#Overall comment-REVIEWER 1

Review of "Assessing sedimentological proxies for characterizing tropical storm deposits in the Chandipur coastal region of Bay of Bengal, India: A modern analog for paleotempestology"

Saha et al presents an investigation on the sedimentological characteristics of tropical storm deposits in the Chandipur coasta region by using grain-size distribution, end-member modeling analysis, SEM grain-morphoscopic and microtextural analysis inspired in Mycielska and Woronko (1998), and multivariate statistics. The topic is very relevant to the fields of paleotempestology and coastal hazard assessment because of the studies on forecasting tropical storms and sea level rise deposits remain limited. The authors present a dataset over 5 transects along the Barrier bar located in the Bay of Bengal; for this specific case samples were extracted at ~10 cm from the surface. The manuscript also employs a multi-proxy approach that might have a potential value. However; several aspects of the study require clarification and strengthening before the discussion and conclusions can be fully supported. One of my main concerns goes to the evidence linking the different sediment populations that were identified to the different types of deposits. In the case of the overwash deposition (cluster 3), it is largely inferential and it is difficult to conclude something from Figure 11. Finally, the current manuscript lacks direct validation that the samples obtained were generated by specific documented storm events.

#Response of Comment

We thank the reviewer for their positive assessment of the manuscript's relevance to paleotempestology and coastal hazard assessment, and for the constructive comments that have helped us substantially strengthen the study. We address the reviewer's central concern, that the linkage between the identified sediment populations and specific depositional processes, particularly the overwash interpretation of Cluster 3, was largely inferential through revisions detailed in our point-by-point responses below (Major Comments 1–7). In brief, we have clarified that the storm-overwash attribution of Cluster 3 does not rest on any single line of evidence (e.g., EM4 alone or fractured C-type grains alone), but on the convergent combination of granulometric end-member modelling, Cailleux morphoscopic classification, PCA/cluster analysis, spatial distribution across the barrier–marsh transects, and SEM-based microtextural evidence (Major Comments 1, 3, 4, 5, 6). We have also enhanced Figure 10 to more clearly distinguish the aqueous, aeolian, and overwash depositional environments (Minor Comment 10), and have added zoomed supplementary SEM imagery to better resolve the diagnostic microtextural features referenced in the text (Minor Comment 11). Regarding the reviewer's concern about direct validation against specific documented storm events, we have explicitly clarified and acknowledged this limitation throughout the revised manuscript (Major Comment 2). Our surface-sediment sampling, completed approximately two weeks after Cyclone Titli's landfall, cannot resolve event-specific attribution to individual storms (e.g., distinguishing the contributions of Cyclone Titli from the earlier Tropical Storm Daye or associated depressions). We have therefore reframed the study's objective accordingly: rather than attributing the sampled deposits to a specific documented storm, our aim is to characterize the sedimentological and micromorphological signatures that distinguish storm-associated overwash deposits from the surrounding background depositional regime, establishing a modern sedimentological analogue that can support future paleotempestological investigations when combined with independent chronological and stratigraphic evidence. We believe these revisions, together with our detailed responses to each major and minor comment below, address the reviewer's principal concerns and have substantially improved the clarity, rigor, and interpretive transparency of the manuscript

Major-comments:

#Comment 1- Insufficient validation of the overwash deposition

One of the main conclusions of the manuscript is that EM4 and the associated morphoscopic cluster (NU and C grains) represent storm-overwash deposits (Fig. 10). Nevertheless, this interpretation seems to be based on grain-size characteristics and the presence of fractured grains, which can be a good assumption, but other high-energy coastal processes are not excluded. In addition, the presence of this distribution over most of the transects is not well discussed.

REPLY:

We thank the reviewer for this important comment. We have clarified and strengthened the discussion in the revised manuscript to make the basis of the storm-overwash interpretation more explicitly. The attribution of Cluster 3 is not based solely on EM4 or fractured C grains, but on the combined evidence from grain-size end members, Cailleux morphoscopy, PCA and cluster analysis, followed by spatial distribution and SEM-based microtextural observations. EM4 shows a positive association with C and NU grains, and these characteristics collectively define Cluster 3. Its concentration in the northeastern and central sectors of the back-barrier marsh, together with the relatively coarse and angular grain population, supports an interpretation involving episodic high-energy landward sediment transport. We have expanded this discussion in the revised manuscript and related the observed association to storm-driven overwash in the barrier–marsh setting.

