Forum Reply

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Wyoming on the run—Toward final Paleoproterozoic assembly of Laurentia

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We thank Hrncir et al. (2017) for giving us the opportunity to elaborate on a new model for final amalgamation of Laurentia. We emphasize the most pertinent two aspects of their Comment.

(1) Separation between Wyoming and Superior cratons at 1.90 Ga. Paleomagnetic data support a reconstruction that connects southeast Wyoming (WY) to southern Superior (SU) from ca. 2.65 to 2.15 Ga (Kilian, 2015). Subsequent rifting of the two cratons is clearly marked by the intrusion of multiple coeval dike swarms (Kilian, 2015) and the widespread development of passive margin sequences along the edges of both cratons. Although there are numerous potential reconstructions using the paleomagnetic data from the ca. 1.90 Ga Sourdough dikes alone (indicated by the small circle in our figure 3 (Kilian et al., 2016)), the simplest geodynamic model favors a large ocean between WY and SU at that time. If, as Hrncir et al. suggest, WY and SU remain coupled at 1.90 Ga (near 'Position B' in our figure 3), the Sourdough dike data require that WY would have rotated ~30º counterclockwise from 2.15 to 1.90 Ga before pirouetting ~150º clockwise from 1.90 to 1.75 Ga around the southwestern promontory of SU. Terranes known to rotate >90º relative to adjacent landmasses within 150 m.y. are oroclinally folded ribbon-like features, not intact Archean cratons. If, as we propose, a large ocean existed between WY and SU ('Position A' in our figure 3), then the two cratons would have traveled through opposing hemispheres past the north pole, satisfying paleomagnetic data with modest and unidirectional rotations from 2.15 to 1.72 Ga.

(2) Final docking of Wyoming and Superior at 1.72 Ga. In complex orogenic belts such as those between WY and SU, the timing of docking is best constrained by the age of the latest, dominant period of convergent deformation. In the Hartville Uplift (HU), east of the Laramie Mountains, the dominant deformation is late east-west shortening (Day et al., 1999) manifested by the >70-km-long, Hartville-Rawhide fault, a high-grade, mylonitic reverse fault with 10 km of east-side up displacement (Krugh, 1997), and by a west-vergent imbricate thrust stack (Day et al., 1999). The timings of deformation for these features come from concordant U-Pb dates of magmatic zircon; they are not cooling dates, nor are they vulnerable to resetting. The Hartville-Rawhide fault is <1.745 Ga, and a subordinate mylonite is <1730 Ma. The imbricate thrust fault is directly dated to 1714 ± 2 Ma (Krugh, 1997). The Haystack granite, which Hrncir et al. suggest may have reset ages in the HU, had a 1.720 Ga Rb-Sr date, but is 1.745 Ga based on concordant U-Pb zircon data. The 1714 Ma magmatism in the HU is restricted to tourmaline-bearing pegmatitic pods and dikes that occur along the eastern flanks of the uplift. They are compositionally similar to the coeval Harney Peak granite in the Black Hills (BH), which has been modeled to form due to shear heating during final thrusting and convergence (Nabelek and Liu, 1999). We adopt the same interpretation for the pegmatites in the HU, especially in light of the direct date on coeval thrusting at the surface.

Additional evidence for final docking of WY and SU at ca. 1.72 Ga occurs in the east central Laramie Mountains, where ca. 1.76 Ga north-vergent fabrics are crenulated and overprinted by west-vergent fabrics dated to 1722 ± 6 Ma by syndeformational titanite growth (Allard, 2003).

The kinematic history of the BH is more protracted and complex than in the HU, but does not necessarily relate to the history of the eastern margin of WY until close to the time of final docking. Northward shortening in the BH at 1.78 Ga is modeled to relate to Cheyenne belt accretion, but the BH may have been several 100 km south of their current position, along strike of the Cheyenne belt ca. 1.78 Ga—an idea supported by 1740–1715 Ma north-south strike-slip shear zones along the eastern and western flanks of the BH (Allard and Portis, 2013).

