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Reply to comment by Jianguo Liu, Wen Yan, Zhong Chen, Han Chen, Jun Lu on "Holocene evolution in weathering and erosion patterns in the Pearl River delta"

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1. Introduction

In their comment on *Hu et al*. [2013], Liu et al. argue that the sediment in two cores collected north of the island of Lantau located in the delta of the Pearl River (Figure 2) is not supplied from the Pearl River but from local sources, or possibly from along the coast toward the east where restricted bay now contain sediment similar in composition to pre-2.5 ka sediment from the two core sites. As a result *Liu et al*. believe that the mineralogy of the Pearl River has not changed substantially during the Holocene in the way that *Hu et al.* [2013] argued but that the observed trend is related to a change in provenance from local to Pearl River starting around 2.5 ka. The trends in clay mineralogy and bulk sediment chemistry seen the cores show changing degrees of chemical alteration and were interpreted by *Hu et al*. [2013] to reflect the influence of changing environmental conditions, particularly monsoon rainfall intensity, and human settlement in the Pearl River basin. One important implication of this conclusion was that interpretation of deep-sea clay records is complicated because if single river systems have variable clay mineral signatures then deep sea records that derive sediment from more than one source are harder to interpret than for example, if the vast majority of the smectite can always be assigned to erosion from Luzon, or all the kaolinite to the Pearl River [*Liu et al*., 2007].

Generally speaking, geologists are in agreement that changing climatic and weathering regimes produce different clay mineralogy and alteration states of the sediment in soil profiles. This material is then transferred to rivers and deposited in the marine offshore [*Nesbitt et al*., 1980; *Thiry*, 2000]. Consequently, the idea that a river would respond to fluctuating environments should not be surprising, unless the response times of weathering to climate change were very long. However, sedimentary systems in SE Asia do generally seem to track monsoon intensity in the recent geological past at the millennial scale [*Boulay et al*., 2007; *Colin et al*., 2010; *Colin et al*., 2006; *Hu et al*., 2012] and these changes are interpreted to be the result of changes in temperature and humidity within basins of relatively stable provenance. Most recently, a core from offshore the Congo system in West Africa was interpreted to reflect both climate change in the Early Holocene and more recent anthropogenic disruption of the landscape [*Bayon et al*., 2012]. In this context, a lack of change in Pearl River sediment during the Holocene when the climate is known have changed substantially would be surprising.

The onset of agriculture has been widely linked to increased erosion rates globally [*Syvitski et al*., 2005], so it would be unusual if the Pearl River with its relatively dense human settlement spanning a considerable length of time did not respond to this influence. The core sites studied by *Hu et al*. [2013] lie in the mouth of the Pearl River, and modern satellite images show them now to be dominantly affected by sediment flux from the north from the modern river (Figure 1). Such a location would also suggest that the Pearl River is the most likely source in the recent past, at least since sea level stabilized close to the present value. Evidence suggesting otherwise would have to be convincing in order to invalidate this rather straightforward assumption, especially given the relative sediment discharge volumes of the Pearl compared to its small neighbors. That the mineralogy in modern Daya and Dapeng Bays is similar to the pre-2.5 ka core sediment does not prove the sediment comes from there, since we do not even know what the mineralogy in those bays was like before 2.5 ka.

2. Current Patterns in the Delta

While there is no doubt that much of the sediment exiting the delta is displaced toward the west by the long-shore current [*Liu et al*., 2009], within the river mouth itself the flux of water and sediment is

