# 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 3 – review" by Anonymous Referee 3**

For the numbered comments of Referee #3 (R3) see our responses below. There are some helpful detail corrections. Referee #3 articulates two major concerns which are general but lacking argumentation to be comprehensible. – The first of these points is the alleged "lack of reference to previous work"; the second point is that R3 requires "more regional information" and alleges "false claims" and "outraging" political statements. We note that the tone of some of the comments by this referee is uncalled for, in parts offensive and/or unprofessional.

**Referee 3 – C1 line 9***:" Most important is a shocking lack of reference to previous work, including numerous papers on the Hinton Geothermal Potential and numerous papers of the hydrogeological properties of the same aquifers studied."*

**Answer:** There is no explanation where the opinion of "shocking" comes from, nor which references he/she has in mind. The only possible aspects relating to this point (the list points with numbers are dealt below) are two demands:

*"[...] The authors need to do [...] some basic background research to place their work in context [...]"* and *"[...] There is a surprising lack of reference to numerous previous geothermal studies in the Hinton area, including some on the same reef systems. As well, since these units also produced major oil fields there has been extensive research conducted on the hydrogeology. A simple web search for terms like 'Hinton geothermal' or 'Nisku hydrogeology' will provide the authors with numerous papers of relevance that should be cited. Rather than 'superficially' I would say the area has been extensively studied. Try a bit of background research as part of your study! [...]"*

Our on-line literature research, as conducted during the writing process of the manuscript, scored 1720 hits. As is common practice, we cited but the most pertinent ones of these. Below [1-20] are the first 20 hits from GOOGLE Scholar to "Hinton geothermal" with our comments. Most of these papers are already known to us and are either cited directly by us or are included within a cited reference. Others of this list are not relevant at all for this area. Hence, this comment by Referee 3 has no basis in fact.

**Referee 3 – C1 line 12:**"*As it stands this works is completely out of context of earlier work and its (sic) not clear that it adds much new information to what is already known*."

**Answer:**

Our reply to this comment by Referee 3 is the same as the concluding remark to the previous one: his/her comment has no basis in fact.

- This work was triggered by previous studies which suggest that at least some of the Upper Devonian carbonate aquifers are suitable for geothermal utilization (Weides and Majorowicz, 2014; Weides et al., 2013, Lam and Jones, 1985). First 3D models were created using data from several thousand wells (Weides et al., 2013, Ardakani and Schmitt, 2016) to assess the geothermal potential of the Upper Devonian carbonates and further formations, but according to the authors, further research is necessary to evaluate the geothermal potential on a smaller scale. Furthermore, previous studies provided very few hard data on the geothermal and petrophysical reservoir properties of the rocks. The aim of this study is to investigate the Upper Devonian carbonates on a more regional scale and to provide an initial data set of rock properties which are relevant to geothermal exploration and modeling. This is presented in this paper.
- The Upper Jurassic Malm-Aquifer in the Southern German Molasse Basin has already been proven to be suitable as a geothermal reservoir (Birner et al., 2012; Böhm et al, 2013; Homuth et al., 2015; Wolfgramm et al., 2017). Despite their different ages, the Upper Devonian aquifer systems in Alberta and the Upper Jurassic Malm-Aquifer in Germany show several similarities regarding rock types, thicknesses, depth and deformation and hydrogeological properties. Therefore, the exchange of knowledge regarding reservoir exploration would be very valuable. This is the aim of the MalVonian project, which is described in the introduction of this manuscript. The work presented in this manuscript represents the initial phase of the MalVonian project.
- The outcrop analogue concept was successfully applied in the Southern German Molasse Basin to assess the geothermal potential of the Malm-Aquifer (Homuth et al., 2015). For this reason, we considered it appropriate to apply this methodology to the Upper Devonian carbonates in Alberta. With respect to geothermal purposes, this was not realized before in the Alberta Basin. Furthermore, the outcrops presented in this manuscript have not been reported yet (except for outcrop Nigel Peak). Internal industrial reports are usually not publicly available and therefore cannot be taken into account at this point. To correlate the outcrops with stratigraphically equivalent

formations in the reservoir, we analyzed core samples from seven wells (Leduc and Nisku Formation). The Devonian succession in the reservoir is described in detail in chapter 3.