#Comment 2- Temporal mismatch between storm events and sediment sampling

The manuscript states that surface sediments were collected in 2018 from the upper ~10 cm of sediment. A 10 cm thick surface sample may integrate multiple depositional events occurring over months or years. Consequently, it is difficult to directly associate the observed sediment characteristics with specific storms such as Daye or Titli. The authors should discuss the temporal resolution of the sampling strategy and the extent to which the sampled material can realistically be attributed to individual storm events.

REPLY:

We thank the reviewer for this important comment. Regarding the sampling timeline, the overwash sampling was completed approximately two weeks after Cyclone Titli's landfall in October 2018. This timeframe is consistent with previously studied washover deposits that were sampled within 3 weeks to 2 months following storm landfall (Williams, 2015; Ketthong et al., 2024). Regarding the extent of the overwash collection, the deposit (~10 cm thick) shows direct contact with the subsurface marsh deposit at the distal portion of the washover lobe, while the proximal portion overlies the vegetation of the coastal barrier dunes. Regarding the records of the storm Daye and cyclone Titli, which made landfall two months and two weeks before our sampling, we could not differentiate the individual deposition of these two events. We acknowledge this limitation; however, our study is not intended to provide event-scale attribution of sediment to individual storms. Rather, our objective is to characterize the sedimentological associations of the barrier–marsh system and develop a modern analogue for tempestological investigations.

#Comment 3- Interpretation of fractured grains (C grains)

The manuscript repeatedly interprets fractured grains as indicators of storm activity due to high-energy collisions and other factors. While previous studies have reported similar observations, fractured quartz grains can originate from multiple processes including sediment recycling, beach swash processes, mechanical weathering, and fluvial transport. The authors should better justify why fractured grains in this setting specifically indicate storm overwash rather than generic high-energy transport.

REPLY:

We thank the reviewer for this important observation. We have clarified that fractured C-type grains are not interpreted as uniquely diagnostic of storm activity, but as evidence of high-energy mechanical modification. In the present barrier–marsh setting, their significance for storm-overwash interpretation comes from their co-occurrence with the relatively coarse EM4 population and fresh angular NU grains, their occurrence within the interior back-barrier marsh, and the associated SEM microtextural features. This combination indicates episodic high-energy landward sediment transport rather than simply local high-energy reworking. Because storm-driven inundation provides a plausible mechanism for transporting coarse, angular beach/intertidal sediment across the barrier into the back-barrier marsh, the C-grain population, together with the other sedimentological proxies and spatial context, is interpreted as consistent with storm-related overwash rather than as an independent storm indicator.

#Comment 4- End-member interpretation requires stronger support

The assignment of EM1–EM4 to distinct transport modes (suspension, suspension with saltation, aeolian transport, and overwash transport) appears largely conceptual. No independent hydrodynamic measurements or transport modelling are shown to validate these interpretations. The authors should explain more clearly how each end-member was linked to a specific transport process and discuss uncertainties associated with these assignments.

REPLY:

We thank the reviewer for this important comment. Regarding the association of granulometric end-members with distinct transport modes, these interpretations are generally based on characteristic grain-size distribution curves and their sedimentological context. Rahman and Plater (2014), for example, demonstrated that distinct grain size components can be related to different aqueous transport modes, with a relatively coarse “fast-tide” component associated with saltation and traction load under faster tidal velocities and a finer “slow-tide” component associated with settling from suspension during slower flow velocities. In the present study, EM1 is interpreted as analogous to the finer, suspension-dominated component, whereas EM2 is interpreted as representing the relatively coarser population associated with comparatively stronger flow conditions. Similarly, Rodriguez et al. (2013) have shown that the grain-size distribution curves of washover deposits are characterized by a coarser mean grain size and poorer sorting than aeolian-transported dune sediments, supporting the interpretation of the relatively finer and better-sorted EM3 as an aeolian-associated end-member and the relatively coarser EM4 as an overwash-associated end-member.

#Comment 5- Cluster analysis may reflect environmental gradients rather than process groups

The PCA and cluster analysis identify three groups interpreted as aqueous, aeolian, and overwash deposits (Fig. 10). However, the observed clustering may simply reflect spatial gradients across the barrier-marsh system. The authors should demonstrate that the clusters represent distinct depositional processes rather than a continuum of environmental conditions.

