Earth Surf. Dynam. Discuss.,
doi:10.5194/esurf-2017-8-AC2, 2017

Earth Surface Dynamics Discussions

Interactive comment on "Multiple controls on sediment grain properties of Peruvian coastal river basins" *by* Camille Litty et al.

Camille Litty et al.

camille.litty@geo.unibe.ch

Received and published: 4 May 2017

Dear referee,

Thank you very much for handling our paper. We considered the comments as very constructive and have improved the paper accordingly. The major changes include the improvement of the introduction with a clear explanation of how tectonics and climate operate to potentially influence the grain size pattern. Based on this, we phrased a distinct hypothesis to be tested. We also we improved the methods part by adding additional information about the sampling strategy and the data collection. We have used the Pearson's correlation coefficient to obtain statistically robust correlation between our grain size data and the morphological characteristics of the basins including mean basin slope, denudation rate and basin size, and shear stresses exerted by

Printer-friendly version

Discussion paper

the streams. We found distinct correlations between the grain size pattern and these variables and have framed the discussion accordingly. Therefore, we found the grouping of basins into northern and southern domains no longer as useful and have thus re-structured the paper accordingly. In summary, the major changes include: âĂć Presentation of a clear outline of how tectonics and climate could influence the grain size pattern, and based on this, a formulation of a distinct hypthothesis âĂć Presentation of more details of how we have collected and analysed the data âĂć Testing through state-of-the art statistical methods whether basin shape, sediment flux and streams' shear stresses have a measurable control on the grain size pattern. We have thus re-structured the discussion part accordingy.

Please find below a point-by-point response of how we have handled the suggestions and comments. Thank you very much for your hard work. On behalf of the co-authors

Camille Litty

Response to Referee #2

The authors rule out a tectonic control by simply stating that greater surface uplift rates should result in larger clast sizes. Why?

This has been explained in the introduction, which we have sufficiently modified thereby addressing the points of reviewer 1.

The mechanism underpinning this assumption (e.g., enhanced landsliding as a result of incision, etc) is very important if you want to look for tectonic signals in sedimentological data.

Yes indeed; we thus have modified the introduction accordingly.

The Methods section requires more information about where the grain size were collected.

Improved and expanded.

‘Along a highway’ isn’t very helpful – were the measurements made at equivalent locations in the longitudinal profiles of the catchments?

Done and improved.

If you want to compare measurements from one catchment to another, it’s important to demonstrate that the data come from comparable sampling sites.

Yes, done and we have specified this point.

It would also be helpful to know where the discharge data were collected in the catchments. I appreciate that the coordinates are listed in Table 1, but some description is needed about whether the discharge data represent equivalent points in the catchments; i.e., if one catchment is sampled at the mouth and another at the headwaters, how can a meaningful comparison be made?

We have taken the discharge data from Reber et al., in review in Terra Nova. These authors provide the full information about the data source.

I have some major criticisms of the results. Uncertainties are needed on the grain size percentiles, because the scatter in Fig. 3a is larger than the trends the authors interpret.

The grain size data have too large a scatter, so interpretations of trends are indeed not possible. We have changed the manuscript accordingly. We have worked on statistical correlations using the Pearson’s coefficient and no correlation has been found between the D50 and the latitude. Uncertainties on the grain size percentiles are also about 3 mm. This value corresponds to the precision limits of the measurements with the software ImageJ and of the digital pictures resolution.

The way the authors describe the grain size data from line 162 onwards implies a systematic variation from north to south, which is not really true.

Indeed, we have changed the analyses, and there is indeed not such a trend.

It should be clarified that the rates of grain size change from north to south refer to an average regression fitted to the data.

We have changed the analyses, and there is not such a trend.

The whole paragraph from line 171 is not really a description of results, and could be moved to the Discussion.

We have changed the analyses, so this paragraph has been removed.

However the final point (line 176) is very important and needs some explanation.

