Solid Earth Discussions

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Reply on RC2

Jin Lai et al.

Author comment on "Structural diagenesis in ultra-deep tight sandstones in the Kuqa Depression, Tarim Basin, China" by Jin Lai et al., Solid Earth Discuss., https://doi.org/10.5194/se-2021-85-AC2, 2021

Dear Dr. Maria Mutti, Dr. Federico Rossetti and reviewers:

Thank you very much for your constructive advices on my manuscript **SE-2021-85** (**Structural diagenesis in ultra-deep tight sandstones in Kuqa depression, Tarim Basin, China**) submitted to your journal "**Solid Earth**".

We have carefully revised the manuscript considering the remarks made by the two reviewers and the editors, and would like to re-submit it for your consideration. We have addressed the comments raised by the reviewers, and the amendments are highlighted in red or blue in the revised manuscript. We are indebted to you and the two anonymous reviewers for your constructive comments, which improve the manuscript significantly.

We also download some papers recently published in **Solid Earth**, and revised the references format carefully. Further some papers published recently in your journal have been cited in the revised manuscript (highlighted in blue in the references lists).

The point by point responses to the two reviewers' and Editor's comments are listed below.

Below, the original comments are in black, and our responses are in blue.

- Comments of Editor

Dear Authors,

When posting your author comments (ACs), you can choose between new comments or co-listing of existing ones. Please also consider replying to community comments (CCs) from the scientific community.

Reply:

Thank you for your constructive comments.

Reviewer #2: Dr. Sara Elliott

- This paper discusses the structural diagenetic history of the Lower Cretaceous Bashijiqike Formation within the Kuqa depression, Tarim Basin, China. The paper focuses on remnant pore types within various lithologies caused by varying degrees of compaction based on calculated horizontal stress differences, as well as mechanical fracturing and dissolution.

This paper claims to have done a comprehensive structural diagenetic study, but it appears they focused more on the structure and less on the diagenesis. Specifically, this paper lacks a thorough petrographic-diagenetic analysis, and as such lacks paragenetic sequences through time in relation to tectonics and structural events.

Reply:

Thank you for your constructive comments.

This comment is similar with the comments of reviewer's comments, and I have provided detailed responses to the comments. This study only briefly describes the diagenesis type and degree, and the paragenetic diagenetic history of the studied rocks. This is because that the diagenesis modifications, diagenetic evolution and porosity evolution histories are discussed in detailed in our previous studies Lai et al., 2017a.

Lai et al. (2017a) has discussed the diagenesis, diagenetic minerals as well as diagenetic evolution of the Bashijiqike Formation of Kuqa depression, and now it has got a total of 95 Google Scholar citations, and has been selected as an ESI highly cited paper.

Therefore in order to avoid repetition and redundancy, the diagenesis type and degree, and the paragenetic diagenetic history of the studied rocks are also briefly mentioned. Thank you for your consideration.

Thank you for your constructive comments.

After reading I am left with numerous questions including:

- How does lithology compare with depth, pore types, and cement composition/abundance? The authors made it clear that fracture abundance increases in areas of low horizontal stress, but does fracture abundance also change based on lithology? Did fracturing occur throughout diagenesis, e.g. did fracturing stop before the late-stage calcite infilled primary porosity? And, therefore, when exactly did the fractures act as conductive fluid pathways? How variable is the cement fill within fractures? What are the cement morphologies and textures? When did dissolution start within the diagenetic sequence? Where did all of the diagenetic calcite originate? Does all of this calcite cementation occur after dissolution is complete, or is there also evidence of dissolution of late-stage cements? Was some other mechanism partially responsible for porosity reduction or gain besides fracturing and horizontal stresses? How does compaction, cementation, fracturing & porosity change with regard to sample structural position, e.g. anticline hinge vs limb etc.?

Reply:

Thank you for your constructive comments.

☐We have added a Figure (Figure 2) to show the lithology variations with depth. In addition, the fracture abundance within various lithologies (Figure 7) is also added.

☐Fracture is actually changing with lothologies, and the fine-medium grained sandstones have the highest abundance of fractures (Figure 7).

☐ Fracturing actually occur throughout diagenesis (Figure 18-20). There is no doubt that the open fractures act as conductive fluid pathways, while the calcite-filled fractures have non contribution for fluid flow.

☐ How variable is the cement fill within fractures? What are the cement morphologies and textures?: The variable cements are common within fractures, and the cement morphologies and textures are described in the previous studies Lai et al., 2017a, Lai et al., 2017b.

☐ When did dissolution start within the diagenetic sequence? Where did all of the diagenetic calcite originate? Does all of this calcite cementation occur after dissolution is complete, or is there also evidence of dissolution of late-stage cements? : Dissolution can occur due to meteoric water flushing and can be caused by charging of organic-acid rich fluids. Diagenetic calcite is mainly due to the high paleo salinity. Thin section observation shows that there is no evident dissolution of late-stage cements (Lai et al., 2017a).

