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Sedimentary facies of the upper Cambrian (Furongian; Jiangshanian and Sunwaptan) Tunnel City Group, Upper Mississippi Valley: New insight on the old stormy debate

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ABSTRACT

New data from detailed measured sections permit a comprehensive revision of the sedimentary facies of the Furongian (upper Cambrian; Jiangshanian and Sunwaptan stages) Tunnel City Group (Lone Rock Formation and Mazomanie Formation) of Wisconsin and Minnesota. Heterogeneous sandstones, comprising seven lithofacies along a depositional transect from shoreface to transitional-offshore environments, record sedimentation in a storm-dominated, shallow-marine epicontinental sea. The origin of glauconite in the Birkmose Member and Reno Member of the Lone Rock Formation was unclear, but its formation and preserved distribution are linked to inferred depositional energy rather than just net sedimentation rate. Flat-pebble conglomerate, abundant in lower Paleozoic strata, was associated with the formation of a condensed section during cratonic flooding. Hummocky cross-stratification was a valuable tool used to infer depositional settings and relative paleobathymetry, and the model describing formation of this bedform is expanded to address flow types dominant during its genesis, in particular the importance of an early unidirectional component of combined flow. The depositional model developed here for the Lone Rock Formation and Mazomanie Formation is broadly applicable to other strata common to the early Paleozoic that document sedimentation along flooded cratonic interiors or shallow shelves.

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1. Introduction

The Upper Mississippi Valley (UMV) is a classic area for Cambrian stratigraphy in Laurentian North America (Berg, 1954; Berg et al., 1956; Ludvigsen and Westrop, 1985). It contains lithostratigraphic units of regional importance and a biostratigraphic sequence of continental significance (Berg, 1954; Berg et al., 1956; Lochman-Balk, 1971). This study focuses on the Furongian (upper Cambrian; Jiangshanian and Sunwaptan stages) Tunnel City Group (Lone Rock Formation and Mazomanie Formation) (Fig. 1) exposed in Wisconsin and Minnesota (Fig. 2). The section represents a shallow-marine environment dominated by clastic sedimentation and storm deposition during a time of exceptionally high sea level (Sauk III subsequence of Palmer, 1981) (Sloss, 1963, 1988; Bunker et al., 1988).

Most units in the Cambrian succession of the UMV have been relatively well-studied (Dott, 1974; Driese et al., 1981; Haddox and Dott, 1990; Runkel, 1994, 2000; Byers and Dott, 1995; Hughes and Hesselbo, 1997; Runkel et al., 1998, 2007, 2008; Tape et al., 2003), but the Tunnel City Group has not been treated in detail since the work of Berg (1953, 1954) and Berg et al. (1956). For cratonic seas adjacent to nonvegetated terrains, no modern analogs exist to aid interpretation, so regional-scale lithostratigraphic and biostratigraphic studies are necessary to develop comprehensive models that explain the origin of extensive sandstone units in the UMV (Haddox and Dott, 1990; Runkel et al., 1998, 2007, 2008; Tape et al., 2003). This newer field-based study of the Tunnel City Group provides an opportunity to examine several topics of both geological and paleobiological interest.

Most early studies of the Tunnel City Group were conducted prior to the development of conceptual models for hummocky cross-stratification (HCS) (Dott and Bourgeois, 1982, 1983; Walker et al., 1983) and the recognition of syneresis cracks as subaqueous features (Plummer and Gostin, 1981; Haddox and Dott, 1990; Hughes and Hesselbo, 1997; Tanner, 1998). Early interpretations of the latter as desiccation cracks resulted in the seemingly straightforward assumption that tidal influences were predominant during deposition of the Tomah Member of the Lone Rock Formation (e.g., Hamblin, 1961; Byers, 1978; Mossler, 1992). Even after HCS, abundant in the Reno Member of the Lone Rock Formation, became recognized as a structure unique from other types of stratification, its utility toward understanding the hydrodynamic conditions that operated during its formation had to await experimental studies (e.g., Arnott and Southard, 1990; Southard et al., 1990; Dumas et al., 2005; Dumas and Arnott, 2006).

A reformed approach in context of these new insights has permitted construction of the first comprehensive model for the depositional history of the Tunnel City Group, which builds on models provided for the

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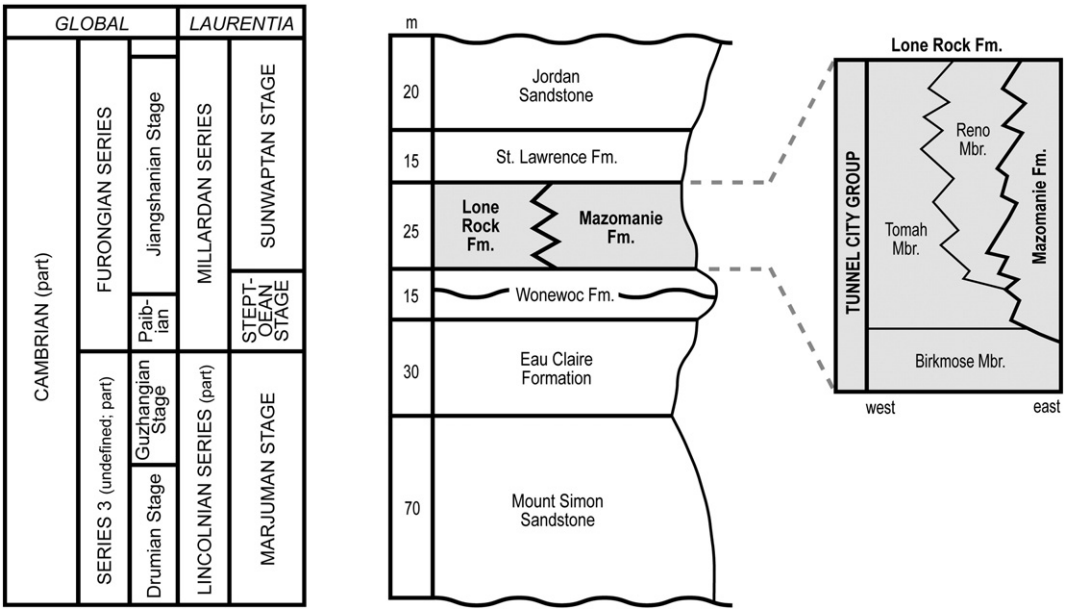