We have added an all paragraph on the gravel front in the discussion

Why are there catchments in the middle of the study area that apparently have much bigger grain size differences (only sand and no gravel) than the catchments examined in the paper?

We have discussed this point.

The authors are apparently aware of much larger grain size variability in the area but have ignored those catchments, and it is not clear to me why.

We have discussed this point.

There are some issues with Fig. 3. The data in panel A are compressed to the bottom of the graph and half the plot isn't used – please expand the data so the reader can better see the trends (the annotations can go above the graph). In panel B, I am concerned that some of the data points are missing between 5-15 degrees latitude. Why are there only 6 points (compared to 11 in A)?

Figure 3 has been improved. The ratio b/a has not been measured at each sampling site so there are less data points in the ratio plot than in the percentiles one.

Also, which percentile has been used to calculate the a/b ratio?

There is no percentile used. We measured the length of the a-axis and the b-axis were per pebble. This gives us one value for the ratio. We repeated this for 500 pebbles, yielding a mean value per sampling site.

Next, it appears the coarsest grain sizes from the northern group of catchments are being exported from the shorter catchments that only drain west of the western escarpment. Those with larger upstream reaches crossing the western escarpment have equivalent grain sizes to the southern catchments. This difference is quite apparent by comparing Figs 1 and 3, and may invalidate the north/south grouping of catchments.

Yes indeed; we also realized that and have rewritten the discussion part of the paper.

The final part of the results contrasts Figs 5 and 6.

Yes indeed. We have completely changed this part of the analysis

The authors suggest that there are no correlations between grain size and the chosen parameters in

Fig. 5, but that there are correlations when the catchments are grouped (Fig. 6).

We have changed this part of the analysis

This isn't really a comparison, because the two figures are showing different things. I cannot tell how Fig. 5e and 5f would compare to Fig. 6 if the same normalisation was performed on discharge.

Indeed, please note that we have changed this part of the analysis

Why was discharge normalised in Fig. 6a but not elsewhere in the paper? And why have the authors chosen those particular grain size percentiles and variables in Fig. 6?

This has been changed and corrected. Indeed, this did not make sense.

It seems they have simply plotted everything against everything else and shown two unrelated correlations that are not particularly convincing and do not test a particular hypothesis.

We have framed our paper around a hypothesis. So this aspect has been changed. We have made a new figure showing the data from south to north and a correlation matrix using the Pearson's correlation coefficient to give statistically robust analyses.

I am confused about why the southern catchments should be characterised by comparing runoff normalised by area with D50, while the northern catchments should be characterised by their gradients as a function of D96.

We have changed this part of the analysis

The Discussion attempts to address some important questions about grain size patterns observed in river networks and how they might record various forcings. Unfortunately, it is inconclusive and unclear. The authors claim around line 219 that fluvial transport dominates the Majes basin – if so, why does the D50 not fine over a 100 km distance?

We have addressed this point.

In section 4.2, do the arguments here require that smaller rivers in smaller basins are moving coarser material? This needs to be clarified.

We have changed this part of the analysis

For section 4.3, what is the actual difference in climate between the northern and southern domains?

We have changed this part of the analysis; we no longer perform this grouping.

In Fig. 1c, apart from the wetter patch near Huaraz (which actually overlies a catchment exporting finer grain sizes!), the two areas look similar. I recommend the authors plot the runoff data and/or precipitation against latitude (following Fig. 3) if they want to argue there is a relationship here.

We have changed this part of the analysis

They need to show that the two domains are actually different and that climate correlates with grain size if they want to make that argument.

We changed this discussion accordingly

In section 4.4, the authors could clarify whether the smaller catchments in the northern group were glaciated as well, or only the larger ones? Because the coarsest data seems to only come from the smaller catchments, and this is an important difference that needs to be addressed.

We have clarify this point

These smaller catchments also drain proportionately more of the Coastal Batholith, which might indicate an erodibility control on grain size.

We have changed this part of the analysis and the discussion accordingly.

