Applications of synchrotron based X-ray microprobe techniques in environmetal nanoparticle research

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Natural and manufactured nanoparticles (diameter < 100 nm) are becoming of interest to environmental scientists due to the poorly understood fate and transport processes in aquatic-terrestrial environment. Detection of nanoparticles in natural substrates such as soils and sediments are extremely difficult due to the inherent heterogeneities of natural samples and the instrumental limitations (e.g. detection limit and spatial resolution). The instrument with nano-scale resolution such as High Resolution Transmission Electron Microscopes can only view several square microns at one time, and not suited for the detection of nanoparticles in a large background ranging from millimeters to centimeters. The advent of high-brightness synchrotron facilities capable of microfocused (μ) X-ray absorption spectroscopy (XAS) and synchrotron based X-ray fluorescence (SXRF) spectroscopy has enabled researchers to come closer to determining the speciation and spatial distribution of nano and micron size-particulates with sensitivity of as low as a few ppm of targeted elements. The recent development in synchrotron based X-ray microprobe techniques allows us to investigate the spatial distribution of nano-/micron-size particles in a large background (e.g. 30 x 40 cm). In particular, meso-SXRF and μ-SXRF imaging can be effectively combined to understand the distribution and chemical state of nano-/micron-size grains in a large background (e.g. thin section). Using examples of case studies, this study will discuss 1) the applications of synchrotron based X-ray microprobe techniques (i.e. meso- and micro-SXRF imaging, micro-SXRD, and micro-XAS) for the environmental nanoparticle research in sediment and rock samples and 2) the gap between the current S-X-ray microprobe techniques and our research needs.

Deciphering slab inputs from arc outputs

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The characteristic ‘subduction zone signature’ of arc-backarc magmas includes: elevated alkali, alkali earth, Pb and actinide abundances relative to rare earth elements (REE) of equivalent mantle residue-melt incompatibility; depleted high field strength element abundances; shifts varying from slight to major relative to mid-ocean ridge basalts (MORB), towards higher $^{87}Sr/^{86}Sr$, $^{207}Pb/^{204}Pb$, $^{208}Pb/^{204}Pb$, and lower $^{143}Nd/^{144}Nd$ and $^{176}Hf/^{177}Hf$; high H_2O contents and elevated fO_2 relative to MORB. For many years, the geochemical community has sought to account for these characteristics.

It is known three major sources are involved in the genesis of arc magmas: subducted plate; mantle wedge; and overriding plate. For most arc magmas, the mantle wedge is the dominant source of major elements, but is variable compositionally on a global scale. The spectrum of arc magmas include boninite to high-K basalts, and are likely sourced respectively from a range of peridotite sources including harzburgite to fertile, amphibole-phlogopite-bearing lherzolite.

We know also that globally, subducted slab inputs are variable both spatially (%s of carbonate, silicic, hydrothermal, clastic sediment types; relative porpotions of Layer 2 and mantle exposed and the extent of hydration/carbonation of these materials) and temporally (inbound of these same sediment types as a function of global plate positions and ocean compositions, plus the post-Jurassic development of pelagic carbonates). In modern arcs, the geochemical charactertistics of erupted magmas reflect these variable inputs.

A consensus to explain these collected characteristics is the subducted plate experiences both dehydration and partial melting – the derived fluid, possibly supercritical, penetrates rapidly (<~5ka; Th-U disequilibria evidence) upwards into the advecting mantle wedge. Partial melting of the wedge takes place due both to fluid ingress as well as some decompression, mostly in the spinel peridotite field. Mass balance of inputs versus outputs are better reconciled if the total arc output is at least ~ 0.25 (i.e. 5km^3/year) of the global MORB flux. Many uncertainties persist including: role of serpentine; stability of subducted carbonate; nature of slab-derived fluid; mode of mantle melting; redox controls; mode of fluid-melt transfers.