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Size, shape and orientation matter: fast and semi-automatic measurement of grain geometries from 3D point clouds

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1 Practical explanations about the choice of parameters

We here give some practical explanations about using G3Point and provide some advice on the choice of the parameters. We refer to the main manuscript for a full description of the methods. G3Point is here applied to an arbitrary subset of point cloud obtained by SfM. The represented point cloud of ~2 10^5 points covers a surface of 1 m^2.

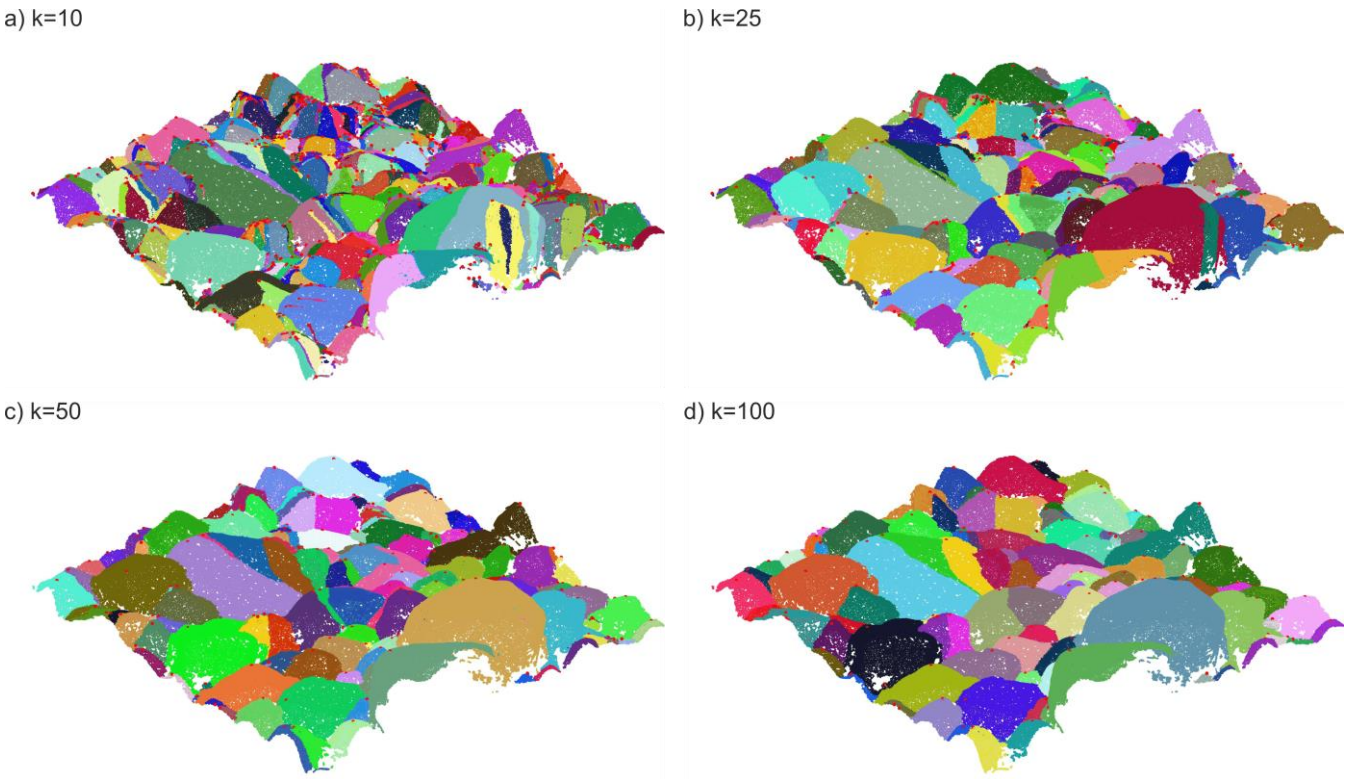

Figure S1: Influence of the k parameter on the initial segmentation: a) k=10, b) k=25, c) k=50 and d) k=100. Each color represents the unique label of a grain obtained after the waterhsed initial segmentation described in section 2.1 of the main manuscript. The represented point cloud covers a square surface of 1x1 m.