The arguments in this section are vague and undeveloped and jump from glaciers to lithology without offering any precise interpretations.

Yes, indeed. We have removed this part as it was non-conclusive.

- "Contrariwise" is an unusual word, and I recommend using something like "on the contrary" instead

We have learned this word from an English native speaker, so we have kept it.

- Refer to "El Niño", not "the El Niño" or "the El Niño effect" (it is not an effect). Also, on line 114 you equate El Niño with ENSO – they are not exactly the same thing. El Niño is one phase of ENSO and brings particular weather patterns, but ENSO refers to the overall oscillation between El Niño, neutral, and La Niña states in the tropical Pacific

Yes, indeed. We have removed this part.

- "Strong precipitation rate" implies a high intensity of precipitation, which is quite different to a greater overall amount of precipitation

Yes indeed, and we have removed this part as our dataset is not precise enough. We mainly focus on the streams' shear stresses.

- Lines 107-109. This is confusing – hot air cannot rise and is trapped against the foothills, but also cools at high altitude?

Yes, indeed. We have changed this sentence.

- Line 112. If you refer to Pisco, mark it on the map

It was referring to Piura which is outside of our study area so we have removed the sentence

- Line 143. The D96 is not the maximum particle size

This has been corrected

- Line 183. This sentence makes a big claim and needs to be supported by some key citations

Citations have been added to support the sentence.

- Line 293. Is the fracture spacing 10-20cm? Because this is the particle size range. I'm sure fracture spacing sets the sizes of large boulders, but I'm not convinced this mechanism applies to pebbles

Yes indeed. We have removed this part of the paper as it was non-conclusive.

- Line 295. The authors state that abrasion makes particles more spherical, and then say it doesn't. Please clarify which it is

We have clarified this point. As particles are transported over longer distances, abrasion tends to equalize the length of the three axes, thus making a particle more spherical. While this concept is likely to be valid for pebbles with a homogenous fabric, it likely fails to describe abrasion and break-down of material with an inherited planar geologic fabric (such a gneisses and sediments).

- Line 300. Yet the southernmost catchments in the southern grouping are very small, but show the roundest clasts. Is this not contradictory?

Yes, indeed. We have changed this part

- Fig. 5. These axes should be reversed

The figure has been removed and another figure with the same axis for every graphs

---

Interactive comment on Earth Surf. Dynam. Discuss., doi:10.5194/esurf-2017-8, 2017.

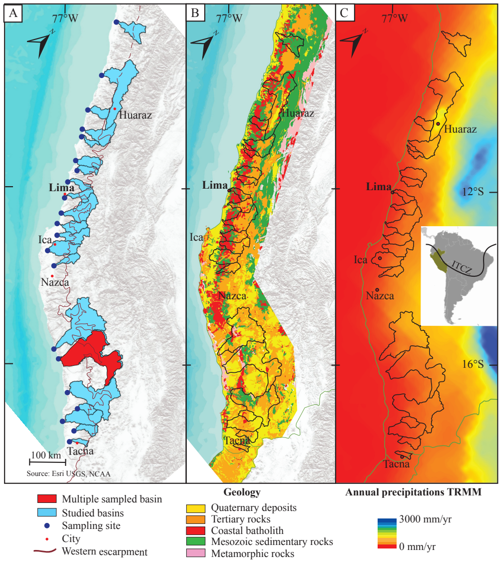

Figure 1: A: Map of the studied basins showing the sampling sites and the western escarpment (western escarpment modified after Trauerstein et al., 2013). **B:** Geological map of the western Peruvian Andes. **C:** Map of the precipitation rates showing the spatial extend of the ITCZ, modified after Huffman et al., 2007.)

Fig. 1.

