Interactive comment on "Controls on the distribution of the soil organic matter in mountain permafrost regions on the north Qinghai-Tibet Plateau" by C. Mu et al.

Anonymous Referee #3

1. Unfortunately, this manuscript falls short of delivering what is in the title. The authors present a very comprehensive and valuable dataset from deep boreholes. This data certainly warrants publication, but it also warrants more careful scientific analysis and context. The strength of the data is the deep boreholes, but the authors have failed to address how long term accumulation may affect SOM.

Response: Thank you very much for your helpful review. We appreciate your acknowledgement of the difficulty in obtaining this data from deep boreholes. We revised this manuscript in the revised version according your comments and suggestion. Detailed information was listed as the responses.

2. As the authors themselves point out, high-latitude regions are highly dynamic and sensitive to environmental change. Therefore, the basic hypothesis that SOM at 20 m depth is controlled by the present day surface vegetation community seems rather implausible and needs further justification.

Response: Thanks. We realized that the fundamental mechanisms for the SOC accumulation and preservation were the soil formation and paleoclimatic conditions. However, these data were largely unavailable or difficult to perform statistical analysis since they are difficult to be

described quantitatively. In contrast, the vegetation and soil texture are more accessible, therefore, if close relationships between vegetation and soil texture could be found, it would be potentially helpful to upscale deep SOC to a regional scale in the future.

We expected these relationships based on three concepts: 1) In a small area, the climatic conditions are similar; 2) The difference of present vegetation reflects the topography and pedogenesis for different sites; 3) The differences of topography and pedogenesis among different sites have been lasted long time during the accumulation of the SOC.

The statistical analysis showed there were close relationships between the SOC and soil textures and vegetation types and the relationship should be explained as that these factors reflect the process of SOC accumulation and preservation instead of controlling factors. Therefore, in the revised version, we changed the title into "Close relationships between deep organic carbon and soil texture with vegetation types in permafrost regions over Heihe River basin, Qilian Mountains, China".

To clarify the relationships between SOC and vegetation and soil texture, we added the effects of soil formation process on the Qinghai-Tibetan Plateau in the discussion section in the revised version as below:

"From the basic theory of SOC in permafrost carbon and results from this study, a conceptual framework was proposed as Figure 7. Topography has been long recognized as an important factor in the distribution of permafrost and soil water content (Noetzli et al., 2007), and consequently has important effects on the vegetation types (Wang et al., 2006). The landform determined sediment processes and even soil textures during pedogenesis (Yoo and Mudd, 2008). In this study, the PT9, EB1 and EB2 sites have north facing aspects with poor drainage

conditions, and thus belong to swamp meadow types. The distribution of PT sites follows a pattern from mountain hills to mountain foot along with elevation gradients: (PT9, PT6) > PT7 > PT4 > PT5 > (PT10, PT11, PT12). From the vegetation types, it could be seen that drainage conditions, which usually were greatly affected by microrelief conditions (Schoeneberger, 2002), are extremely important to vegetation types (Tab 1). In QTP, previous studies showed that soil texture, vegetation, and soil water content are of great importance for the existence of permafrost (Wang et al., 2012; Wu et al., 2015). This framework was consistent with the basic theory of SOC accumulation and preservation (Wang et al., 2012; Wu et al., 2015). It has been also known that the fine particles can protect the SOM from decomposition by the adsorption effects (Jardine et al., 1989), and soil water could be a controlling factor in microbial decomposition through limit the microbial growth and oxygen availability (Mu et al., 2016). In addition, soil water content interacts with texture and vegetation (Mohanty and Skaggs, 2001). This study showed close relationships between soil texture, water content, vegetation and SOC. Therefore, the effects of these factors on the SOC could be both direct and indirect, which via the permafrost (Fig. 7). From this schematic diagram, it is obvious that geomorphology is the fundamental factors in the determination of SOC by the mechanisms of pedogenesis."

