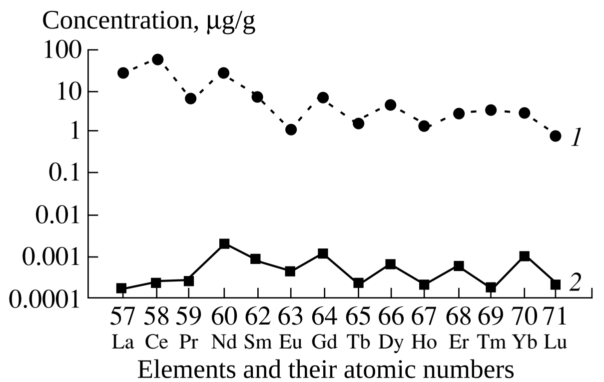

Fig. 2. Contents of lantanoids in the bone tissue of grouse from the Middle Urals: (*1*) clarkes in the lithosphere, (*2*) concentrations in the skeleton.

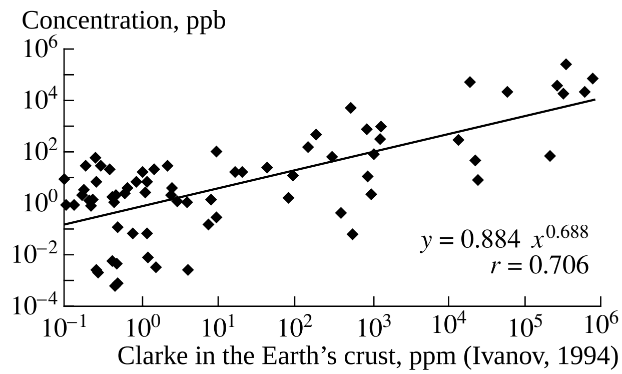

Fig. 3. Concentration of chemical elements in grouse bone tissue as a function of their clarkes in the lithosphere.

tanoid group in living organisms is an example confirming this assumption. Vtorova and Markert (1995) showed that the concentrations of lantanoids in plants depend on their contents in parent rocks, with the concentrations of elements with even atomic numbers exceeding those of odd-numbered elements. Lantanoid accumulation in the bone tissue of grouse has the same sawtooth pattern as in plants and correlates well with clarkes of these elements in the lithosphere (Fig. 2). Thus, the concentration spectra typical of the lithosphere appear to retain their specific pattern in every part of the flow of matter through the trophic chains of natural ecosystems.

There is a certain correlation between the contents of elements in soils and tissues of living organisms. This conclusion is illustrated by the dependence of the chemical composition of bird bone tissue on the contents of elements in the lithosphere (according to Ivanov, 1994), which is shown in Fig. 3. As data are presented on a logarithmic scale, the linear correlation of macro- and microelement composition of the bone tissue with clarkes of chemical elements in the Earth's crust is obvious. This phenomenon reflects important processes related to the establishment of multielement cycles involving several trophic levels of natural ecosystems.

Contents of macro- and microelements in the bone tissue of grouse from the Middle Urals

Content, μg/kg (ppb)	Elements
>1000	Na, Mg, Al, Si, K, Ca, Fe, Cu, Zn, B, S, P, Sr, Cr, Sn
100–1000	Ti, Mn, Ni, Se, Zr, I, Ba, Pb
10–100	Li, Sc, V, As, Bi
1–10	Ga, Ge, Rb, Mo, Ru, Pd, Cd, Sb, Te, Cs, Nd, Gd, Yb, W, Hg, U, Co
0.1–1	Be, Y, Nb, Ag, In, La, Ce, Pr, Sm, Eu, Tb, Dy, Ho, Er, Tm, Lu, Hf, Ta, Re, Ir, Os, Pt, Au, Tl, Th, Rh

The geographic specificity of biogeochemical cycles manifests itself when the background levels of chemical elements in living organisms from different regions are compared. We compared our data concerning the Middle Urals with published data for other areas of European Russia, Eastern Europe, Northern Caucasus, and Mongolia (Lebedeva, 1999). The results showed that the contents of most metals (Cr, Fe, Mn, Co, Ni, Pb, Mo) and arsenic in the bone tissue of birds from the Middle Urals were close to the lower limits of their global background concentrations. Only the concentrations of aluminum, copper, and zinc were higher than in other background regions of Eurasia.

Our data on the chemical composition of bird bone tissue can be used in studies on biogeochemical cycles and regional biomonitoring of the environment.

ACKNOWLEDGMENTS

This work was supported by the Russian Foundation for Basic Research, project no. 99-05-64587. The authors are grateful to D.A. Krivolutskii for inducing us to perform this study and to I.P. Gutarenko and O.V. Yulanov for help in collecting the material.

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