Initial segmentation (see Section 2.1)

During the initial segmentation of the point cloud, the only parameter influencing the results is the *k* parameter, which directly represents the number of nearest neighbors used for the watershed algorithm. A low value of *k* can lead to over-segmentation, as watersheds smaller than the actual grains can be segmented due to local maxima or roughness (Fig. S1). On the contrary, a high value of *k* can lead to under-segmentation, as small grains can be merged into a single label. We recommend using a trial-and-error approach (< 10 tests), with a visual qualitative validation, to identify a suitable value of *k*. We also recommend favoring over-segmentation to under-segmentation, as the segmentation correction workflow provided with G3Point (see

Section 2.2) aims to correct over-segmentation. In Figure S1, the cases with $k = 10$ and 25 clearly results in a too significant over-segmentation of the point clouds. On the contrary, the case with $k = 100$ starts to show some under-segmentation. The case with $k = 50$ shows limited over-segmentation and no obvious under-segmentation. It is therefore considered as a suitable value for this point cloud, which leads to 167 labels in the example shown on Figure S3. If required, this value of k can be refined by adopting a dichotomic approach.

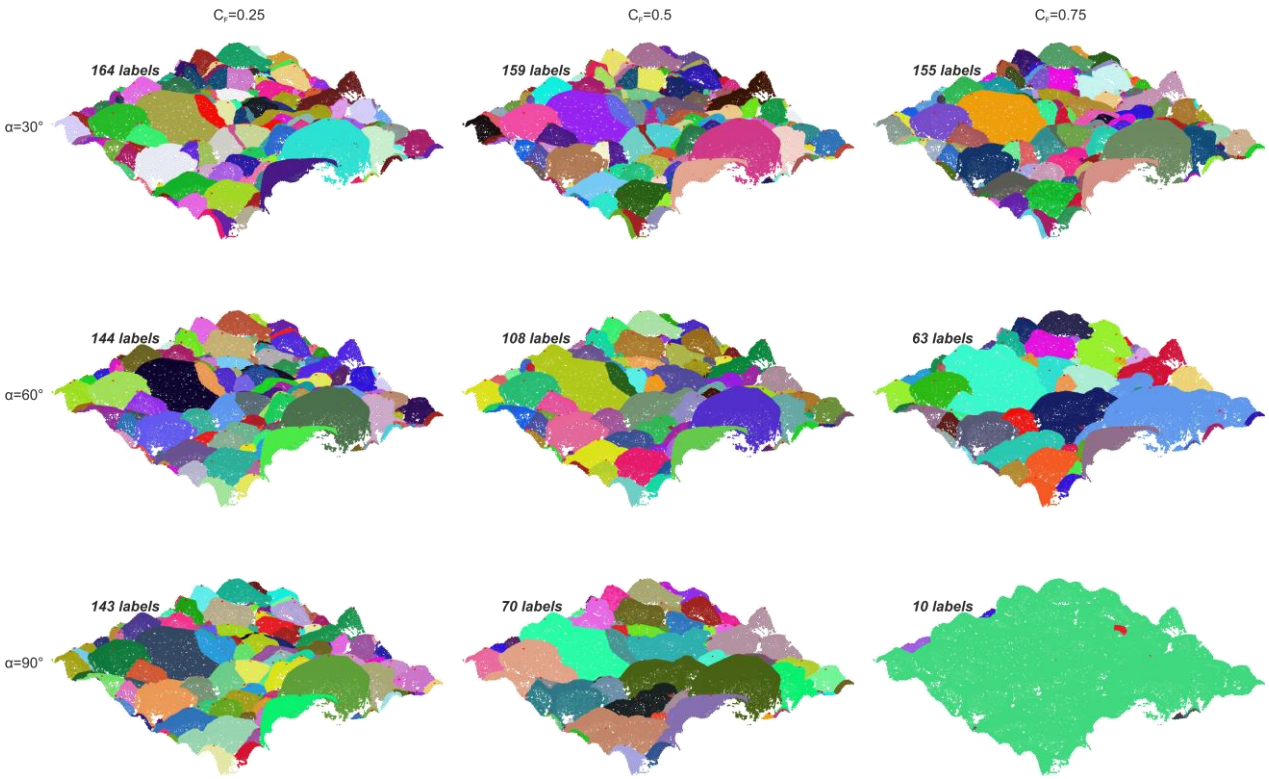

Figure S2: Influence of the $\boldsymbol{C_F}$ and $\boldsymbol{\alpha}$ parameters on the correction from over-segmentation (see Section 2.2). $\boldsymbol{C_F}$ increases from left to right, while $\boldsymbol{\alpha}$ increases from top to bottom of the figure. The number of labels resulting from the correction of the initial segmentation is shown on the figure. The represented point cloud covers a square surface of 1x1 m.

