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Timing and extent of maximum transgression across Laurentia during Late Ordovician: New evidence from Slave Craton, Canadian Shield

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A B S T R A C T

Conodonts from the Slave Craton of the Canadian Shield provide solid evidence for estimating the timing and extent of the maximum transgression across Laurentia during the Late Ordovician. Upper Ordovician limestone xenoliths and a continuous limestone interval have been recovered from the Middle Jurassic Jericho kimberlite pipe piercing into the central Slave Craton of the Canadian Shield, an area that lacks Phanerozoic sedimentary cover nowadays. All fourteen limestone xenolith samples contain diverse conodonts, among which seventeen species belonging to twelve genera are recognized. This fauna is represented by *Plegagnathus dartoni* (Stone and Furnish), indicating an early Richmondian (Late Ordovician) age. In general, the fauna is characteristic of deposition in a shallow and open marine environment. This newly discovered fauna, in addition to those previously found on Canadian Shield and vicinity, provides reliable evidence that 1) the Ordovician inundation on the now-exposed Slave Craton by shallow seas occurred in the early Richmondian; 2) the previous recognized transgression during the second phase of Taconian orogeny, the Taconic tectophase, in the southeastern Laurentia in the early Chatfieldian (Late Ordovician) was only the initiation of the Taconic transgression; 3) the Taconic transgression reached its maximum extent and much of Laurentia was submerged in the early Richmondian.

1. Introduction

Different approaches have been used in reconstructing global sea-level history for the entire or part of the Palaeozoic (see Miller et al., 2005 for detail); and almost all indicate that relative sea levels were high during the latest Middle and Late Ordovician time. An integrated history of global sea-level fluctuations for the entire Palaeozoic was reconstructed using stratigraphic sections from pericratonic and intracratonic basins (Figs. 1–3 of Haq and Schutter, 2008). In this approach, Upper Ordovician succession in south central Oklahoma State was designated as the Reference District (Longman, 1981; Barrick, 1986; Bauer, 1987; Ross and Ross, 1992; Schutter, 1992), and ancillary sections located in the New York State (Fisher, 1977; Anderson et al., 1978; Ross and Bergström, 1982), southern Sweden, Siberian Platform and Bohemia (Haq and Schutter, 2008; supporting online material) were used to relate the highest sea level in the entire Palaeozoic to early Chatfieldian time (Late Ordovician) (Fig. 1) (the terms Edenian, Maysvillian and Richmondian appearing in the following text are within the Late Ordovician; Fig. 1). The highest sea level recognized by Haq and Schutter (2008) is similar in age to the Trentonian (roughly equal to the Chatfieldian and Edenian), the early one of the two peaks (Trentonian and Early Silurian) identified by Sloss (1964) within the Tippecanoe sequence when interior basin development coincided with the time of subsidence of Laurentia as a whole.

Laurentia, also known as the North America Craton, was situated on the palaeo–equator in the Late Ordovician (e.g., Witzke, 1990; Niocaill and Smethurst, 1994; Niocaill et al., 1997; Scotese, PALEOMAP Project). Of the six cratonic depositional sequences from the uppermost Precambrian to Quaternary defined by Sloss (1963), the Tippecanoe sequence developed during the Middle Ordovician to the Early Devonian under the influence of compressional, collisional tectonics along the southeastern cratonic margin, the Appalachian margin, due to subduction and island arc collisions during the Taconian orogeny (Ettensohn, 2008; Lavoie, 2008) (Fig. 1). Therefore, numerous previous studies on Ordovician sea-level changes on Laurentia have focused on the Appalachian Basin, a composite, retroarc foreland basin, which in many ways is the type foreland basin and the type area for the Wilson cycle (Ettensohn, 2008).

