A New Method for Distinguishing the Original Textural Properties of Loess that Has Been Mixed with Underlying Sediment

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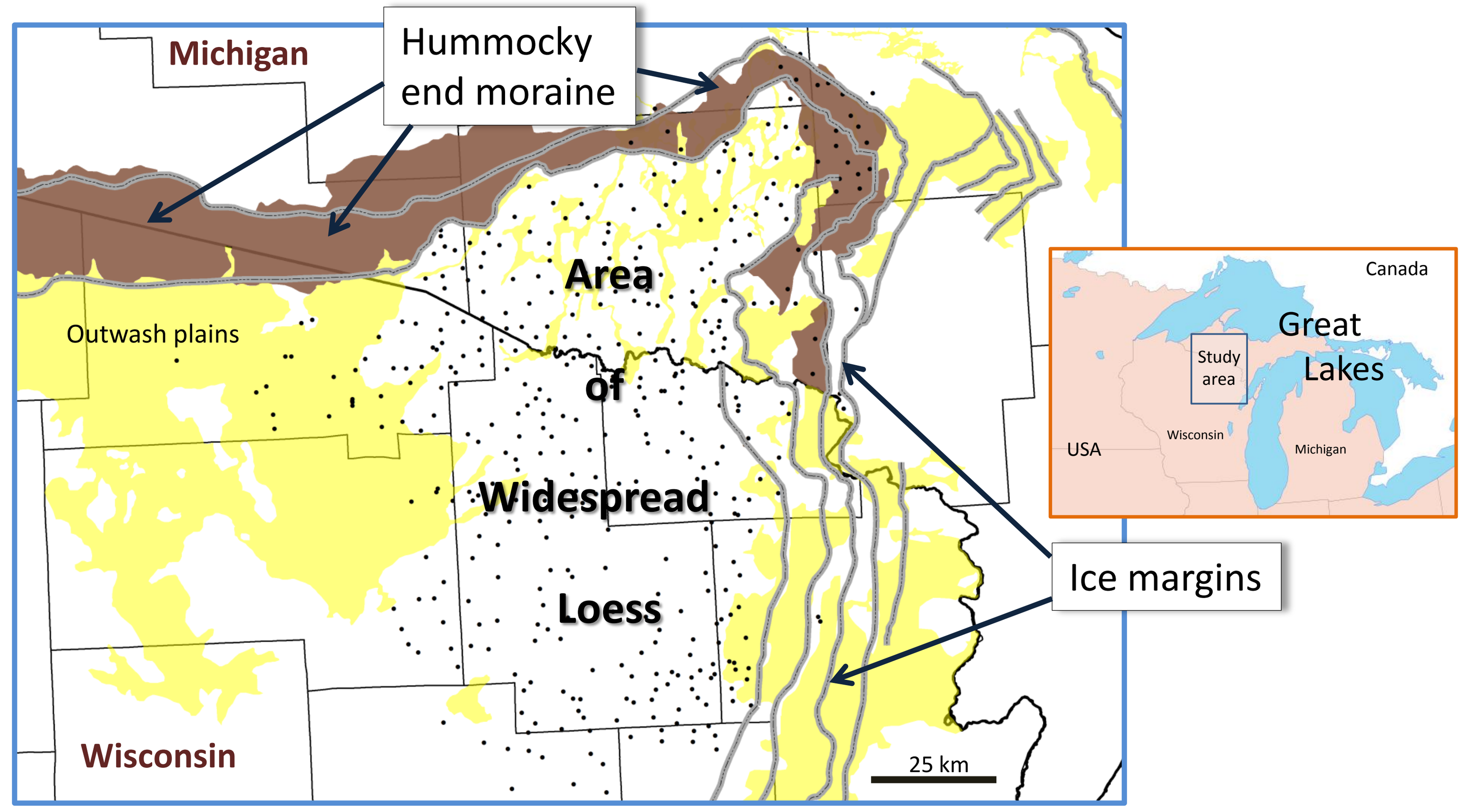
Introduction

Most loess has unimodal textural curves, with a peak in the silt fraction. However, in thin loess areas, where loess overlies coarse-textured sediment, it often has a bimodal textural curve, due to pedoturbation.

We present a method that can tease out these two textural signatures and thus, estimate the original particle size distribution of the loess. In this method the coarser sediment portion of such a "mixed" particle size distribution curve is removed, or "filtered out." The end result is a curve (and data) that better reflect the original textural characteristics of the loess.

