Interactive comment on "From oil field to geothermal reservoir: First assessment for geothermal utilization of two regionally extensive Devonian carbonate aquifers in Alberta, Canada" by Leandra M. Weydt et al.

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Author's comment on "Referee comment 2 – Reviewer 2 Comments to: From oil field to geothermal reservoir: First assessment for geothermal utilization of two regionally extensive Devonian carbonate aquifers in Alberta, Canada" by Anonymous Referee 2

Dear Reviewer,

Thank you for processing our manuscript and for your very valuable comments. Your questions and advice are answered below.

Referee 2 – C2 line 8: "*Some information on the samples prep. and orientation should be given (saturated or dry; whether or not the thermal conductivities are known to be the vertical (perpendicular thermal conductivity)?"*

Answer: Thermal conductivity was measured according to the method of Popov et al. (1999) on dry samples as shown in Fig. 1. Therefore, thermal conductivity of the core samples represents the "horizontal" thermal conductivity. We will add Fig. 1 to the relevant chapter, Material and Methods, in the manuscript.

Sample preparation: To minimize the transmission of optical heater radiation into reference standards and rock samples resulting from optical transparent surfaces (Popov et al., 2016), black paint was applied along a scan line on the sample surfaces as well as on the standards. Measurement of the plane surfaces of the core samples in order to estimate the thermal anisotropy was not allowed.
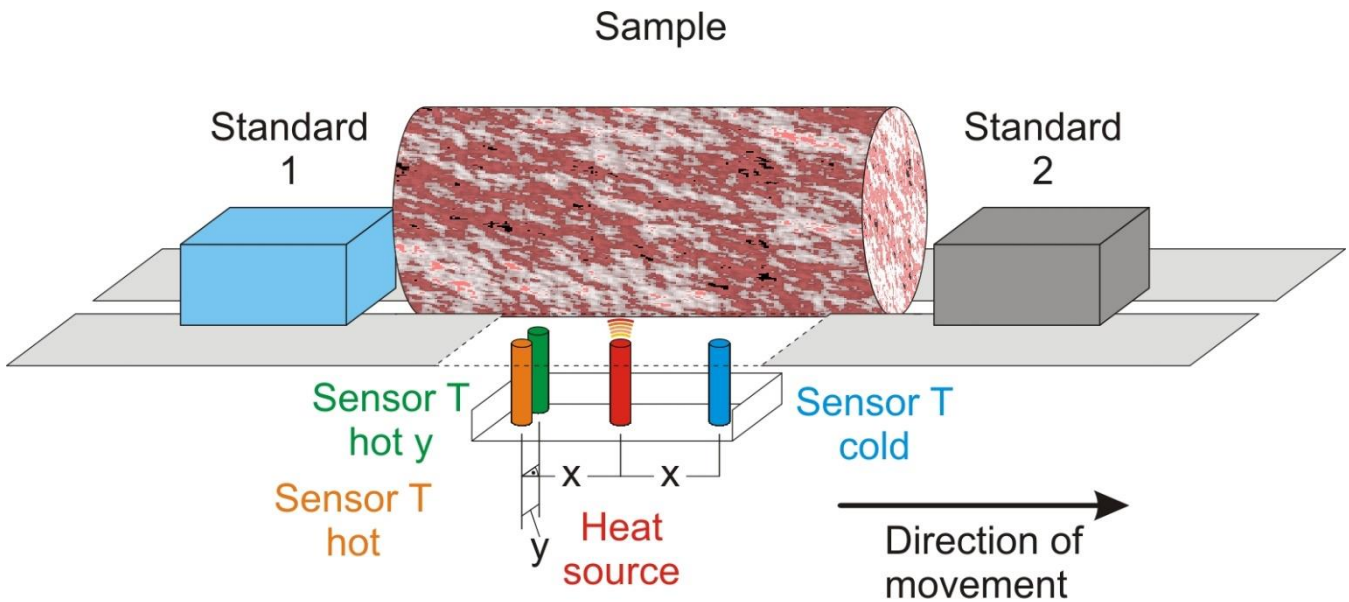
Figure 1: Schema of the thermal conductivity measurements of the analyzed core samples (Sass and Götz, 2012).

Referee 2 – C2 line 11: *"As to compare above thermal conductivity , porosity new measurements with previously published results, I would recommend reference to Beach et al., Geothermics, Vol. 16, No. I, pp. 1-16, 1987 with averages based on hundreds of thermal conductivity and porosity for carbonates and other rock types from mainly Hinton- Edson area."*

Answer: Ok.

The data set included in Beach et al. 1987 comprises thermal conductivity values measured on several hundred "water-saturated porous samples" (Beach et al. 1987, p.3). These thermal conductivity values were measured with a divided-bar apparatus and are stated as the vertical or perpendicular thermal conductivity.