REPLY:

We thank the reviewer for this comment. We interpret the three clusters as sedimentological associations consistent with different depositional processes, while acknowledging that their spatial distribution partly reflects environmental gradients across the barrier–marsh system. However, the clustering is not based on spatial position alone; rather, it arises from distinct depositional processes that produce three different sediment distributions, characterized by different grain-size ranges and morphoscopic characteristics of individual grains.

#Comment 6- Limited use of SEM microtextural evidence

SEM analysis is presented as an important component of the study, yet the interpretation remains largely qualitative. The manuscript would benefit from more detailed presentation of representative SEM images and clearer explanation of how specific microtextures distinguish storm transport from normal marine reworking. From Figs. 6, 12 and 13, it is hard to see the difference between shine and mate particles.

REPLY:

We thank the reviewer for this important comment. The differentiation of storm-deposited grains from normally deposited or reworked grains has been investigated in earlier research by Costa et al. (2012). For example, storm-deposited grains have been reported to exhibit angular and fresh surfaces, a relatively higher abundance of adhering particles, and dissolution features compared to the adjacent nearshore deposits. Regarding the difference between shiny and matte particles, this distinction can be observed only in the grains documented under the optical microscope (Fig. 6). However, it cannot be observed in the SEM images because the imaging was performed using secondary-electron imaging, through which surface lustre cannot be assessed.

#Comment 7- Lack of comparison with documented modern overwash deposits

Several studies have described sedimentological characteristics of known storm deposits from other regions. A more detailed comparison between the Chandipur deposits and established modern overwash analogs would strengthen the interpretation.

REPLY:

We thank the reviewer for this valuable suggestion. We have expanded the discussion by comparing the Chandipur sedimentological characteristics with documented modern storm-overwash deposits, including Tropical Cyclone Pam in Vanuatu (Hong et al., 2018), Superstorm Sandy at Tiana Beach, New York (Bennington & Farmer, 2015), and hurricane-induced event beds in a New England salt marsh (Castagno et al., 2021). We also discuss recent storm-deposit studies and quartz-grain studies from the eastern Baltic (Kalińska-Nartiša et al., 2018, 2024).

#Minor comments:

#Comment1-

From line 87-91: this paragraph has to be more specific. Here the authors can relate the grain characteristics (size, shape, etc) to the storm derived sediments.

REPLY:

We thank the reviewer for the suggestion. The paragraph has been revised to more specifically relate grain-size, sedimentary end members (EMMA), grain morphology, and SEM microtextures to storm-induced high-energy sediment transport. The modified portion is provided below:

"Accordingly, this study employs a combination of sedimentological techniques, including granulometric analysis to characterize grain-size distributions, End-Member Mixing Analysis (EMMA) to identify and quantify sedimentary end members, grain-surface morphological analysis to assess grain shape and surface characteristics, and scanning electron microscopy (SEM)-based microtextural analysis to identify surface features associated with sediment transport and mechanical modification, thereby characterizing sediments associated with storm-induced high-energy transport."

#Comment-2 Line 118-119: *explain why the samples were only at 10cm from the surface*

REPLY: We have addressed this point in our response to **Major Comment 2** above.

#Comment-3 Line 127-129: explain better why the authors used a solution of (NaPO3)6.

REPLY: We thank the reviewer for this suggestion. We have clarified the purpose of using sodium hexametaphosphate in the sample preparation procedure. The revised text now states:

"A volume of 10 mL of a 0.05 normal solution of sodium hexametaphosphate $(NaPO_3)_6$ was introduced into the sample as a dispersing agent to minimize flocculation and promote the separation of aggregated fine particles before conducting the measurement."

