Response to Anonymous Referee #2

This study presents an experimental study of the calcite dissolution-induced permeability change in carbonate rocks. The electrical conductivity is used to monitor the experiment, and the measured electrical conductivity is used to infer material pore structure changes. Insights into the link between k and electrical conductivity (and related parameters) are made. In general, this manuscript is well-written and easy to follow. The reported experimental data are new and provide valuable datasets other researchers can use for similar purposes. The data analysis is based on using theoretical models, and thus it gives many insights that otherwise can not be obtained from traditional data analysis.

Therefore, I am in favor of publication.

The authors wish to thank the reviewer for this positive general comment about the manuscript, highlighting the value of the study.

Specific comments:

I have several minor comments and hope the authors can consider in revising their manuscript.

1. Different flow conditions

   Page 6 (line 102): the authors mentioned E04 and E05 have different flow conditions. Also, the Peclet number is introduced here to characterize the flow condition. It would be helpful if the authors could talk a bit more about the dissolution pattern related to these two flow conditions. Are we expected to see different flow patterns for these two samples? Based on the experimental results, it seems that the dissolution patterns of the two samples are quite similar.

The point stated by the reviewer is accurate and the authors will add it to the discussion of the results concerning micro CT images and electrical measurements. The dissolution patterns should be quite similar regarding the close values of the Peclet numbers. However, the percolation of E05 happens in almost three times more than the percolation time of E04. Micro CT images show that this difference in flow regime already has an impact on the dissolution pattern. Indeed, even if both samples end up with dominant wormholing, E05 presents a peripheric portion invaded by the acid solution and which has an important impact on the electrical conductivity.

2. Section 3.2

   The authors provide some analysis of the chord length distribution of the two samples before and after the experiment. The current version of the manuscript does not explain very well what a “chord length” is and how “chord length” is related to “pore size” and “pore throat” size. Moreover, the main parameter mj estimated from chord length distribution is also not well explained in terms of its physical meaning. Also, the authors mentioned (Line 230) “the evolution of mj is not a sufficient indicator of the effect of dissolution on the sample”. If this is the case, what is the purpose of keeping Section 3.2 then?

First, the authors agree with the reviewer about the need of adding to the manuscript the definition of the chord length distribution. This statistical correlation function has been developed in the study of Torquato and Lu (1993). It is applied to two-phase random media composed of fully penetrable spheres polydisperse in size and corresponds to “the probability of finding a line segment of length *z* wholly in one of the phases when randomly thrown into the sample.” For the study of porous media, the chord length distribution is determined for the phase outside the spheres. From this definition, chord length distribution only has a statistical meaning regarding pore size, but does not provide information on the distribution of pore bodies and pore throats. Second, the parameter m_j is an exponent in capillary size distribution proposed in the study of Jackson et al. (2008), already cited in the manuscript when presenting the analytical model. The authors propose to add the following clarification to the revised version of the manuscript. The proposed capillary size distribution is based on a frequency distribution related to the average capillary radius. The increase of analytical parameter m_j describes how this continuous distribution of pore size is skewed toward smaller capillary radii. Third, the purpose of Section 3.2 is to confront the proposed capillary size distribution, on which the analytical model is based, to the statistical distribution derived from the micro CT images of the real carbonate samples studied in this manuscript. In this section, the capillary size distribution of the analytical model shows accurate agreement with the statistical data. This is a major validation of the hypothesis on which the model is based, which guarantees the reliability of the following interpretation of the model’s results. To emphasize that this section is an effective contribution to this study, the preceding lines will be added to the revised manuscript.

Ref: Torquato, S.; Lu, B. Chord-Length Distribution Function for Two-Phase Random Media. Phys. Rev. E **1993**, 47, 2950, doi: 10.1103/PhysRevE.47.2950.

3. I feel that there are too many metrics/parameters discussed in this study. (Yes, one valuable benefit of the experiment in this study is that it can provide different types of data for analysis). A discussion of all of the acquired parameters/properties makes it somehow difficult for readers to understand the key findings of this study. In my opinion, the most interesting and unique finding of this study is that the constrictivity changes significantly during dissolution; in contrast, the hydraulic tortuosity does not change. Other discussions such as k-Ï□, k-F, and Λ-k relations, are less important than hydraulic tortuosity and constrictivity. My suggestion is to put more emphasis on the discussion on hydraulic tortuosity and constrictivity.

The authors are grateful to the reviewer for underlying his interest in the significant role played by constrictivity during dissolution. However, the authors do think that depending on the field research of the reader, the other findings are also of interest. To address the reviewer's concerns about prioritization, we propose adding emphasis on constrictivity in the abstract, the title of the dedicated section 3.3, and the conclusions.