Correction from over-segmentation (see Section 2.2)

Correction from over-segmentation, by merging pair of labels (i, j), occurs based on three criteria, summarized below:

- Criterion 1: the distance d_{ij} between the summits of these two labels must be small relatively small compared to the sum of their characteristic radius, $l_j + l_j$. The criterion to merge the pair of grains (i, j) together is therefore $d_{ij} < C_F(l_i + l_j)$, with C_F a scaling factor.
- Criterion 2: the two labels must be neighbors.

- Criterion 3: the 3D angle between the normals of the crest points of labels *i* and *j* should be smaller than a threshold α.

These three criteria must all be respected to merge a pair of labels. We here illustrate the influence of changing C_F, the scaling factor, and α, the maximum threshold angle between two labels, on the correction of the initial segmentation, based on the previous example with $k = 50$ (Fig. S1). In Figure S2, C_F varies between 0.25, 0.5 and 0.75, while α varies between 30°, 60° and 90°.The two end-members cases, when considering C_F=0.25 and $\alpha = 30$ (top-left of Figure S2) or C_F=0.75 and $\alpha = 90$ (bottom-right of Figure S2) are respectively too restrictive or too permissive, and lead to164 or 10 labels, compared to 167 before correction. Keeping $\alpha = 30$ while varying C_F, or keeping C_F=0.25 while varying α, lead to a limited number of label merging as the number of labels remain greater than 140. The case with $\alpha = 60$ and C_F=0.75 leads to 108 labels and to a visually satisfying segmentation, despite a few cases of under-segmentation. Once again, these two parameters can be refined by a dichotomic approach.