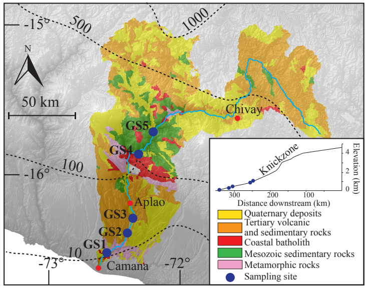

Figure 2: Geological map of the Majes basin overlain by the precipitation pattern (Precipitation data from Steffen et al., 2010., where the black dashed lines show precipitation rates (mm/yr). GS1 to GS5 represent sites where grain size data has been collected. The right corner shows the Majes river long profile.

Fig. 2.

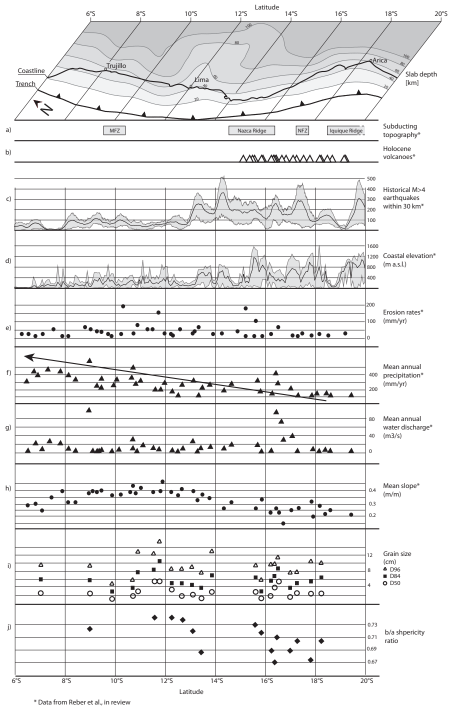

Figure 3: Topography of subducting Nazca plate, where slab depth data has been extracted from earthquake.usgs.gov/data/slab/. This N-S projection also illustrates: a) tectonic lineaments such as submarine ridges and MFZ: Mendaña Fracture Zone; NFZ: Nazca Fracture Zone; b) Holocene Volcanoes; c) Earthquake data, taken from earthquake.usgs.gov/earthquakes/search/; number of earthquakes M>4 within 30 km radius window; d) Coastal elevation. The data has been extracted from a 20 km-wide swath profile along the coast. The three lines represent maximum, mean and minimum elevations within the selected swath; e) Catchment averaged denudation rates have been corrected for quartz contents; f) Mean annual precipitation rates; g) Mean annual water discharge; h) Mean basin slope i)Grain size results for the intermediate (b)-axis of the pebbles in the streams from north to south at the sampling sites presented in Figure 1; j) Ratio between the intermediate axis and the long (a)-axis (modified after Reber et al., in review).

Fig. 3.

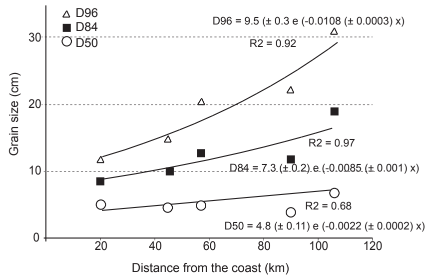

Figure 4: Grain size results along the Majes River.

Fig. 4.

