Earth Syst. Sci. Data Discuss.,
https://doi.org/10.5194/essd-2018-139-RC1, 2018

Open Access Earth System Science Data Discussions

Interactive comment on "Geology datasets of North America for use with ice sheet models" *by* Evan J. Gowan et al.

Anonymous Referee #1

Received and published: 8 December 2018

General comments:

This paper presents three geologic maps spanning northern North America and Greenland, showing quantities related to sediment at the ice-bed interface. As discussed, sediment has important effects on basal sliding and hydrology in ice sheet models of Quaternary glacial cycles. The effect of these maps is illustrated using the PISM ice sheet model, comparing simulations at LGM to those using uniform sediment properties. The geological data sources, methods of assimilation and resulting maps are well described, although that is mostly outside my experience, and the points below are from an ice-sheet modeling perspective.

The datasets themselves (Figs. 1-3) may be a worthwhile contribution for this area of ice-sheet modeling. However, the relationship to model parameters and usage pre-

Printer-friendly version

Discussion paper

sented in the paper is not as useful. An alternative would be not to include any linkage at all with physics and modeling, and just to present Figs. 1 to 3 as descriptions of the real world, and leave it to users to make the links to ice-sheet models. But the former is included here (Table 3, Eq. (1) and the PISM runs), and its physical basis could be improved and made more useful, as discused below.

Specific comments:

1. A Coulomb rheology model is adopted as used in the PISM model (Eq. 1), and one parameter (shear friction angle phi) is chosen to be related to the geologic quantities mapped here. There is little discussion (section 3.1, pg. 7) on the physics of how the map properties in Figs. 1-3 are related to the model's phi, and why phi is chosen over other model parameters such as those involved with N for instance (in Eq. 1, involving basal hydrology). The values chosen for the range of phi (10, 20, 30 degrees, pg. 8 lines 28-29) are not justified well; a reference could be given for how those relate to extremes of hard bed vs. deformable sediment (see (5) below). More discussion would be helpful on how the 3 quantities mapped here (sediment distribution, grain size, bedrock type) relate physically to sliding, why three maps are useful rather than one, and how they relate to other parameters in sliding models and not just phi. As a bonus, relations to Weertman sliding coefficients could be provided as well as to Coulomb parameters.

2. In section 2.3 discussing sediment properties, the text says "Glacial sediments tend to be very poorly sorted, so these values should be assessed as being an average composition" (pg. 5 lines 12-13). Confusingly, the rest of the section seems to discuss grain-size properties only of the fine-grained material (matrix) that enclose pebbles and boulders (clast), and exclude the pebbles+boulders themselves. (Grain-size values in Table 3 are sub-millimeter). Do the clay and silt classes (pg. 5, lines 18-19) have significant fractions of pebbles+boulders, which is only mentioned for sand (line 21)? If so, what are the ranges of that fraction for each class? Do pebbles+boulders significantly influence the bulk(?) physical properties in Table 3? Both clast and matrix play cru-

cial roles in sediment deformation in Evans et al.'s comprehensive review (referenced here: Earth-Sci. Rev., 2006), especially their sections 5.1 to 5.4 on the "till-matrix framework".

3. Another perhaps naive physical question: if sedimentary till has been transported over long distances under the ice in previous glacial cycles, wouldn't the sediment properties be related to parent bedrock type(s) far upstream, and not to the local bedrock type as assumed here? This seems to be addressed by lines 26-28 on pg. 5 referring qualitatively to Fulton (1989), but isn't large-scale sediment transport a major feature of Quaternary glaciations?

4. (related to (1) above). The spatial patterns of the 3 datasets in Figs. 1-3 are all quite similar. That is, roughly speaking they all show mainly one value for Hudson Bay and the outer regions of the former LGM Laurentide, and mainly another value for Canadian Shield regions surrounding Hudson Bay, the Canadian Rockies, and Greenland. So not surprisingly the patterns of model LGM delta(ice-thickness) sensitivities shown in Figs. 4d-6d are all quite similar to each other.

Although the patterns are similar, the magnitudes of phi in Figs. 4b-6b differ. For instance, the values over Hudson Bay vs. Canadian Shield regions are generally ∼10 vs. 20 degrees in Fig. 4b using map # 1, ∼20 vs. 30 degrees in Fig. 5b using map # 2, and ∼10 vs. 30 degrees in Fig. 6b using map # 3. It is left for ice-sheet modelers to choose which map is best for phi, for which no guidance is given.

