Response to Reviewer 1

Thank you for your comments and valuable feedback on my manuscript. Based on your feedback and that of two other reviewers, I have made major revisions to my manuscript. The details of the revisions are listed below. To make it easier for you to re-review, I have highlighted the revised sections in yellow in the manuscript.

Comments: After going through the introduction of the article, I have a very hard time understand the purpose of this contribution and the authors ignore several decades of research done in the area related to provenance and paleoclimatic reconstructions. I dont see how utilizing 16 samples from a well can therefore help unravel complex tectonic and paleoclimatic processes that are characteristic of the area during the middle Permian.

Based on your feedback, I have rewritten the abstract of the paper as follows:

Turpan-Hami Basin, Junggar Basin and Bogda area all belong to the southern part of the ancient Asian ocean in the Paleozoic era (Korobkin and Buslov, 2011; Jiang et al., 2015). During the Early Carboniferous to Early Permian, they began momentously to separate due to the continuous expansion of the Bogda Rift and began to enter the basin-forming period in the Middle Permian (Miao et al., 2004; Novikov, 2013; Jiang et al., 2015; Wang et al., 2019; Zhang et al., 2019). The Middle Permian is a momentous stage in the tectonic evolution of the Turpan-Hami basin. During this period, the expansion of the Bogda Rift stopped. With the gradual withdrawal of seawater from Xinjiang, the sedimentary environment of the Turpan-Hami basin gradually shifted to continental facies, and the sedimentary center gradually shifted from the Bogda area to Taibei Sag (Miao et al., 2004; Shi et al., 2020; Li et al., 2022). Taodonggou Group mudstones are widely deposited in the Turpan-Hami Basin. Previous studies have confirmed that Taodonggou Group mudstone is a very good to excellent source rock with huge hydrocarbon generation potential (Song et al., 2018; Miao et al., 2021; Miao et al., 2022; Miao et al., 2022a). It has been found that the organic matter types of the Taodonggou mudstone can be classified into two categories, with the upper and lower sections being Type III and the middle section being Type II (Miao et al., 2021; 2023).

The hydrocarbon generation potential of mudstone is closely related to its sedimentary environment (Wu et al., 2021; Li et al., 2022; Zhang et al., 2019; Zhao et al., 2021; Miao et al., 2004). Regarding the sedimentary environment of the Taodonggou Group mudstone, previous researchers have conducted extensive research. Miao et al. (2004) believed that the mudstone in the Taodonggou Group was deposited in a warm and humid paleoclimate, high-salinity water bodies, and an anoxic environment. Yang et al. (2010), based on the sedimentary characteristics of the Taerlang Formation and the Daheyan Formation, believed that the Taodonggou Group was deposited in a subhumid climate and that climate change is periodic. Wei (2015) also confirmed that the paleoclimate change of the Taodonggou Group stratum has a cyclical feature through tree rings and is mainly a warm and humid paleoclimate. At the same time, Song et al. (2018) also confirmed this by using the elemental geochemical characteristics of the Taodonggou Group shale outcrops in the field; Tian et al. (2017) analyzed the biomarkers of the Taodonggou Group in 7 outcrops around the Turpan-Hami Basin and concluded that the mudstone of the Taodonggou Group was deposited in a balanced, filled lake with little or no terrestrial organic matter, a large amount of algal *organic matter input, and weakly alkaline, hypoxic to hypoxic brackish water. Miao et al. (2021) found biomarkers in the Taodonggou Formation mudstone from wells YT1 and L30 from different perspectives of Tian, which may be related to the weathering effect of outcrop samples. Through the research of the above scholars, we have found that there is some controversy over the sedimentary environment of the Taodonggou Group, and the relationship between the cyclic changes in the sedimentary environment and the changes in the organic matter types of the Taodonggou Group mudstone is still unclear.*

In addition, the provenance and sedimentation mode of sediments also have a significant influence on the organic matter types in mudstones (Mei et al., 2020). Mudstone belongs to a category of fine-grained sediment that is challenging to analyze using traditional heavy mineral analysis methods (Rollinson, 1993; Roser and Korsch, 1988; Gehrels et al., 2008). Therefore, elemental geochemical methods can be employed for provenance analysis (McLennan et al., 1983; Kröner et al., 1985; Li et al., 2020). Elemental geochemical analysis compares the major, trace, and rare earth element characteristics of mudstones in the sedimentary area with those of lithologies in the provenance area to determine the lithology of source rocks, weathering degree, and tectonic background of the sediment source area (Li et al., 2020; Floyd and Leveridge, 1987; Basu et al., 2016). Previous studies have found that the sediment source not only affects variations in the salinity of lake water but also influences the input of nutrients and terrestrial organic matter, thus impacting the quality of mudstones (Li et al., 2020; Deditius, 2015; Essefi, 2021). The tectonic activity in the source area not only affects changes in the sedimentary center but also influences the source area (Miao et al., 2022b; Pinto et al., 2010). Therefore, reconstructing the location and sedimentation mode of the sediment source area is of great significance for understanding the variations in organic matter types in the Taodonggou Group mudstones.