River name	Sample name	Altitude (m)	Latitude (DD WGS84)	Longitude (DD WGS84)	D50 (cm)	D84 (cm)	D96 (cm)	b/a	Catchment area (km2)	Mean elevation (m.a.s.l.)	Mean slope (m/m)	Slope at the sampling site (m/m)	Distance form the western escarpment (km)	Mean annual precipitation (mm/yr) (Reber et al., in review)	Mean annual water discharge (m3/s) (Reber et al., in review)	Denudation rates (mm/ka) (Reber et al., in review)	Denudation rates uncertainties (mm/ka) (Reber et al., in review)	Denudation rates corrected for Qz content in bedrock (mm/ka) (Reber et al., in review)
Tacna	PRC-ME1	231	-18.12	-70.33	2.3	6.2	10.0	0.70	899	2733	0.28	0.015	48	149.6	3.4	13.3	3.6	12.2
Rio Sama Grande	PRC-ME3	455	-17.82	-70.51	2.5	5.5	10.6	0.67	2150	3105	0.3	0.013	73	136.4	4	28.6	5.3	27.7
Ilo / Rio Osmore	PRC-ME5	1072	-17.29	-70.99	2.6	5.1	7.8	0.70	1783	3398	0.26	0.018	53	137.8	3.4	21.4	4.8	18.6
Rio Tambo	PRC-ME6	145	-17.03	-71.69	1.5	3.6	7.5	0.69	12885	3568	0.24	0.051	141	216.3	38.1	89.7	16.7	72.1
Tambillo / Rio Sihuas	PRC-ME802	117	-16.34	-72.13	2.0	6.0	10.0	0.69	1708	3285	0.15	0.019	70	170.2	30.1	34	6.4	27.7
Camana / Rio Majes	PRC-ME7	69	-16.51	-72.64	5.2	8.7	11.6	0.67	17401	3635	0.23	0.005	188	283.9	68.4	127.5	23.4	106.8
Ocona / Rio Ocona	PRC-ME9	14	-16.42	-73.12	4.8	6.8	10.0	0.71	16084	3745	0.26	0.004	192	414.7	91.1	242.1	45	184.1
Nasca / Rio Grande	PRC-ME1402	15	-15.85	-74.26	1.3	3.0	6.0	0.71	1412	2716	0.32	0.014	48	283.6	20.4	46.1	8.6	29.4
Chacaltana / Rio Ica	PRC-ME15	3	-15.63	-74.64	2.9	6.4	9.6	0.73	4677	2204	0.26	0.003	88	188.4	12.1	27	5.7	25.1
Humay District / Rio Pisco	PRC-ME16	400	-13.73	-75.89	3	6.6	13		3649	3464	0.34	0.013	62	272.6	13.6	104.1	20.4	69.1
Chinca Alta / Rio San Juan	PRC-ME17	75	-13.47	-76.14	1.3	3.8	7.6	0.69	3090	3197	0.37	0.01	78	237.8	10.1	61.2	11.7	44.1
Rio Canete	PRC-ME19	23	-13.12	-76.39	2	4.6	8.8	0.72	6029	3648	0.4	0.01	100	318.4	26.4	66.8	12.3	51.2
Rio Omas	PRC-ME20	33	-12.67	-76.65	1.6	4.8	8.8	0.73	2322	3294	0.41	0.0076	78	257.6	8.2	27.1	5.4	17.9
Rio Lurin	PRC-ME22	40	-12.25	-76.89	3	5	8.8	0.74	1572	2568	0.38	0.022	70	175.5	3.7	38.5	7.1	23.6
Lima / Rio Chillon	PRC-ME39	402	-11.79	-76.99	5.3	10.5	15.5		1755	2942	0.39	0.018	51	204.7	4.9	82.2	15.5	53.4
Rio Chancay	PRC-ME23	72	-11.61	-77.24	5.5	8.3	12.5	0.74	3059	2697	0.39	0.01	66	211.4	8.9	97.7	18.4	52.8
Rio Supe	PRC-ME25	74	-11.07	-77.59	2.8	7.7	13		4306	2365	0.38	0.012	82	275.4	3.8	41.7	7.7	25.6
Rio Pativilca	PAT-ME	10	-10.72	-77.77	1.8	3.6	6		4607	3378	0.44	0.014	74	490.6	30.9	260.1	48.8	190.9
Huarmey	PRC-ME38	24	-10.07	-78.16	1.7	3.4	5.2		2072	2337	0.37	0.004	78	340.1	9.8	19.7	4.5	10.1
Rio Santa	PRC-ME27	80	-8.97	-78.62	2	5.4	9	0.72	12313	3262	0.38	0.005	65	571.7	96.1	71.2	13.4	70.4
San Martin de Porres	PRC-ME30	67	-7.32	-79.48	2.9	6.3	10		3882	2292	0.34	0.007	126	472.8	25.4	30.5	5.9	25.8

Table 1 : Location of the sampling sites with the altitude in meters above sea level.
The table also displays grain size results together with the rivers' and basins' properties and hydrological properties.
Morphometric dataset for the sampled drainage basins. All calculations are based on the 90 m resolution DEM (NASA)
The precipitation, water discharge data and the denudation rates are from Reber et al., in review

Fig. 5.

