Composition of the upper continental crust revisited: insights from sedimentary rocks

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The chemical composition of the upper continental crust is widely regarded to be known with some confidence and the values from Taylor and McLennan (1985) are widely cited. Many upper crustal trace element values are based on very large compilations of typical upper crustal igneous rocks (e.g. Ba, Zr); large scale sampling programs in shield areas (e.g. Hf, Nb, Cr, Ni, with Canadian Shield values (e.g. Shaw *et al.*, 1976; Eade and Fahrig, 1973) weighing heavily in the model), and various canonical ratios (e.g. U from Th/U = 3.8; Cs from Rb/Cs = 30). Comparison of results from large scale sampling programmes undertaken in different regions of the world and a recent global compilation of igneous rock compositions (Condie, 1993) show that there is in fact considerable variability in the estimated abundances of a number of key trace elements (Table 1). The cause of this variability is likely due to a combination of real regional variations, difficulties in formulating meaningful averages, and analytical difficulties.

Plank and Langmuir (1996) have questioned upper crustal estimates of Nb and Cs on the basis of correlation between these elements and Al_2O_3 in marine sediments. Trends intersect the upper crust Al_2O_3 concentration at 13.7 and 7.3 ppm, respectively and these were considered better estimates for Nb and Cs. Using sediment compositions to provide an averaging mechanism for the upper crust is well established for relatively immobile elements such as *REE* and Th (Taylor and McLennan, 1985). However, in the past this approach has not been used for other trace elements because of the possibility that sedimentary processes, such as weathering, sorting and recycling, may affect their distribution to an extent that would make such estimates relatively unreliable.

The trends defined in the study of Plank and Langmuir (1996) result mainly from dilution of marine terrigenous sediment with low trace element-bearing siliceous and carbonate sediment and thus their result begs the question of how sedimentary

TABLE 1. Selected trace elements (ppm) for various average sediments and upper crust

	Canadian Shield A (*Shaw*)	Canadian Shield B (*Eade*)	Central China (*Gao*)	Scotland (*Bowes*)	New Mexico (*Condie*)	Upper crust (*Condie*)	Upper crust (*Taylor*)	PAAS (*Taylor revised*)	Loess (*various sources*)
V	53	59	96	–	–	86	60	140	77
Cr	35	76	53	<50	19	104	35	100	56
Co	12	–	13	35	8	18	10	20	11
Ni	19	19	22	25	13	56	20	60	20
Rb	110	–	–	85	187	83	112	160	79
Zr	237	190	–	135	180	160	190	210	279
Nb	26	–	–	4	–	9.8	25	19	13.7
Cs	–	–	–	–	–	–	3.7	6	4.7
Ba	1070	730	508	795	590	633	550	650	483
La	32.3	71	28.5	55	43	28.4	30	38.2	29.4
Hf	5.8	–	–	–	–	4.3	5.8	5.0	7.8
Ta	5.7	–	–	–	–	0.79	2.2	2	0.87
Pb	17	18	30	–	–	17	20	20	15
Th	10.3	10.8	7	–	13	8.6	10.7	14.6	9.62

processes affect the distribution of Cs, Nb and various other trace elements. Nevertheless, the substantial discrepancies among various estimates based on mapping exercises and abundances in marine sediments leads to the conclusion that estimating certain upper crustal trace element abundances may best be accomplished from the terrigenous sediment data base.

The upper crustal composition proposed by Taylor and McLennan (1985) used sedimentary compositions either directly or indirectly (from canonical ratios) to estimate abundances of *REE*, Y, Th, Sc, Rb and U and reported values in Taylor and McLennan (1985) require no change using the approaches discussed below.

The trace element compositions of various terrigenous sedimentary reservoirs (e.g. average sediment, sandstone, greywacke, shale, loess, suspended river sediment, marine sediment) have been reported recently by various authors or calculated for this study. On plots of La versus the various trace elements it is possible to evaluate many of the large scale geochemical effects of sedimentary processes (mainly weathering and mineral sorting) and thus constrain the trace element abundances in the upper crustal source. Where possible, abundances so estimated are confirmed through examining relevant canonical ratios (e.g. Zr/Hf, Nb/Ta) and by evaluating relationships among geochemically similar elements (e.g. Rb *vs* Cs; V *vs* Ni).

In comparison to the values of Taylor and McLennan (1985), upper crustal abundances determined in this analysis of the sedimentary data base suggest the following. There are no significant differences for Zr, Hf, Pb and Ba and the previously established values of Taylor and McLennan (1985) are accepted. The abundances of Nb and Ta are lower by nearly a factor of 2, consistent with the conclusion of Plank and Langmuir (1996). Abundances of ferromagnesian trace elements (V, Cr, Ni, Co) are higher by up to a factor of two. The upper crustal abundance of Cs is estimated to be about 5 ppm which is higher than the estimate of Taylor and McLennan (1985) but not as high as the estimate of Plank and Langmuir (1996). Where significant differences exist, the estimates from the sedimentary data base are considered more reliable.

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