#Comment-4 Line 155: *Why the samples were sieved only for the grain morphoscopic and microstructural study? This comes back to the grain size distribution. It should be well explained. The reader can get confused.*

REPLY: We clarify that sieving was performed specifically to separate the sediment into specific grain-size fractions for morphoscopic analysis and was not used to determine the bulk grain-size distribution. Accordingly, we have modified the methodology to clarify the purpose of the sieving procedure and avoid confusion with the granulometric analysis. The revised section is pasted below

"In addition to the granulometric analysis, grain morphoscopic analyses were performed on all the samples of the five transects. All samples were sieved for 20 minutes, following the method of Mycielska-Dowgiałło (2007). The roundness and surface features of the grains were determined using a Nikon microscope at a magnification of 50×, following Kalinska-Nartisa et al. (2018). The characteristics of quartz grains were classified according to two criteria: (1) grain shape, including angular, partially rounded, and well-rounded forms, and (2) surface type, including matte and shiny surfaces, following the Cailleux (1942) methodology, subsequently extended by Mycielska-Dowgiałło and Woronko (1998)."

#Comment-5 Line 172-178: *There is too much explanation on the SEM details, instead, the authors should focus more on the characterization of rounded/angular shine/mate surfaces. This process seems that was very random.*

REPLY: We thank the reviewer for this suggestion. The classification used for the characterization of grain shape and surface characteristics, particularly the rounded/angular and shiny/matte surface features, follows the established Cailleux (1942) methodology, as extended by Mycielska-Dowgiałło and Woronko (1998). This methodology has been applied in combination with other sedimentological proxies to strengthen interpretations of sediment transport and depositional environments, including aeolian grains and aeolian transport (Martewicz et al., 2022), high-energy and flood-related sediment transport (Martewicz et al., 2025), storm-related coastal deposits (Kalińska et al., 2024).

#Comment-6 From section 3.3 on: *authors called EM as the end-member method, but sometimes, I got confused with the other nomenclature (shape/brightness), what about the authors renamed as EMMA as stated in section 3.1*

REPLY: Thank you for this valuable observation. As suggested, we have renamed the end-member analysis as End-Member Mixing Analysis (EMMA) throughout the manuscript, while retaining EM/RM only for the classification of grain shape and surface characteristics to avoid confusion.

#Comment-7 Section 3.4: *This section should be enhanced, this is the one that leads the discussion and conclusions. See major comments.*

REPLY: We thank the reviewer for this suggestion. Now, as suggested we have enhanced the role of regional dynamic drivers in the manuscript. The revised section is pasted below

"The region experienced several storm events during 2018. During 2018, the tropical storm Daye and a Category 3 cyclone Titli had major impacts, along with three deep depressions, Land Depression 02, 03, and 05, as named by the IMD (Supplementary Figure 1). During the occurrence of these events, it was observed that wind velocities reached maximum speeds ranging from 10 to 20 m/s. These storm events coincided with a marked increase in significant wave height, peaking at approximately 2.5–3.2 m against a non-storm background generally below 1 m, which, combined with elevated wind speeds, is consistent with enhanced onshore sediment transport dominated by overwash events (Supplementary Figure 2)."

#Comment-8 Line 229: *Authors say that only CL3 to CL5 have moderate to poor sorting, but I see that all the transects have this distribution (Fig.2)*

REPLY: We agree with the reviewer's observation and have revised the relevant statement in the manuscript to accurately reflect the observed sorting distribution across all transects (Figure 2).

#Comment-9 *Figure 4 and 5 should have a label of the colormaps, what the colors represent?*

REPLY: We thank the reviewer for this helpful observation. The colour scales in Figures 4 and 5 have been revised and clearly labelled to indicate the meaning of the colour gradients. In Figure 4, the colour scale represents the EM contribution (%), ranging from 0% (yellow) to 60% (red). In Figure 5, the colour scale represents the frequency (%) of the respective quartz-grain morphoscopic categories, ranging from 0% (yellow) to 60% (red). The modified figures are pasted below:

