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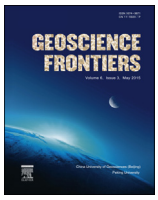

Research paper

Did prolonged two-stage fragmentation of the supercontinent Kenorland lead to arrested orogenesis on the southern margin of the Superior province?

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ABSTRACT

Recent geochronological investigations reinforce the early suggestion that the upper part of the Paleoproterozoic Huronian Supergroup of Ontario, Canada is present in the Animikie Basin on the south shore of Lake Superior. These rocks, beginning with the glaciogenic Gowganda Formation, are interpreted as passive margin deposits. The absence of the lower Huronian (rift succession) from the Animikie Basin may be explained by attributing the oldest Paleoroterozoic rocks in the Animikie Basin (Chocolay Group) to deposition on the upper plate of a north-dipping detachment fault, which lacks sediments of the rift phase. Following thermal uplift that led to opening of the Huronian Ocean on the south side of what is now the Superior province, renewed uplift (plume activity) caused large-scale gravitational folding of the Huronian Supergroup accompanied by intrusion of the Nipissing diabase suite and Senneterre dikes at about 2.2 Ga. Termination of passive margin sedimentation is normally followed by ocean closure but in the Huronian and Animikie basins there was a long hiatus – the Great Stratigraphic Gap – which lasted for about 350 Ma. This hiatus is attributed to a second prolonged thermal uplift of part of Kenorland that culminated in complete dismemberment of the supercontinent shortly before 2.0 Ga by opening of the Circum-Superior Ocean. These events caused regional uplift (the Great Stratigraphic Gap) and delayed completion of the Huronian Wilson Cycle until a regional compressional tectonic episode, including the Penokean orogeny, belatedly flooded the southern margin of the Superior province with foreland basin deposits, established the limits of the Superior structural province and played an important role in constructing Laurentia.

1. Introduction to the Huronian and Animikie basins

The evolution of the Great Lakes area during the important transition from Archean to Proterozoic was controlled by evolving plate tectonics. The foundation for early Paleoproterozoic basins was the late Archean supercontinent Kenorland (Williams et al., 1991) which subsequently broke apart on what is now the southern margin of the Superior province. These processes terminated before intrusion of the Nipissing diabase suite at about 2.2 Ga but closure of the Huronian Ocean and deposition in a foreland basin setting did not take place until about 1850 Ma. This exceptionally long time interval, for which there is no stratigraphic record in these basins has been called the Great Stratigraphic Gap (Young, 2013a, Fig. 11).

The objectives of this paper are to attempt to explain the complex stratigraphic relationships between early Paleoproterozoic rocks of the Lake Superior and Lake Huron regions and in similar basins in SE Wyoming and in Nunavut, and to place the evolution of these glaciated basins into the broader context of tectonic events that led to definition of the Superior province. In a broader context an attempt is made to explain the Great Stratigraphic Gap and the unusually long time period – about 650 Ma (from about 2.45 Ga to about 1.80 Ga) – involved in the Huronian Wilson Cycle. Although the Wilson Cycle was conceived as including events involved in ocean closure followed by re-opening (Wilson, 1966) it is here used in a modified sense to represent events occurring between the

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initiation of fragmentation of a supercontinent (thermal uplift, extrusion of flood basalts, rifting) and tectonic and sedimentary manifestation of ocean closure and suturing. In other words it refers to the sequence of events from birth to death of an ocean, rather than vice-versa, as in the original usage. Following early suggestions that the Huronian Supergroup of Ontario and western Quebec was equivalent, in a general way to early Proterozoic rocks of northern Michigan, Wisconsin and Minnesota, it was proposed (Pettijohn, 1943; Young, 1966; Young and Church, 1966) that some formational correspondence exists between the two basins. Recent geochronological studies (Vallini et al., 2006; Craddock et al., 2013) have provided support for early suggestions that the upper part of the Huronian Supergroup (Cobalt Group) corresponds to the formations of the Chocolay Group in northern Michigan. There are, however, no satisfactory explanations of how these stratigraphic relationships evolved. The present distribution of these rocks (Fig. 1) must differ considerably from that at the time of deposition for the presence of the much younger Mid-Continent Rift (M.-C.R.) assemblage (~1.1–1.0 Ga) means that the southern portion of the Animikie Basin (classical Penokean orogenic belt) was formerly north of its present location. There are several unanswered questions regarding relationships between the supracrustal Paleoproterozoic rocks of the Huronian Basin and those of the Lake Superior region. These include the reasons for the absence, in the Lake Superior area, of the lower Huronian formations (those older than the glacial deposits of the Gowganda Formation) and the origin and meaning of the pre-Penokean (~2.2 Ga) deformation of the Huronian Supergroup, first noted almost fifty years ago by Church (1966, 1968). A third unknown is the origin and tectonic significance of the abundant and voluminous mafic intrusions of the Nipissing suite (~2.2 Ga). The Penokean orogeny is now considered to have occurred between about 1890 Ma and 1830 Ma (Schultz and Cannon, 2007). It is proposed that, rather than representing a compressional orogenic episode, primary folding of the Huronian Supergroup, particularly in the area south of the Murray Fault Zone (Fig. 1) may have resulted from large-scale gravitational sliding associated with development of a north-sloping basin, possibly related to 'back-tilting' of large fault blocks associated with fault movements and thermal elevation of the area south of the Huronian Basin.

