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SHORT COMMUNICATIONS

On the Reliability of Estimates of the Average Chemical Composition of the Upper Continental Crust and River Discharge

A. A. Yaroshevskii

Division of Geology, Moscow State University, Vorob'evy gory, Moscow, 119992 Russia
Vernadsky Institute of Geochemistry and Analytical Chemistry, Russian Academy of Sciences, ul. Kosygina 19, Moscow, 119991 Russia

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The classical problem of estimating the abundances of the chemical elements in the Earth's crust is a challenge for geochemists. Its main complexity is related to the tremendous geochemical heterogeneity of the crust, which brings out the need to devise a method for the generalization of particular data that would provide a means to overcome this difficulty [1]. Clarke and Washington [2, 3] used a method of simple computation of the average composition of igneous rocks, which were considered as the primary material of the Earth's crust. Using geochemical balance arguments, Goldschmidt [4] demonstrated that this estimate is in agreement with glacial deposits, which provided a basis for the first model of the chemical composition of the continental crust. Based on an expanded geochemical database and application of the principle of geochemical balance, Vinogradov [5, 6] and Taylor [7] modified to some extent the values reported by Clark and Washington, which did not fundamentally change the general picture. An approach to the calculation of the average composition of the crust on the basis of the abundances of main rock types was pioneered by Poldervaart [8], but its modern quantitative basis was developed by Ronov [9]. This approach yielded an independent estimate for the average composition of the crust. A comparison of these independent estimates (see the book by Ronov et al. [9]) suggested that the models of Clark–Washington–Goldschmidt and Taylor probably overestimated the abundance of basic igneous rocks (basalts), whereas the values obtained by Vinogradov appeared to be similar to the composition of the granite metamorphic layer obtained by Ronov and his colleagues.

However, both the results of calculations based on the principle of geochemical balance and the values obtained from the abundances of main rock types are obviously only an approach to the real picture. Unfortunately, there currently exists no plausible way to estimate the degree of their deviation from the true average chemical composition of the Earth's crust. Therefore, any opportunity to check these fundamental geochemical parameters of natural materials is important. Such an opportunity can be provided by the data on the average composition of river discharge from continents. A reasonable "average sample" of the material of river discharge may be a proxy for the material of the continental crust exposed on the erosion surface of continents naturally averaged over the global area of the source provinces. In reality, such a sample cannot be procured, but, owing to the tremendous volume of investigations (including special studies) on the geochemical structure of global river discharge, it appears possible to calculate this average composition with sufficient reliability. Such estimates were published by Lisitsyn and Gordeev in the 1970s [10–12] and in a recent book by Savenko [13]. A comparison of these data with our estimate [9] for the average compositions of components of the continental crust yielded interesting results.

The table presents estimates of the chemical compositions of the sedimentary and granite-metamorphic shells of the continental crust and the composition of suspended loads of the world's rivers. Assuming that the proportion of the sedimentary and granite-metamorphic shells exposed on the surface of continents is 3 : 1 and taking into account the fractions of elements in the solid load of rivers, these values were recalculated to the average composition of the continental surface (source provinces) and to the composition of the bulk river discharge. The results are compared in the three last columns of the table. The following important conclusions can be drawn from this comparison.

First, the estimates of the average composition of the bulk river discharge obtained by Savenko on the basis of a much more extensive database do not differ significantly from the results of Gordeev and Lisitsyn; given the present-day statistical data (average for the world's 126 rivers in Savenko's book); these estimates must probably be regarded as stable.

Comparison of the average compositions of the upper continental crust (source provinces) and the river discharge, wt %

Component	Sedimentary shell of continents	Granite-metamorphic shell of continents	Solid discharge from continents	Fraction of element in solid discharge, %	Bulk discharge from continents		Average composition of rocks on the surface of continents
					1	2	
SiO_2	58.5	65.2	63.5	96.0	58.7	59.0	60.1
TiO_2	0.743	0.548	0.710	99.8	0.630	0.680	0.690
Al_2O_3	14.5	15.2	16.1	99.6	14.3	16.1	14.7
Fe_2O_3	6.46	5.93	7.70	99.8	6.89	7.53	6.36
MnO	0.130	0.088	0.211	98.0	0.190	0.148	0.120
MgO	3.74	2.89	2.37	63.0	3.35	3.36	3.53
CaO	11.2	4.16	5.34	46.0	10.3	7.69	9.46
Na_2O	2.21	3.08	1.53	47.0	2.90	3.18	2.43
K_2O	2.52	2.90	2.54	84.2	2.74	2.31	2.61
Sum	100.003	99.996	100.001		100.000	99.998	100.000

Note: The chemical compositions of the sedimentary and granite-metamorphic shells of continents are given after Ronov et al. [9]; the chemical composition of the solid discharge from continents is after Savenko [13]; the fraction of elements in the solid discharge is after Gordeev [12]; the bulk discharge from continents is calculated (1) from the composition of the solid discharge after Savenko, taking into account the fractions of elements in the solid discharge after Gordeev, and (2) using the data of Gordeev and Lisitsyn [10] and Lisitsyn [11]; and the average composition of rocks on the surface of continents was calculated using the compositions from the first two columns taking into account the ratio of surface areas occupied by the rocks of the sedimentary cover and shields (3 : 1) [9].

Second, the average composition of the continental surface calculated from the data on the compositions of the sedimentary and granite-metamorphic shells of the continental crust appeared to be almost identical to the estimated composition of river discharge.

Of course, it should be so, but the compositions of these two types of materials were obtained using absolutely independent sources of information! This agreement provides strong evidence that our knowledge is definitely not far from the truth. Perhaps, the geochemical problem of the estimation of the average chemical composition of the upper continental crust should be considered solved. The chemical composition of the lower part of the continental crust, its granulite–basic layer, remains to be determined, but the available material is yet insufficient for the conclusive solution of this problem.

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