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Interactive comment on "Dynamics and mechanics of tracer particles" *by* C. B. Phillips and D. J. Jerolmack

Anonymous Referee #3

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General comments

The authors performed a thorough field study and contributed valuable data and insights to the scientific community. Therefore, I suggest that the paper be published after a thorough revision. Much of the revision should focus on clarifying the text and avoiding jargon.

The paper by Phillips and Jerolmack is very long and should be shortened. A lot of information is squeezed into the paper which makes the text very dense and difficult to read, hence shortening means eliminating some chapters and expanding on the remaining ones. I suggest taking out sections 4.3 and 5.2 which are difficult to follow, described in an especially short-handed way, are speculative, and seem to be offset from what has been described in previous sections. The remaining chapters contain ample material for a paper.

The authors use the term “alluvial” quite liberally. The paper would merit from a more critical view and discussion of the term “alluvial”.

Currently, most of the figures are poorly legible and need to be published in a substantially enlarged scale.

Specific comments

Abstract A lot of different findings are reported in telegram style. Abstract space is limited, hence the authors present information too brief to be comprehensible at a stage in which the reader has not yet read the paper.

L.8: “exponentially distributed” vague; perhaps:... decrease exponentially with travel distance p. 431, L.13: . . .weak correlation. . . positive or negative? L.4: comma after Unfortunately

L.16/17: The finding by Wolman and Miller that effective discharge is near bankfull flow and near a flow at which the bed D50 size is mobilized is not general. Several studies have observed a difference between Qbf and Qeff and suggested that Qeff systematically increases with sediment rating curve steepness (e.g., Hayward 1980; Nash, 1994; Bunte, 1995, 2002; Emmett and Wolman, 2001; Vogel et al. 2003; Barry et al., 2008; Doyle and Shields, 2008; Quader and Guo, 2009). A similarity between Qbf and Qeff appears to be limited to fully alluvial systems in which almost all particle sizes present on the bed are routinely mobile and cause rather flat bedload transport relations with exponents Qb = aQˆb of about 3 or less, i.e., typically sand-bedded streams or otherwise highly mobile streams. The authors report partial transport for almost all of their observed transport events, suggesting that that stream is not highly mobile.

Partial transport is probably dominant time wise in the study stream, but partial transport is not dominant with respect to channel formation.

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p. 432, L.6: . . .sample. . . suggest: integrate L. 22: step-pool vs. alluvial: step-pool is not the antithesis to alluvial. The term step-pool describes a channel morphology but not the degree of bed mobility. Step-pool streams can be highly mobile–and alluvialâĂŤif they receive sufficient sediment supply. Step-pool streams with high sediment supply may route large amounts of coarse sediment while the steps may be preserved or be destroyed. By contrast, step-pool streams may also be almost entirely sediment starved an immobile. The term “alluvial” refers to a high degree of bed mobility that encompasses nearly all particle sizes on the bed. Alluvial gravel-bed streams typically exhibit pool-riffle or braided morphology with bars comprised of particle sizes that are routinely mobile, but even step-pool and plane-bed streams may become alluvial given sufficient sediment supply in relation to transport capacity.

P. 433, L. 11: . . .much smaller. . . suggest: much shorter L15: define “number density” of moving grains

P.434, L8: define “surface density” L. 21ff: . . .heavy-tailed statistics. . .summation of exponential step lengths. . . Given that this section is meant to serve as an introduction to the topic, I suggest avoiding jargon. Rather provide a visual description of the distribution of step lengths.

P. 435, L. 6: . . .two limits. . . you are not really proposing limits, but rather you include the full range of possibilities of motion between one little step and continuous motion. Perhaps “end members” may be a better term.

P. 437, L. 3: please explain what you mean by “equilibrium profile” A stable profile of longitudinal sorting in which particle sizes decrease downstream? I would expect that tracer particles sort according to size within the reach scale, reflecting natural spatial sorting mechanisms such as downbar and bankward fining. The authors should explain that they are not concerned with reach-scale longitudinal variability. Please explain: “elongation of this sorting profile” L. 5/6 downstream (transport?) distance? Please explain: Extraction length L.8: extracted? Do you mean entrained or deposited?