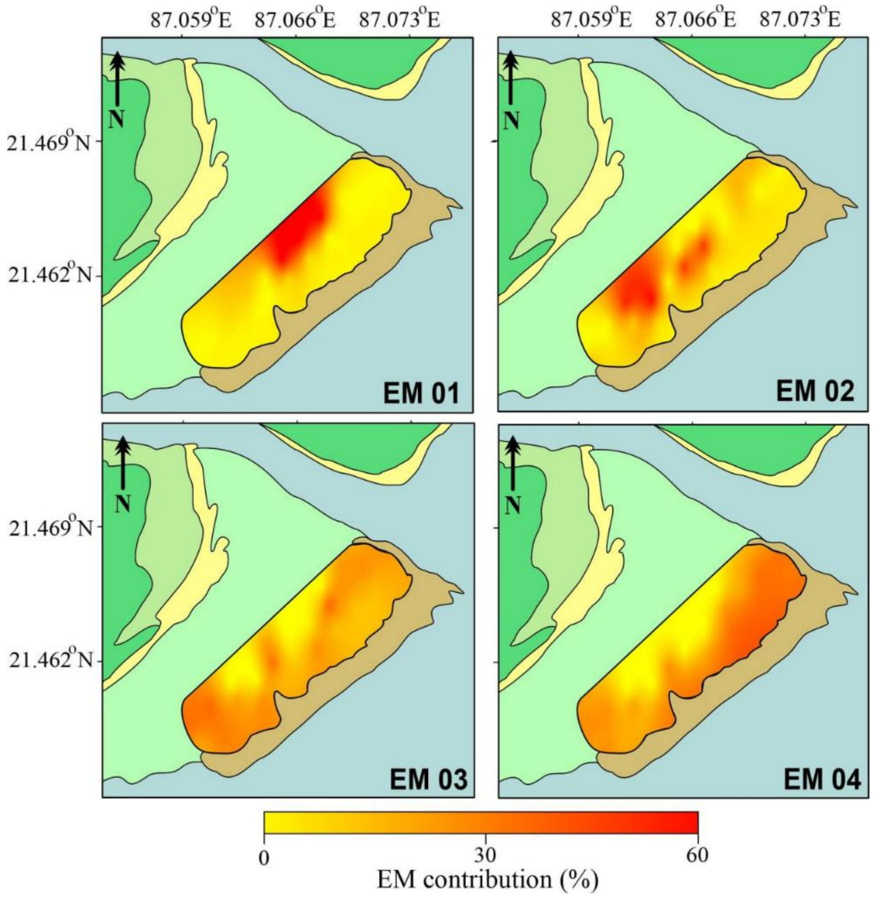


Figure 4: The presented graphs depict the spatial representation of the four end-member contributions.