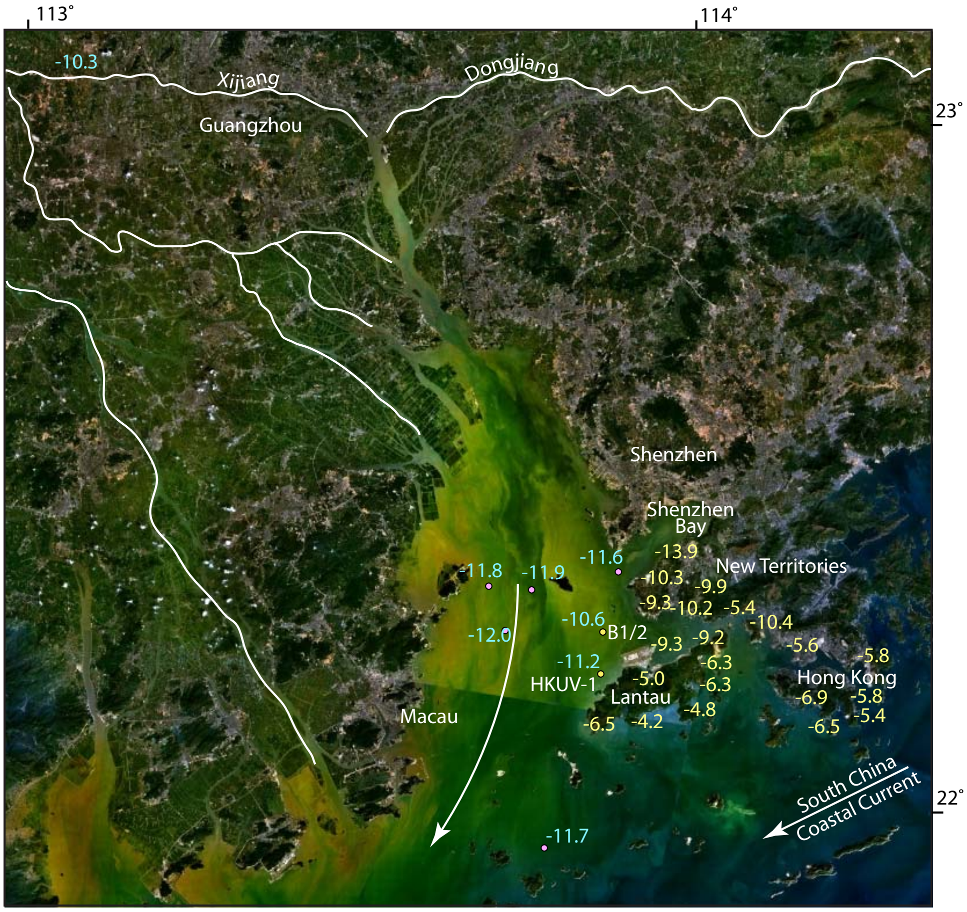

Figure 1. False color satellite image of the Pearl River delta from NASA's Worldwind, showing the core sites, the major river branches and the Nd isotope composition of sediments in the area. The ε_{Nd} values shown at Cores HKUV-1 and B1/2 are the youngest sediments in the cores. Blue colored ε_{Nd} values show surface samples from *Shao et al*. [2009]. Yellow colored ε_{Nd} values are from basement rocks onshore [*Darbyshire and Sewell*, 1997].