The BH basement could be a sliver of the Sask or Superior craton, or entirely exotic. Ages of 2.60 and 2.55 Ga, found in BH granites, are very rare in WY. Granites previously thought to be those ages have been redated to 2.65–2.63 Ga by modern U-Pb zircon techniques. There are more differences between the Paleoproterozoic sedimentary sequences of southeastern WY and the BH than there are similarities. In our model, the broad Proterozoic orogenic belt is a tectonic collage of Archean microcontinents (aeromagnetic highs), surrounded by Proterozoic rocks. The presence of aeromagnetic lows, plus variations in other geophysical characteristics, argues against a continuous Archean craton between the Bighorn Mountains and BH (Worthington et al., 2016).

The 1.72 Ga date for docking between WY and SU postdates the timing of accretion along the Cheyenne belt and refutes the idea of a single broad Yavapai orogen stretching from Wyoming to the Great Lakes. We model the 1.72 Ga suture to continue to the southeast, manifested by the southeastward-trending arm of the Central Plains Orogeny. Our wide-ocean hypothesis for 1.90 Ga, with subsequent accretion of WY at 1.72 Ga, is consistent with paleomagnetic and tectonic data, avoids awkward relative rotations between adjacent blocks, and is testable by future geological and geophysical study.

REFERENCES CITED

Allard, S.T., 2003, Geologic evolution of Archean and Paleoproterozoic rocks in the northern Palmer Canyon block, central Laramie Mountains, Albany County, Wyoming [Ph.D. thesis]: Laramie, University of Wyoming, 389 p.

Allard, S.T., and Portis, D.H., 2013, Paleoproterozoic transpressional shear zone, eastern Black Hills, South Dakota: Implications for the late tectonic history of the southern Trans-Hudson Orogen: Rocky Mountain Geology, v. 48, no. 2, p. 73 doi:10.2113/gsrocky.48.2.73.

Day, W.C., Sims, P.K., Snyder, G.L., Wilson, A.B., and Klein, T.L., 1999, Geologic map of Precambrian rocks, Rawhide Buttes West Quadrangle and part of Rawhide Buttes East Quadrangle, Hartville Uplift, Goshen and Niobrara Counties, Wyoming: U.S.G.S. Investigation Series I-2635, 14 p.

Hrncir, J., Karlstrom, K., and Dahl, P., 2017, Wyoming on the run—Toward final Paleoproterozoic assembly of Laurentia: Geology: Comment: v. 45, p. e411, doi:10.1130/G38826C.1.

Kilian, T.M., 2015, Precambrian paleomagnetism of mafic dike swarms and the Wyoming craton: Implications for an Archean supercontinent [Ph.D. thesis]: New Haven, Connecticut, Yale University, 329 p.

Kilian, T.M., Chamberlain, K.R., Evans, D.A.D., Bleeker, W., and Cousens, B.L., 2016, Wyoming on the run—Toward final Paleoproterozoic assembly of Laurentia: Geology, v. 44, p. 863–866, doi:10.1130/G38042.1.

Krugh, K.A., 1997, Uranium-lead thermochronologic constraints on the early Proterozoic tectonic evolution of the Hartville Uplift, southeast Wyoming [EP20251 M.S.]: Laramie, University of Wyoming, 77 p.

Nabelek, P.I., and Liu, M., 1999, Leucogranites in the Black Hills of South Dakota: The consequence of shear heating during continental collision: Geology, v. 27, p. 523–526, doi:10.1130/0091-7613(1999)027<0523:LITBHO>2.3.CO;2.

Worthington, L.L., Miller, K.C., Erslev, E.A., Anderson, M.L., Chamberlain, K.R., Sheehan, A.F., Yeck, W.L., Harder, S.H., and Siddoway, C.S., 2016, Crustal structure of the Bighorn Mountains region: Precambrian influence on Laramide shortening and uplift in north-central Wyoming: Tectonics, v. 35, p. 208–236, doi:10.1002/2015TC003840.