# Forum Comment

https://doi.org/10.1130/G39987C.1

# Tropical weathering of the Taconic orogeny (i.e., “orogen”) as a driver for Ordovician cooling

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Swanson-Hysell and Macdonald (2017) follow Kump et al.’s (1999) proposal that decreasing temperatures through the Ordovician (e.g., Trotter et al., 2008) are largely explained by $CO_2$ sequestration with weathering of silicates exposed by Taconic arc-Laurentia collision. They propose higher weatherability of the west-east–trending Taconic orogen that they shift to a more equatorial, wet-tropical setting. The concerns that may be raised by a reader are whether the following are all responses to this orogeny: (1) the Ordovician temperature record, (2) the strontium and neodymium isotope record interpreted to reflect the Taconic orogeny (Swanson-Hysell and Macdonald, 2017), and (3) the interpreted $pCO_2$.

The amount and rate of $CO_2$ sequestration with weathering of obducted Taconian mafics and ultramafics likely do not have an analog in the late Cretaceous and early Eocene arcs discussed by Jagoutz et al. (2016). The Taconic arc system had an ~4500 km length (i.e., Alabama–west Newfoundland–northern Irish-Scottish Grampian orogen). Continuation of Taconic arcs past Greenland (Swanson-Hysell and Macdonald’s figure1) is speculative as east Greenland was not part of the Taconic orogen and northern Ellesmere Island (Pearya terrane) and Southwest Svalbard likely form the northern Caledonides (Cocks and Torsvik, 2011). Although the Taconic orogen is comparable in length with the subduction complexes discussed by Jagoutz et al. (2016), is it possible, following the Kump et al. (1999) and Swanson-Hysell and Macdonald’s syntheses, that weathering of Taconic arc successions and sequestering of $CO_2$ would have decreased global temperatures? This question is appropriate, as Taconic mafic and ultramafic bodies are isolated and small (~25 km wide in the Bay of Islands Complex) (Williams and Talkington, 1977) and do not reach the size (up to 200 km wide) that allowed great $CO_2$ consumption with weathering of the Neo-Tethyan arcs (Jagoutz et al., 2016).

Except for terminal Ordovician glaciation, most of the period featured a climate maximum (e.g., Sheehan, 2001). This meant warm, humid conditions across a wider range of latitudes, as shallow epeiric seas with high insolation onlapped reflective continents and led to high levels of the greenhouse-gas water vapor. These post-greenhouse, hyperwarming conditions accompanied high Early Ordovician (particularly Tremadocian) and Caradocian sea levels (Landing, 2012). It is peculiar that Swanson-Hysell and Macdonald (also see Boucot et al., 2013) limited the “warm and wet tropics” to a modern equatorial distribution when these conditions and high weatherability of obducted arc rocks would have extended much farther north and south with eustatic maxima. Swanson-Hysell and Macdonald reinterpreted existing 1990s paleolatitude data on Taconic arc complexes to shift the east Laurentian margin 10° north into the “wet tropics” to allow for greater weatherability and $CO_2$ sequestration. This proposed latitudinal shift is unnecessary—even the “classic,” south-tropical position of east Laurentia placed the orogen in the “warm and wet tropics” with high sea levels (Landing, 2012).

Ordovician temperature and geochemical trends suggest $pCO_2$ and tectonic history had little to do with climate changes through the period. The high earliest Ordovician temperatures (Trotter et al., 2008) correspond to high eustatic levels, and later Early Ordovician temperatures mirror lower eustatic intervals (Landing, 2012). By the Kump et al. (1999) tectonic-$pCO_2$ model, this entire Early Ordovician interval should have had low temperatures, given coeval orogeny along the 6000-km-long Altaid belt (Dobretsov and Buslov, 2007).

If Ordovician temperatures tracked tectonic developments, then Swanson-Hysell and Macdonald’s (their figure 2C) 460 Ma “exhumation of the Taconic arcs” should have led to temperature fall—but it marks a temperature *rise* (Trotter et al., 2008) that comports with eustatic rise at the onset of the trans-Laurentian Tippecanoe Sequence (Landing, 2012). This transgression would also have led to more mature $^{87}Sr/^{86}Sr$ ratios with lowered continental weathering (e.g., Young et al., 2009). These Sr-ratios would not have reflected arc erosion (*contra* Swanson-Hysell and Macdonald, 2017), More positive $\varepsilon_{Nd}$ at 460 Ma is also consistent with eustatic rise and diminished weathering of Precambrian basement, and not necessarily arc erosion. That “arc exhumation” and arc-continent collision took place at 460 Ma (Swanson-Hysell and Macdonald, 2017) may be not consistent with the active explosive, 460–450 Ma volcanism recorded in central Laurentia (Huff et al., 2010) that suggests arc-continent collision was not completed by 460 Ma.