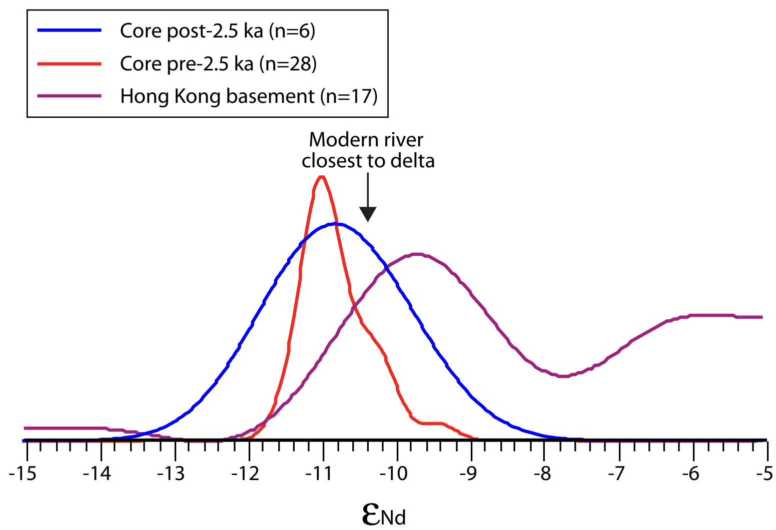

Figure 2. Kernel density diagram showing the range of ε_{Nd} values for the HKUV-1 and B1/2 cores before and after 2.5 ka. We also compare with the most downstream Pearl River sample from *Liu et al*. [2007], as well as basement rocks in Hong Kong adjacent to the coast facing the drill sites [*Darbyshire and Sewell*, 1997]. The core sediments do not change at 2.5 ka and are too negative to be derived from local Hong Kong sources.

dominantly toward the south, with very little sediment being carried from further along the coast to the East. The lack of major sediment flux from the east is one of the reasons that Hong Kong's Victoria Harbor is such a good anchorage because it does not fill up with sediment from these eastern other sources. Sediment from the east would have to pass through the harbor to reach the drill sites and there is scant evidence for significant flux by this route. Moreover, the drill sites are located to the northeast of Lantau Island, which effectively acts as a shield to the currents flowing from east to west along the coast. These currents are restricted south of Lantau and Hong Kong Islands (Figure 1). In order for these long-shore currents to deliver sediment to the sample sites they would either have to come around Lantau Island and against the flow of the Pearl River in order to deliver sediment, or come between Lantau and Hong Kong and the mainland. If any sediment is coming this way then this is now volumetrically insignificant.

Sea level has been constant since $\sim$7 ka [*Siddall et al*., 2003], so there is no reason to believe that the current system would have been radically different in the past when the changes in sediment composition occurred. Furthermore, *Zong et al*. [2009] have shown that the three major tributaries of the Pearl River have been in a relatively stable position, with the confluence close to the modern city of Guangzhou since the Early Holocene, so we know that compositional variations at the core sites are not related to them receiving material from a single tributary in the past. The expectation from the *Hu et al*. reconstruction is that the core sites have been receiving a mixed-signal for much of the Holocene in the way that they are today.

Zong et al. [2010] provide further information that suggests the sediment in Core HKUV-1 is coming from a much wider area than local sources. That study measured isotope ratios and major metal elements from the same HKUV-1 core that *Hu et al*. [2013] studied. These data revealed an expansion in crop production and metal smelting upstream in the Pearl River basin about 2000 years ago. *Zong et al*. [2010] interpreted carbon isotopes from HKUV-1 to indicate input of organic matter from sugarcane, a C4 plant and thus to reflect the spread of agriculture in the delta upstream. There has been no significant agriculture on Lantau or the other Islands in the delta so unless the organic material was derived from a completely different source than the clastic material then the sediments must also have an origin upstream in the main Pearl River, and not be derived from local sources.

If a change from local sedimentation to supply from the Pearl River had been the underlying reason for the compositional change that *Hu et al*. [2013] instead attributed to anthropogenic impact then it would be merely coincidental that this correlates with the time of intensified settlement within southern China and the change in carbon isotopes identified by *Zong et al*. [2010]. In contrast, synchronous change in clay mineralogy and bulk sediment chemistry with changes in anthropogenic proxies [*Zong et al*., 2010] provides a ready explanation for why the erosional regime onshore would be changing. If we are to believe the alternative hypothesis of *Liu et al*. then we might ask why the long-shore current would dominate through much of the Holocene and then suddenly change $\sim$2000 years ago. Such a change is unlikely given the stability of sea level over that time period and the generally slow SE-progradation of the Pearl River delta [*Zong et al*., 2009]. The large volume of the Pearl River, especially within the confines of the delta defined by the Islands and peninsulas of the region would be hard for any longshore current to overwhelm.

