Review of Tobias K. D. Weber, Sascha C. Iden, and Wolfgang Durner
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Peatland bog pedogenesis is reflected in unsaturated hydraulic
properties

I found this paper interesting with respect to our understanding of how peat degradation changes peat soil properties. In particular, I liked the concept of putting some quantification to peat pore sizes in the acrotelm, the "living" uppr 50 cm or so of peat columns. The shallower the peat, the greater the hydraulic conductivity whereas as the peat becomes more humified hydraulic conductivity—or at least the bulk hydraulic conductivity--becomes less.

Having aid this, I found the authors appear to have missed quite a bit literature on peatland hydrology. Decades of research on peatlands in northern Minnesota and in Canada show that ombrotrophic bogs are not necessarily supported by only precipitation. Clymos, Ingram's and Boelter's early work are dated related to peat soil hydraulic properties. Groundwater discharge can force water upwards into the base of domed bogs, supporting them during drought. To find out if groundwater discharge from regional flow systems provides hydrologic underpinning of bogs, hydrologists now sample pore water into the catotelmic (highly humified peat) and measure at least its pH and specific conductance. The authors might do a search on papers by Paul Glaser, Jeff Chanton, and myself (Donald Siegel). Paul's and my work showed how the hydraulic conductivity of peat may not change with increasing bulk density because of the secondary porosity issue.

These studies and others also show that much of the water that moves through peat can occur through preferential flow paths along fibrous roots and the like, far down into the catotelm. This funneling of water makes modeling the actrotelm using the Richard's equation questionable except at the largest of scales (big areas). Doing experiments on cores won't necessarily capture the system processes. I note that the authors of this paper describe their bog forming in a valley, which would suggest that upward groundwater discharge into it could play a role—not just lateral which they show. And, if groundwater does enter at the bottom of peat profiles, it can dilate the peat pores opening them up and increasing the hydraulic conductivity (D. Ours and Siegel). I see that the authors cite others who have worked on the same bog before, and I recommend they write a few paragraphs describing what others found and from what approach.

I don't have the time to review all the other papers. It could very well be, that this bog in question formed from lake pedogenesis. In this case, the preferential flow issue may not be as important as in the vast mires I and others have studied. The deep peat in paludafied lakes largely comes from decomposing algal remains to my understanding, superceded on top by mosses eventually. So the bog may look like a bog in say, Siberia, but hydraulically it might behave very differently. Paludified catotelmic peat really gets dense and humified compared to peat in other settings and may behave more in line with the Dickey Clymo model. I think the authors need to address this question head on. What kind of bog it is and how did it form?

Ironically, the same problems with the Richardson equation applies to mineral soils in forested terrains. Check out Jeff McDonnel's and Keith Bevin's recent papers on this issue. They argue that new theory has to be developed to address how water moves through unsaturated soils of all types, at least at the scale short of regional synthesis. Indeed, preferential flow is so important that Zeno Levy recently published a paper showing that solutes can move from active pore spaces into dead pores to create strange geochemical signals in the catotelm (a dual porosity issue). Chanton's isotopic work showed that much of the methane generated in wetlands may come from modern labile carbon that is driven down deep though the acrotelm into the catotelm. Bacteria use this labile carbon to form methane at depth and the methane episodically blows out when the water table drops, and in the process, no doubt creates preferential flow paths all the way to the top.

So, no—I don't buy into the notion that mosses only take water from the upper few cm of peat soils. This makes no sense from what I know of peatland hydrology.

I fully understand that the authors of this paper only looked at the very fibrous peat in the upper 50 cm of the peat column. And that's ok. But they neglect preferential flow and I think this makes their work less useful. The experimental method also strikes me as problematic. In all the years I have taken cores of peat, we take care NOT to freeze them. How can freezing not affect porosity of peat, since frozen water notoriously creates porosity though expansion. Plant cells burst. I see this every time I accidently leave an orange in my freezer too long (for use in drinks). I think the authors need to address this more, rather than cite a paper saying there is no problem.

I also have a problem treating peat porosity akin to soil porosity, talking about pore diameters as if they were spheres. They are not. Peat pores can be linear and vertical, horizontal etc. We are looking at a living system of plants in laid down decomposed plants. Perhaps at the end, some kind of uniform matrix pore distribution can occur, but even then, I see the preferential issue, so clear from a great deal of independent research. At least in mire peat.

Finally, peat can have lower saturated hydraulic conductivity in natural setting because of methane buildup in the pores of question. In natural peatlands, methane can fill up to 20% of lower acrotelmic and then deeper catotelmic peat at times. Check out a paper by Don Rosenberry on this. So flushing out small pieces of peat with DI or air destroys some of the process you want to figure out.

While I have some issues with this paper, I do find some good things too. I liked the hypotheses being proposed and the math seems solid to me. The math results agree with their conclusions, but of course, they would have given thT inversely fitting a model using the Richards equation can be done by uaing different suites of assumed parameterizations. The model is non-unique—as are all mathematical models of hydrology. Even given the lack of recognition for dual porosity and preferential flow being not incorporated into the equation and van Gnutchen solution, I would want to see more sensitivity analysis to show that the parameterization chosen was the best of the lot.

The authors do mention macropores just before their conclusion:

"*that from a soil hydrological perspective, the water storage domain consist of an active and inactive porosity delimited at a pressure head of $h = -100$ cm".*

While I'm uncertain the -100 cm head applied for peatlands in general, this result needs to be stated or addressed more clearly before the conclusion proper. I think that there may be more active porosity than what the authors think because of methane ebullition and plants other than sphagnum with roots penetrating deeper than 30 cm or so. Are there spruce or other trees in the peat system studied? In places where fen vegetation occurs, I have seen sedge roots go down far deeper, meters. These can funnel labile carbon to depth among other things.

So, my recommendation is for the authors to clarify more for the readers (e.g. when citing a fact like freezing doesn't matter--say why), and address some of the issues I bring up.

I recall a conversation I had with Sandy Verry, who with Boelter, did the earliest work on peat permeability from a small kettle lake bog setting. Paul Glaser and I were coming up with orders of magnitude greater values using piezometers and other sampling devices in the Glacial Lake Agassiz peatland. I asked Sandy what he thought and he said he was not surprised, that they only took samples where they saw no roots and other structures. He said his work reflected matrix and not bulk peat.

Perhaps all that is needed may be for the authors of this paper to state something like that. Recognize that preferential flow may be the driver at larger scales but in its absence, their conceptual model works.

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