The Tippecanoe sequence is divided into two subsequences by a disconformity between the Ordovician and Silurian systems (Sloss, 1988). The lower Tippecanoe subsequence was formed during the Taconian Orogeny and foreland-basin sedimentation, which is divided into two phases, defined as the Blountian and Taconic tectophases (Ettensohn, 2008) (Fig. 1). The two tectophases reflect collision and subduction and final collision of the Appalachian margin with an island arc; their initiations are marked by unconformities beneath the upper Whiterockian of upper Middle Ordovician and at the Turinian (Blackriverian)–Chatfieldian (Rocklandian) boundary of lower Upper

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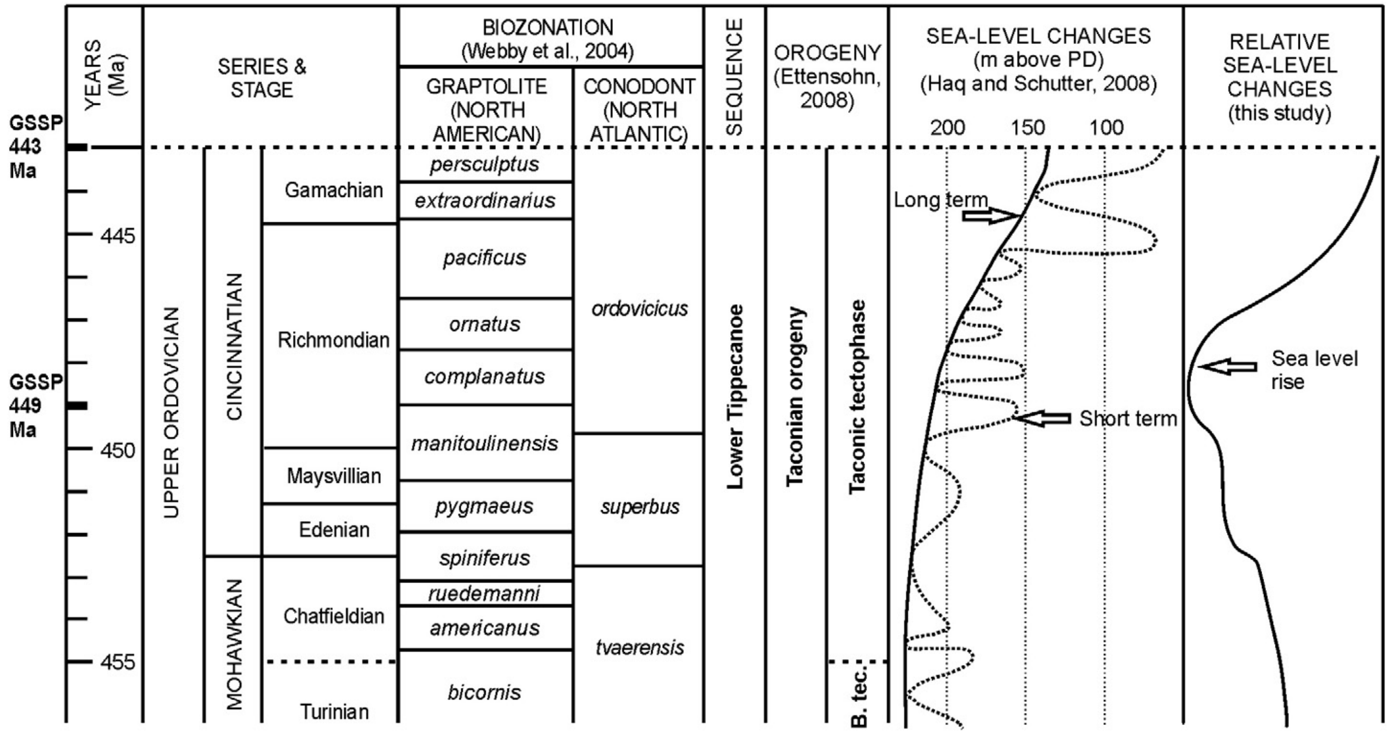

Fig. 1. Late Ordovician time scale, biozonation, sequence, orogeny and sea level changes. B. tec: Blountian tectophase.