3. Provenance Evidence

Two lines of evidence argue that any local contribution to the core sites must have been rather small. The streams that drain the Islands in the Pearl River delta are heavily laden with sand derived from the granites and high silica volcanic rocks that dominate the geology of Hong Kong and Lantau. In contrast, Cores HKUV-1 and B1/2 comprise clay and clayey silt, with no indication of proximal sandy deposits. However, the strongest evidence demonstrating that the sediments analyzed by *Hu et al*. [2013] were dominantly from the Pearl River comes from Nd isotope compositions. Comparison of the youngest sediments in these cores with surface samples from the Pearl River Mouth [*Shao et al*., 2009] show that they have similar values, with the youngest drill samples slightly more positive in ε_{Nd} values than other sediments in the modern delta, but these sediments are substantially more negative that any possible source rocks that could have supplied the cored area (Figure 2). Nd is considered a good provenance proxy because this is not affected by alteration [*Goldstein et al*., 1984] and should not be affected changing environments. In contrast, comparing clay minerals or chemical compositions in coastal rivers or bays with the sediments in the cores as *Liu et al*. do is unreliable because changing environmental conditions could affect these proxies.

Hu et al. [2013] noted a slight change in ε_{Nd} values at HKUV-1 and B1/2, between 8 and 6.5 ka, but there is no such change around 2.5 ka when *Liu et al.* propose a change from local to Pearl River provenance. Figure 2 shows that while there is variability the sediments prior to and after 2.5 ka have essentially the same composition. They also lie close to the published values from the most downstream sediment from the dominant Xijiang tributary [*Liu et al*., 2007], consistent with this being a dominant source. The cored sediment are consistently more negative in ε_{Nd} values compared to local source rocks, especially on Lantau, which is the closest landmass to the drill sites and where granites and rhyolites have ε_{Nd} values as high as -4.2 and no less than -9.3 [*Darbyshire and Sewell*, 1997]. This evidence shows that if there is a local contribution to the sediments then this is rather small compared to the flux from the Pearl River. A dominant local source can be excluded.

4. Conclusions

Sediments sampled from the Pearl River mouth, north of Lantau Island are located directly in the stream of the modern river and have receiving the bulk of their sediment flux from that source since the Early Holocene. Longshore transport does not enter significantly into the river mouth and there is no evidence that it has not done so since sea level stabilized after ~7 ka. Sediment flux rates from the east are small compared to that delivered by the Pearl River and what is contributed mostly passes south of Hong Kong and Lantau Islands away from the core sites. Nd isotope evidence indicates a stable provenance for sediment at the core locations during the Holocene consistent with continuous supply from the Pearl River. Changes in bulk chemistry and clay mineral weathering proxies at core sites HKUV-1 and B1/2, are consistent with what might be expected based on the common interpretation of these proxies being sensitive to changing environmental conditions, both natural and anthropogenic. Although alternative sediment provenances are hard to complete dismiss, there is no compelling evidence to show that a straight-forward interpretation of the delta cores is invalid. The impact of human activities on landscape appears to be significant and the modern Pearl River is not in a natural state compared to before 2.5 ka.

References

Bayon, G., B. Dennielou, J. Etoubleau, E. Ponzevera, S. Toucanne, and S. Bermell (2012), Intensifying weathering and land use in iron age Central Africa, *Science*, *335*, 1219–1222, doi:10.1126/science.1215400.

Boulay, S., C. Colin, A. Trentesaux, S. Clain, Z. Liu, and C. Lauer-Leredde (2007), Sedimentary responses to the Pleistocene climatic variations recorded in the South China Sea, *Quat. Res.*, *68*, 162–172.

Colin, C., L. Turpin, D. Blamart, N. Frank, C. Kissel, and S. Duchamp (2006), Evolution of weathering patterns in the Indo-Burman Ranges over the last 280 kyr: Effects of sediment provenance on Sr-87/Sr-86 ratios tracer, *Geochem. Geophys. Geosyst.*, *7*, Q03007, doi:10.1029/2005GC000962.

