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Using soil residence time to decipher landscape dynamics

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Hilly landscapes evolve as a result of spatial variation in erosion rate, which is reflected in differences of soil characteristics. One of these characteristics, soil residence time, is key for quantifying landscape dynamics. Soil residence time refers to the mean age of the ensemble of particles making up the soil. On a hillslope, where the soil corresponds to the actively transporting colluvial material, the age of a particle is equivalent to the time since it was detached from the underlying bedrock. Soil residence time is determined by, firstly, the position of a soil on a hillslope and the soil flux rate, since these factors determine travel times for soil particles detached from upslope positions to reach the point of interest, and, secondly, the erosion rate, which determines the rate at which fresh (zero age) particles of bedrock are introduced into the soil. The special case of a steady state hillslope with roughly uniform soil depth implies a spatially uniform soil residence time. On a detachment limited hillslope, soil particles are chemically unweathered at the time of detachment, and consequently the residence time of the soil is reflected in the overall soil weathering status. Departures from spatially uniform soil residence time, as reflected in soil weathering, therefore, can be used to identify, quantify and understand spatial and temporal variability in catchment erosion.

In this study we use soil residence time estimated via a chronofunction of soil colour to investigate landscape dynamics in the Oregon Coast Range, northwestern USA, a strongly dissected ridge and valley landscape, underlain by a uniform turbidite sequence (Tyee Formation), believed to closely approximate steady state (rock uplift equals erosion). Using B horizon colour data from a 1:25,000 soil map and the chrono-

function, we show that a broad swath of the eastern margin of the Oregon Coast range in the vicinity of the headwaters of the Siuslaw catchment has been isolated from base level lowering as a result of tectonically driven drainage capture at the margin of the Willamette Valley. The remainder of the study area generally has soil residence times in the order of 10^3-10^4 years (Inceptisols), consistent with steady erosion at rates established from independent studies. Isolated areas of deep seated landslides and river terraces, however, have become insulated from base level lowering such that soil transport has declined and soil residence times have increased to the order of 10^5years (Ultisols).

We also investigated variation of soil residence time within three 3^{rd}-order drainage basins with different base level controls. The Hoffman Creek catchment drains directly into the Siuslaw River, whereas the Sweet Creek and Kentucky Creek catchments have successively more significant impediments to base level lowering caused by mafic dikes intruded in the Tyee sandstone. Frequency distributions and probability density functions (pdfs) of soil residence time clearly discriminate the erosional behavior of the three catchments. The Hoffman Creek pdf showed an exponential distribution, whereas the Kentucky Creek pdf approximated a power law distribution. Hoffman Creek soil residence times are consistent with steady erosion, whereas the Kentucky Creek clearly shows transient behaviour. Parts of the catchment have adjusted topographically to a lower stream incision rate with consequent slower soil fluxes and longer soil residence times, whereas other parts retain a (steeper) topographic legacy of an earlier phase of stream incision. Sweet Creek displays intermediate behaviour and characteristics.