Geophysical Research Abstracts
Vol. 21, EGU2019-4843, 2019
EGU General Assembly 2019
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Denudation rates from meteoric ^{10}Be/^{9}Be ratios in quartz-poor lithologies

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About 75% of the terrestrial land surface of our planet is covered by sedimentary rocks, but about 80% of this area is composed of fine-grained shale or carbonate lithologies. When also including mafic rocks, a large global terrestrial area is inaccessible to the *in situ* ^{10}Be cosmogenic nuclide method, as it requires the presence of sand-sized quartz minerals. Hence, in order to quantitatively constrain the erosion and weathering rates of these areas and to derive globally meaningful solid and solute fluxes, new methods are required. A recently developed tracer to study Earth surface erosion and weathering is the meteoric ^{10}Be/^{9}Be ratio[1], from which meteoric denudation rates (D_{met}) can be calculated. Meteoric cosmogenic ^{10}Be is deposited from the atmosphere onto Earth surface, where it is adsorbed to any fine-grained solid material or, depending on pH, is present in the dissolved form, whereas stable ^{9}Be is a trace metal released by weathering.

We show the broad versatility of this new approach by its application to two geomorphically contrasting settings. In the transport-limited setting of the middle European uplands of the Slavkov Forest, Czech Republic, small (<1 km^2) neighboring catchments of similar size, climate, slope, and vegetation are underlain by mafic (amphibolite), ultramafic (serpentinite), and felsic (granitic) rocks. Quartz is present in all these catchments in the bedrock or in quartz veins, making a comparison with *in situ* cosmogenic-derived denudation rates (D_{insitu}) possible. Due to acid rain deposition in the 20th century, pH values of stream waters vary from acidic to alkaline, depending on the acid buffering capability of individual lithologies. By balancing the depositional ^{10}Be flux with the exported dissolved and particulate ^{10}Be flux, we show that steady state attained before industrial soil acidification in all three catchments, suggesting a negligible loss of dissolved Be due to acidic conditions. This is supported by the overall agreement of D_{met} with D_{insitu} in the studied catchments that range from 0.04 to 0.08 mm/yr[2].

In the supply-limited setting of the high and steep mountainous island of Taiwan, among the World´s highest denudation rates prevail due to high uplift rates and frequent typhoon attacks. We studied Taiwan´s longest river, the Zhuoshui River (3000 km^2), where headwaters are dominated by slate with D_{met} ranging from 4-8 mm/yr, agreeing with published long-term exhumation rates. In the mid-lower sandstone-dominated reaches, lower D_{met} agree with published D_{insitu}, being in the order of 1-2 mm/yr. We suggest that a gradual dilution of the sediment contribution from the rapidly-eroding slate in the headwaters with sediment from slowly-eroding sandstone reaches is responsible for the downstream decrease in D_{met}.

In both these settings representing geomorphic end members, denudation rates calculated from the ^{10}Be/^{9}Be ratio of the particle-bound Be are very similar to independent denudation rate estimates and prevailing lithological and geomorphological conditions. This agreement evidences the versatile potential of the meteoric ^{10}Be/^{9}Be proxy to quantify Earth surface processes in a wide range of landscapes, lithologies, hydrological conditions and sediment transport processes.

[1] von Blanckenburg, F., et al. EPSL, 2012.

[2] Dannhaus, N. et al., GCA, 2018.