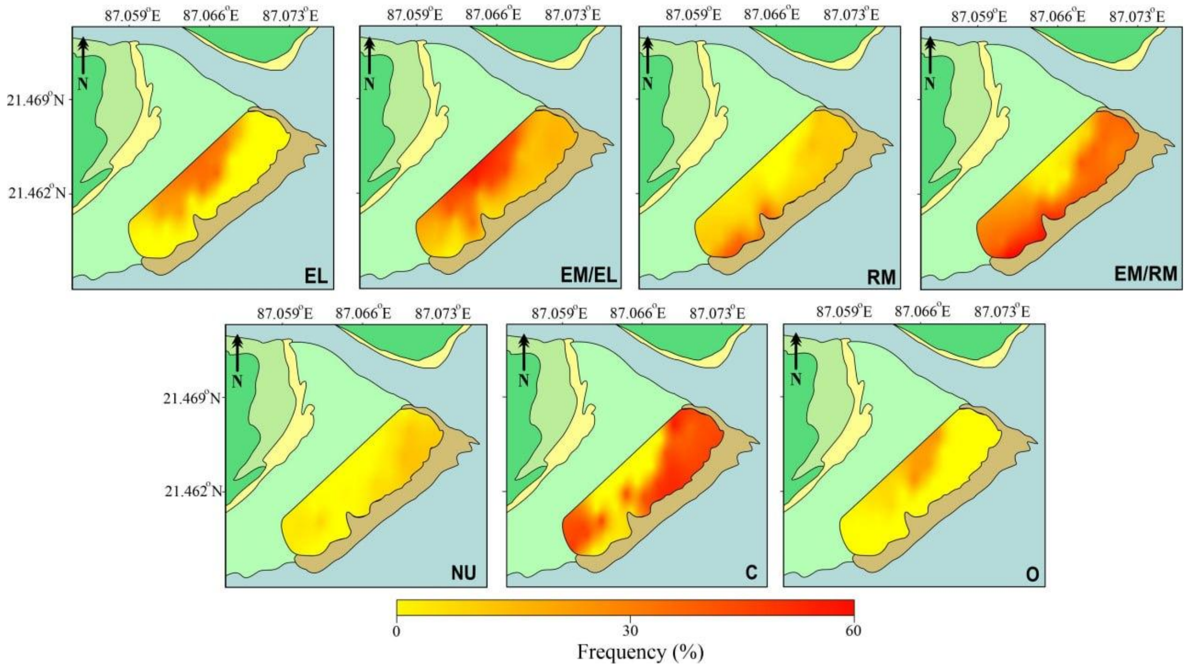
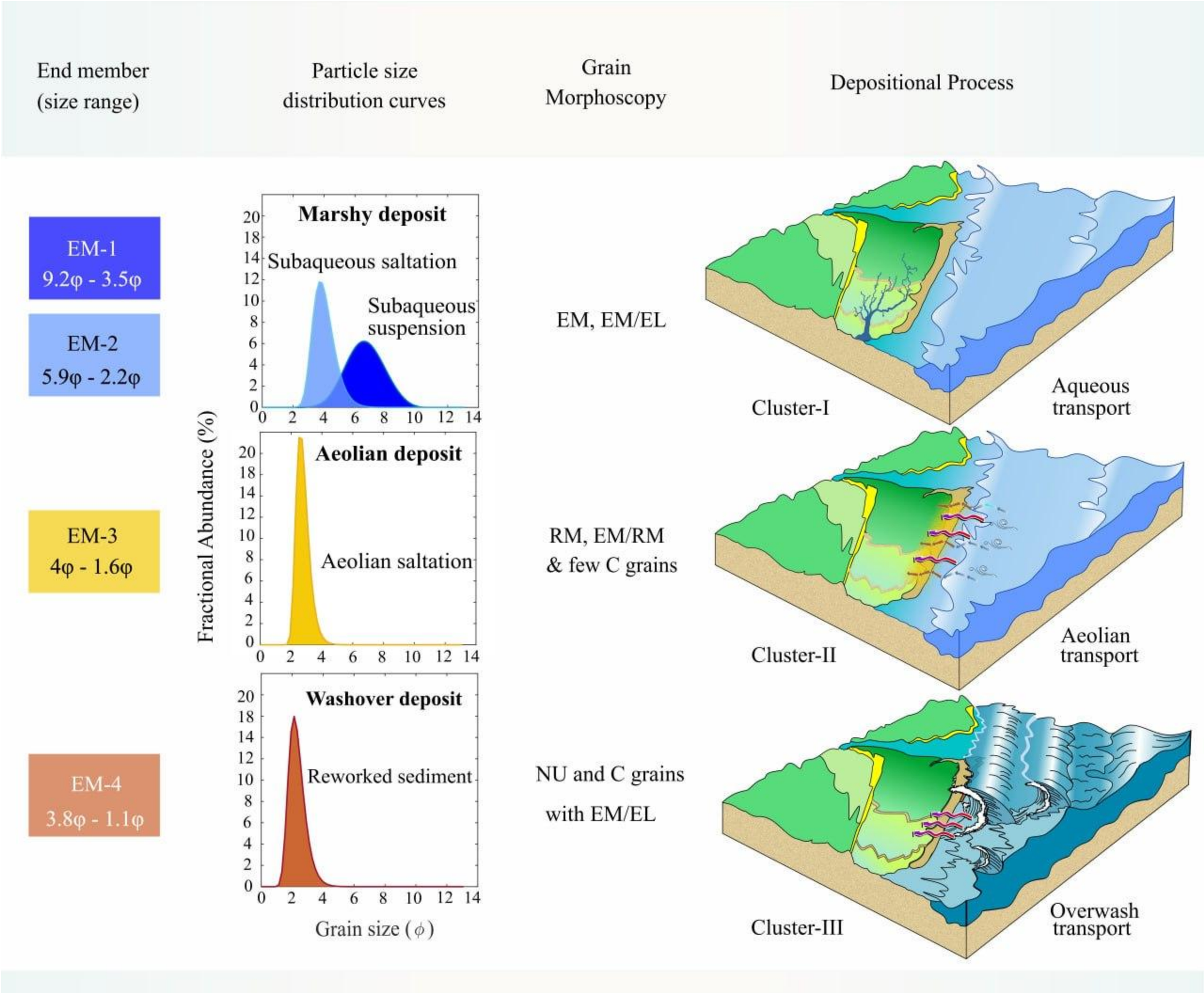


Figure 5: The spatial distribution of frequency distributions of all classes of quartz grains (RM, EM/RM, EL, and EM/EL, NU, C, and O) are presented in these graphs.