Based on the mineralogical and elemental geochemical characteristics of 16 mudstone samples collected from the YT1 well, this study aims to reconstruct the paleoclimatic features, provenance, and tectonic background of the sedimentary period in the source area of the Taodonggou Group mudstones. It also aims to explore the influence of sedimentary environment, provenance changes, and sedimentation mode on the deposition of the Taodonggou Group mudstones, in order to reveal the formation process of the mudstones.

As you suggested, I have revamped the title of the manuscript based on the 16 samples and the new title is " *Mineralogical and elemental geochemical characteristics of Taodonggou Group mudstone in Taibei Sag, Turpan-Hami Basin: Implication for its formation mechanism* ".

Comments: Very little is mentioned about the stratigraphy of the area, despite the fact of refined stratigraphy for the Taodongou group by Wan Yang and his colleagues. Authors disregard some of the work that Yang and others have done in the area with regards to paleoclimate, provenance, and environmental conditions in the Turpan-Hami Basin.

Thank you very much for your recommendation. Yang et al.'s research in the Turpan-Hami Basin is very detailed, and there exists too much recognizable knowledge in the forty-odd pages of the paper. Therefore, I have combined the results of that paper and some work done by previous authors to summarize the stratigraphic characteristics of the Taodonggou Group and placed it inside the geological introduction. In addition some gravity flow deposits and other depositional types are also cited by me as depositional modes in the discussion.

Comments: In the discussion, the authors start discussing paleoclimate in the region. They go on about their results (which should be included in the results section and not in the discussion) and they have one paragraph that says that they speculate the mudstone was deposited in a warm, humid and hot climate and that these results are similar to those by the same author using biomarkers. This completely disregard previous work in the region and has very minimal discussion on paleoclimate in general for the entire region. What is the novelty and how do these results compare to what has been speculated for the area before? Yang et al. (2010) found a significant amount and well developed calcisols in alluvial fans of the Taodongou group, which would suggest a different paleoclimatic setting than the one discussed here. There are others that have also looked at paleosols (Tabor and his students) which is also disregarded here.

Based on your comments, I have reorganized the conclusion of the article to place the depositional environments based on elemental analyses in the results section, as they should belong in the results. There are many paleoclimate studies on the Middle Permian of the Turpan-Hami Basin, the earliest one is Miao et al. (2004) who judged the climate as warm, humid and hot based on elemental ratios, but his samples are small and there is no discussion on the applicability of the results. Wei et al. (2016) confirmed this based on the age of the trees, and concluded that the Middle Permian of the Turpan-Hami Basin was in the northern subtropical zone of clear seasonality, and the climate was relatively warm and humid, but there were intermittent relatively hot climates. Song et al. (2018) also confirmed that the climate was warm and humid, but there were hot and humid climates based on the Zhaobishan profile and the Taerlang profile. The author proved it again using YT1 well elements and biomarkers. Obviously these are different from Yang et al. study, which considered the climate as semi-arid and semi-humid climate possibly intermittent hot climate. In addition, calcareous nodules do exist at the top of the Taerlang Formation, and oil-bearing calcareous nodules are a typical feature of the Taerlang Formation. However, a warm and humid climate is more favorable for the formation of calcareous nodules. The reason is that (1) warm and humid climate conditions are favorable for the dissolution and deposition of calcium salts in the water body. When water bodies containing calcium ions enter rock crevices or caves, due to changes in environmental conditions, such as temperature, pressure or chemical reactions, calcium ions will precipitate and form calcareous nodules. (2) Calcium nodules in water bodies such as lakes, rivers and oceans are also related to climate. Warm and humid climatic conditions favor the growth of organisms and mineral precipitation in water bodies. Some organisms, such as algae and corals, convert dissolved calcium ions in water into calcium nodules by absorbing them.