Sites, Sampling and Lab Analyses

Loess samples were taken from 390 upland sites in the Great Lakes region, USA (see map below). Here, loess is typically 20-70 cm thick and commonly underlain by sandy glacial deposits. At most sites, pedoturbation has mixed some of the sandy, lower materials into the loess, resulting in a particle size mode within the 25-75 µm fraction (from the loess), and a secondary mode in the 250-500 µm fraction (from the pedoturbated sand) (Schaetzl and Luehmann 2012).



Samples were disaggregated, homogenized, and prepared for particle size analysis (psa) on a Malvern Mastersizer laser particle size analyzer. Psa data were exported into a spreadsheet in 105 size slices, or "bins," that range from 0.1 to ≈1000 µm. These data were then "filtered" to better determine their original textural characteristics.

Availability of Filter Code

The code used for this filtering process is provided in the form of a Microsoft Excel macro at:
http://www.geo.msu.edu/schaetzl/links.html

The Filtering Procedure

BACKGROUND: PSA data are "filtered" to remove data from sand fractions that have been mixed up and into the silty loess. As shown in Figures 1 and 2, the filtering process consists of three parts: (1) **cutting**, or removing the data for particle size bin values of the assumed "mixed-in" sediments, (2) **interpolating** new values for those particle size bins, and (3) **normalizing** the remaining data to reflect the constructed distribution curve on a volume percentage basis. The first step identifies which data should be preserved. Then, a spline interpolation is used to fill in the portion of the distribution curve that was removed due to influence from the coarser sediment. Finally, values are normalized so that the new particle size distribution curve values sum to 100% of the volume.

THE CUT: To interpolate a new particle size distribution curve, the range of x-axis values that need to be filtered out are determined. The lower x-axis value of this range is the cutoff point (Fig. 1B). The cutoff point is the bin where the slope of the particle size distribution curve begins to reflect enrichment by coarser sediment. Data within particles size bins coarser than the cut off point are removed.

THE INTERPOLATION: To fill in the missing portion of the new sediment curve, values are calculated between the cutoff point and where the "finer" particles size distribution curve would be expected to return to the x-axis (i.e., have values of zero). This x-intercept interpolation point is based on characteristics of the near-side curve slopes of the preserved values (Fig. 1C). A spline interpolation algorithm is then used to generate new values between the cutoff point and x-intercept (Fig. 1D).

THE NORMALIZING: Because the 105 bin values must sum to 100%, the new particle size distribution curve values are normalized. As a result, silt and clay values generally increase proportionately to the amount of sand that had been effectively "removed" by the filtering process. That is, the particle size curve becomes "higher" along parts of the particle size range that were preserved, but the relative proportions are preserved (Fig. 2).

