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

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Summary:

In this paper the author investigates differences in derived cementation exponent m when applying, both, Archie's first law (1942) (EQ1) and a modified form introduced by Winsauer et al. (1952) (EQ2) that includes one additional adjustable parameter a. For this purpose, an analysis of a large dataset comprising formation factor and porosity for over 3500 core plugs from 11 sandstone and carbonate reservoirs was performed. Furthermore, a sensitivity analysis was conducted to determine the impact of measurement errors in porosity, pore fluid conductivity, and temperature on the precision of m from EQ2 with respect to EQ1. The author reaches a number of conclusions summarized in Section 7 of the manuscript where, in my perception, the most important are that (1) EQ2 should perform better than EQ1 and (2) that this may be explained by one or more of the measurement errors stated before. The author carried out an important

task with implications for fundamental rock physics and industrial applications alike. The paper may definitely be suitable for publication in Solid Earth (SE). However, there are a number of major issues outlined in the following that I encourage the author to address before the paper can be recommended for publication.

General comments:

1. Equations: Despite being - potentially - theoretically founded (e.g. Glover, 2009) it should be noted that EQ1 is an empirical correlation, as is EQ2. It is therefore unclear what defines "quality" of EQ1 with respect to EQ2. If this were the R2-parameter of the respective data fit - clearly - the difference is marginal (Fig. 3). Also, when fitting the data with EQ2 (i.e., the a-parameter) this affects m with respect to EQ1 (Fig. 3). In my opinion this is a mathematical result and not some indication of physical quality. What is significantly more important than the negligible differences in the two fits are the (natural) variations in, both, F and m with respect to porosity (or vice versa) within each of the reservoir types (Fig. 1). This should be discussed not least with regards to errors in reserves calculations.

2. Data: As already stated by Anonymous Reviewer #1 it is very unfortunate that the reservoirs are geologically unattributable, not least in connection with potential sources of surface conduction. It even is unclear if the data has been acquired by the author himself or collected from some external source. In any case it should be explained how the measurements have been performed. This also applies to the fluid exchange experiment introduced in Section 5.2. The experimental procedures require more emphasis and the results remain rather qualitative. I had expected some information on changes in fluid chemistry, for example. Not least, the choice of Boise sandstone is unfortunate as it contains ca. 40 % of non-quartz components including ca. 10 % of clay minerals. As a result, the outcome of the experiment is likely to be very different when, as in the data, clean sandstones are concerned.

3. Experimental Errors: With what has been stated before it is impossible to judge

whether the experimental errors in the data, as claimed by the author, are real or simply presumed. This is crucial as otherwise the reasoning that EQ2 works better than EQ1 is unsubstantiated. Furthermore and despite the sensitivity analysis being nicely conducted, how the errors in the measurements had “miraculously” been compensated for by the a-parameter remains absolutely unclear.

Specific comments:

- Section 5.3: Fluid conductivity below say 100 °C changes by ca. 2.3 % per 1 °C! This is also what Fig. 7 shows. From Fig. 7 it is implied that the error in fluid conductivity for 25 °C with respect to 20 °C is ca. 12 % and not 20 % as stated in the text.

- The manuscript contains significant amounts of repetitive or redundant statements, in particular with respect to what is initially stated in the abstract and ultimately concluded in Section 7. This should be improved.

- Section 3 should be included in Section 6 and the latter should be more logically organized with respect to the principal findings outlined in the previous sections.

- Text in Sections 6 and 7 should not be presented as a list of statements.

- The author should choose between “resistivity” and “conductivity”, e.g., in Fig. 6 and its caption.

Technical corrections:

- The inset-graphs in Fig. 1 should be enlarged.

References:

Archie, G. E.: The electrical resistivity log as an aid in determining some reservoir characteristics, Trans. AIME, 146, 54–67, 1942.

Glover, P. W. J.: What is the cementation exponent? A new interpretation, The Leading Edge, 82–85, doi: 10.1190/1.3064150, 2009.

Winsauer, W. O., Shearin, H. M., Masson, P. H., and Williams, M.: Resistivity of brine-saturated sands in relation to pore geometry, AAPG Bulletin 36, 253–277, 1952.

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