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Monitoring aggregate disintegration with laser diffraction: A tool for studying soils as sediments

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One of the more important characteristics of soil that becomes hillslope, fluvial, or aeolian sediment is the presences of aggregates, which disintegrate at varying rates and to varying degrees during transport. Laser diffraction particle size analyzers allow monitoring of aggregate disintegration as a sample of soil or sediment suspended in water is circulated continuously through the measurement cell (Bieganowski et al., 2010, Clay Minerals 45-23-34; Mason et al., Catena 87:107-118). Mason et al. (2011) applied this approach to aeolian sedimentary aggregates (e.g. clay pellets eroded from dry lakebeds), immersing dry samples in DI water and circulating them through a Malvern Mastersizer 2000 particle size analyzer for three hours while repeated size distribution (SD) measurements were made. A final measurement was made after sonication and treatment with Na-metaphosphate. In that study, most samples approached a steady SD within three hours, which included both primary mineral grains and persistent aggregates. The disintegration process could be modeled with a first-order rate law representing the disintegration of a single population of aggregates. A wide range of model parameters were observed among the samples studied, and it was suggested that they could be useful in predicting the behavior of these aggregates, under rainfall impact and during slopewash or fluvial transport. Addition of Ca^{++} to the suspension altered aggregate behavior in some but not all cases.

We applied the same method to dry, unground material from upper horizons of soils sampled along a bio-climatic gradient in northern Minnesota, USA, all formed in lithologically similar glacigenic sediment. These ranged from Alfisols (Luvisols) formed under forest since the last deglaciation, to Alfisols under forest that more recently replaced grassland, and Mollisols (Chernozems) that formed entirely under grassland vegetation. Few of these soil samples approached a steady SD within three hours, and modeling aggregate disintegration required the assumption of at least two aggregate populations. Upper horizons of soils formed under grassland displayed relatively slow disintegration throughout the procedure, with a large proportion of aggregates remaining after three hours. E horizons from forest soils, with low organic matter (OM) and clay content, displayed rapid early distintegration of a large portion of the aggregates, followed by much slower breakdown of the remainder (i.e. the two populations modeled had very different rate constants). OM content is clearly the overriding control on aggregate behavior, but we are also exploring effects of clay content and mineralogy, cation chemistry, and other factors. The differences in aggregate behavior are likely to be relevant to transport and deposition of sediment eroded from these soils, and possibly to the transport of OM or nutrients with eroded soil. We hope to incorporate this method into ongoing field studies of soil erosion with colleagues at UW-Madison.