Overall, I believe that the Taodonggou Group strata were deposited in a warm, humid and hot climate

Comments: The second part of the discussion is the parent rock. The authors also discuss their results and how their results suggest that the parent rocks are andesitic and felsic. But what about the 40 years of work done on the Carboniferous of the study area? The geological complexity is not discussed and they don't compare the results to those published in the past about provenance. There are very complicated lithologies exposed in both the Tian Shan and Bogda Shan that are Carboniferous in age and I don't think I have seen significant felsitic rocks in the area. Also, these rocks have been buried and dramatically changed tectonically. Can these ratios be influenced by burial processes and postdepositional modification?

There has been a lot of research on the origin of the Turpan-Hami Basin. Currently, it is believed that the Permian origin of the Turpan-Hami Basin mainly comes from the Bogda Mountains in the north and the Jueluotage Mountains in the south, but the main difference lies in the uplift time of the Bogda Mountains. Shao et al. (1999) believed that the origin of the Turpan-Hami Basin is mainly composed of felsic volcanic rocks and andesites. He believed that during the Permian period, the main origin of the Jueluotage Mountains' intermediate acidic igneous rocks was from the uplifted part of the Bogda Mountains, while the uplifted Bogda Mountains were a secondary source, and the main source of the Hami Basin was the Halike Mountains erosion area. In addition, the U-Pb isotope composition measurement results of detrital zircons in the Permian sandstone show good isochron correlation (R^2=0.98), and the isochron age is (283 ± 67) Ma, which is consistent with the formation age (268 ± 13) Ma of the source area's granitic rocks within the error range, indicating that the main source of the mineral sand in the Turpan-Hami Basin is from the granitic body in the late stage of the Late Hercynian period, which is the southern source area of the Jueluotage Mountains, thus he believed that the sandstone inherited the origin of the Lower Permian in the Carboniferous. Zhao et al. (2020) analyzed the origin of the Tian Shan region based on a large amount of U-Pb dating data. According to this result, the early origin of the Turpan-hami Basin should be consistent with the Bogda Rift area. However, Song et al. (2018) believed through element analysis that the parent rock types are also andesites and felsic volcanic rocks, mainly from the Bogda Mountains. In the paper by Jonathan Obrist-Farner and Wan Yang (2017), the Permian Quanzijie Formation has neutral rocks, but Jonathan Obrist-Farner and Wan Yang believed that the Upper Quanzijie Formation (260.4-265.8 Ma) is close to the Taodonggou Formation (255-260 Ma) in the manuscript. The preservation degree of the mudstone source of the Taodonggou Group was analyzed using the intersection diagram of Th/Sc and Zr (Figure 13a), and the results showed that the source of the Taodonggou Group mudstone was well preserved and could be used to analyze the provenance information.

Comments: The third part of the discussion is related to the uplift of the Bogda Shan. This is still debated and finding that the provenance is different between the Taodongou and Lucaogou Groups/Formations is not sufficient to make the argument about Bogda uplift. Others have argued that these basins were part of a rift system during that time.

Thank you for your comments, However, I hold a different view. Many previous studies have suggested that during the Bogda Rift period, the Junggar Basin, Turpan-hami Basin, Yaggar Basin, and Jimusaer Basin were a single entity with consistent source and organic matter types. This led to early interpretations of the hydrocarbon generation potential and sedimentary environment of the Taodonggou Group using Lucaogou Formation shale from the Junggar Basin or the Jimusaer Basin as examples, as done by Gang Gao et al. (2006) and Shiju Liu et al. (2020). However, their sources are no longer the same today, which should be able to infer that the Bogda Mountains have already uplifted or partially uplifted. This result is also consistent with the latest research findings (Li et al. (2022) and Wang et al. (2018)).

Li et al. (2022) and Wang et al. (2018) inferred that the Bogda Mountains were uplifted at 289.8 Ma-265.7 Ma, which is significantly earlier than the deposition of the Taodonggou Group (260 Ma-255 Ma), a debate that may be related to Yang et al.'s suggestion that the Taodonggou Group stratigraphy was deposited at 275-294.6 Ma, a stratigraphic time that clearly includes the Turpan-Hami Basin Lower Permian Yierxitu Formation (or Aidinghu Formation). The bottom of the Lower Permian Yierxitu Formation consists of gray-green siltstone and tuffaceous sandstone, and the middle part of the Formation is dominated by yellowish-green and grayish-purple basaltic rocks, locally interspersed with dacite. Tuff and tuffaceous sandstone, and the top is mainly gray-black and black mudstone interbedded with siltstone and sandstone.

Comments: Similarly, there is no discussion on the paleosedimentary environment nor the following sections, mainly just description of the results. Dyoxic (should be dysoxic) is also misspelled in the discussion and in the figures. How does this compare to what has already been published in the area? How does it compare to similar sedimentary basins elsewhere?