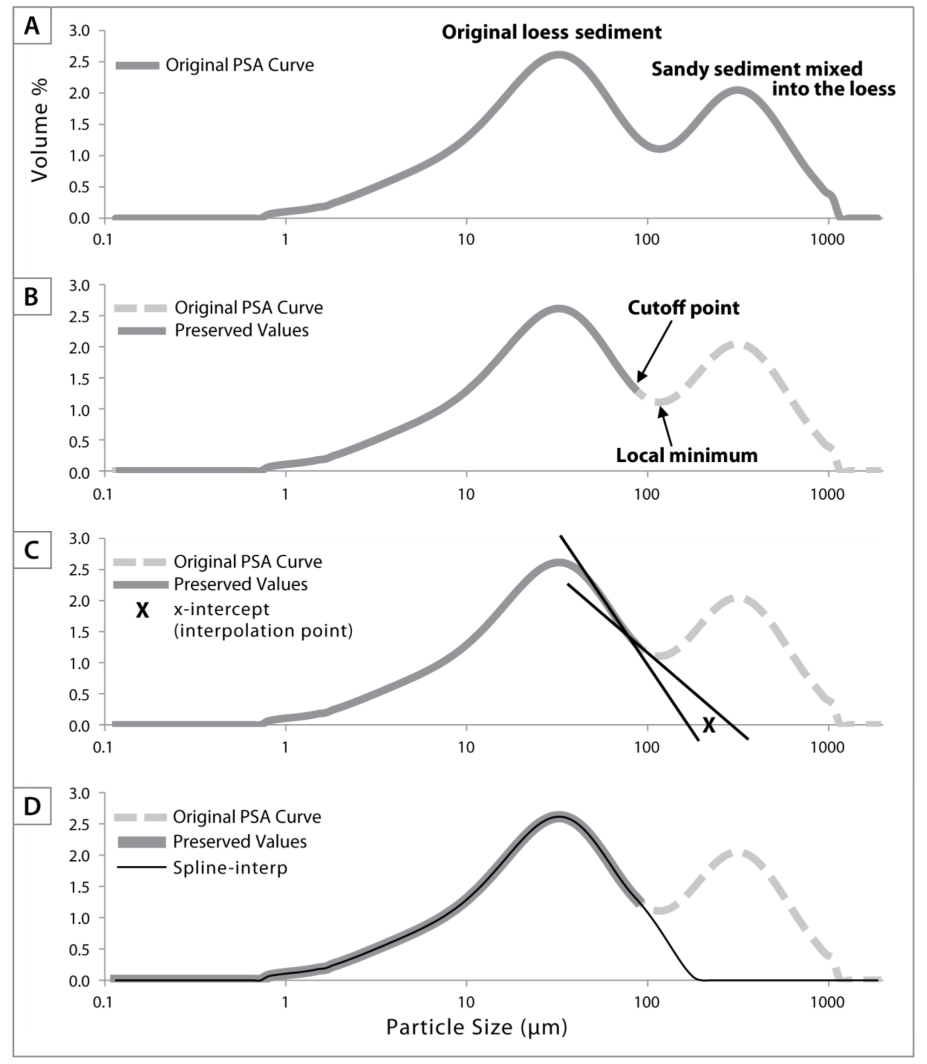


Figure 1. Illustration of filtering process. (A) Original bimodal distribution of loess. (B) Bin values of particle sizes finer than the defined cutoff point are preserved; data for bins that are coarser are removed. (C) An x-intercept is calculated for the end-point to the interpolation. (D) New bin values are calculated by spline interpolation - between the preserved values and the x-intercept point. Figure 2 (below) illustrates the final step in the process – normalizing the new psa data, so that they all total to 100%.

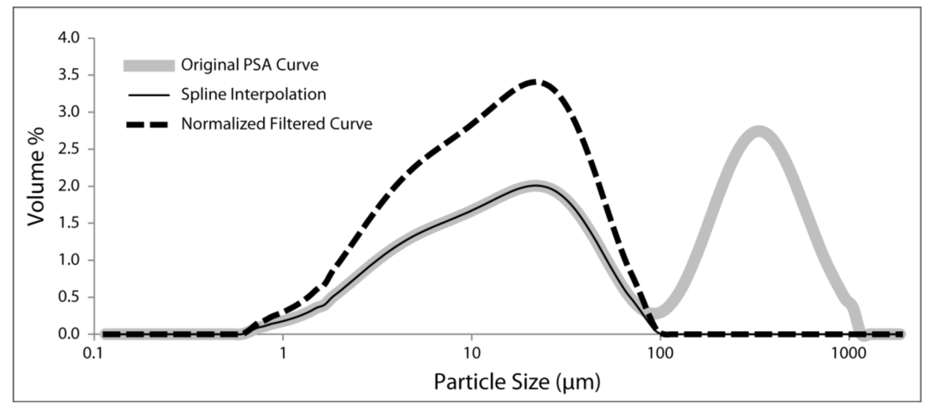


Figure 2. Example of an original and a filtered particle size curve, illustrating how normalizing all bins to sum to 100% increases the volume percent of the preserved values.

Results

Our filtering approach preserves as many observed bin values as possible and derives the modeled portion of the curve on the shape characteristics of only the preceding downslope side of the curve (Fig. 3). In so doing, it avoids potential errors that derive from "fitted function" approaches to this problem (Sun et al., 2004; Weltje and Prins, 2007). Filtered curves provide reasonable and reproducible estimates of the original particle size distribution of the eolian portion of the mixed sediment. In particular, it preserves the mode of the "finer" sediment, critical to loess studies.

