Paleotethyan faunal/floral evidence in the Mississippian Maritimes Basin of Canada: An overview

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Abstract.—In this study, middle to late Mississippian microfossil assemblages from the Maritimes Basin of eastern Canada (Nova Scotia, SW Newfoundland, and New Brunswick) are closely compared to those from Western Paleotethys basins. The comparison is focused mainly on foraminifers and calcareous algae. Most foraminifers and algae described from the Maritimes Basin are considered cosmopolitan, and the occurrence in western Europe and northern Africa of taxa previously considered endemic to the North America Realm suggests a close paleobiogeographic relationship. This European/African correlation is further supported by other foraminiferal/algal taxa, the importance of which were previously overlooked, including: Plectogyranopsis ex gr. P. hirosei (Okimura, 1965), Mikhailovella Ganelina, 1956, Koktubina windsorensis (Mamet, 1970), Polysphaerina bulla Mamet, 1973, Mstinia Dain in Dain and Grozdilova, 1953, Haplophragmina Reitlinger, 1950, Omphalor Fhlykova, 1969, Pseudolithostra Vdovenko, 1971, Pseudendothyra Mikha1ov, 1939, Saccamminopsis (Sollas, 1921) Vachard and Cózar, 2003, Kamaenella Mamet and Roux, 1974, and Anthracoporella Maslov, 1956. Some species recorded in the Maritimes Basin have been typically recorded in Britain and Ireland in the southern platform of Laurussia. This implies a connection via the Rhenohercynian Ocean, whereas statistical analyses suggest that Maritimes Basin assemblages are closer to those of the Gondwana platform, which could have been established via the Paleotethys Ocean, and also with terranes northwest of the Variscan Front, in which its most logical connection should be with a still-open Rheic Ocean during the Visean and early Serpukhovian. Those taxa demonstrate a more-or-less continuous faunal and microfloral interchange between the Maritimes Basin and the Western Paleotethys paleobiogeographic realm. Furthermore, the width of the Paleotethys and Rheic oceans separating these regions is not considered excessive, particularly during the late Visean and early Serpukhovian.

Introduction

The Maritimes Basin of Atlantic Canada comprises Middle Devonian to early Permian strata (Gibling et al., 2019) and includes SW Newfoundland, Nova Scotia, and New Brunswick (Fig. 1). Its underlying substrata are composed of a series of amalgamated terranes of peri-Gondwana affinity that drifted from Gondwana during Ordovician times (e.g., Waldron et al., 2015; Gibling et al., 2019) or even from the Prererozoic/early Cambrian (e.g., Landing, 2005). By the Middle Devonian, these terranes were supposedly attached to the North American craton (e.g., van Staal et al., 1998; Murphy et al., 2004). This episode is related to the closure of the Rheic Ocean (Fig. 2) that started in the Early Devonian and by the early Carboniferous was considered according to some authors essentially closed (e.g., Nance et al., 2012, and references therein). McKerrow et al. (2000) considered that the Rheic Ocean was open during the Devonian and the collision occurred during the early Carboniferous. During the Devonian, the ocean was not wide enough to prevent the migration of key fauna. A similar scenario was adopted by Torsvik and Cocks (2004, 2013), although they considered the relatively narrow Rheic Ocean was located northward of Armorica. South of Armorica, Torsvik and Cocks (2004, 2013) interpreted a wide Paleotethys Ocean, with Gondwanaland displaced to a more southerly position. Since the Middle Devonian, Stampfli and Borel (2002) only considered a vast Paleotethys Ocean to the south, and the Rhenohercynian Ocean to the north, separated by the macro-European Hunic terrane. In contrast, Stampfli et al. (2013) considered a wide Rheic Ocean during the Frasnian and Famennian (Upper Devonian) between the Meguma/Avalonia terranes and the newly formed continent (Laurussia). Stampfli et al. (2013) considered that closure of the Rheic Ocean occurred during the Touraisian, coincident with opening of the Paleotethys Ocean to the south.

It must be taken into consideration that tectonic models developed for the Maritimes Basin by North American researchers are usually related to the Alleghanian orogeny, and that this zone is typically compared with the Appalachian style (e.g., Waldron et al., 2015; Gibling et al., 2019). This is illustrated by the postulated collision of the terranes with the North American part of Laurussia during Devonian times. Eastern Appalachian tectonic units have been correlated with those in Britain and Ireland, suggesting a pre-collision (Devonian) separation of ~800 km between Newfoundland and Ireland (Waldron et al., 2018).
Facies and tectonic models reflecting similarities between Mississippian rocks in Ireland and the Maritimes Basin were first claimed by Belt (1929, 1944, 1969), and the first faunal arguments corroborating this hypothesis based on rugose corals were published contemporaneously (Lewis, 1935). Nevertheless, the general paleogeographic models disagree, and the idea has not been unanimously accepted by all authors who have studied the diverse fauna and microflora. These later authors supported the hypothesis that the Maritimes Basin was closer to the American Appalachians than to Europe (e.g., Globensky, 1967; Mamet, 1968, 1970; Jansa and Mamet, 1984). Other authors have progressively revealed new data that disagree with this distant paleogeographic position for the Maritimes Basin and Europe, showing additional sedimentological similarities between the Maritimes Basin and Ireland/Britain (Giles, 1981, 2009; Mitchell, 1992; von Bitter et al., 2007). Transgressive-regressive events have been recognized in the Visean Windsor Group (e.g., Giles, 1981, 2009; Fig. 3), which were compared with the major cycles defined in northern England by Ramsbottom (1973). Mitchell (1992) showed unconformities with similar timing and duration, and similar fault control for basin initiation and subsidence, and thus, stratigraphic similarities between the Maritimes Basin and Northern Ireland. All of those previous studies, as well as some faunal and floral similarities, were summarized by von Bitter et al. (2007).
Material and methods