Printer-friendly version

Discussion paper

	Distance from the coast (km)	Altitude (m)	Latitude (°)	Longitude (°)	D50	D84	D96	b/a
GS1	20	69	-16.51	-72.64	5.2	8.7	11.6	0.67
GS2	45	283	-16.37	-72.49	4.8	10	15	0.69
GS3	57	378	-16.28	-72.45	5.4	12.7	21	0.65
GS4	90	700	-16.00	-72.48	3.3	12	22.5	0.67
GS5	106	882	-15.86	-72.45	6.2	19	31	0.71

Table 2: Location of the sampling sites in the Majes basin and grain size results in the Majes basin.

Fig. 6.

	Altitude (m)	*Latitude (DD WGS84)*	*Longitude (DD WGS84)*	***D50 (cm)***	***D84 (cm)***	***D96 (cm)***	***b/a***	*Catchment area (km2)*	*Mean elevation (m.a.s.l.)*	*Mean slope (m/m)*	*Distance form the western escarpment (km)*	*Mean annual precipitation (mm/yr)*	*Mean annual water discharge (m3/s)*	*Shear stress*	*Denudation rates (mm/ka)*	*Denudation rates corrected for Qz content in bedrock (mm/ka)*
Altitude (m)	1.00															
Latitude (DD WGS84)	-0.36	1.00														
Longitude (DD WGS84)	0.46	-0.97	1.00													
D50 (cm)	0.09	0.00	-0.01	1.00												
D84 (cm)	0.14	0.04	-0.03	**0.87**	1.00											
D96 (cm)	0.18	0.02	-0.02	**0.73**	**0.93**	1.00										
b/a	-0.30	0.66	-0.71	0.09	0.00	-0.02	1.00									
Catchment area (km2)	-0.25	-0.12	0.12	**0.31**	0.16	0.04	-0.25	1.00								
Mean elevation (m.a.s.l.)	0.21	-0.38	0.37	0.03	-0.07	-0.03	**-0.49**	0.53	1.00							
Mean slope (m/m)	-0.23	0.72	-0.78	-0.07	-0.10	-0.03	**0.63**	-0.28	-0.20	1.00						
Distance form the western escarpment (km)	-0.32	-0.14	0.14	**0.35**	0.16	0.03	**-0.33**	0.84	0.37	-0.35	1.00					
Mean annual precipitation (mm/yr) (Reber et al., in review)	-0.43	0.65	-0.61	-0.08	-0.16	**-0.23**	0.21	0.44	0.11	0.39	0.30	1.00				
Mean annual water discharge (m3/s) (Reber et al., in review)	-0.30	0.03	-0.01	0.18	0.05	-0.07	-0.13	0.87	0.51	-0.23	0.64	0.66	1.00			
Shear stress	0.45	-0.11	0.14	**0.23**	**0.33**	**0.39**	-0.06	-0.21	0.09	0.06	-0.23	-0.43	-0.37	1.00		
Denudation rates (mm/ka) (Reber et al., in review)	-0.23	0.04	-0.09	**0.34**	0.09	0.00	-0.09	0.56	0.53	0.12	0.48	0.50	0.56	-0.07	1.00	
Denudation rates corrected for Qz content in bedrock (mm/ka) (Reber et al., in review)	-0.22	0.01	-0.04	0.30	0.06	-0.03	-0.17	0.64	0.57	0.05	0.54	0.54	0.65	-0.11	0.99	1.00

Table 3: Results of the statistical investigations, illustrated here as correlation matrix values.
The valuess in bold show significant correlation between the grain size data and the morphometric parameters and basins characteristics

Fig. 7.