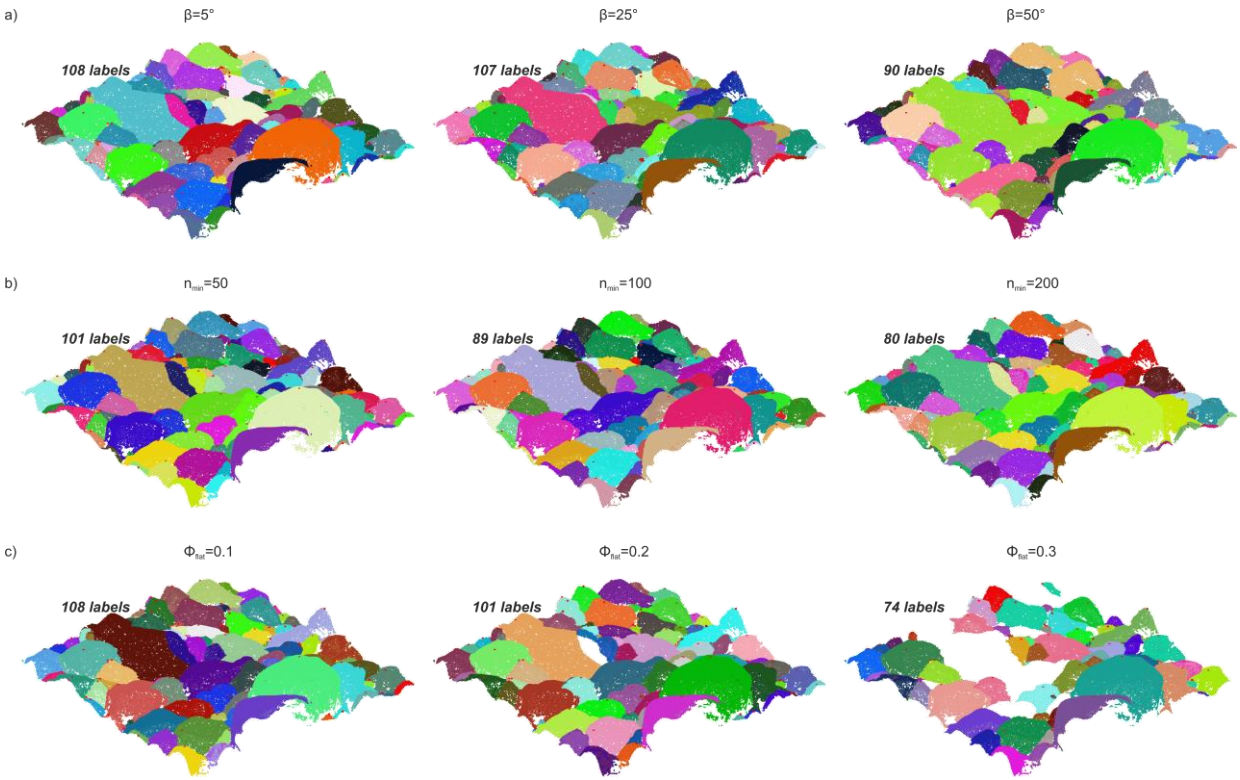

Figure S3: Influence of the a) $\boldsymbol{\beta}$, b) $\boldsymbol{n_{min}}$ and c) $\boldsymbol{\emptyset_{flat}}$ parameters on the cleaning of the segmentation (see Section 2.3). Parameter value increases from left to right. The number of labels resulting from the cleaning of the segmentation is shown on the figure. Removed labels appear in white. The represented point cloud covers a square surface of 1x1 m.

Segmentation cleaning operations (see Section 2.3)

Three independent criteria can then be used to clean the segmentation. We here show results of the segmentation cleaning operations which are applied to the segmentation obtained with $k = 50$, $\alpha = 60$ and C_F=0.75 (central panel of Figure S2).

- The first criterion consists in applying only criterion 3 of previous section (see Section 2.2), which consists in merging two labels i and j if the 3D angle between the normals of their crest points is smaller than a threshold β. Figure S3a shows the impact of using this criterion when considering values of β ranging between 5° and 50°. Too large values of β lead to under-segmentation, while values smaller or equal than 25° lead to no significant impact on the segmentation. In this example, using this criterion does not lead to any gain.
- The second criterion removing grains with less than n_{min} points. Figure S3b shows the results of this cleaning operation when varying n_{min} between 50 and 200. In this example, most identified labels are defined by a few hundreds points due the relative high point density of the point cloud. Mostly artefacts are removed when considering $n_{min} = 50$, while using larger values start to remove real grains from the segmentation.
- The third criterion consists in removing flattish or over-elongated grains, which can correspond to patches of fine grains. Flattish or over-elongated grains are identified as grains with a ratio between their minimum or intermediate dimension over their maximum dimension lower than a threshold $\emptyset_{flat}$. Figure S3c shows the results of this cleaning operation when varying $\emptyset_{flat}$ between 0.1 and 0.3. As this point cloud does not contain patches of fine grains, applying this criterion mostly removed over-elongated grains which here correspond to over-segmented labels. This is particularly true when using $\emptyset_{flat} = 0.2$. On the contrary, $\emptyset_{flat} = 0.1$ does not remove any label, and $\emptyset_{flat} = 0.3$ removes numerous labels which correspond to true grains.

