Forum Reply

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A newly identified Gondwanan terrane in the northern Appalachian Mountains: Implications for the Taconic orogeny and closure of the Iapetus Ocean

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We (Macdonald et al., 2014) used new geochronological data to delineate the suture between Laurentia and Gondwana in the New England Appalachians and reassess the tectonic evolution of the Taconic orogeny. Detrital zircon ages demonstrate that the Moretown Formation (Fm) was deposited on a peri-Gondwanan terrane, referred to as the Moretown terrane, and metamorphic and igneous ages suggest that it accreted to extended fragments of the rifted Laurentian margin, represented by the Rowe Schist, by 475 Ma. De Souza and Tremblay (2014) instead assert that the new detrital zircon data are consistent with a Laurentian provenance for the Moretown Fm, particularly from Neoproterozoic rift-related rocks, and they further claim that there is no evidence for a suture between the Moretown Fm and the Rowe Schist of the Laurentian margin.

De Souza and Tremblay begin by correlating the Cram Hill Fm in Vermont, which overlies the Moretown Fm, with the Saint-Daniel Mélange in Quebec, which they interpret as a Middle Ordovician foreland deposit that overlies rocks equivalent with the Moretown Fm. The Cram Hill Fm is correlated with the structurally highest rocks in the Hawley Fm, and Macdonald et al. (2014) showed that Laurentian detrital zircon contributed detritus to the Hawley Fm by ca. 475 Ma. Thus, De Souza and Tremblay's correlation is consistent with our model, which calls for accretion of the Moretown terrane by the Early Ordovician (ca. 475 Ma). De Souza and Tremblay are correct that the 502 ± 4 Ma age cited as a minimum age constraint on the Moretown Fm is from an intrusion in rocks mapped as Cram Hill Fm (Ratcliffe et al., 2011), but we suggest that the intruded rocks are better correlated with the Moretown Fm. Moreover, De Souza and Tremblay's assertion that the 502 ± 4 Ma intrusion is in the Cram Hill Fm is inconsistent with their correlation of the Cram Hill Fm with the 465–460 Ma Saint-Daniel Mélange.

De Souza and Tremblay cite Stanley and Ratcliffe (1985) to support their claim that the Moretown Fm was derived "in part from the erosion of metamorphosed rift clastics and volcanics exposed in the Green Mountains anticlinorium". Stanley and Ratcliffe (1985, p. 1239) actually suggested that the Moretown Fm originated from "emerged parts of an accretionary wedge made up of older rocks now exposed in the Rowe Schist, Underhill, and equivalent formations" in a basin bounded by an accretionary wedge to the west and an island arc to the east. Our data demonstrate a dramatic difference in detrital zircon ages between the unarguably Laurentian-derived Rowe Schist and the Moretown Fm (Macdonald et al., 2014). Further evidence for a suture is provided by the high concentration of ultramafic lenses near this contact in New England (Ratcliffe et al., 2011).

De Souza and Tremblay's claim that the Moretown Fm was deposited at or after 475 Ma and contains detritus from Laurentian Neoproterozoic rift-related magmatism is unlikely for several reasons. Neoproterozoic zircon dominates the Moretown Fm, but constitute <5% of dated grains in Laurentian Paleozoic strata (Cawood and Nemchin, 2001). This is probably because Neoproterozoic mafic magmatism was zircon-poor and by 475 Ma was either eroded or deeply buried beneath younger continental margin rocks. Hodych and Cox (2007) documented Laurentian plume- and rift-related magmatism between 615 and 550 Ma, which is younger than a large population of 700–615 Ma grains and older than seven grains from the Moretown Fm, which were dated with CA-TIMS between 545.7 ± 0.3 and 513.8 ± 0.6 Ma (Macdonald et al., 2014). Five of these grains were broken into two fragments that were dated separately and gave the same date, demonstrating that none of our dates are "too young" due to Pb loss or metamorphic overgrowths. The lack of 545–514 Ma Laurentian rift-related magmatism suggests these Moretown Fm grains are from elsewhere. The nearest rocks of this age occur in Ganderia (New River Fm; Fyffe et al., 2009). Finally, Neoproterozoic zircon from our Moretown Fm samples have moderately low Nb/Th, which is consistent with derivation from subduction-related rather than rift-related rocks (Tani et al., 2010).

Detrital zircon in Paleozoic strata of the Iapetan rifted margin of Laurentia are dominated by Mesoproterozoic Grenville grains (Cawood and Nemchin, 2001), whereas detrital zircon from sedimentary rocks on Gondwanan terranes are dominated by grains from late Neoproterozoic arcs (Fyffe et al., 2009). Our data demonstrate that this sharp contrast in provenance coincides with the Rowe Schist-Moretown Fm boundary. We suggest that the Early Ordovician (ca. 475 Ma) accretion of the peri-Gondwanan Moretown terrane to the peri-Laurentian Rowe belt, and their subsequent shared tectonic, depositional, and magmatic histories contributed to the cryptic nature of this suture. Our model predicts that younger syntectonic units such as the Saint-Daniel Mélange, Hawley Fm, and Cram Hill Fm should overlap both Laurentian and Gondwanan elements of the Taconic orogen.