Please clarify. L.9: input or? Source L.13: "extracted by deposition"? Please explain L.15: ...95% recovery at any time between floods or at the point downstream from which on no further entrainment occurred? L.16: ...that the (insert) "longitudinal" sorting L.16: ...of the gravel mixture (at any point X*? L.22: ...standard deviation of the grain size distribution of the seeded tracer particles or of the tracers at a distance X* downstream? Given that Section 2.3 is meant to serve as an introduction, I would suggest clarifying and simplifying this section, and perhaps providing a sketch diagram.

P. 438, L.15ff: The 1.2 km long study reach is reported to be nearly straight with minimal meandering. It seems to be a plane-bed channel (which may have a meandering thalweg), but based on the Montgomery-Buffington stream classification, a plane-bed morphology is not expected at a stream gradient as low as 0.0078 m/m, a gradient for which a pool-riffle morphology is more typical. Could the authors comment on this apparent misfit? The bed is perhaps too coarse to permit that pools and riffles are shaped by the commonly occurring flood events. The coarse plane-bed channel seems to be another indication that the study reach should not be characterized as alluvial, but perhaps as a coarse scour channel. Figs. 3 a and 3b should be published at a considerably enlarged scale.

P. 439, L.9: ...variability in the (insert) surface grain size distribution, ... The D50 and D84 can typically be determined relatively accurately from a pebble count, even if only 100 or 200 particles are collected. How many particles were collected per pebble count? L.14: What are the D50 and D84 sizes? Seems that the D84 is about 300 mm in both study reaches, but Fig. 1 is too small to actually determine those sizes. L.24: was the tracer deployment reach located at the start of the flood plain?

P. 440, L.19: ...downstream of the "input?" location of the ... L.21: ...downstream of the start of the alluvial plain...Were the tracers not inserted just at the upstream end of what the authors call alluvial plain? L.21ff: Statistical values...I do not understand that sentence. Please clarify what you did and why you did it.

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P.441, L.3: …95% of the tracers recovered…at any of the 5 or 6 individual surveys with and increasingly longer L for each survey?

I suggest preparing a new fig. that in analogy to Fig. 5 shows the (linear) decrease of fraction mobile vs. U*c and placing that fig. where the two methods for determining U*c are discussed.

P. 442, L.22: (insert) “Shields” stress

P. 443, L.8ff: In 5 out of the 6 flood events, only between about 5 and 40% of the tracers moved, hence only a small percentage of the bed D50 particles are typically mobile. With no bars visible in the photos of the study reach, I don't see how those few mobile D50 particles act to shape the channel. Channel morphology is set by the large and typically immobile large cobbles and boulders. I doubt that such a channel should be classified as alluvial. It seems to be a scoured channel bed over which particles typically smaller than the bed D50 size move without much effect on determining channel morphology.

Fig. 6: Caption: Why “Frequency magnitude distribution…?” and not simply cumulative frequency distribution? The term “frequency magnitude distribution” makes it appear as if a Wolman and Miller magnitude-frequency plot was being referred to. Inset to fig. 6b: the authors should use the same scale for I* in the inset and the main figure.

L.23 …threshold of motion (insert) “of the bed D50 size.” L.29 … threshold of motion (insert) “of the bed D50 size ?”

P. 444, L.12: what are the Q, U*, tau*, and I* of the characteristic flood? I suggest indicating those values in all diagrams of Q, U*, tau* and I*. L. 21: What are the characteristics to those two flood with shorter transport distances? L.24ff: We plot the dimensionless tracer distance… Please show the plot in a figure.

P. 445, L. 17: suggest “increases” rather than “scales”

L.19: …less embedded… that raises the interesting question of how deeply the tagged

D50 particles were embedded in the bed. The authors may not know how deeply particles were embedded, but perhaps the authors could provide a value of how many of the recovered tracers were found on the surface (were the tagged particles painted as well?). The authors must know something about this subject to make the statement that tracers from population 2 were less embedded than those from pop. 1.

P. 446: Could the authors refresh the reader's memory about why a linear relationship is expected or reasonable between X/D and I*?