Fig. 1. The Furongian Tunnel City Group of the Upper Mississippi Valley includes the Lone Rock Formation and Mazomanie Formation (shaded). The Mazomanie Formation is partly correlative with upper parts of the Lone Rock, replacing it to the east. The Lone Rock Formation contains the interbedded Birkmose Member, Tomah Member and Reno Member, in ascending order (Mbr. = Member). Upper Cambrian chronostratigraphic nomenclature is from Babcock and Peng (2007) and Peng et al. (2012). Units studied include parts of the Steptoean and Sunwaptan trilobite stages of Laurentia (Ludvigsen and Westrop, 1985). Modified from Mahoney et al. (1997).

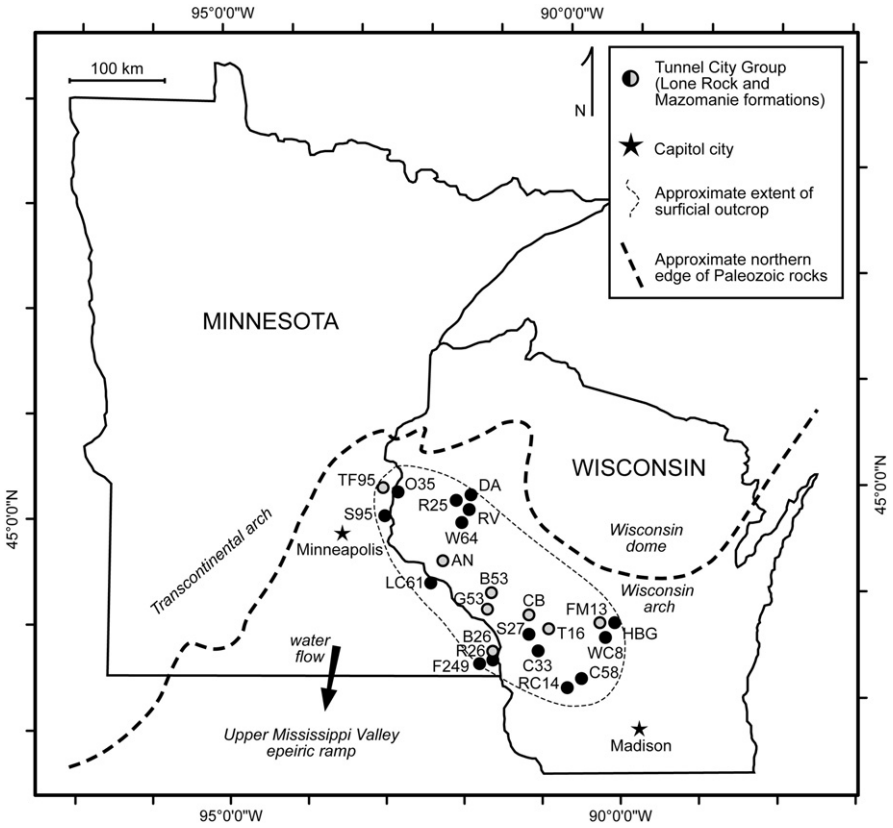

Fig. 2. Locality map for the Tunnel City Group (lightly shaded locations are included in cross-section in Eoff, 2014, her Fig. 5). Deposition occurred on the low-relief surface of the Upper Mississippi Valley epeiric ramp (Runkel et al., 2007, 2008). Water flow during deposition was to the south-southwest (modern coordinates) (Potter and Pryor, 1961). Adjacent areas of high relief, such as the Transcontinental arch and Wisconsin dome and arch, provided clastic sediment and affected sedimentation patterns. Modified from Mahoney et al. (1997), Runkel (1994) and Runkel et al. (1998). Localities named for nearest town and highway. Minnesota: B26 = Brownsville; F249 = Freeberg; LC61 = Lake City; R26 = Reno; S95 = Stillwater; TF95 = Taylors Falls. Wisconsin: AN = Arkansaw; B53 = Blair; C33 = Cashton; CB = Cataract; C58 = Cazenovia; DA = Dallas; FM13 = Friendship Mound; G53 = Galesville; HBG = Horseshoe Bluff; O35 = Osceola; RC14 = Richland Center; R25, RV = Ridgeland; T16 = Tomah; S27 = Sparta; W64 = Wheeler; WC8 = White Creek. Detailed measured sections available in Eoff (2008, her appendix I).