Boron isotope measurements of oil shale and coal combustion products

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Boron is concentrated in kerogen because of its abundance primarily in plant material where it is a nutrient to levels of 100 ppm, but becomes toxic at higher levels. Boron isotopes are useful for identifying organic sources because the isotopic compositions of organic sources are distinctly light (<0‰) compared to most terrestrial minerals and water. Boron is not redox sensitive, therefore it is useful in tracing a variety of environmental impacts related to energy resources.

The isotopic fractionation of B was measured between kerogen-water as a function of thermal maturity in the Bakken oil shale. Isotopes were measured by secondary ion mass spectrometry (SIMS) which requires calibration of B-concentrations depending on the mineral matrix. Ion implants of B were made into several carbon matrices including single crystal carbon, glassy carbon, and kerogen with vitrinite reflectance values of 0.5, 1.0 and 3.0%. The sputter yield of B is affected by the H-content of the kerogen, thus calibration must take into account this matrix effect. Notably we found that kerogen extracted from shale using HF-HCl treatments removes B, therefore we used NanoSIMS to measure B/C ratios on areas small enough (100nm) that clay particles could be avoided.

The new calibrations allow analysis of B in C matrices for comparison with B in silicates. We studied B-concentrations and isotope ratios of coal, fly ash, bottom ash and aerosol particles collected from sites near a coal stock yard, ash pond and water inlet of the Dangjin coal-fired power plant in South Korea. The coal contains 10s-100s ppm B, with $\delta^{11}B$ values from -23‰ to -3‰. Boron partitions into fly ash with concentrations up to 100 times the coal, while B in the aerosols is 100 times less. Fly ash B-isotopes are 5-10‰ heavier than the coals suggesting fractionation during combustion. Aerosol $\delta^{11}B$ values follow a different mixing trend showing up to 30‰ ^{11}B enrichment in the ash pond due to fractionation during combustion and processing, or to mixing with seawater. B-isotopes can trace organic sources and may be useful for tracking associated contaminants.