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A newly identified Gondwanan terrane in the northern Appalachian Mountains: Implications for the Taconic orogeny and closure of the Iapetus Ocean

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On the basis of detrital zircon U-Pb ages, MacDonald et al. (2014) propose a new Gondwanan terrane, the Moretown terrane, which would have been accreted to Laurentia during the Taconic orogeny in the New England Appalachians. This terrane, solely represented by the Moretown Formation, would be bound to the west by the Red Indian Line, the Iapetan suture between Laurentia and Gondwana. We present an alternative interpretation that takes better account of the Neoproterozoic to Ordovician geological history of the Vermont and Quebec Appalachians, where there is no evidence for such a suture.

In northern Vermont, the Moretown Formation is overlain by the Cram Hill Formation, which correlates with the Saint-Daniel Mélange of Quebec (Doolan et al., 1982). The Saint-Daniel Mélange (ca. 465–460 Ma) forms the base of an Ordovician peri-Laurentian synorogenic forearc basin interpreted to be the result of the syn- to late-Taconian exhumation of the orogenic wedge (Tremblay et al., 2011). The Cram Hill Formation also overlies the Umbrella Hill Conglomerate, which unconformably overlies Cambrian Laurentian margin metasandstone of the Stowe Formation (Doolan et al., 1982). It has also been proposed that the Umbrella Hill Conglomerate locally grades upward into the Moretown Formation (Doolan et al., 1982). Based on stratigraphic relationships and petrography, Stanley and Ratcliffe (1985) argued that the Moretown Formation derived in part from the erosion of metamorphosed rift clastics and volcanics exposed in the Green Mountains anticlinorium and was deposited in an Ordovician forearc setting.

The maximum age of the Moretown Formation can be constrained by the youngest dated detrital zircon at 513.8 ± 0.5 Ma (MacDonald et al.), but attributing a minimum age yields ambiguous results due to superposed deformation and metamorphism, especially where the Moretown Formation shares complex relationships with 496 to 462 Ma intrusions and fault-bounded slivers (Ratcliffe et al., 1998). MacDonald et al. propose to use the 502 ± 4 Ma U-Pb age of the Newfane tonalite (Aleinikoff et al., 2011), that they cite as crosscutting the Moretown Formation. However, the dated sample of this tonalite was collected from the Cram Hill Formation, not the Moretown. Nevertheless, the 475.0 ± 0.1 Ma Hallockville Pond Gneiss in Massachusetts seems to clearly intrude the Moretown Formation (MacDonald et al.). On these bases, we prefer to use maximum and minimum ages of ca. 514 and 475 Ma for the deposition of the Moretown Formation, the latter age being possibly as young as ca. 465 Ma if one considers the stratigraphic relationships of northern Vermont. Regarding that the oldest preserved arc-related rocks are dated at ca. 496 Ma in the area (i.e., the Barnard Gneiss; Ratcliffe et al., 1998), the formation of a forearc basin represented in part by the Moretown Formation, could have been initiated as early as late Cambrian–earliest Ordovician. In Vermont and adjacent Quebec, Taconian orogenesis on the Laurentian margin has been attributed to ophiolite obduction, accretion of volcanic arc rocks and nappe emplacement that were initiated at ca. 475–470 Ma (Tremblay et al., 2011; Castonguay et al., 2012).

MacDonald et al. demonstrate that the Moretown Formation shows a dominant Neoproterozoic detrital zircon population between ca. 650 and 520 Ma, with minor peaks at ca. 1050 and 1200 Ma. As a result, they propose an easterly Gondwanan source and that the Moretown Formation must have a different provenance relative to peri-Laurentian clastic rocks, which are dominated by ca. 1000 and 1500 Ma detrital zircons attributed to Grenvillian sources. However, rift-related ca. 615 to 550 Ma volcanic rocks, dikes, and clastic sedimentary rocks are locally prominent along the Laurentian margin, especially along the axis of the Ottawa-Bonnechère graben and the Sutton–Green Mountains anticlinorium (Hodych and Cox, 2007). These Neoproterozoic rocks thus represent alternative sources of detritus that could have been eroded from uplifted Taconian forearc highs and deposited within a forearc basin, in part represented by the Moretown Formation.

Also, MacDonald et al. cite Tucker and Robinson (1990) as attributing to Gondwana the 613 ± 3 Ma gneisses of the Pelham dome, and use this as an argument to better delineate the Red Indian Line. However, Tucker and Robinson (1990) state that distinguishing between a Gondwanan and Laurentian affinity for these rocks is not possible based simply on the presence of Neoproterozoic rocks.

Relocating the Red Indian line to the west of the Moretown Formation is not reconcilable with data from northern Vermont and Quebec, where there is no evidence for such a suture or a subduction polarity reversal during the Late Ordovician, as suggested by MacDonald et al. The detrital zircon record of the Moretown Formation can be alternatively explained by the erosion of Ediacaran Iapetan rift facies during the Taconic orogeny and formation of a peri-Laurentian forearc basin, without requiring Gondwanan contributions.

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