

Interactive comment on “Geologic characterization of nonconformities using outcrop and whole-rock core analogues: hydrologic implications for injection-induced seismicity” by Elizabeth S. Petrie et al.

Anonymous Referee #3

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The topic of the geological attributes of rocks near cover-basement contacts is of topical interest owing to issues related to fluid injection and induced seismicity. The paper is well within the scope of the journal. It's a well presented and clearly illustrated paper.

The Introduction should be improved by adding a specific statement of a claim or claims for the paper. We know from the Introduction that the attributes of the basement-cover interface zone is important and we have an outline or agenda for what nonconformities were examined and how. But there is no statement of the 'here we show that' variety to motivate the reader to read through the details. Such a statement should be

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added. There are several places in the text where vague or ambiguous usages could be improved.

The Discussion presents some inferences about fluid circulation and the interpretations of structures and mineral deposits. As it stands some of this text seems speculative. The arguments should at least be bolstered by pointing to some of the extant structural diagenesis literature.

Where the text describes 'fractures' and fracture mineralization, the descriptions could be more complete (and meaningful). More information could be provided on whether the fractures are 'opening mode' or faults. The use of the term 'vein' is unhelpful, particularly with respect to structures in the cover above the nonconformities. Mineral fill in fractures is common throughout sedimentary sequences (e.g. Laubach et al. 2019, Reviews of Geophysics) and such mineral deposits could provide evidence of the post depositional structural and fluid history of these zones. So a more meaningful description of these features could be useful. Note also that there are a number of published studies of fracture systems in basal Cambrian and in Ordovician sandstones of the midcontinent and other Laurentia cover rocks, and the fracture sets have a range of ages and origins. Some statement as to how representative these outcrops are of the midcontinent nonconformity zones would be helpful.

45 I think I follow what you are saying here about the definition of the 'nonconformity zone', but perhaps the definition could use sharpening. Are you talking about some volume of rock near the nonconformity that is somehow altered from what it would be if the same rock was not near the nonconformity? Do you only mean rocks in the basement or could this include rocks above the nonconformity? Can you try to make the definition more explicit?

60 Where you mention 'the nonconformity' it might help reader if you remind them here that you mean 'the nonconformity in the US midcontinent region'.

67 The Introduction would be improved by adding an explicit claim here that could start

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with the statement 'here we show that. . .' Motivate the reader rather than just providing a list of what you did.

68 But are these overlying rocks mostly quartz-rich sandstones? Isn't the basal Cambrian sandstone pretty common? I see that you outline the geology you looked at in section 2.1. Do you discuss how representative these might be?

70 Where in the Introduction do you alert the reader that you present modeling?

86 'detailed' is vague; can you replace this statement with a scale (or range of scales)? Or just omit, since the resolution level is implied by the instruments you used.

90 Is there a reason for the order that you describe the localities? Same question for the listing in section 2.1. A representative selection?

95 How low is the porosity?

100 if the fractures are bedding parallel as you say, it would be hard for them to extend into basement. Or do you mean the reduction spots are not in basement?

101 Are these slip surfaces in basement subparallel to the bedding parallel 'fractures' in the cover. Are the cover fractures faults?

110 By 'span the contact' do you mean the faults extend into the cover?

115 Something is awkward in the phrasing here.

130 Are you saying fault rock is only found in faults? Clarify text.

144 Quartz lined and quartz-filled fractures are common in quartzose sandstones even distant from nonconformities. The mineral deposits may not necessarily represent mineralization 'events' since the fractures themselves are reactive surfaces (e.g. Lander and Laubach 2015, GSA Bulletin).

155 and preceding text. What kind of 'fractures'; opening mode, or faults? Are there crosscutting relations here that provide evidence for the relative timing of these struc-

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tures? Are you implying that the shear zone in the basement is somehow related to the fractures in the cover? (Wouldn't that be surprising?)

165 Is this the porosity range at the site you sampled? It seems a stretch to say that this is the range for the Mt Simon generally, since porosity ought to reflect thermal exposure/burial history and that could vary regionally. Clarify.

183 space

186 'multi-layered veins and/or fracture mineralization'; are these different things?

192 'porous'; but can you specify how porous?

197 'structural discontinuities' seems vague.

203 Is the thickness of the nonconformity zone specified at the outset of each description above? And how did you decide where the boundaries of the zones are?

203 What is the opposite of 'in situ' mineral growth?

206 Maybe put in a table? And refer to in description.

201 The first paragraph of the Discussion seems vague and disorganized. Are these structures in the nonconformity zone' or in the basement or the cover? Are these only 'small faults' or are some of the fractures opening mode?

209 The 'non fractured'; do you mean that these zones lack fractures in general, or that in areas where fractures happen to be absent, the host rock attributes might have these effects?

210 'we note that. . .'; what is the basis for this inference? That there are porous rocks above the basement rocks?

219-220 I don't see how it follows that the 'vein mineralogy' provides evidence for cross unconformity flow. Are you talking about mineral filled fractures in the basement or in the cover? Note that from mineral composition alone it can be challenging to find evi-

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dence for fluid flow (see for example, Denny et al.2020 GSA Bulletin). Maybe this point needs more development or the conclusion should be presented in a more nuanced way.

226 In the older rock mechanics literature there are examples of fracture systems in basement associated in typical midcontinent crystalline rocks that extend to depths of hundreds of meters and then abruptly stop; so zones of penetration of alteration could be much more than 5 m (and might be heterogeneous, if linked to deep seated fractures). See references by Aubertin.

226 'that impacts' or 'that would be expected to impact'?

236 But are these the 'bed parallel' fractures?

239 What do you mean by 'deep circulation'? The basement rocks are not all that far from porous sedimentary rocks, which likely contain fluids.

241 Where did you mention what the mechanical properties of these rocks is? Did you measure them, or is that an inference from the rock types? An example of mechanical properties inhibiting fracture in the setting you are concerned with is in Ellis et al. 2012, J. Geol. Soc. London.

255 do you mean 'faults'?

259-264 Is this your claim?

265 Is this modeling work prefigured in the Introduction?

282 How representative are these various types you identify?

303 'Laubach' is the correct spelling.

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