5. Model ice-thickness results in Figs. 4-6 are compared with those using a uniform value of phi=30. The delta(thickness) magnitudes in the (d) panels seem smaller and much less extensive than in early Laurentide studies exploring sediment vs. hard-bed effects, such as Fisher et al. (1985) and Licciardi et al. (1998) referenced here on pg. 2, line 14. Perhaps this is due to smaller contrasts in yield stress here than in the earlier studies, and a larger range of phi could be used than 10 to 30 degrees.

6. In several places the text mentions or implies stratigraphic relationships between the

underlying bedrock, layers of glacially derived sediment, perhaps layers of earlier (or Holocene?) non-glacial sediment, and water bodies; for instance on pg. 3 lines 1-3, pg. 4 lines 1-4, pg. 4 line 19. For a non-geologist, it is challenging to conceptualize this clearly, and to keep straight what the stratigraphic relationships are (for glacial vs. non-glacial sediment), and whether they are important. I suggest slightly expanded discussion in places. Also a simple diagram would be helpful that shows the various idealized stratigraphic cases, with labeled horizontal rectangles one on top of each other. The cases would always have underlying bedrock, then one case with bedrock covered by glacial sediment (perhaps with horizontal breaks indicating patchiness), another with bedrock + non-glacial sediment, another with bedrock + glacial sediment + water body, etc.

7. If possible, ranges of thickness values for each type of layer could be shown in the diagram suggested above. These are mentioned in places in the text, and could be gathered there. The paper says (pg. 7 line 14) "it is not possible to give a detailed quantitative estimate of (sediment) distribution and thickness", but even rough ranges would be helpful. Melanson et al. (QSR, 2013, Fig. 1), and Hildes et al. (QSR, 2004, Fig. 4) produced sediment thickness maps based on Fulton et al. (2005) referenced here; could a guide be provided here? Maps of sediment thickness are not so important for models of LGM or the last glacial cycle, but are more helpful for longer-term studies of Plio-Pleistocene variations involving sediment evolution, such as Ganopolski et al., Clim. Past, 2011.

8. The areas in Figs. 4d-6d where model LGM delta(ice thicknesses) are appreciable occur mostly around the margins of the ice sheet. The paper suggests this is controlled in part by areas where the bed is sufficiently warm and wet to allow sliding in the PISM model (pg. 8 line 35). This could be corroborated by showing a model map of basal temperature or basal melt rate for 21 ka.

Technical points:

pg. 5 lines 30-33: The classification relating bedrock to grain size is given for silt (line 30) and sand (line 32), but seems to be missing for clay.

pg. 6 line 11: The name "Felsic volcanic" is used twice. Possibly the 2nd should be "Mafic volcanic".

pg. 7 line 4-6: Table 3 is discussed in section 3.1, before Eq. (1) and shear friction angle and cohesion (quantities in the table) are discussed in section 3.2. This could be resolved easily by referring to Eq. (1) and following text in the table caption.

pg. 7 lines 9-11. The two consecutive sentences beginning "The patchiness of sediment..." and "The lack of sediment.." seem to say nearly the same thing. Is the distinction one of horizontal scale?

pg. 7 line 17: Regarding drainage of water under the ice, perhaps clarify in a few words that the permeability of bedrock under the sediment "aquifer" is involved here, I think. (As opposed to permeability of sediment as in Table 3, which would use map # 2 for grain size and not map # 3 for bedrock type).

pg. 8 line 34; pg. 9 line 13; pg. 9 line 22: These sentences say that south of the Great Lakes at LGM, the ice sheet extends further than in the reference simulation. However there is no discernible difference in the margin locations south of the Great Lakes in Figs. 4a vs. c, 5a vs. c, 6a vs. c. How many km does "further south" mean in the sentences, and why is it not visible in the figures?

Minor corrections/suggestions: pg. 1 line 4: Should be "distribution of surficial". pg. 3 line 22: "When" should be "In". pg. 4 line 11: Is "bend simplify" intended? pg. 4 line 16; pg 5 line 9; pg. 7 line 4; pg. 9 line 9,15: "on" should be "in". pg. 6 line 18: Should be "as most of these". pg. 7 line 11: Should be "of the latter". pg. 7 line 17: "later" should be "latter".

Interactive comment on Earth Syst. Sci. Data Discuss., https://doi.org/10.5194/essd-2018-139, 2018.

Printer-friendly version

Discussion paper