Thanks again for your comments, the typos I have fixed. The structure of the manuscript has been adjusted, and the article now focuses on the formation mechanism of the Taodonggou Group mudstones in the Turpan-Hami Basin. I have completed the latest version of the manuscript, and I have highlighted the revised parts in yellow.

Response to Reviewer 2

Thank you for your comments and valuable feedback on my manuscript. Based on your feedback and the other two reviewers, I have made revisions to my manuscript. In order to make it easier for you to review again, I highlighted the revised parts in blue in the manuscript.

Comments: The authors' samples are mudstones, and the results of sandstone research such as shao (1990; 2001) are cited in the discussion section, while the distribution of mudstones in relation to sandstones needs to be added by the authors;

Thanks to your suggestion, I have summarized the relationship between the middle sandstone and mudstone of the Taodonggou Group stratigraphy in a geologic context by summarizing the characteristics of the Taodonggou Group stratigraphy as follows:

The Daheyan Formation is composed of a sequence of sandstone and conglomerate deposits, with locally interbedded gray to dark gray mudstone. It is unconformably overlain by the Yierxitu Formation. The Taerlang Formation is predominantly composed of gray-black mudstone, with localized occurrences of gray-green siltstone and medium-grained sandstone.

Comments: In the results section, the authors use "~" extensively, and the use of "~" and "-" is different and needs to be adjusted by the authors;

Thank you for your suggestion, I have replaced "~" with "-" in the manuscript as follows:

The XRD test results of 16 samples from Well YT1 are shown in Table 1 and Figure 2. As can be seen from Table 1 and Figure 2, Taodonggou Group mudstones are composed of clay, quartz, calcite, plagioclase, barite, and K-feldspar, and some samples contain siderite and pyrite. The content of clay is the highest (23.9%–70.9%, mean 40.78%), followed by quartz (17.2%–59.2%, mean 34.69%), calcite (1%–35.4%, mean 16.97%), barite (0%–13.3%, mean 4.21%), plagioclase (0%–5.4, mean 2.93%), and K-feldspar (0%–2.3, mean 0.9%).

Comments: The word is misspelled, "dysoxic" should be rewritten as "dyoxic";

Thanks to your review, I've rewritten "dysoxic" to "dyoxic" throughout the manuscript and highlighted the corrected word in blue.

Comments: In provenance, the authors analyzed the provenance of the Turpan-hami Basin Taodonggou Group mudstone and the Junggar Basin Luchaogou Formation mudstone, but they abbreviated the Taodonggou Group mudstone as "P2td" and the Luchaogou Group mudstone as "P2l". This is not recommended, and we suggest the authors change it for international readers;

Thanks to your suggestion, I have removed abbreviations like P2td and P2l from the manuscript, and the relevant text and figures are below:

At present, there are many opinions about the time of the Bogda Mountain uplift. They think that the initial uplift of Bogda Mountains occurred in Early Permian (Carroll et al., 1990; Shu et al., 2011; Wang et al., 2018; Li et al., 2022), Middle Permian (Zhang et al., 2006; Liu et al., 2018; Wang et al., 2018), Late Permian-Early Triassic (Zhao et al., 2020; Guo et al., 2006; Wang, 1996; Sun and Liu, 2009; Tang et al., 2014; Wang et al., 2018), Middle Triassic (Guo et al., 2006), Early Jurassic (Green et al., 2005; Liu et al., 2017; Ji et al., 2018) and Late Jurassic (Yang et al., 2015). If the initial uplift of the Bogda Mountains was after the middle Permian, the parent rock types of the Taodonggou Group mudstone in the Turpan-Hami Basin and the Luchaogou Formation mudstone in the Junggar Basin should be the same.

We have counted the element geochemical characteristics of Luchaogou Formation in the Junggar Basin (Li et al., 2020) and found that the parent rock type of Luchaogou Formation mudstone in the Junggar Basin is greatly different from that of P_2td, which is felsic volcanic rock (Fig. 14). As a result, Bogda Mountain's initial uplift should be Late Permian-Early Triassic in the Early Permian or Middle Permian.