☐ Was some other mechanism partially responsible for porosity reduction or gain besides fracturing and horizontal stresses? The answer to this question is that the structure patterns may also affect the fracture assemblages and then the fracture-diagenesis

☐ The change of compaction, cementation, fracturing & porosity with regard to sample structural position, e.g. anticline hinge vs limb is already discussed in section 5.3. The structural position will affect the horizontal stress differences, and the relationships between compaction, fracturing and horizontal stress differences have been discussed in Section 5.3. We have added this sentence in Section 5.3.

Thank you for your constructive comments.

- The answers to some of these questions may be sprinkled throughout the paper, but they should really be brought together in the discussion section to form a more comprehensive structural-diagenetic history of the study area. The authors are missing discussion of numerous diagenetic processes and, thus, paragenetic sequences, which are essential in a structural-diagenetic study.

Reply:

Thank you for your constructive comments.

The issues (diagenetic processes and, thus, paragenetic sequences) you mentioned have been fully discussed in our previous studies Lai et al., 2017a, and we have cited these previous works. However, Lai et al., 2017a has not linked diagenesis with structure patterns, fractures and in situ stress, and in this study, we focused on the structural diagenesis analysis.

Thank you for your consideration.

Thank you for your constructive comments.

- **In section 4.2. Diagenesis type and degree:** Various authigenic (diagenetic) minerals and cements are mentioned including calcite, dolomite, quartz, and clays, yet throughout the results and discussion the only cement mentioned is calcite. Therefore, it appears that there is only one diagenetic mineral obstructing porosity in these rocks, even though it's mentioned that others are present. It would be nice to have some volume numbers here for the various cements to prove that calcite is the most volumetrically important, and perhaps include some closeup images of these cements as well. What are their textures and morphologies? Cement texture can provide a lot of structural information, and various cement morphologies affect fluid flow differently.

Reply:

Thank you for your constructive comments.

We have added in the Section 4.2, and SEM images are presented to show the quartz cements and clay minerals of illite and smectite mixed layer (Fig.5I, 5J).

From the aspect of volumetric abundance, the carbonate cements are the most important, while other cements such as quartz cements and clay minerals have less impact on reservoir quality.

The quartz cements occur as small authigenic quartz crystals (Fig.5I), while the mixed-layer illite/smectite clays occur as pore filling fibrous or webby morphologies (Fig.5J).

Thank you for your consideration.

Thank you for your constructive comments.

- **COPL-CEPL:** I agree that there appear to be no trends with depth regarding COPL & CEPL, but I wonder if lithology has something to do with lack of depth trends. I also wonder if all mentioned diagenetic minerals were considered cements and including in "CEM" when calculating CEPL, rather than just the calcite cement. If not, then their CEPL calculations will probably underestimate cementational porosity loss. I wonder this because nowhere do the authors discuss where the compositional data they used to calculate COPL-CEPL came from, i.e. did they point count thin sections? Use previously published numbers? Visual Estimations?

Reply:

Thank you for your constructive comments.

As can be seen from Fig.6, the COPL and CEPL show no evident relationships with burial depth, and this is attributed the complex structural diagenesis the sandstones experienced.

In addition, as we can see from the Figure 2 of the revised manuscript, the lithology has no evident variation in the vertical direction, and the lithology is mainly fine-medium grained sandstones, therefore the lithology has little effect on COPL and CEPL.

We have taken all the diagenetic minerals into consideration as cements including in "CEM" when calculating CEPL, and CEPL is true values.

All the data used in the COPL and CEPL calculation are derived from point counting, and mainly 300 points are selected per thin section.

Thank you for your constructive comments.

- **SEM data:** Pg 8: Text reads "SEM (scanning electron microscope) (secondary electron image) coupled with an energy dispersive x-ray analyzer was used to detect the various types of clay minerals and recognize the micropores within clay minerals." Nowhere again throughout the paper was SEM data mentioned or shown in any way. Neither do the authors ever comment on the clay mineral compositions they supposedly detected with EDS. What were the secondary electron images used for?

Reply:

Thank you for your constructive comments.

First of all, we have added two SEM images (Figure 5 of the revised manuscript) in the study.

The energy dispersive x-ray analyzer was used but the data are not presented, and therefore we deleted the descriptions about EDS. Thank you for your consideration. The secondary electron images are used to detect the pores and clay minerals associated with the freshly broken rock surfaces.

The SEM images are used in Section 4.2 to show the quartz and clay minerals.

Thank you for your constructive comments.

- **Miscellaneous –**

7.1. It's evident to me that there are dark cement rims on many of the framework grains within these rocks (possibly iron oxide rims, but most likely clay rims from feldspar dissolution, see figure 3B & E), and not once is this discussed. Is this lithology-specific? Depth related? Are any of the open fractures lined with similar minerals? Authigenic mineral rims on framework grains often inhibit cementation into the intergranular pore space. The authors claim their rocks are mostly compaction-dominated, but perhaps their compactional porosity loss calculations are overestimated if they're ignoring some diagenetic cements.

Reply:

Thank you for your constructive comments.