An alternative interpretation that changes in $pCO_2$ controlled global temperature is that the Ordovician temperature curve records major eustatic level changes in the Tremadocian, late Darriwillian, and Katian stages. The cause of very low latest Ordovician temperatures would be increased albedo with low eustatic levels and Gondwanan ice cap development.

## REFERENCES CITED

Boucot, A.J., Chen, X., Scotese, C.R., and Morley, R.J., 2013, Phanerozoic paleoclimate: An atlas of lithologic indicators of climate: Society for Sedimentary Geology (SEPM) Concepts in Sedimentology and Paleontology, No. 11: Map Folio, 28 maps.

Cocks, L.R.M., and Torsvik, T.H., 2011, The Palaeozoic geography of Laurentia and western Laurussia: a stable craton with mobile margins: Earth-Science Reviews, v. 106, p. 1–51, https://doi.org/10.1016/j.earscirev.2011.01.007.

Dobretsov, N.L., and Buslov, M.M., 2007, Late Cambrian–Ordovician tectonics and geodynamics of Central Asia: Russian Geology and Geophysics, v. 48, p. 71–82, https://doi.org/10.1016/j.rgg.2006.12.006.

Huff, W.D., Bergström, S.M., and Kolata, D.R., 2010, Ordovician explosive volcanism. in Finney, S.C. and Berry, W.B.N., eds., The Ordovician Earth System: Geological Society of America Special Paper 466, p. 13–28, doi:https://doi.org/10.1130/2010.2466(02).

Jagoutz, O., Macdonald, F.A., and Royden, L., 2016, Low-latitude arc-continent collision as a driver for global cooling: Proceedings of the National Academy of Sciences of the United States of America, v. 113, p. 4935–4940, https://doi.org/10.1073/pnas.1523667113.

Kump, L.R., Arthur, M., Patzkowsky, M.E., Gibbs, M.E., Pinkus, M.T., and Sheehan, P.M., 1999, A weathering hypothesis for glaciation at high atmospheric pCO2 during the Late Ordovician: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 152, p. 173–187, https://doi.org/10.1016/S0031-0182(99)00046-2.

Landing, E., 2012, Time-specific black mudstones and global hyperwarming on the Cambrian–Ordovician slope and shelf of the Laurentia palaeocontinent: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 367–368, p. 256–272, https://doi.org/10.1016/j.palaeo.2011.09.005.

Sheehan, P.M., 2001, The Late Ordovician mass extinction: Annual Review of Earth and Planetary Sciences, v. 29, p. 331–364, https://doi.org/10.1146/annurev.earth.29.1.331.

Swanson-Hysell, N.L., and Macdonald, F.A., 2017, Tropical weathering of the Taconic orogeny as a driver for Ordovician cooling: Geology, v. 45, p. 719–722, https://doi.org/10.1130/G38985.1.

Trotter, J.A., Williams, I.S., Barnes, C.R., Lécuyer, C., and Nicoll, R.S., 2008, Did cooling oceans trigger Ordovician diversification? Evidence from conodont thermometry: Science, v. 321, p. 550–554, https://doi.org/10.1126/science.1155814.

Williams, H., and Talkington, R.W., 1977, Distribution and tectonic setting of ophiolites and ophiolitic melanges in the Appalachian orogen, in Coleman, R.G. and Irwin, W.P., North American Ophiolites: Oregon Department of Geological and Mineral Industries: Bulletin, v. 11, p. 1–11.

Young, S.A., Saltzman, M.R., Foland, K.A., Linder, J.S., and Kump, L., 2009, A major drop in seawater 87Sr/86Sr during the Middle Ordovician (Darriwillian): links to volcanism and climate?: Geology, v. 37, p. 951–954, https://doi.org/10.1130/G30152A.1.