- Thermal conductivity measurements presented in Beach et al. (1987) were measured on several hundred plugs of all sediment rocks in the Hinton-Edson area – not only on the Upper Devonian carbonates. In this paper there is no information given about the well location, depth level or formation of the analysed plugs. Thermal conductivity is given as average values for 13 different lithologies in the basin (limestones, dolomite (better dolostones), shales, sandstones …). Therefore this data set provides a more general overview about thermal conductivity in the Hinton-Edson area. The data set presented in this manuscript provides thermal conductivity values specific for the Leduc Formation of the SCCC and RMRT as well as for three members of the Nisku Formation. The data set gives a first impression how the rock properties change within the reservoir (e.g. Nisku Formation).

**Referee 3 – C2 line 5:**" 1) *Introduction: the reason why Alberta has such a high per capita CO2 emission is that it is developing the worlds [sic] second largest oil field, but with a very small population base (approximately 1o% of that of Saudi Arabia that is developing the worlds [sic] largest oil field). Most of Alberta oil is exported to the US, so its [sic] questionable CO2 accounting to log it all against the producer rather than the consumer. Therefore the introduction provides some misleading statistics that have questionable value in a science paper."*

**Answer:** The $CO_2$ emissions per capita are a matter of public record and have been used for decades in all political and economic discussion of relevance, most recently by the current Federal Government and the IPCC. There is nothing 'misleading' in using them the way we did. Rather, the comment by R3 appears to be tainted by the opinions of the petroleum industry and/or the community of climate change deniers.

**Referee 3 – C2 line 11:**" *2) Introduction: The reason for such small hydro usage in Alberta is that southern Alberta is the driest part of Canada – there are very limited opportunities for hydro in the province. But as a nation Canada has over 70% of power production by renewable energy, one of the cleanest grids in the world. So again, the intro has very misleading information.*"

**Answer:** Our study is about Alberta, not about Canada as a whole. The considerable amount of hydro-electric power generation in eastern Canada is irrelevant to our study.

**Referee 3 – C2 line 15:**" 3) *Introduction: To suggest that there is a political climate that favours business over environment, and its [sic] doubtful if Alberta will want to transition to a cleaner energy system is simply outrageous – politics does not belong in a science paper. Besides, Albertans have recently elected a government that has one of the most aggressive environmental programs in North America, including implementing the largest carbon tax in Canada. Such statements that speak to the politics of a place the authors do not live in, and to speculate about future decisions Albertan's will make, have absolutely no place in a science paper."*

**Answer:** Climate change is science and policy. Geothermal energy research deals with it. The political background was triggering this research. It is a question of taste if a political statement will belong to a science paper or not. That may stay with R3.

Furthermore, to suggest that authors are entitled to comment on scientific matters with a political dimension only if they live in the area of interest smacks of racism. Besides, one of us – Prof. Machel – has been a resident of Alberta for more than 30 years. At this point we are compelled to conclude that R3 is biased to the point of having disqualified himself as a reviewer of our work.

**Referee 3 – C2 line 22:**" *4) The authors make a false claim that there is no geothermal utilisation. For direct heat use Canada is about 7th in the world (see summary by Raymond 2015). Also, within Alberta the Leduc reef is already being used for direct heat. There are also cleaver thermal storage systems in southern Alberta as well as direct heat use of waters produced from the Western Canada Sedimentary Basin in Saskatchewan, as well as planned drilling this year for electrical production wells. The authors clearly need to do more research on the state of geothermal usage in their study area."*

**Answer:** Several errors caused by misreading. Talking about "no geothermal energy utilization" (p 2, ln 27), we are discussing hydro and wind "power plants" (introduced in p 2, ln 23) "in the province" (Alberta) (p 2, ln 26f); In this sentence we are neither discussing "direct heat", nor "Canada" in general, nor "Saskatchewan".

**Referee 3 – C2 line 29:**" *5) Page 3, line 9: what is Malm*?"

**Answer:** Malm" is mentioned 5 times in the MS: 3times referred to as "Upper Jurassic Malm-Aquifer […] in Southern Germany", the other times as "German Malm Formation" and "Malm and Devonian" (p 3, ln 9). – Despite the given explanations and the hint in the immediately following line – (it's a) "regionally extensive carbonate aquifer system(s)" (p 3, ln 10f) – we will make some changes to make it absolutely clear to everybody who will not read to that line: "~~Malm and Devonian~~" "Malm Formation and Devonian Period

**Referee 3 – C2 line 29:**" *6) Page 3, C2 line 10. This gets very confusing,. Are you meaning that the overall project studies 3 aquifers or this paper? On line 12 you say there are only two aquifers in Alberta you study which is the subject of this paper. Its also not clear what is meant by two of four? What four?*"

**Answer:** These lines should be read as they are written. To make this clear to all:

- The MalVonian project focuses on the geothermal assessment of three regionally extensive carbonate aquifer systems: the Upper Jurassic Malm-Aquifer in Southern Germany and two Upper Devonian carbonate complexes in Alberta – the Southesk-Cairn Carbonate Complex (SCCC) and the Rimbey-Meadowbrook Reef Trend (RMRT).
- The work presented in this manuscript represents the first phase of the MalVonian project, starting with the investigation of the Upper Devonian carbonate complexes in Alberta (SCCC and RMRT = two aquifer systems).