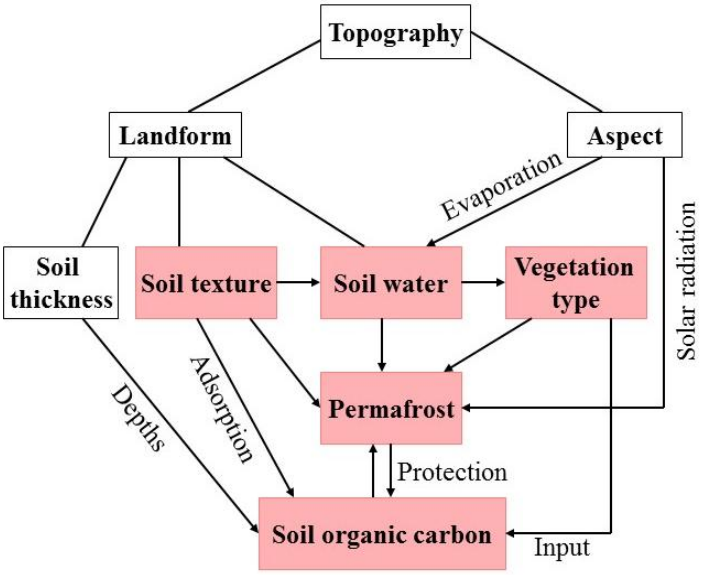

Figure 7 A schematic diagram for the relationship between environmental factors and soil organic carbon (SOC) in mountain permafrost area. The solid lines show the components of environmental conditions, arrows show the direct effect of one factor on the other. There is also another possible effect of soil water content on the soil organic carbon via affecting the microbial growth and oxygen availability (Mu et al., 2016).

"The QTP is a young plateau that was uplifted since Palaeogene epoch, and the parent materials for soils distributed in the vast areas on the plateau were mainly alluvium associated mountain processes (Zheng and Yao, 2004). Therefore, the sampling area could be potentially considered as example for the study of SOC distribution for the other areas on the QTP. Since the sampling area for PT sites is less than 100 km^2, and has similar meteorological conditions, thus the great differences for SOC among these sites could be attributed to the difference of topography, which affects the SOC via the pedogenesis (Fig.7). For the deep SOC stocks, the paleoclimatic conditions may also played important roles during the SOC accumulation (Schuur et al., 2009). However, this data is largely unavailable, which limited the further study of deep

SOC in mountain permafrost. This study showed that the SOC both in upper layers and deep layers, which could be down to tens of meters, has close relationship with vegetation and soil texture. Although the accumulation process of SOC is difficult to be interpreted in this study due to the lack of chronological sequences of the soil layers, the results demonstrated that vegetation types and soil textures are useful proxies for the predictions of SOC in both upper and deep layers. Since these data are more accessible in regional scale (Li et al., 2015; Wang et al., 2016), it would be possible to upscale the SOC pools in the regional scale using vegetation types and soil texture data in the future."

3. The boreholes used in this study were drilled into thick alluvial and colluvial deposits in areas of accumulation. It is highly likely that various geomorphic process have affected the erosion as well as deposition/sedimentation of sediment in the uphill areas of these locations, together with vegetation dynamics, surface hydrology, active layer dynamics etc. has exerted a strong control over SOM distribution and chemistry. These processes have been acting over many millennia and to state that present day surface vegetation controls the SOM distribution to depths of 20 m is a gross oversimplification. The authors should consider addressing the issue of different landforms/depositional environments instead. Table 1 provides an idea of the type of geomorphic characterization the authors can pursue to analyze these issues.

Response: Thanks very much for your valuable comments. After carefully looking over the sampling sites, we realized that the soil thickness was related to the geomorphic conditions, thus the pedogenesis affected the SOC accumulation and preservation. After a carefully consideration, the geomorphic characterization is difficult to describe quantitatively and could not be performed

statistically analysis. Therefore, we presented a schematic diagram (Figure 7) in the revised version to discuss about this. The revisions were seen as the response to Question 2.

4. The authors also show interesting analyses of the influence of soil texture on SOM and briefly mention the possibility of changes in vegetation communities over time affecting the stable isotope ratio of carbon.

Response: Thanks for the comments.

5. Pertinent follow up questions are: How is soils texture linked to landforms? What is the age of different investigated strata? Is there any link between vegetation and soil texture and/or slope stability? I would recommend that the authors pursue these results in more depth. While vegetation seems like a useful proxy, especially since it is easy to map and scale, the authors present no evidence to support that the vegetation has remained the same in these sites over the long times when these sediments accumulated.

Response: Thanks very much for these interesting questions. The statistically analysis showed that close relationship between the SOC and texture and vegetation types. However, this should not be explained as the controlling factors, it should be more appropriate to attribute the accumulation of SOM to the soil formation process, which links to the factors you mentioned above. As our response to Question 3, these factors were difficult to describe quantitatively and could not perform statistical analysis, we present a schematic diagram to discuss the relationship to landform, as well as the links between the vegetation and soil texture and slope.

(1)How is soil texture linked to landforms?

