

A new estimate of major elements in the average upper continental crust: a holistic study of igneous and sedimentary rocks with implications for surface processes evolution

ROBERTA L. RUDNICK¹, PENG-YUAN HAN¹, KANG CHEN² AND ZHAOCHU HU²

¹University of California, Santa Barbara

²China University of Geosciences (Wuhan)

An accurate estimate of the average composition of the continental crust is important for understanding crust formation, crust-mantle recycling, and how surface processes influence the atmosphere, oceans, and mantle. However, this effort has been hampered by the crust's inherent heterogeneity, with existing estimates subject to significant uncertainties^[1].

By systematically examining element concentrations and ratios in fine-grained sedimentary rocks (loess, glacial diamictites, and shales) and a large dataset of continental igneous rocks, we derive a new estimate for the major element composition of the average upper continental crust (UCC, with two standard errors): $\text{SiO}_2 = 63.55 \pm 0.62$ wt.%, $\text{TiO}_2 = 0.74 \pm 0.03$ wt.%, $\text{Al}_2\text{O}_3 = 15.24 \pm 0.51$ wt.%, $\text{FeO}_T = 5.26 \pm 0.20$ wt.%, $\text{MnO} = 0.10 \pm 0.01$ wt.%, $\text{MgO} = 2.54 \pm 0.10$ wt.%, $\text{CaO} = 4.84 \pm 0.19$ wt.%, $\text{Na}_2\text{O} = 3.35 \pm 0.11$ wt.%, $\text{K}_2\text{O} = 3.06 \pm 0.11$ wt.%, $\text{P}_2\text{O}_5 = 0.22 \pm 0.01$ wt.%, and $\text{LOI} = 1.10 \pm 0.04$ wt.%.

Compared to previous estimates, our new estimate has lower compatible elements (e.g., TiO_2 , CaO , FeO_T , and MgO) than those derived from averaging igneous rocks, but higher soluble elements (e.g., Na_2O , CaO , and P_2O_5) than those obtained by large-scale surface sampling. These differences could result from biases in earlier approaches: averaging igneous rocks may oversample mafic compositions, while large-scale sampling may be affected by local heterogeneity and chemical weathering. Overall, our new methodology should provide a novel and more accurate approach for estimating the composition of the UCC.

The new results confirm the evolved, granodioritic composition of the UCC. From mass balance, the contribution of sediments to the UCC (whether contained in the sedimentary cover or incorporated into the crystalline bedrocks) is estimated less than 40%, suggesting that the UCC maintains a predominantly igneous composition despite modifications over geological history. The solubility of major elements during continental weathering are ranked as $\text{Ca} \approx \text{Na} \approx \text{Mg} > \text{K} \approx \text{Mn} \approx \text{P} \gg \text{Si} \approx \text{Ti} \approx \text{Fe} \approx \text{Al}$, exerting a significant control on seawater chemistry for many elements.

[1] Rudnick & Gao (2003), *Treatise on Geochemistry, The crust* 3, 1-64.