2 Supplementary figures

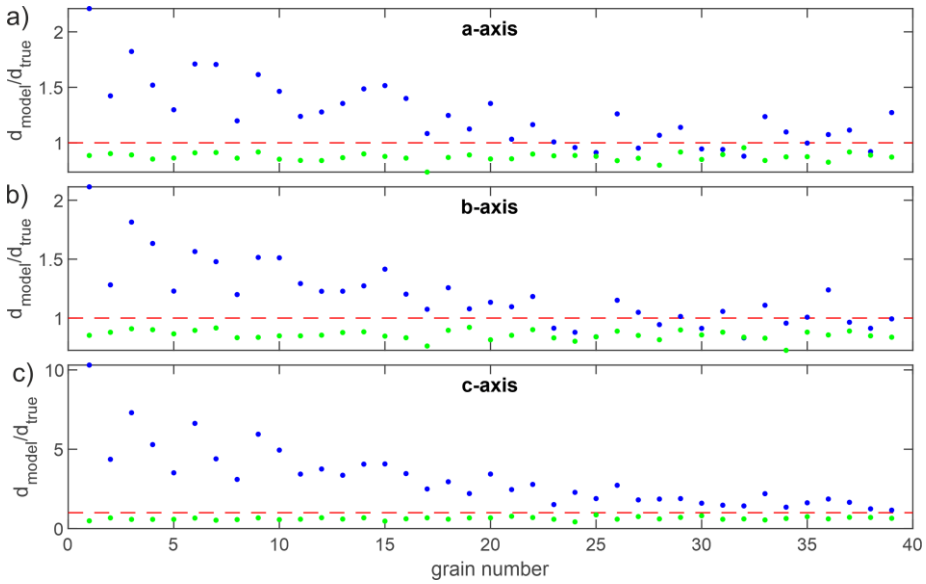

Figure S4. Ratios of the ellipsoid diameters $\boldsymbol{d_{model}}$ over the cuboid lengths $\boldsymbol{d_{true}}$ for the a) $\boldsymbol{a}$ −axis, b) $\boldsymbol{b}$ −axis and c) $\boldsymbol{c}$ −axis of the 39 grains (represented in the same order than in Fig. 4). The horizontal red dashed lines represent the value of 1, while the blue or green dots represent the ratios obtained with the DLSF or IE ellipsoids, respectively.