- The Upper Devonian succession in the Alberta Basin comprises four aquifer systems named D1 to D4 as shown in Fig. 3 and 4. In this work, we focused on the Leduc (D3) and Nisku (D2) aquifer system. This makes two out of four.

**Referee 3 – C3 line 4:**" *7) Page 3, ln 17: This discussion on German aquifers seems out of place in a paper on Alberta, what is the relevance? I would remove this section*."

**Answer:** Hard review shall settle on a reading and understanding of the whole text. We doubt that R3 was doing this. In the introduction we made a very clear statement that our research is dealing with a comparison of the carbonate reservoir systems in Alberta and in the Northern Alps on a large scale. This is what the paper is about.

There is no sense in removing this section, because it is relevant to understand the chosen combination of methods.

**Referee 3 – C3 line 5:**" *8) Page 3, ln 23: It seems very odd to introduce looking at outcrops to understand the subsurface as some kind of new approach. Geologists in the petroleum and mining industry have been doing this pretty much ever since geology was invented – its pretty much the very foundation of geology in fact. This is nothing new and certainly not an original idea of Homuthetal2015.*"

**Answer:** We did not claim that outcrop analogue studies are a new approach. It is new in the context described above. In Alberta there are no papers published yet reporting such an approach. It is not of any scientific value to hint on reports oil industry may have in their tresors.

**Referee 3 – C3 line 10:** "*9)Page4,ln2: Delete'literally'and also,use theCanadian spelling of "Centre" not 'Center' as that is the formal spelling of the Core Centre."*

**Answer:** Agreed.

**Referee 3 – C3 line 11:**" *10) Page 4, ln 3 ".., results of drill stem test.."*

**Answer:** Agreed.

**Referee 3 – C3 line 12:**" *11) Page 4, ln 6: There is a surprising lack of reference to numerous previous geothermal studies in the Hinton area, including some on the same reef systems. As well, since these units also produced major oil fields there has been extensive research conducted on the hydrogeology. A simple web search for terms like 'Hinton geothermal' or 'Nisku hydrogeology' will provide the authors with numerous papers of relevance that should be cited. Rather than 'superficially' I would say the area has been extensively studied. Try a bit of background research as part of your study!*"

**Answer:** See answer above.

**Referee 3 – C3 line 19:**" *12) Page 4, ln 9: here you say 3 aquifers and above it was two?*"

**Answer:** See answer above.

**Referee 3 – C3 line 19:**" *13) Page 4, ln 21: the formal name is 'Rocky Mountains'*"
**Answer:** Accepted.

**Referee 3 – C3 line 20:** "*14) Page 4, ln 25: closer to 2 million.*"
**Answer:** (Dec 21) Oct 1, 2017: "Half of population" literally is (4306039 / 2) = 2.153 million (www.finance.alberta.ca or http://www.finance.alberta.ca/aboutalberta/osi/demographics/Population-Estimates/index.html). R3 again is dealing with invalid data.

**Referee 3 – C3 line 21:**" *15) Page 5, ;n 32: how does this reef trend relate to the Leduc ? need more clear descriptions of everything, same for page 6, ln 9 and 26. Lots of various terms used with no clear description what they all are.*"
**Answer:** It is not clear, what "[…] need (sic) more clear descriptions of everything." implies exactly. This is a listing which geological groups and members built the aquifer according to the given references. For more detail a reader of the paper shall consult the literature cited herein.

**Referee 3 – C3 line 23:**" *16) Page 9, ln 11: need ref for timing of larimide*"
**Answer:** Accepted.

**Referee 3 – C3 line 24:**" *17) Page 9, line 13: if there are similar fractures in both, isn't I more reasonable that they have the same origin, rather than invoking two different ones?*"
**Answer:** In outcrop and thin section two fracture types were identified. They differ in scale (microns versus centimeters). The larger ones are crosscutting the smaller ones. There is no further structural analysis in this paper. We reject this comment.

**Referee 3 – C3 line 25:***" 18) Section 5.2 this is not petrography*"
**Answer:** What else?

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