Colin, C., G. Siani, M.-A. Sicre, and Z. Liu (2010), Impact of the East Asian monsoon rainfall changes on the erosion of the Mekong River basin over the past 25,000 yr, *Mar. Geol.*, *271*(1–2), 84–92, doi:10.1016/j.margeo.2010.01.013.

Darbyshire, D. P. F., and R. J. Sewell (1997), Nd and Sr isotope geochemistry of plutonic rocks from Hong Kong; implications for granite petrogenesis, regional structure and crustal evolution, *Chem. Geol.*, *143*, 81–93.

Goldstein, S. L., R. K. O'Nions, and P. J. Hamilton (1984), A Sm-Nd isotopic study of atmospheric dusts and particulates from major river systems, *Earth Planet. Sci. Lett.*, *70*(2), 221–236.

Hu, D., P. Böning, C. M. Köhler, S. Hillier, N. Pressling, S. Wan, H.-J. Brumsack, and P. D. Clift (2012), Deep sea records of the continental weathering and erosion response to East Asian monsoon intensification since 14ka in the South China Sea, *Chem. Geol.*, *326–327*, 1–18, doi:10.1016/j.chemgeo.2012.07.024.

Hu, D., P. D. Clift, P. Böning, R. Hannigan, S. Hillier, J. Blusztajn, S. Wang, and D. Q. Fuller (2013), Holocene evolution in weathering and erosion patterns in the Pearl River delta, *Geochem. Geophys. Geosyst.*, *14*, 2349–2368, doi:10.1002/ggge.20166.

Liu, Z., C. Colin, W. Huang, K. P. Le, S. Tong, Z. Chen, and A. Trentesaux (2007), Climatic and tectonic controls on weathering in south China and Indochina Peninsula: Clay mineralogical and geochemical investigations from the Pearl, Red, and Mekong drainage basins, *Geochem. Geophys. Geosyst.*, *8*, Q05005, doi:10.1029/2006GC001490.

Liu, J. P., Z. Xue, K. Ross, J. W. H., Z. S. Yang, A. C. Li, and S. Gao (2009), Fate of sediments delivered to the sea by Asian large rivers: Long-distance transport and formation of remote alongshore clinothems, *Sediment. Rec.*, *7*(4), 4–9.

Nesbitt, H. W., G. Markovics, and R. C. Price (1980), Chemical processes affecting alkalis and alkaline earths during continental weathering, *Geochim. Cosmochim. Acta*, *44*, 1659–1666.

Shao, L., P. Qiao, X. Pang, G. Wei, Q. Li, W. L. Miao, and A. Li (2009), Nd isotopic variations and its implications in the recent sediments from the northern South China Sea, *Chin. Sci. Bull.*, *54*(2), 311–317, doi:10.1007/s11434-008-0453-8.

Siddall, M., E. J. Rohling, A. Almogi-Labin, C. Hemleben, D. Meischner, I. Schmelzer, and D. A. Smeed (2003), Sea-level fluctuations during the last glacial cycle, *Nature*, *423*(6942), 853–858.

Syvitski, J. P. M., C. J. Vörösmarty, A. J. Kettner, and P. Green (2005), Impact of humans on the flux of terrestrial sediment to the global coastal ocean, *Science*, *308*, 376–380.

Thiry, M. (2000), Palaeoclimatic interpretation of clay minerals in marine deposits; an outlook from the continental origin, *Earth Sci. Rev.*, *49*(1–4), 201–221.

Zong, Y., G. Huang, A. Switzer, F. Yu, and W. W.-S. Yim (2009), An evolutionary model for the Holocene formation of the Pearl River delta, China, *Holocene*, *19*, 129–141.

Zong, Y., F. Yu, G. Huang, J. M. Lloyd, and W. W.-S. Yim (2010), Sedimentary evidence of Late Holocene human activity in the Pearl River delta, China, *Earth Surf. Processes Landforms*, *35*, 1095–1102, doi:10.1002/esp.1970.