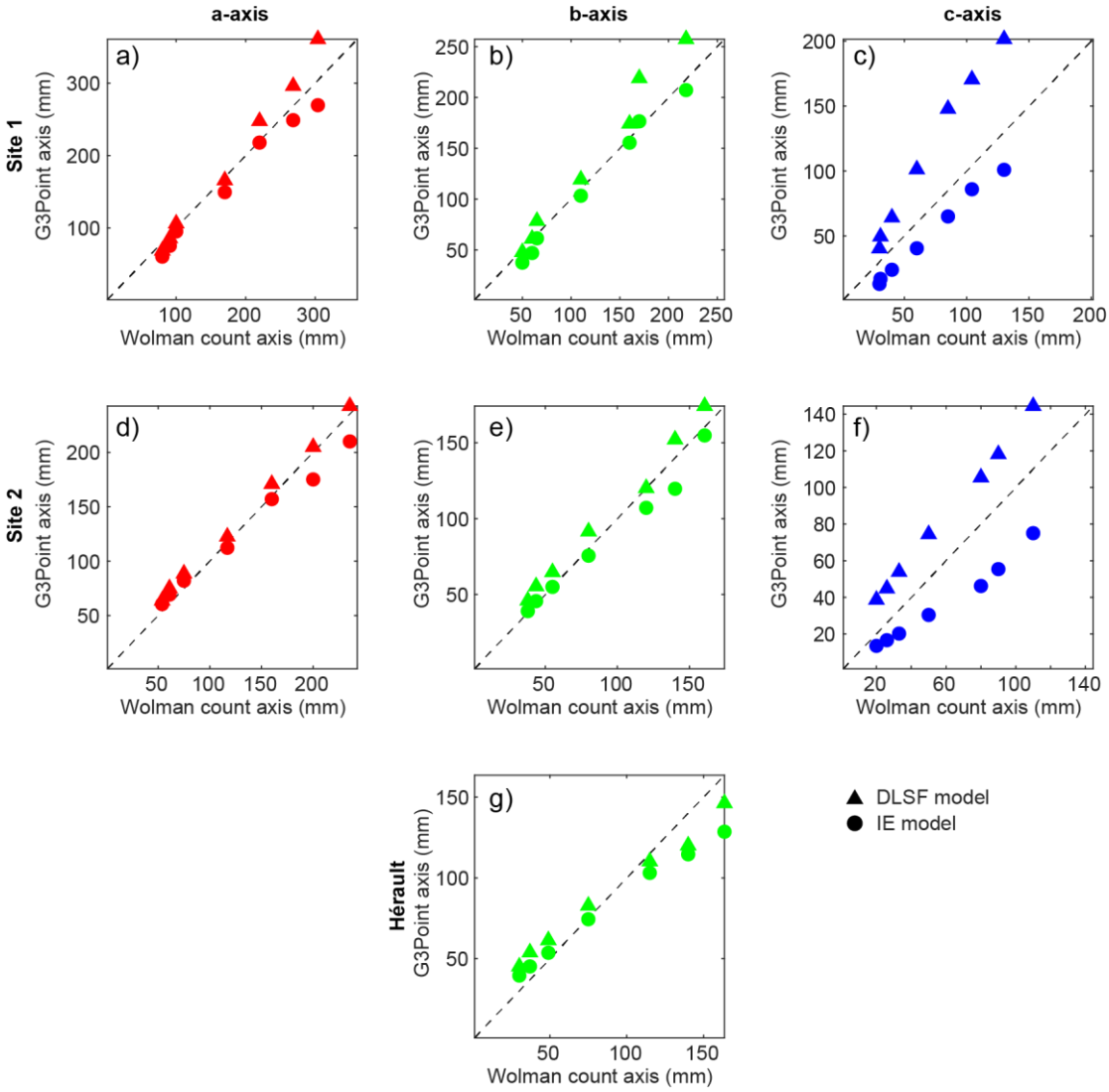

Figure S5: Comparison of the key percentiles (10^{th}, 16^{th}, 25^{th}, 50^{th}, 75^{th}, 84^{th}, 90^{th}) obtained by manual counts and by G3Point at the three study sites and for the three diameters. Triangles and circles correspond to the DLSF and IE models, respectively. The dash lines indicate a 1:1 ratio (points under/above the line indicate that G3point under/over-estimates the percentile with respect to field measurements).

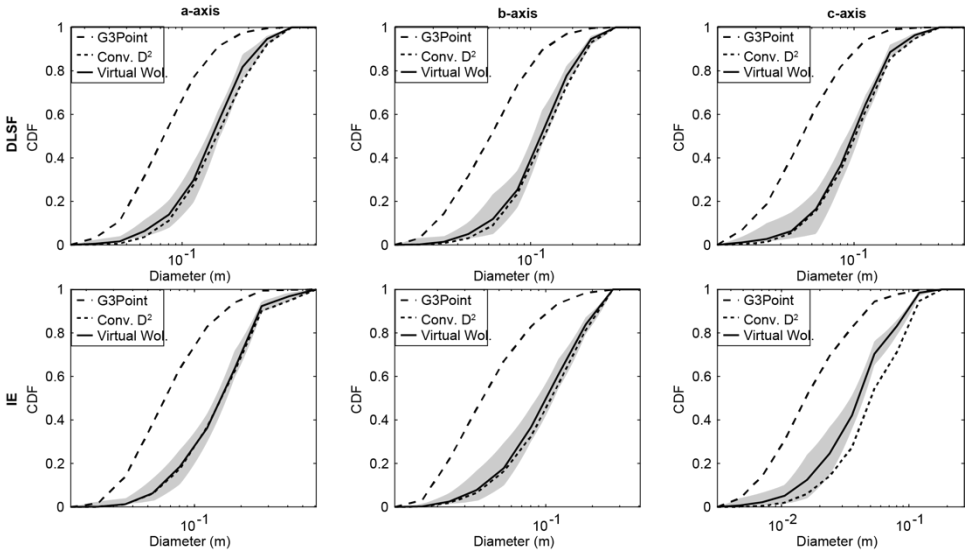

Figure S6: Conversion of G3Point grain-size distribution into a Wolman-like distribution, for Chateau Renard Site 1 and for the two fitting methods (DLSF and IE). The initial G3point distribution is an area-by-number one (large dashed line) that can be converted to a grid-by-number one with a conversion factor of 2 (small dashed line). Alternatively, a virtual Wolman count can be performed on the fitted grains (black line). The shaded envelop indicates the variability observed with 25 realizations.