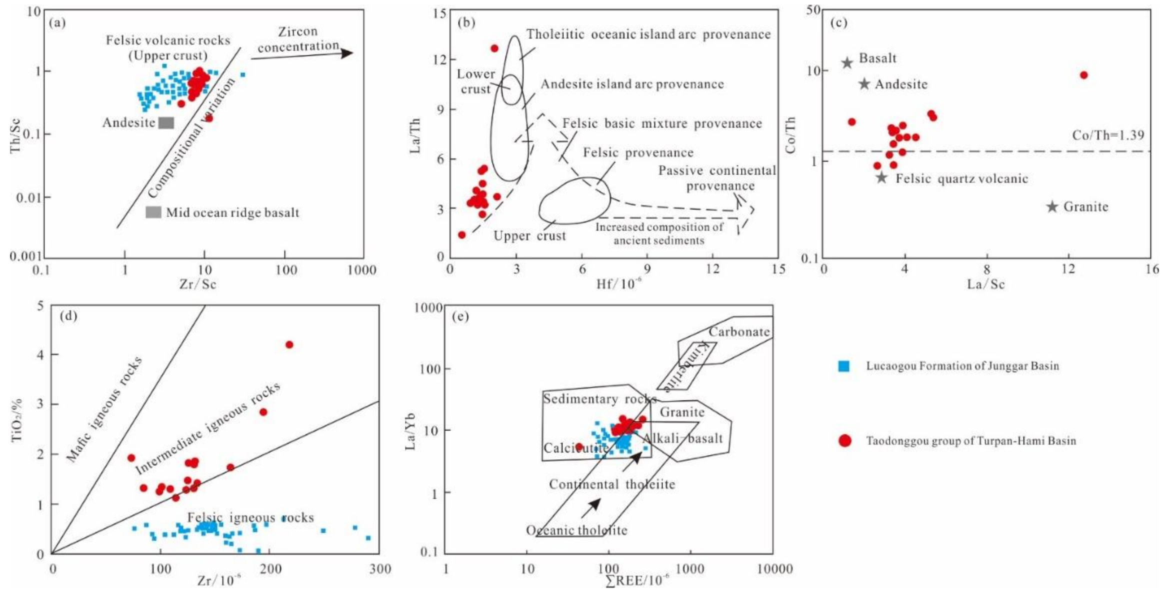

Figure.13 Parent rock type of Taodonggou Group in YT1 well (Data of Lucaogou Formation in Junggar Basin are from Li et al., 2020): (a) Th/Sc and Zr/Sc intersection diagram(modified after Floyd and Leveridge, 1987); (b) La/Th and Hf intersection diagram(modified after Floyd and Leveridge, 1987); (c) Co/Th and La/Sc intersection diagram(modified after Wronkiewicz and Condie, 1987); (d) TiO_2 and Zr intersection diagram; (e) La/Yb and ∑REE intersection diagram (modified after Allègre and Minster, 1978)

Comments: Fig. 8 needs to add a legend, Fig. 11 needs to be adjusted, there are too many blank spaces, and Fig. 14 needs to add organic matter composition and type.

Thanks to your suggestions, I have completed the revision of the figures, which appear in a different order due to the changes made to the structure of the manuscript, as follows:

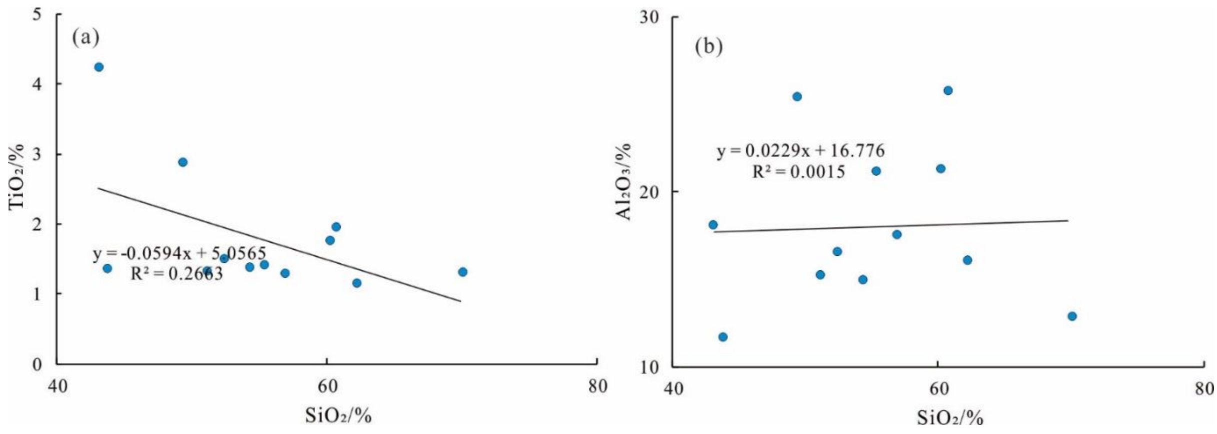

Figure.9 Intersection diagram of TiO_2 and SiO_2 (a) and intersection diagram of Al_2O_3 and SiO_2 (b)

