doi:10.1130/G32737C.1

Forum Comment

Early Cambrian metazoans in fluvial environments, evidence of the non-marine Cambrian radiation

Neil S. Davies* and Martin R. Gibling
Department of Earth Sciences, Dalhousie University, Halifax, Nova Scotia B3H 4R2, Canada

A recent study has suggested that early Cambrian trace-fossil–bearing strata in the Wood Canyon Formation (California) provide the oldest evidence for metazoans in continental environments (Kennedy and Droser, 2011). Although the search for superlatives in the history of terrestrial life is an attractive vein of research, suspected fossil evidence must be presented within a robust sedimentological framework. This is complicated in strata deposited prior to the evolution of land plants because the differentiation of clastic continental and shallow marine sediments is problematic (Dott et al., 1986). Lower Paleozoic clastic successions are often typified by sheet-like sandstones regardless of marine or continental influence, and confident paleoenvironmental interpretation of such successions is usually reliant on the occurrence of body fossils or minerals such as glauconite. Some sedimentary structures, such as hummocky cross-stratification, may imply a marine influence, but such signatures are indicative of process rather than environment per se, and must be treated with great caution (Davies et al., 2011a). It is acutely inadvisable to use the absence of such physical features as support for a fluvial origin, as advocated by Kennedy and Droser.

Other evidence used by Kennedy and Droser to identify the middle Wood Canyon as fluvial largely originates from the conclusions of previous studies. However, in a more recent field study we suggested that the presence of trace fossils implies the middle Wood Canyon was deposited within a distal, marine-influenced braid plain (Davies et al., 2011b). All the sedimentary characteristics listed by Kennedy and Droser could have been formed in a marine-influenced setting. For example, one criterion they used is the presence of stacked 1.5-m-scale, unidirectional, trough cross beds of cobble conglomerate. Kennedy and Droser (p. 584) state that such bedforms "are not known in marine environments." However, they are known from a number of modern and ancient gravelly shoreface deposits (e.g., Hart and Plint, 1989; Dashtgard et al., 2010). Similarly, the submature sandstone composition is not a guarantor of a fluvial origin. Although arkose compositions predominate in Cambrian alluvial successions (Davies and Gibling, 2010), there are also examples of Cambrian arkose marine sheet sandstones (Long and Yip, 2009). As such, the physical sedimentological characteristics alone are ambiguous and the paleoenvironmental interpretation cannot be certain enough to justify a hypothesis with as potentially great significance as a "non-marine Cambrian radiation" (p. 583).

Furthermore, even if the trace-fossil–bearing strata were deposited by fluvial processes, it is probable that metazoan colonization occurred during marine flooding. The physical and ecological marine-fluvial interfaces in modern environments are spatio-temporally gradational and fluctuant (Dalrymple and Choi, 2007). During the early Paleozoic, when fluvial activity lacked the regulating influence of vegetation, such interfaces were even more prone to back-and-forth migration due to the balance of episodes of flashy progradational sedimentation and subsequent marine flooding (Cotter, 1983; Davies et al., 2011b). In such settings, particularly given the shallow cratonic gradient of many Cambrian continental-marine transects, marine conditions may have extended far landward during periods of fluvial quiescence, permitting the overprinting of alluvium with a marine ichnofabric and accessory mudrocks. Pertinent to such an interpretation, the trace-fossil horizons of the middle Wood Canyon are always associated with mudrock (Kennedy and Droser's "overbank facies"). Mudrock is particularly rare in Cambrian alluvium, due largely to the propensity of fines to be deflated offshore by wind (Dalrymple et al., 1985). When compared with other Lower Paleozoic successions, the co-occurrence of fines and trace fossils strongly suggests marine influence.

