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Interactive comment on "Archie's Law – A reappraisal" *by* P. W. J. Glover

Anonymous Referee #1

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This paper seeks to bring clarity to a field that has become increasingly murky since empirical modifications to Archie's Law have yielded a large range of fitting-parameter values that remain unexplained. The author takes a step by step approach to an analysis of the sources of systematic error in the measurement of the rock properties pertinent to Archie's Law. He discusses the relative importance of each and provides helpful recommendations for best practice. In this way, this will be a powerful contribution the Petrophysics community and a strong reminder to use empirical laws with caution (or better: with critical thinking) when theoretical laws are available.

Prior to publication I have some minor remarks which I'd like to see addressed.

(1) The author states that the data here presented must remain "unattributable" in order to be published. This may be normal in industry settings but, from a scientific point of view, this is alarming. At the very least, non-disclosure of the provenance of the rocks used herein precludes reproduction of the work by the interested reader, which is poor

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scientific practice. In the Data Availability section, the author reiterates that these data are confidential. I find this unappealing in a to-be peer reviewed scientific article and it would be desirable to divulge the data sets presented. This is especially true for a journal such as Solid Earth where the data availability is a key component of their open access policy.

(2) No experimental methodology is quoted that would indicate to the reader how the author measured the resistivity values quoted. Nor is a reference given for the data in which a methodology is contained. While it may be a routine measurement technique, the author goes on to critique the methods employed by others. As such one would expect a pristine methodology protocol to be a useful addition herein.

(3) The premise of the manuscript is that Eq. 1 is theoretically valid and that Eq. 2 is not. The question the author asks is then why is Eq. 2 widely used? The answer the author gives, in the form of a long discussion that is the majority of the manuscript, is concerned with measurement error in (almost) all previous studies. However, another possibility that is only given cursory mention (by way of Eq. 4; see below) is that Eq. 2 is in fact more valid and that an additional piece of physics is necessary to properly understand the empirical value . Were this indeed the case, the author points out that would need to be variable in porosity to account for the “paradox” as porosity approaches 1. The author may be interested to pursue statistical predictions of pore space spatial correlation lengths (to give one example) for random heterogeneous media. These descriptions often contain the key pieces of information that predict well how the role played by empirical adaptations of idealized laws for rocks are in fact wrapped in the random heterogeneous nature of porous materials.

(4) Eq. 4 and Eq. 5 are, as the author rightly states, identical to Eq. 2. This is a good example of over-analysis where simple statements would suffice. In this example: early on the author states clearly and confidently that Eq. 2 is an empirical modification of the more theoretically rigorous Eq. 1. Then rather than repeat Eq. 2 in another form to demonstrate that there may indeed need to be a modification made, one could simply

state that indeed one possibility is that Eq. 2 is the true answer and, therefore, that the physical meaning of -parameter should be found. Instead the author restates Eq. 2 as Eq. 4, replacing with and deciding that we might like to know to what is related. This is a roundabout way of suggesting that the empirical modification would be justified if were better defined.

(5) On line 18 of page 10, the author states that it not possible (currently) to determine which porosity is appropriate for use with Eq. 1. This is not in keeping with the author's assertion that Eq. 1 is theoretically rigorous. If it is founded on good theoretical grounds as I conclude that it is, then the porosity required is the measured porosity that best approaches the true total porosity. However, Eq. 1 contains the resistivity of water in the pores. In this case, it may be the most desirable to consider only water-saturated pores.

(6) The author refers to himself as I in places, e.g. I hypothesize (line 22 on page 9), and to himself as we in other places, e.g. We have compared (line 12 on page 7). Please standardize and be consistent.

(7) The text is often verbose and points are overstated. While I appreciate the rigour the author has brought to these problems associated with empiricism in Petrophysics, there is a limit to how much analysis is necessary to establish the errors associated with misuse of empirical fitting when theoretical laws are available.

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