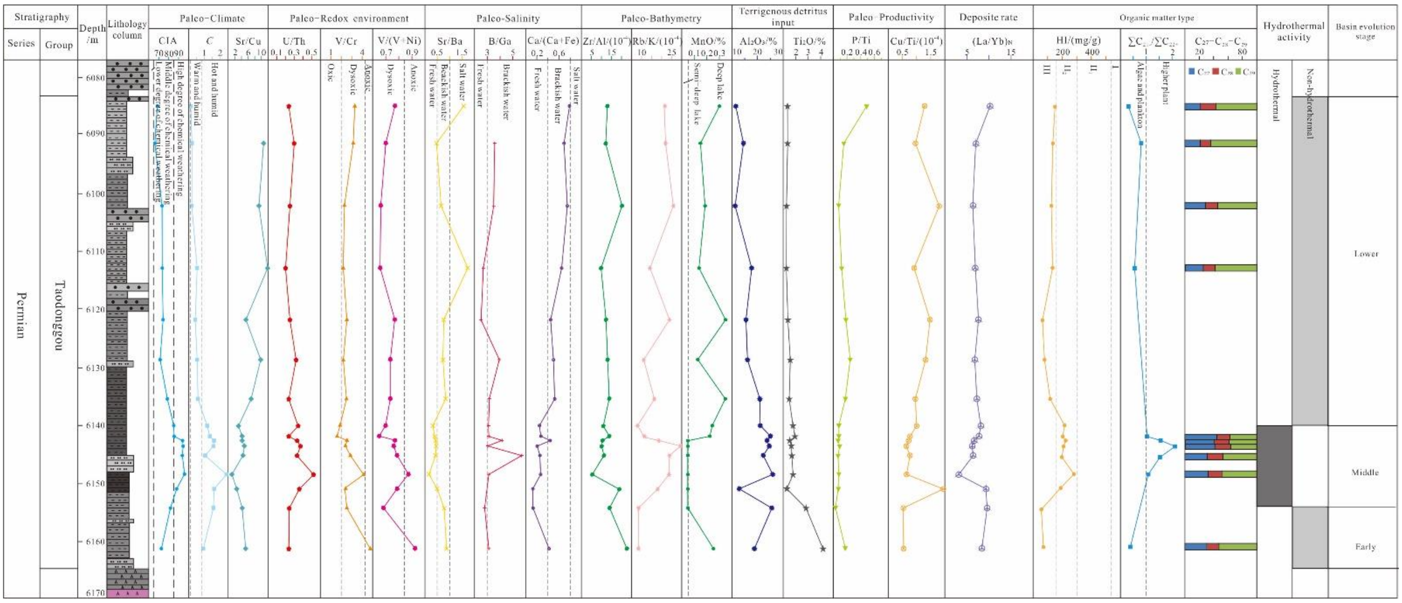

Figure.12 The geochemical profile of the Taodonggou Group in YT1 well

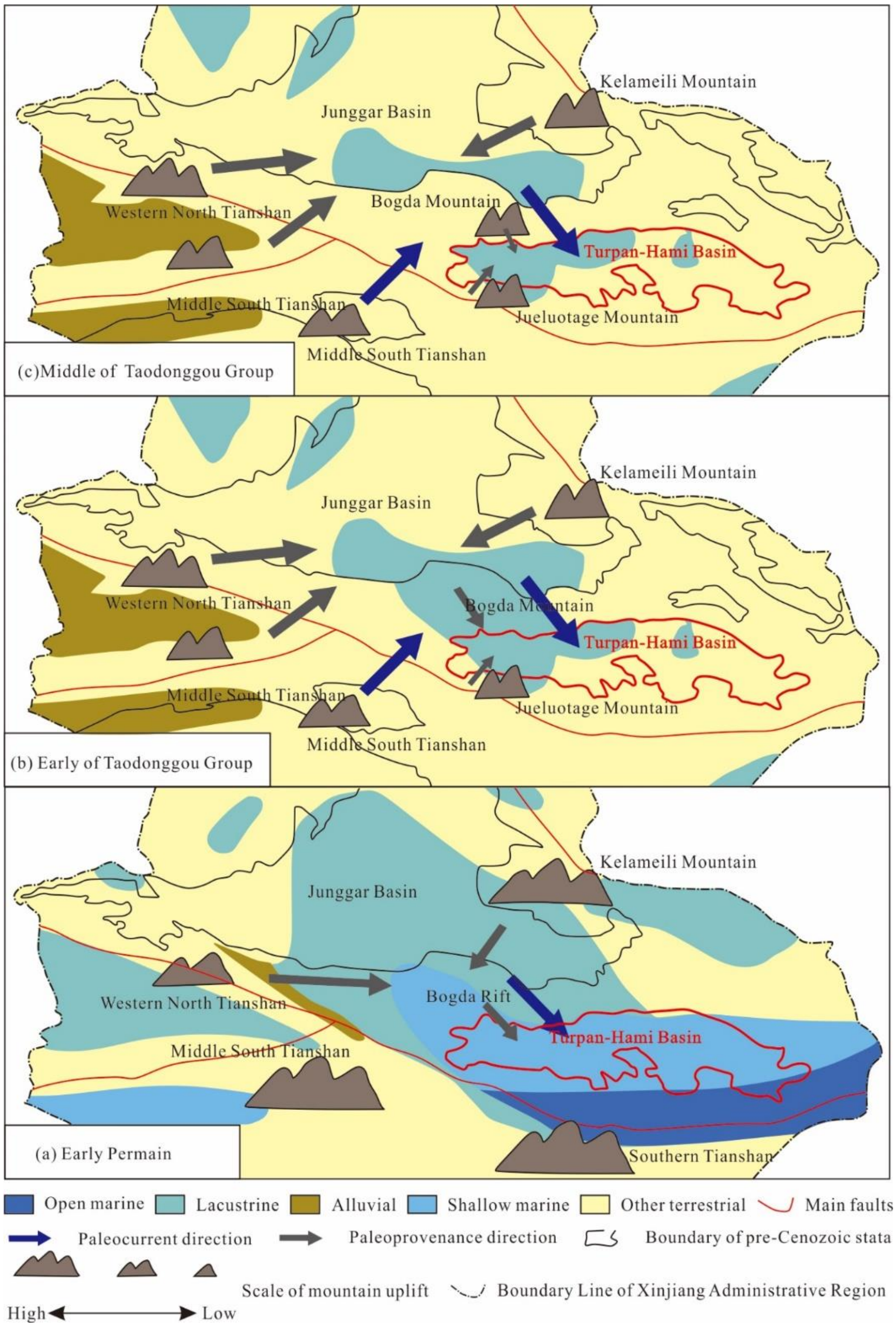

Figure. 14 Provenance location from Early Permian to Middle Permian in Tianshan area (modified after Zhao et al., 2020): (a) Early Permian; (b) Early of Taodonggou Group; (c) Middle to later of Taodonggou Group

Response to Reviewer 3

Thank you for your comments and valuable feedback on my manuscript. Based on your feedback and that of two other reviewers, I have made major revisions to my manuscript. The details of the revisions are listed below. To make it easier for you to re-review, I have highlighted the revised sections in green in the manuscript.

Comments: The other one is that it is my first time to see a paper that proposed source rocks (mudstones) with kerogen type III can be deposited in deep lake facies. Is it really deep lake facies or kerogen type III? I doubt that. I think it is necessary to add evidences from Rock-Eval pyrolysis (vertical variations in HI) and sedimentary analysis (from core observation or references) to support this viewpoint as well as the lake basin evolution mode in the section 5.5. Because I remain suspicious of this mode. For example, although the authors used a plenty of ratios of elements to support their opinions on paleo-bathymetric variation, it seems that the lithology column of well YT1 shows an opposite variation. Why the dark black mudstones can be deposited in shallower water environment (middle stage), whereas the grey mudstones were deposited in deeper water environment. Is there gravity flows influencing lithology change and source rock quality in the studied area? Again, sedimentary analysis and Rock-Eval pyrolysis are vital and indispensable for basin evolution reconstruction and source rock formation, but they are absent.

Thank you for your comments. I have added evidence of organic geochemistry. This section was not added before because the research results have been published in another journal and the author's paper in 2021. Therefore, I only included citations in the main text. However, in order to support the existence of Type III kerogen in the deepwater area, I have followed your advice and added HI, as well as the ratio of ∑C21-/∑C22+ and C27-C28-C29. These all serve as evidence that Type III kerogen shale was deposited in a deepwater environment (Fig.12).