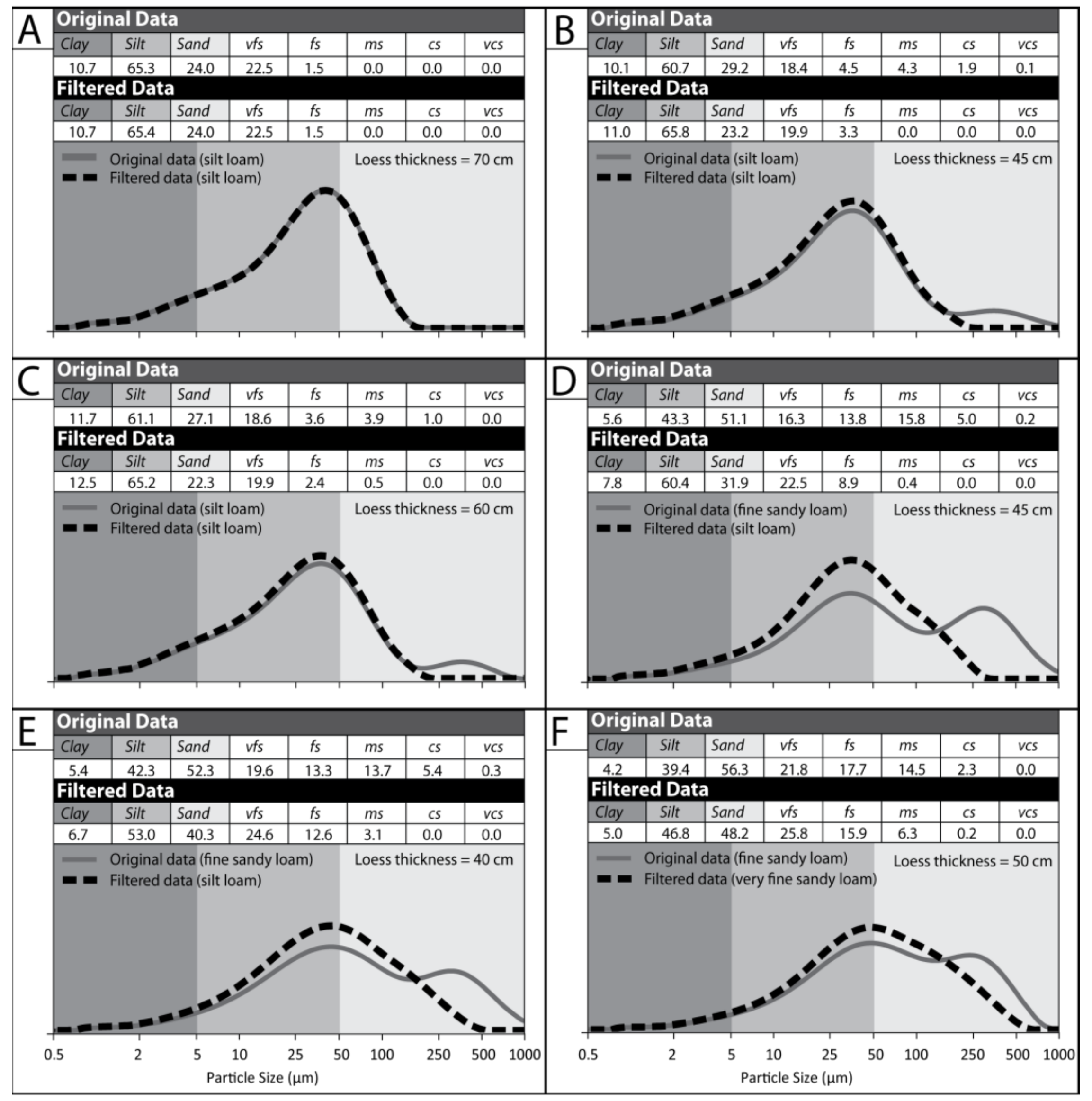
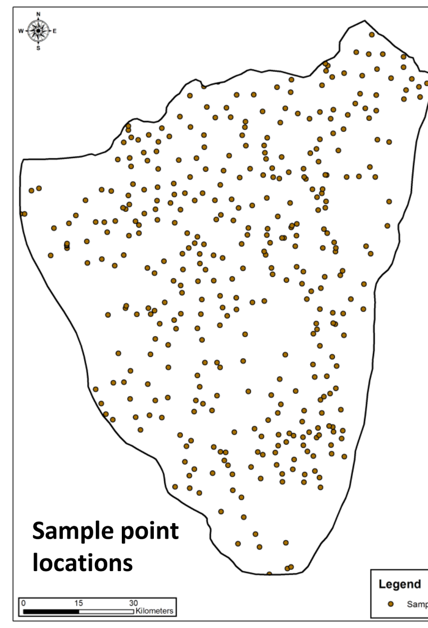
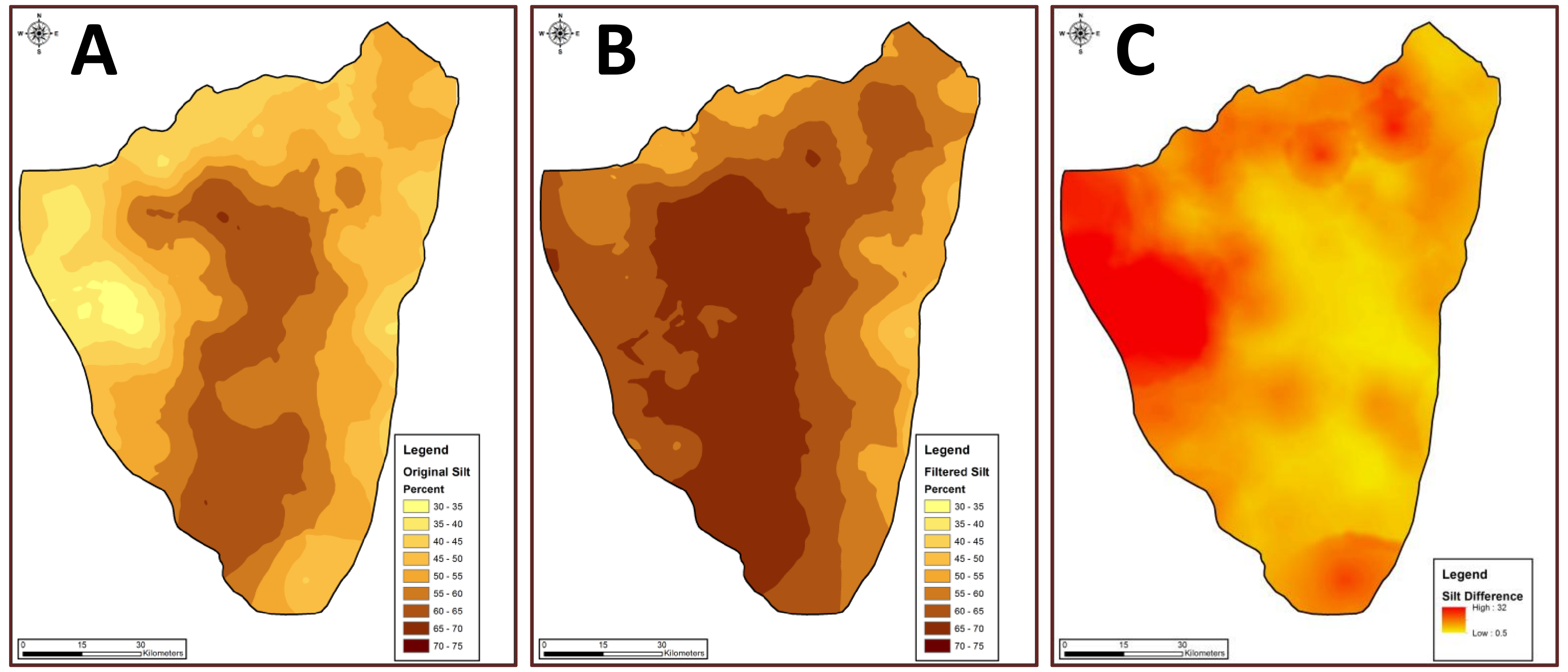


Figure 3. Examples of particle size curves from loess samples, presented in their original and their "post-filtering" forms. Associated data are also provided.

Application of the Filtering Method in Loess Studies

Using data from our 390 samples (below), we created maps of loess particle size data, using ordinary kriging in a GIS. Our data included (A) the traditional (raw) data on total silt content in the loess, which ranged from 14 to 71%, and (B) silt contents using filtered data, which ranged from 25 to 73%. On average, a typical loess sample had 10% sand filtered out during this process, showing the degree to which pedoturbation has impacted the loess in this region (Schaetzl and Luehmann 2012). Use of "raw" psa data from loess that has had sand pedoturbated into it can lead to misleading or inaccurate interpretations.





Silt content (original data) Silt content (filtered data) Difference map of silt content

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