In the course of a separate study, we have actively undertaken fieldwork looking for trace fossils in the alluvial parts (as inferred by previous researchers) of 12 Cambrian-Ordovician formations worldwide. Neither we nor they found trace fossils in any of these, which in some cases constitute hundreds of meters of well-exposed strata (Davies and Gibling, 2010; Davies et al., 2011b). Studies suggest that pre-vegetation alluvial systems were highly unstable landscapes, where overbank deposits were transient accumulations prone to erosion by channel migration and eolian winnowing, and where rivers themselves were sheets of barren sand prone to flashy ephemeral flooding events. The reason for the absence of trace fossils in Cambrian alluvium may simply be that the stable terrestrial landscapes and persistent physical habitats suitable for sustained metazoan colonization were extremely rare during this interval.

*Current address: Department of Geology and Soil Science, Ghent University, Krijglaan 281 s.8, 9000 Gent, Belgium.

REFERENCES CITED

Cotter, E., 1983, Shelf, paralic, and fluvial environments and eustatic sea-level fluctuations in the origin of the Tuscarora Formation (Lower Silurian) of central Pennsylvania: Journal of Sedimentary Petrology, v. 53, p. 25–49.

Dalrymple, R.W., and Choi, K., 2007, Morphologic and facies trends through the fluvial–marine transition in tide-dominated depositional systems: A schematic framework for environmental and sequence-stratigraphic interpretation: Earth-Science Reviews, v. 81, p. 135–174, doi:10.1016/j.earscirev.2006.10.002.

Dalrymple, R.W., Narbonne, G.M., and Smith, L., 1985, Eolian action and the distribution of Cambrian shales in North America: Geology, v. 13, p. 607–610, doi:10.1130/0091-7613(1985)13<607:EAATDO>2.0.CO;2.

Dashtgard, S.E., MacEachern, J.A., Frey, S.E., and Gingras, M.K., 2010, Tidal effects on the shoreface: Towards a conceptual framework: Sedimentary Geology, doi:10.1016/j.sedgeo.2010.09.006.

Davies, N.S., and Gibling, M.R., 2010, Cambrian to Devonian evolution of alluvial systems: The sedimentological impact of the earliest land plants: Earth-Science Reviews, v. 98, p. 171–200, doi:10.1016/j.earscirev.2009.11.002.

Davies, N.S., Rygel, M.C., and Gibling, M.R., 2011a, Marine influence in the Upper Ordovician Juniata Formation (Potters Mills, Pennsylvania): Implications for the history of life on land: REPLY: Palaios, v. 26, p. 677, doi:10.2110/palo.2011.p11-051r.

Davies, N.S., Gibling, M.R., and Rygel, M.C., 2011b, Alluvial facies during the Palaeozoic greening of the land: Case studies, conceptual models and modern analogues: Sedimentology, v. 58, p. 220–258, doi:10.1111/j.1365-3091.2010.01215.x.

Dott, R.H., Jr., Byers, C.W., Fielder, G.W., Stenzel, S.R., and Winfree, K.E., 1986, Aeolian to marine transition in Cambro-Ordovician cratonic sheet sandstones of the northern Mississippi Valley, U.S: Sedimentology, v. 33, p. 345–367, doi:10.1111/j.1365-3091.1986.tb00541.x.

Hart, B.S., and Plint, A.G., 1989, Gravelly shoreface deposits: A comparison of modern and ancient facies sequences: Sedimentology, v. 36, p. 551–557, doi:10.1111/j.1365-3091.1989.tb02085.x.

Kennedy, M.J., and Droser, M.L., 2011, Early Cambrian metazoans in fluvial environments, evidence of the non-marine Cambrian radiation: Geology, v. 39, p. 583–586, doi:10.1130/G32002.1.

Long, D.G.F., and Yip, S.S., 2009, The Early Cambrian Bradore Formation of southeastern Labrador and adjacent parts of Quebec: Architecture and genesis of clastic strata on an early Paleozoic wave-swept shallow marine shelf: Sedimentary Geology, v. 215, p. 50–69, doi:10.1016/j.sedgeo.2009.01.001.