Cover Letter

Dear referee:

On behalf of all co-authors, we thank you and the reviewer for the careful review and constructive comments on our manuscript entitled " **Lacustrine methane release on the Tibetan Plateau as an important driver of Early Miocene global warming** " (Manuscript ID: EGUSPHERE-2025-5342).

We appreciate the reviewer's expertise and time invested in evaluating our work. The feedback has significantly improved the manuscript. We will carefully address all major concerns, including a discussion on whether methane in lakes is oxidized, as well as the evaluation of its potential global climatic impact.

We will revise the manuscript and submit a marked-up version of the manuscript.

We believe the revised manuscript now fully addresses the concerns raised and hope it is suitable for publication.

Sincerely, Authors of manuscript number EGUSPHERE-2025-5342.

Part 2: Point-by-Point Response

Response to Reviewer

We sincerely thank Professor Dickens for the thorough and insightful review, which has helped us strengthen the manuscript substantially.

Major Issues:

<1> Learning from other paleo-lakes

We know that during other past warm climate intervals that many anoxic lakes have an active and persistent methanotroph population that prevents CH4 escaping into the atmosphere (see seminal papers on Green River formation during early Eocene, for example). Thus, without any supporting evidence for enhanced methanogenesis or changes in methane oxidation (e.g. d13C of bacterial lipids), the overall conclusions are unsupported by the existing data. I would suggest the authors explore whether there are other more direct indicators for methane cycling that can either support or disprove their conclusions.

Author Response:

Thank you for this critical comment, which we fully agree highlights a key limitation in the original submission. We will revise our interpretation to emphasize that whether methane production was enhanced or methane was being oxidized.

From the article, it is evident that, due to the isotopic fractionation associated with the methanogenesis process, methane preferentially incorporates a large amount of ^{12}C. If this methane were subsequently oxidized, it would introduce substantial ^{12}C into the water column, which would otherwise be depleted in ^{12}C, thereby enriching the dissolved inorganic carbon (DIC) pool in ^{12}C. However, the inorganic carbon isotope record throughout the Dingqinghu Formation indicates persistent ^{13}C enrichment during the entire depositional interval. This observation rules out the possibility of significant methane oxidation. Furthermore, the present study has already excluded other mechanisms capable of producing positive excursions in carbonate carbon isotopes. The magnitude of the positive shift in carbonate $\delta^{13}C$ therefore points to substantial methane release. To obtain direct evidence for enhanced methane release, additional experiments—such as analyses of archaeol abundance and methanogen populations—would be required.

<2> Globally important?

These results are from a single site and its very unlikely that this contributed globally to warming during Miocene. I suggest the authors incorporate data from other nearby sites and confirm that this is likely to be regionally important. Or perhaps look at other early Miocene lakes from around the globe.

Author Response:

We appreciate this point and we will make a modification. Regarding the regional versus global importance of methane release from the Dingqinghu Formation, given the limited lake area during the depositional period, the methane flux released from this system was indeed relatively low in terms of its direct global impact. Consequently, the authors will frame the methane release from the Dingqinghu Formation primarily in terms of its regional significance. At the same time, by integrating data from contemporaneous lakes elsewhere, the study will explore the broader influence and contribution of global lacustrine methane emissions to Early Miocene climate change.

<3> Lack of references

There are many geochemical ratios used throughout but unsupported by references. e.g. "W(V)/W(V+Ni) ratio indicate deposition under anoxic/reducing conditions" - need to add more detail about the approach and what a high vs low value means...

Author Response:

This was an oversight on our part, and we thank the reviewer for the reminder. The authors will carefully review the geochemical proxies mentioned in the manuscript and provide the corresponding references. For example, the V/(V+Ni) ratio serves as an indicator of redox conditions. Under oxic conditions, vanadium primarily exists in the pentavalent form (V(V)) in the water column and is readily mobile. In contrast, under reducing conditions, vanadium is reduced to the tetravalent form (V(IV)) and becomes enriched in sediments through complexation with organic matter or sulfides. Nickel, by comparison, remains relatively stable under oxic conditions, but its enrichment under reducing conditions is less pronounced than that of vanadium. Consequently, V/(V+Ni) values greater than 0.5 are generally interpreted as indicative of reducing (anoxic) environments, whereas lower values suggest more oxic conditions. This proxy has been widely validated in lacustrine and marine sedimentary settings, particularly in studies of black shales and lake deposits, where the V/(V+Ni) ratio effectively distinguishes oxic from anoxic water columns (Jones and Manning, 1994; Tribovillard et al., 2006).

<4>nfluence of terrestrial input

The authors argue strongly that terrigenous input is minimal (e.g. L286), but your C/N ratio increases dramatically to ~10-2- during the middle of the section, indicating substantial terrigenous input. Anything over 7 is considered to reflect a mixed source of OC (either soil and/or plant OC). Please re-evaluate these sections.