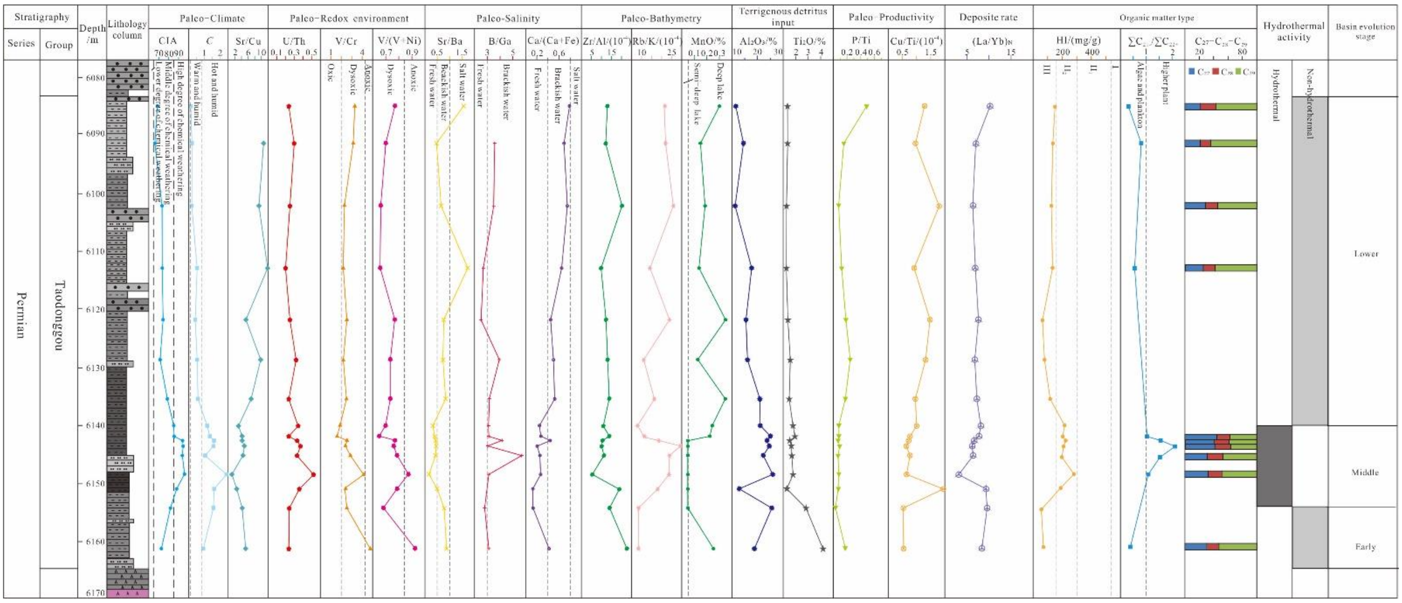

Figure.12 The geochemical profile of the Taodonggou Group in YT1 well

In addition, I have now identified the evidence for gravity flow deposition and have made the necessary changes based on your suggestions. The latest revised section I have nearly placed below. And this section I have highlighted in green text in the revised manuscript.

5.3 sedimentation mode

In previous studies, scholars have believed that the sedimentation of the Permian in the Turpan-Hami Basin is mainly controlled by traction currents (Chen et al., 2003). However, recent research has revealed the presence of gravity flow deposits in the Permian of the Turpan-Hami Basin (Wang et al., 2017; Wang et al., 2018; Xu, 2022). Yang et al. (2010) found poorly sorted debris flow deposits in the Daheyan Formation, and Xu (2022) discovered alluvial and fluvial facies in the Daheyan Formation, consisting of volcaniclastic rocks and conglomerates that are similar in composition to the Lower Permian volcaniclastic rocks and conglomerates. This suggests the existence of gravity flow deposits during the early Permian in the

Turpan-Hami Basin. Wang et al. (2018) also suggested the development of gravity flow deposits and pillow lavas in the Early Permian. Meanwhile, in the early Middle Permian, the sedimentation inherited the provenance and sedimentation style from the early Permian, but the gravity flow deposits transitioned gradually into traction current deposits. Due to the influence of gravity flow deposits, terrestrial organic matter can be transported to the deep lake area (Yu et al., 2022; Li et al., 2011), thereby altering the type of organic matter.

During the middle of the Taodonggou Group, the Turpan-Hami Basin entered the foreland basin sedimentation stage due to the uplift of the Bogda Mountains. The sedimentary environment of the Taodonggou Group in the Tainan Sag is similar to that in the Taibei Sag (Li, 2019). During this time, the sedimentary water body of the Taodonggou Group in the Turpan-Hami Basin became shallower, and the dominant sedimentation style transitioned to traction currents. Xu (2022) conducted lithological observations on the Taerlanggou section, the Zhaobishan section, and the Y well in the Taodonggou Group and found the presence of traction structures of gravity flow origin in the middle and upper parts of the Taerlang Formation. Additionally, a large number of calcareous and iron nodules appeared in the formation, indicating the occurrence of gravity flow deposits during the late-stage sedimentation of the Taodonggou Group. The organic matter type in the mudstones during this period was influenced by gravity flows.