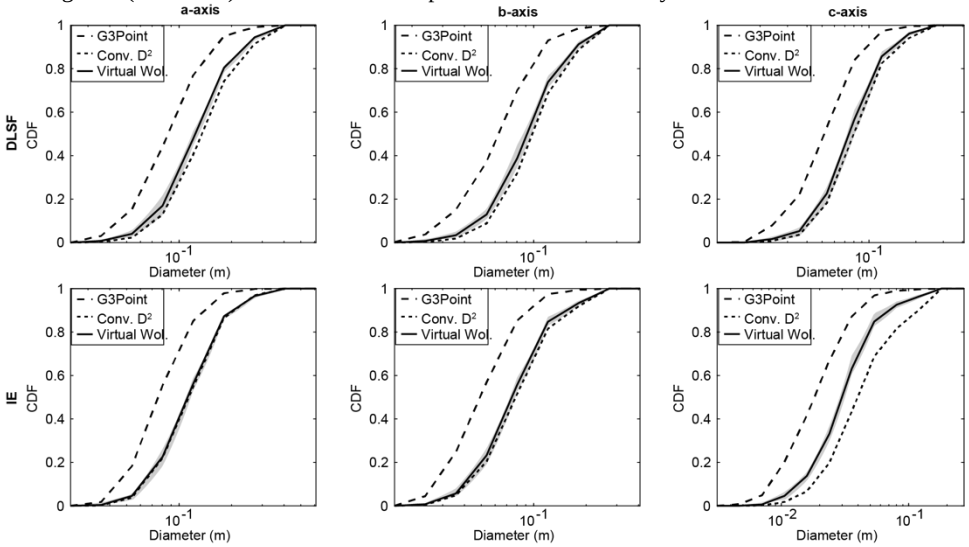

Figure S7: Conversion of G3Point grain-size distribution into a Wolman-like distribution, for Chateau Renard Site 2 and for the two fitting methods (DLSF and IE). The initial G3point distribution is an area-by-number one (large dashed line) that can be converted to a grid-by-number one with a conversion factor of 2 (small dashed line). Alternatively, a virtual Wolman count can be performed on the fitted grains (black line). The shaded envelop indicates the variability observed with 25 realizations.

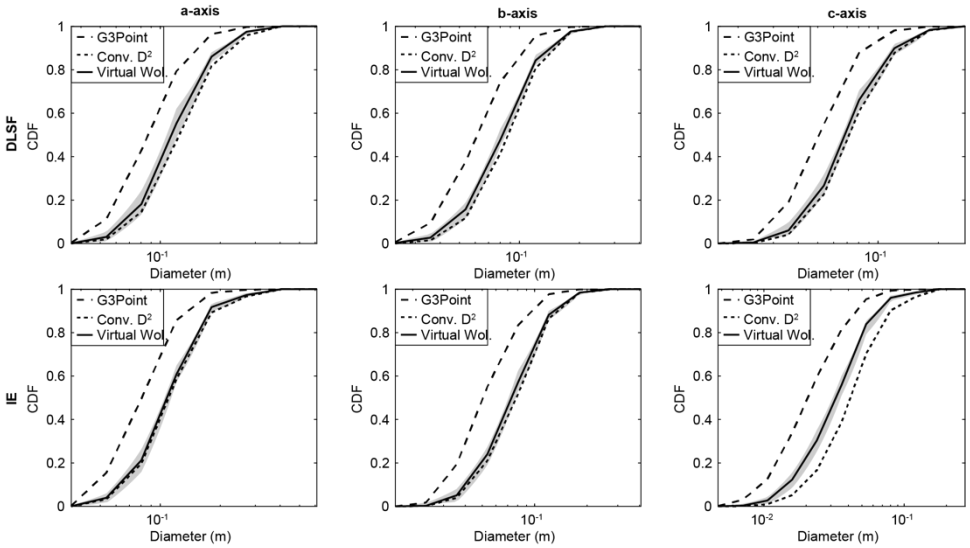

Figure S8: Conversion of G3Point grain-size distribution into a Wolman-like distribution, for the Hérault river and for the two fitting methods (DLSF and IE). The initial G3point distribution is an area-by-number one (large dashed line) that can be converted to a grid-by-number one with a conversion factor of 2 (small dashed line). Alternatively, a virtual Wolman count can be performed on the fitted grains (black line). The shaded envelop indicates the variability observed with 25 realizations.

Site	Method	a-axis			b-axis			c-axis		
		D10 (mm)	D50 (mm)	D90 (mm)	D10 (mm)	D50 (mm)	D90 (mm)	D10 (mm)	D50 (mm)	D90 (mm)
Chateau Renard Site 1	Wolman	80±17	170±48	304±135	50±17	110±38	218±95	30±10	60±20	130±58
	G3Point	65±4	160±8	334±46	43±5	111±8	231±25	27±14	73±30	154±50
Chateau Renard Site 2	Wolman	54±7	117±15	235±25	38±6	80±9	165±23	20±4	50±6	110±20
	G3Point	63±2	118±5	229±16	43±3	84±8	166±10	27±13	53±22	107±35
Hérault	Wolman	-	-	-	30±13	75±18	164±42	-	-	-
	G3Point	-	-	-	43±3	79±4	136±9	-	-	-

Table S1. Characteristic percentiles of the grain-size distributions obtained at the three sites by Wolman counts and with G3Point. D10, D50 and D90 are the 10th, 50th and 90th percentiles of the distributions, respectively. The a-, b- and c- axis are the large, intermediate and small axis of the grains, respectively.