#Comment-10 *Figure 10: In my opinion, this is the most important figure in the manuscript; however the last column should be enhanced, it is difficult to distinguish the aqueous, aeolian, and overwash transport.*

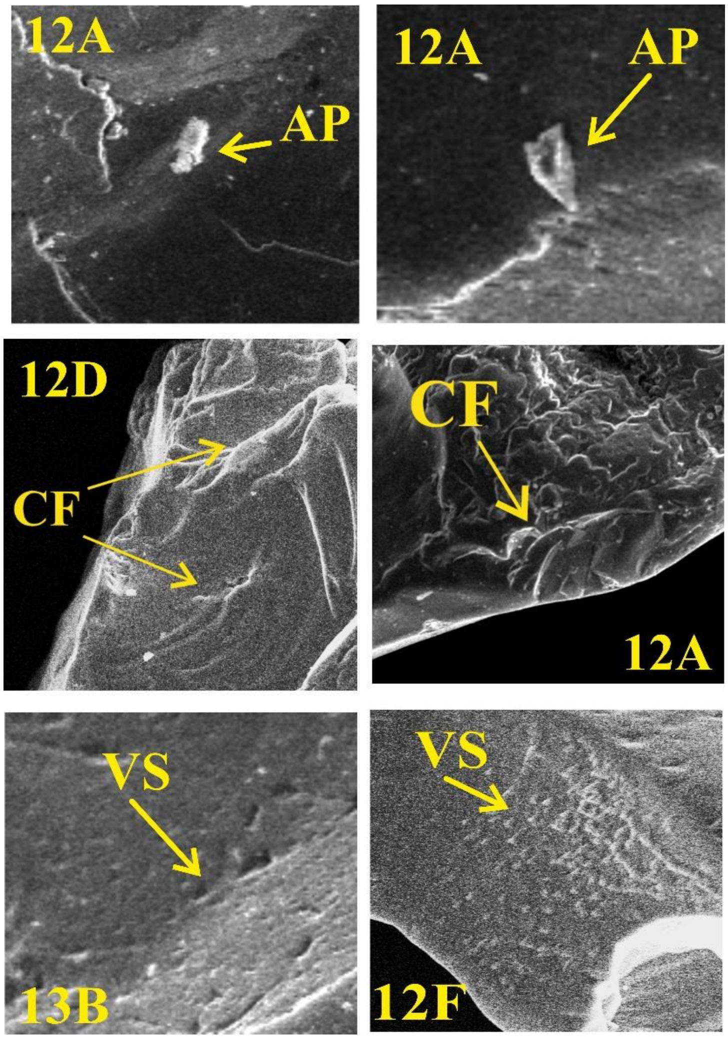
REPLY: We thank the reviewer for this valuable observation. As suggested, we have enhanced the size and clarity of the last column in Figure 10 to improve the distinction among the aqueous, aeolian, and overwash transport/depositional environments. The modified Figure 10 is provided below:



End member
(size range)
Particle size
distribution curves
Grain
Morphoscopy
Depositional Process
EM-1
9.2φ - 3.5φ
EM-2
5.9φ - 2.2φ
Marshy deposit
Subaqueous saltation
Subaqueous
suspension
EM, EM/EL
Cluster-I
Aqueous
transport
EM-3
4φ - 1.6φ
Aeolian deposit
Aeolian saltation
RM, EM/RM
& few C grains
Cluster-II
Aeolian
transport
EM-4
3.8φ - 1.1φ
Washover deposit
Reworked sediment
NU and C grains
with EM/EL
Cluster-III
Overwash
transport
Fractional Abundance (%)
Grain size (ϕ)

#Comment-11 *Figure 12 and 13: The images should be zoomed in to see the real differences of the patterns described. For me, it is difficult to differentiate CF, AP, and VS.*

REPLY: As suggested, some zoomed detailed observations are provided as separate new supplementary figure. The figure is pasted below:



Supplementary figure 3: Enlarged scanning electron micrographs of selected quartz-grain surface microtextures described in Figures 12 and 13. The labels 12A, 12F, and 13B correspond to the respective panels in the main-text figures and indicate the source micrographs from which the enlarged features are presented. AP = adhering particles, CF = conchoidal fracture, and VS = V-shaped percussion marks.