This was revised as below:

"From the soil textures (Fig. 5), it could be found that the ASM sites were mainly silt loams (EB1, EB2, and PT9), AS sites (PT10, PT11, PT12) were mainly sandy loams, while other sites (PT4, PT5, PT6, PT7) have both silt loans and sandy loams, which depended on the depth. This pattern was closely related to the locations of these sites (Fig. 1), i.e., ASM sites located at hillslopes, AM sites located at mountain valley. Interestingly, and the soil thickness, which is also a factor affects SOC because it is an independent factor in the calculation of SOC stocks for a certain depth, largely showed an opposite trend (Fig. 2). From the modes of pedogenesis in mountain area (de Vente and Poesen, 2005; Dietrich and Dunne, 1978), it could be explained as the fine particles in mountain foot and mountain valley have been transported by water. In many areas, the stability of slope usually plays an important role in vegetation (Greenway, 1987; Norris et al., 2008). The slopes of the sampling sites in this study were always smaller than 2.5^{o}, and even with flat landform. The sampling sites were selected at areas without signals of instability of slope during the field work. Thus the slope stability seems not to be an important factor affecting vegetation and soil textures in the present study. Overall, topography, which mainly consists of slope, aspect, and landform, greatly affects the soil texture and further affects the SOC pools."

(2) What is the age of different investigated strata?

This is of great interesting questions pertinent to the SOC accumulation process. Unfortunately, we did not perform the chronological analysis of these samples. Although our goal is to study the patterns of the deep SOC in permafrost regions, we clarified this in the revised version as below:

"Although the accumulation process of SOC is difficult to be interpreted in this study due to the lack of chronological sequences of the soil layers, the results demonstrated that vegetation

types and soil textures are useful proxies for the predictions of SOC in both upper and deep layers."

(3) Is there any link between vegetation and soil texture and/or slope stability?

The relationship between vegetation and soil texture was explained as Figure 7 (See response to Question 3).

For the slope stability, we discussed as below:

"In many areas, the stability of slope usually plays an important role in vegetation (Greenway, 1987; Norris et al., 2008). The slopes of sampling sites in the study were always smaller than 2.5^{o}, and even with flat landform. The sampling sites were selected at areas without signals of instability of slope during the field work. Thus the slope stability seems not to be an important factor affecting vegetation and soil textures in the present study. Overall, topography, which mainly consists of slope, aspect, and landform, greatly affects the soil texture and further affects the SOC pools."

We hope these work would be helpful to the potential readers so they can understand the soil formation process need future work to explain the effects on the process of SOC accumulation.

6. The statistical analyses performed show that the basic SOM chemistry follows patterns described by many other authors. They do not, however, yield any new insights into the controls of SOM in the north Qinghai-Tibet Plateau. At a more detailed level, I am also concerned that some of the unexpectedly high C:N values may be due to very low N% values possibly close to detection limit? In some cases I also wonder about the rationale behind analyses? There is no deeper mechanistic explanation provided for the correlation of % water content to SOC. Also, I

would strongly recommend that the data be made available together with the final publication of this data.

Response: Thanks for your interesting on our original data and encourage us to dig deeper in the data. Our main goal was to explore the patterns of the SOC in deep soils. This was emphasized in the revised version.

We have carefully checked the original data of the nitrogen, the nitrogen contents were largely higher than 0.2 g/kg, which were above the detect limit of the elemental analyzer. In addition, the samples have been analyzed in triplicate, and thus the high C:N ratios were reliable in this study.

The rationale behind the analyses could be excluded from the statistical analysis. However, as you mentioned, the statistical analysis found the relationship, the relationship probably does not mean the mechanisms. Thus the deeper mechanistic explanation was added in the revised version accompanied with the schematic diagram (Response to Q2 to Q3).

For the original data, we also submitted it as supplementary materials. Unfortunately, this data could not be found in the TC Discussions. We submitted it again and provide the link of the data as below:

"All the original data were available on the website of The Cryosphere Discussions (http://editor.copernicus.org/index.php?_mdl=msover_md&_jrl=25&_lcm=oc73lcm74a&_acm=get_supplement_file&_ms=50278&id=704538&salt=1523858444357408567)."

7. With the present analyses I would not recommend that this paper is published in The Cryosphere. The statistical analyses are limited and seem more spurious than hypothesis-driven. While an extensive dataset is available, I find that the authors provide little conclusions or results to significantly increase understanding of SOM accumulation or development in the north

Qinghai-Tibet Plateau. I recommend that the authors take the opportunity to re-examine their extensive dataset and look critically at which landscape processes have led to the interesting SOM dynamics we see in these boreholes.

Response: Thanks very much for the comment. We have revised it substantially, changed the title of the manuscript, and discussed the roles of landscape processes in the SOM accumulation and preservation in the mountain permafrost regions.