Ordovician in the Appalachian foreland basin, respectively (Ettensohn, 1991, 1994, 2008) (Fig. 1). Sea level during the Taconic tectophase was much higher than that during the Blountian tectophase, and the rapid transgression was recorded by the sediments above the regional unconformity between Turinian and Chatfieldian (Ettensohn, 2008, Fig. 4). This observation is the same as that of Haq and Schutter (2008) who also recognized an unconformity and a higher sea level at the Turinian–Chatfieldian boundary (Fig. 1). Thus, these recent studies are in agreement that the highest sea level during the Palaeozoic occurred in Chatfieldian time during the Taconic tectophase.

However, the limited stratigraphical and palaeontological record for the early Taconic tectophase prevents its precise correlation elsewhere on Laurentia, especially on the interior of the Canadian Shield where the huge area of Precambrian rocks is exposed and very few outliers with Ordovician rocks have been found (Williams, 1915; Dresser, 1916; Wright, 1955) (Fig. 2). Unfortunately, these Ordovician outliers have not been paid enough attention in trying to reconstruct Palaeozoic sea level history. However, they are key to determining whether Chatfieldian was a time of maximum transgression all over Laurentia during the Late Ordovician. If not, when did sea level reach its highest point? How long did it take from initiating the transgression to reaching the peak submergence? What was the extent of the maximum transgression during the Taconic tectophase?

This paper documents the occurrence of early Richmondian conodonts recovered from limestone xenoliths in the Middle Jurassic Jericho kimberlite pipe in the central Slave Craton of the Canadian Shield. This recent discovery provides new insight into the timing and extent of the maximum transgression across Laurentia during the Late Ordovician, which was the most extensive of the entire Palaeozoic.

2. Geological setting

The Canadian Shield (Fig. 2) is an assemblage of Archean plates and accreted juvenile arc terranes and sedimentary basins of Proterozoic age that were progressively combined during the interval of 2.45 to 1.24 Ga, with the most substantial growth period occurring during the Trans-Hudson orogeny, between ca. 1.90 and 1.80 Ga (Corrigan et al., 2009).

The Slave Craton (Fig. 2), a composite granite–greenstone Archean terrane (<300 000 km^2), is an important component of the Canadian Shield and one of the most distinct and oldest building blocks of the North America cratonic lithosphere. It is dominated by ca. 2.73–2.63 Ga greenstones and turbidite sequences and ca. 2.72–2.58 Ga plutonic rock, with large parts of the craton underlain by older gneiss and granitoid units. The cratonic block extends latitudinally from the Great Slave Lake at about 61°N to Coronation Gulf on the Arctic Ocean at 69°N, and longitudinally from about 105°W to 117°W (Fig. 2). The Slave Craton includes the Acasta Gneiss that is one of the oldest dated rock units on Earth at 4.03 Ga (Bowring and Williams, 1999). The Middle Jurassic Jericho kimberlite pipe ca.173.1 ± 1.3 Ma (Heaman et al., 2006) was intruded into the Archean granite–granodiorite Contwoyto Batholith (van Breemen et al., 1987), which makes up part of the central Slave Craton.

The "interior" part of the Slave Craton lacks Phanerozoic sedimentary cover, except for unconsolidated glacial deposits. However, Eifelian to early or middle Givetian (Middle Devonian) conodonts preserved in limestone xenoliths from kimberlite pipes in the central Slave Craton (Cookenboo et al., 1998) demonstrate that the "interior" part of the Slave Craton was overlain by Palaeozoic sedimentary rocks. It was estimated that the thickness of the cover sequence at Jericho might have been 500–1000 m during the time (Middle Jurassic) of kimberlite emplacement (Cookenboo, 1999). Using isotopic and mass-balance studies, it was assessed that much of the Canadian Shield was probably covered by up to 2 km of Ordovician to Middle Devonian carbonate units before progressive erosion throughout Mesozoic–Cenozoic time (Patchett et al., 2004).

The Jericho kimberlite pipe occurs about 400-km northeast of Yellowknife, 3-km north of Contwoyto Lake (Fig. 2) (Kopylova and Hayman, 2008). The presently examined kimberlite cores (Fig. 3) drilled by Tahera Diamond Corporation in 2005 are from Pipe JD-03