P. 447, L.3: . . .All (insert) "particle size" distributions Fig. 11: should be substantially enlarged for publication. I also suggest plotting Fig. 11 b in log-log scale to better compare the number of data points that lie above and below, and right and left of the values of 1 on the x- and the y-axes (plot a dashed line for Di/D50 as well). Seems to me that except for the NW quadrant of the plot, there are about equal numbers of data points in each quadrant (about 20 in NE, 30 in SE, and 25 in SW). Does your interpretation still hold if there are about equal number of data points in each of the three quadrants (=except the NW one)? L. 13: should be a comma, not a semicolon behind Eq. (1) L. 25ff: the information on the tracer starting locations should be moved forward in the text to where tracer deployment is described. Fig. 12 needs to be substantially enlarged in the published paper.

P. 448, L.2: . . .deposition of the coarsest particles (insert) "in the reach upstream". L. 11: . . .spatial decrease (insert) "in" L 16: . . .exponential (insert) "function"

P. 449, L. 10: . . .to scale exponentially (with what?) L.15: instead of . . .most like tracer displacement" I suggest most likely displacement of a particle of the bed surface D50 size P. 450, L.13 ff: Indeed,. . .and what are the depth, Q, v, etc. of the characteristic flood and bankfull flow?

P. 451, L. 13: . . .effect on flow resistance, (delete) "that" the resulting. . . L. 14: . . .resulting particle transport (insert?) distance?

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P. 454, L. 14: . . .that tracer remain (delete "s") P. 455, L. 2: It may well be that the frequency of flood events drops below some commonly occurring flood) (e.g. Segura and Pitlick 2010), and that that commonly occurring flood (be that the characteristic or the bankfull event) just starts to transport the bed surface D50 size. But how do the authors then infer that the characteristic (or bankfull) flood performs the maximum geomorphic work? The characteristic flood in the study stream moves some (typically 5-40% it seems) of the bed D50 particles over a few meters per flood event. Such marginal particle motions do hardly have a significant channel shaping effect. There are no reported bars comprised predominantly of particles in the D50 size range and that could subsequently be shaped by the characteristic flood. All that the characteristic flood in the study stream seems to accomplish is to let a few D50 particles scoot a few meter further downstream over an otherwise very rough and mainly immobile bed. I presume that the plane-bed morphology of the coarse bed was shaped by some rarely occurring large event that moved the D84 and larger particles. This kind of channel and bedload movement is often observed in US Rocky Mountain streams in forested watersheds.

I am not surprised by the relative similarity in scaled tracer travel dynamics between the Mameyes and the Bisley 3 sites. Both sites have similar particle size distributions, and both sites transport some D50 particles during commonly occurring floods. The only difference is channel morphology (step-pool vs plane-bed: the lower gradient reach is to flat for step-pool sequences to develop), but there there seems to be no major difference in bed mobility.

References Barry, J.J., Buffington, J.M., Goodwin, P., King, J.G., Emmett, W.W., 2008. Performance of Bed-Load Transport Equations Relative to Geomorphic Significance: Predicting Effective Discharge and Its Transport Rate. J. Hydraul. Eng., 134 (5): 601-615. Doyle, M.W., C.A. Shields, 2008. An alternative measure of discharge effectiveness. Earth Surface Process. Landforms 33:308–316. Emmett, W.W., Wolman, M.G., 2001. Effective discharge and gravel-bed rivers. Earth Surf. Process. Landforms 26, 1369-1380. Hayward, J.A., 1979. Mountain stream sediments. In: Physical Hydrology: New Zealand Experience. D.L. Murry and P. Ackroyd (eds.), p. 193-212. N.Z. Hydrol. Soc. Inc., North Wellington. Nash, D., 1994. Effective Sediment-Transporting Discharge from Magnitude- Frequency Analysis. J. Geology 102(1), 79-95. Quader, A., Guo, Y., 2009. Relative importance of hydrological and sediment-transport characteristics affecting effective discharge of small urban streams in Southern Ontario. J. Hydrol. Eng. 14(7), 698-710. Segura, C., Pitlick, J., 2010. Scaling frequency of channel-forming flows in snowmelt-dominated streams, Water Resour. Res., 46, W06524, doi:10.1029/2009WR008336. Vogel, R.M., J.R. Stedinger, and R.P. Hooper, 2003. Discharge indices for water quality loads. Water Resour. Res. 39(10), 1273, doi:10.1029/2002WR001872.

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