In our previous studies, we actually found this type of grain-coating clay minerals (Lai et al., 2017a). Clay minerals (mixed-layer illite/smectite) thinly coating framework grains help to preserve reservoir quality by forming barriers to quartz cement nucleation (Lai et al., 2017a). Therefore we have added in the section 4.2 to show this type of clay minerals.

In the original manuscript, we have revealed the presence of this kind of clay minerals: "In addition, the pore-line grain contacts also suggest a limited degree of compaction

Thank you for your constructive comments (Fig.5C)." In the revised manuscript, we further added the descriptions about the grain-coating clay minerals.

Actually, there are evident dark cement rims (mixed-layer illite/smectite) on many of the framework grains within these rocks (Fig.4B, 4E), and the presences of authigenic mineral rims on framework grains can inhibit cementation into the intergranular pore space (Lai et al., 2017a).

Thank you for your constructive comments.

7.2. Figures 4G & 4H (especially 4H) are not of high enough quality to portray the dissolution features the paper describes. Recommend taking new images or toning down the highlights/contrast as well as adding arrows to make feature recognition easier.

Reply:

Thank you for your constructive comments.

We have replaced Figure 4H (in the revised manuscript, it is Fig.5H) in the revised manuscript, and the dissolution features are evidently captured. Fig.5G is a evident moldic pores, and it is still kept in the revised manuscript. Thank you for your approval.

Thank you for your constructive comments.

7.3. Pg 6, Line 13: Text reads "Cathode Luminescence (CL) microscopy," correct term is Cathodoluminescence (CL) microscopy.

Reply:

Thank you for your constructive comments.

We have changed the text in section 3. Data and methods.

Thank you for your constructive comments.

7.4. Pg 3, Line 13: Text reads "SEM (scanning electron microscope) (secondary electron image) coupled with.." There is no reason for 'secondary electron image' to be in parentheses.

Reply:

Thank you for your constructive comments.

The SEM images are actually taken by secondary electron image, and the rock freshly broken surfaces are analyzed. Please kindly see Fig.5I and 5J.

Thank you for your constructive comments.

7.5. Perhaps include a stratigraphic section of the Bashijiqike Formation to clarify lithologies vs depth?

Reply:

Thank you for your constructive comments.

We have added a Figure 2 in the revised manuscript to clarify lithologies vs depth.

Thank you for your constructive comments.

7.6. Aside from the numerous grammatical, spelling, and sentence structure errors, the paper is highly repetitive and could easily be pared down.

Reply:

Thank you for your constructive comments.

We have revised the manuscript according to your constructive comments and the comments of Reviewer 1. The technical errors are eliminated by careful checking. We have also double checked the manuscript to avoid any mistakes.

Thank you for your constructive comments.

7.7. The authors are missing discussion of previous structural diagenetic research in the area and how their contribution ties in, so there are some references I think the authors should consider:

Ukar, E. and Laubach, S.E., 2016. **Syn- and postkinematic cement textures in fractured carbonate rocks: Insights from advanced cathodoluminescence imaging**, Tectonophysics 690, Part A, 190-205, doi: 10.1016/j.tecto.2016.05.001

Wang, J., Zeng, L., Yang, X., Liu, C., Wang, K., Zhang, R., Chen, X., Qu, Y., Laubach, S.E., Wang, Q, 2021. **Fold-related fracture distribution in Neogene, Triassic, and Jurassic sandstone outcrops, northern margin of the Tarim Basin, China: Guides to deformation in ultradeep tight sandstone reservoirs.** Lithosphere (Special 1), 8330561. https://doi.org/10.2113/2021/8330561

Baqués, V., Ukar, E., Laubach, S.E., Forstner, S.R., Fall, A., 2020. **Fracture, dissolution, and cementation events in Ordovician carbonate reservoirs, Tarim basin, NW China.** Geofluids, v. 2020, Article ID 9037429, 28 p. doi: 10.1155/2020/9037429

Ukar, E., Baqués, V., Laubach, S.E., Marrett, R., 2020. **The nature and origins of decameter-scale porosity in Ordovician carbonate rocks, Halahatang oilfield, Tarim Basin, China.** Journal of the Geological Society, 177, 1074-1091. doi:10.1144/jgs2019-156

Reply:

Thank you for your constructive comments. We have downloaded the paper your recommend and read them carefully, and cite these references in the manuscript accordingly at the appropriate places. These references are actually about the structural diagenesis and are related to our studies.

Thank you for your recommendation.

Once again, thank you very much for your comments and suggestions which improve the manuscript significantly.

We hope that the revised manuscript is now acceptable for publication in your journal. We appreciate for Editors/Reviewers' warm work earnestly, and hope that the corrections will meet with approval.

We look forward to your information about my revised papers and thank you for your good comments.

With best wishes,

Yours sincerely,

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You - as the contact author - are requested to individually respond to all referee comments (RCs) by posting final author comments (ACs) on behalf of all co-authors no later than 27 Dec 2021 (final response phase). We have provided detailed responses to the two reviewer's comments and revised the manuscript according to the reviewer's comments.

Thank you for handling my manuscript and tireless works.