This data set was not mentioned in the manuscript because it does not contain any information about the origin (well location and depth) of the samples, a reference to the different formations in the basin, nor a detailed rock description. The data set provided in Beach et al. (1987) gives a good overview of thermal conductivity of 13 rock types of the Mesozoic, Cenzcoic and Paleozoic sediments in the Hinton-Edson area. The thermal conductivity values of each rock type represent mean values calculated from different depth levels with varying thickness. The data set gives no information about specific formations and how the properties change within a formation. Therefore, this data set is more useful for large scale observations. In Jones et al. (1984) thermal conductivity in the Hinton-Edson area (most likely the same data set – 936 water saturated samples from 48 wells measured with a divided bar apparatus) is given for four geological formation groups. Jones et al. (1984) states that although a lot of samples were analysed, that some came from very small depth intervals and most of the

cores are from very porous and permeable formations. Therefore, this data set is not representative for all relevant parts in the reservoir.

The aim of this study was to provide a data set specific to the Upper Devonian carbonates which have become of particular interest for geothermal utilization and also for identifying variations of rock properties within its aquifer systems. According to Popov et al (2016), thermal rock properties are critical parameters for thermo-hydrodynamic models and for predicting the lifetime performance of geothermal systems. Therefore, an accurate determination of thermal properties of each relevant formation in the reservoir is necessary. The advantage of the method from Popov et al. (1999) is that it offers quick, non-destructive and contact free measurements on plane or cylindrical samples. Cutting the core samples to a specific size is not required and thus it allowed us to measure all available and intact core samples of each selected well core. Measurements on full size core samples are useful for analysing the formation's heterogeneity.

The thermal conductivity values presented in this manuscript were measured on dry samples, not on saturated samples. It is to emphasize that thermal conductivity values measured on dry samples as well as thermal conductivity values measured on water-saturated samples do not reflect the real conditions in the reservoir and need to be corrected before modelling.

Referee 2 – C2 line 25: "*b) There are many statements related to an assessment of the geothermal energy potential of the carbonate aquifers and reefs in the study area. While porosity, permeanbility , temperature conditions, thermal conductivity ,diffusivity, are important to such evaluation it is not possible to recommend geothermal energy potential without take on other parameters like the hydraulic head, piezometric surfaces, mineralization of aquifer fluids and most important estimate of potential flow rates at well head. In that sense cited by the authors paper by Jones and Lam Can. J. Earth Sci. 1985 went farther and gives such information (see their figs.10-12 and their Appendix figures). I recommend that their results be described, evaluated and briefly discussed in the scope of geothermal energy eval..*"

Answer: Ok. As mentioned before, at this early stage of the project, we focused on examining the Upper Devonian carbonates for geothermal purposes and to measure rock properties which are relevant to geothermal exploration and modelling. The classifications by Sass and Götz (2012) and Bär et al. (2011) were used for the initial evaluation of the measured rock properties. We do not claim that they replace further investigation. As mentioned in the manuscript (p. 13, line 22) "rock property measurements produce conservative results and represent matrix properties only" and additional parameters need to be integrated in a geological model for a reliable reservoir prediction.

Therefore, our statements are not contradictory to the comments by Referee 2. Due to the high number of well data (several thousand wells) that need to be evaluated for a reliable assessment of the Upper Devonian aquifer systems in the study area, the parameters required by Referee 2 are not included in this manuscript. This will be considered in the next phase of the project.

To make this clear, we will add a short section about the most relevant parameters and give an outlook of the next steps according to the hints of Referee 2.

Referee 2 – C3 line 8: *"It is not entirely justified to make statements in the paper like this one: ..."*

Answer: Agreed.

Referee 3 – C3 line 20: *"At their paper The Autors do not address the issue of potential brine production as they do not address parameters needed to estimate it in their paper."*

Answer: Thank you very much for this advice. As mentioned above, this manuscript focuses on rock properties. It was not intended for statements about economic and technical risks during production.

Regarding the recent efforts in the Hinton-Edson area to create an initial geothermal project, it is important to consider the complex hydrogeology in these aquifer systems. Both formations (Leduc and Nisku) contain highly concentrated waters with average TDS values of approximately 200 g/l (Rostron et al., 1997; Michael et al., 2003). Likewise, the Nisku Formation is well known for its sour gas pools (Bachu et al., 2008).

Problems like scaling and corrosion during operation can lead to higher production costs or, in the worst case scenario, to the abandonment of the well. These problems have not been solved in the geothermal industry yet.

The hydrochemistry of the aquifer systems in the study area has been the subject of several previous studies (e.g. Lam and Jones, 1985; Rostron et al., 1997; Buschkuehle and Machel, 2002; Michael et al., 2003, Machel and Buschkuehle, 2008) because it was also the main interest of the oil industry. As Lam and Jones (1985) have showed, these parameters can be very variable on a local scale. In the Hinton-Edson area the salinity ranges from less than 50 g/l up to 180 g/l.

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