Author Response:

Indeed, the C/N ratios in the middle part of the section are relatively elevated, which suggests a certain degree of terrestrial organic matter input during that interval. The authors will compare these values with proxies indicative of terrigenous input, such as Al and Ti concentrations (or Al/Ti, Ti/Al ratios) (Lézin et al., 2013; Murphy et al., 2000), to further investigate whether the elevated C/N ratios primarily reflect an increased supply of terrestrial organic matter or, alternatively, enhanced proliferation of higher (vascular) plants due to lake-level lowering. This integrated approach will help clarify the dominant control on the observed organic matter composition in the middle section.

L68: its much more likely that volcanic CO2 was from other regions anyway – e.g., North Atlantic during early Eocene, or Columbia River Basalts during mid-Miocene.

Author Response:

Regarding the volcanic CO_2 contribution in the L68 section, it is acknowledged that volcanic activity associated with the North Atlantic Igneous Province during the early Eocene and the Columbia River Basalts during the mid-Miocene also contributed to elevated greenhouse gas levels and global warming in their respective periods. Therefore, the authors will adopt a mass balance approach to calculate the methane flux from the Dingqinghu Formation and quantitatively assess its potential impact on global climate, rather than excluding other sources of greenhouse forcing. This integrated evaluation will help contextualize the relative significance of lacustrine methane release within the broader Early Miocene carbon cycle perturbations.

Figure 2: why did you choose to smooth dataset? This approach can be misleading. If you truly want smoothing, use a moving average or something more sophisticated (e.g. smoothing spline/loess regression).

Author Response:

Figure 2 will be revised by applying a smoothing spline or LOESS regression to better represent the trends in the data. This adjustment will enhance the visualization of underlying patterns while preserving the original data points for reference.

L136: more detail on age model required. How much age is captured in the ~40m section? What is sedimentation rate?

Author Response:

The age model for the Dingqinghu Formation in this manuscript primarily draws upon previously published geochronological studies conducted on the same or equivalent sections of the Dingqinghu Formation in the Lunpori area. The sedimentation rate of 107 m/Ma cited herein corresponds to the average rate previously calculated for the second member of the Dingqinghu Formation in the Lunpori section, as determined in earlier work. Accordingly, the present study adopts this published sedimentation rate as the basis for subsequent calculations, including organic matter burial rates and related quantitative assessments (Mao et al., 2019; Xie et al., 2025).

L354: why as 2.5g/cm assumed?

Author Response:

The Dingqinghu Formation is predominantly composed of mudstone, shale, and oil shale. In the burial rate calculations for the Dingqinghu Formation presented by Xie et al., an average bulk density of 2.5 g/cm^3 was assigned to the second member of the formation. This value was derived from extensive data processing and statistical analysis conducted in previous studies, representing a well-supported average density for the lithological assemblage of the Dingqinghu Formation. Accordingly, the present manuscript directly adopts 2.5 g/cm^3 as the representative average bulk density for the Dingqinghu Formation in our calculations of organic matter burial rates and related parameters.

Regarding the additional issues raised in other manuscripts—such as inappropriate use of tenses in the text, missing references, and absence of supplementary materials—the authors will consult with professional colleagues and make the necessary revisions to ensure that the manuscript meets the required standards. We will take a comprehensive revision of the writing for clarity, conciseness, and logical flow.

Reference

Mao, Z., Meng, Q., Fang, X., Zhang, T., Wu, F., Yang, Y., Zhang, W., Zan, J., and Tan, M.: Recognition of tuffs in the middle-upper dingqinghu fm., Lunpola basin, central tibetan plateau: constraints on stratigraphic age and implications for paleoclimate, Paleogeogr. Paleoclimatol. Paleoecol., 525, 44-56, https://doi.org/10.1016/j.palaeo.2019.03.040, 2019.

Xie, G., Li, J., Yao, Y., Wang, S., Sun, B., Ferguson, D.K., Li, C., Li, M., Deng, T., and Wang, Y.: Palynological evidence reveals vegetation succession in the central qinghai-tibet plateau during the late oligocene to early Miocene, J. Syst. Evol., 63, 53-61, https://doi.org/10.1111/jse.13168, 2025.

Lézin, C., Andreu, B., and Pellenard, P.: Geochemical disturbance and paleoenvironmental changes during the Early Toarcian in NW Europe[J]. Chem. Geol., 341: 1–15, https://doi.org/10.1016/j.chemgeo.2013.01.003,2013.

Murphy, A. E., Sageman, B. B., Hollander, D. J., Lyons, T. W., and Brett, C. E. : Black shale deposition and faunal overturn in the Devonian Appalachian Basin: clastic starvation, seasonal water-column mixing, and efficient biolim-iting nutrient recycling[J], Paleoceanogr., 15: 280–291, https://doi.org/10.1029/1999PA000445, 2010.

Jones, B., and Manning, D. A. C.: Comparison of geochemical indexes used for the interpretation of palaeo-redox conditions in ancient mudstones[J]. Chem. Geol., 111: 111–129, https://doi.org/10.1016/0009-2541(94)90085-X , 1994.

Tribovillard, N., Algeo, T.J., Lyons, T., and Riboulleau, A.: Trace metals as paleoredox and paleoproductivity proxies: An update. Chem. Geol., 232, 12-32, https://doi.org/10.1016/j.chemgeo.2006.02.012, 2006.