Evolution of the Great Lakes area during the early Paleoproterozoic began with emplacement of the Matachewan plume, between 2490 and 2450 Ma (Ernst and Bleeker, 2010 and references therein), in the area south of the Huronian Basin. This contributed to stretching and rifting of the late Archean supercontinent Kenorland to produce an ocean on the southern margin of what is now the Superior province. An early manifestation of the break-up process was formation of a thin (few hundred meters) succession of conglomerates and cross-bedded sandstones (Livingstone Creek Formation) and a thick succession of bimodal volcanic rocks (Thessalon Formation and equivalents) and associated mafic and felsic intrusions (see Bennett, 2006; Melezhik et al., 2013, Fig. 7.7). Following this igneous activity a thick (up to about 7 km) succession of sedimentary rocks filled the rift basin that subsequently developed (Young and Nesbitt, 1985; Long, 2004). A different interpretation was favoured by Zolnai et al. (1984) and Bennett et al. (1991) who considered the rift phase to have been very short-lived, involving only the time up to extrusion of the

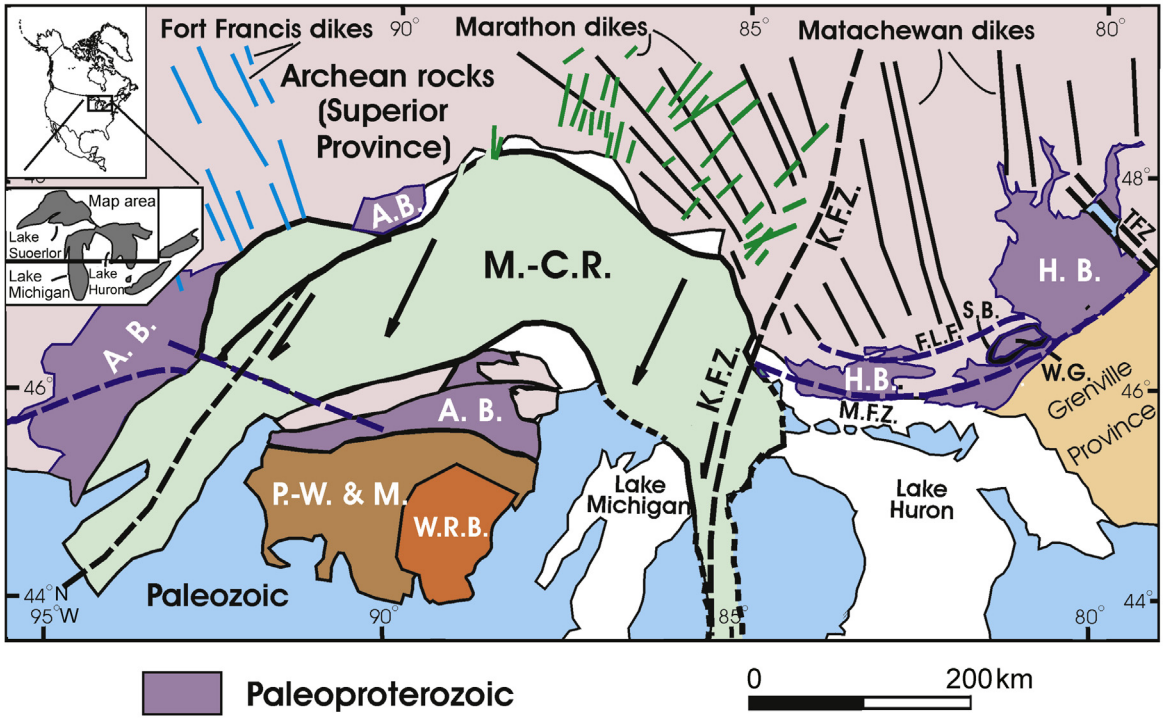

Figure 1. Geological sketch map (after Riller et al., 1999, Fig. 1 and Schultz and Cannon, 2007, Fig. 2) to show the present relationship between Paleoproterozoic rocks of the Lake Superior and Lake Huron areas. Note that the volcanic and sedimentary rocks of the Mid-Continent Rift (1.1–1.0 Ga) must have caused displacement of the Paleoproterozoic rocks in the Lake Superior area. Opening of the Mid-Continent Rift (M.-C.R.) may have been accommodated by movement on a proposed southerly extension of the Kapuskasing Fault Zone (K.F.Z.) into the narrow southeastern portion of the M.-C.R. in Michigan and a possible similar fault zone extending to the SW from the west end of Lake Superior. The continental margin in the Lake Superior area must have lain in a northward indentation relative to the Huronian margin on the east side of the K.F.Z. (see Fig. 3). Arrows in the M.-C.R. show displacement of the Paleoproterozoic Animikie Basin during opening of the M.-C.R. Straight and curved lines in the Superior Province represent dike swarms. Additional abbreviations: A.B. – Animikie Basin; F.L.F. – Flack Lake Fault; H.B. – Huronian Basin; M.F.Z. – Murray Fault Zone; P.-W. & M.- Pembine-Wassau and Marshfield Terranes; S.B. Sudbury Basin; W.G. – Whitewater Group; W.R.B. – Wolf River Batholith (1.47–1.48 Ga).