A binary presence/absence database was analyzed using the PAST v.3.14 software (Hammer, 2016). The Jaccard and Raup and Crick similarity indices were calculated in the cluster using paired linkage (UPGMA). Nonmetric multidimensional scaling (NMDS) was also applied to graphically express the similarity indices among the regions. The Raup-Crick coefficient was used because it minimizes the result of overweighting widely distributed species and is less affected by sampling bias (Raup and Crick, 1979). The database was analyzed at the generic level, because (as demonstrated by Cózar et al., 2018 and Davydov and Cózar, 2019) there was no significant difference with the analysis at the specific level, and it prevents more frequent contradictory interpretations resulting from the species comparison due to more uneven data.

Repositories and institutional abbreviations.—The algal and foraminiferal collections of thin sections used for the statistical analysis are deposited in the following institutions: Royal Ontario Museum, Canada (studies by P. von Bitter); National Museum of Natural History, Washington DC, USA (studies by R.G. Browne, D.E. N. Zeller, and M. Rich); University of Colorado Museum, Boulder, USA (studies by P. Brenckle; part of the collection from northern Arkansas is still in the possession of the author); Institut Royal des Sciences Naturelles de Belgique, Brussels (part of the studies after 2000 by B.L. Mamet); Université de Liège, Belgium (studies by R. Conil and M. Laloux); Université Paul-Sabatier, Toulouse, France (studies by L. Pille); Université de Lille 1, France (studies by D. Vachard); British Geological Survey, Keyworth, UK (studies by I. Burgess and by A.R.E. Strank, C.N. Waters, I. Burgess, and P. Cózar from boreholes in northern England); British Geological Survey, Edinburgh, UK (studies by P. Cózar from boreholes in the Midland Valley of Scotland); University College Dublin, Ireland (studies by I.D. Somerville and S. Gallagher); Université Moulay Ismail, Meknès, Morocco (studies by M. Berkhil); Institute Scientifique de Rabat, Morocco (studies by A. Tahiri); Université Cadi Ayyad, Marrakech, Morocco (studied by A. Tourani); Paleontological Collection, Universidad Complutense de Madrid, Spain (studies by P. Cózar = PC). The collection of M.-F. Perret is lost (personal communication, M.-F. Perret, 2015). The repository of B. Mamet’s pre-2000 samples referred to in this study is unknown (personal communication, A. Préat, 2021).

Algae and problematic algae

A detailed revision of the Carboniferous calcareous algae was published by Mamet (1991), with the main paleobiogeographic aspects more extensively developed by Mamet (1992). These studies summarized knowledge of the calcareous algae in the twentieth century and include a vast paleobiogeographic and biostratigraphic database. However, as Mamet (1991) recognized, the algal nature of numerous taxa used in his paleobiogeographic analysis is rather questionable (e.g., Cylindrofolia Brenckle and Groves, 1987, and Eolithoporella Johnson, 1966). He recognized 135 valid genera with 276 species distributed in three major realms (Fig. 2)—North America, Paleothys, and Arctic (= Boreal)—subdivided into eight
Table 1. Revised late Visean-Serpukhovian algae and problematic algae from the Maritimes Basin, Midcontinent/Appalachian, and western Paleotethys. 0 = absent; 1 = present.

| Genus                      | North America | Maritimes Basin | Britain/Ireland | Moroccan Meseta | SW Spain | Southern France | NW Spain | Sahara |
|----------------------------|---------------|-----------------|-----------------|-----------------|---------|-----------------|---------|--------|
| Amarellina Mamet, 1995a    | 0             | 0               | 1               | 1               | 0       | 0               | 0       | 0      |
| Anatolipora Konishi, 1956  | 1             | 0               | 1               | 1               | 1       | 1               | 1       | 1      |
| Anthracoporellopsis Maslov, 1956 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Aoujgalia Termier and Termier, 1950 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| Aphryosia Garwood, 1914    | 1             | 0               | 1               | 1               | 0       | 0               | 0       | 0      |
| Archaeoliporidae Garwood and Johnson, 1956 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| Asphaltina Mamet in Petryk and Mamet, 1972 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 |
| Asphaltinella Mamet and Roux, 1978 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 |
| Asphaltinoides Devera, 1987 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Asteroaoujgalia Brenckle, 2004 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 |
| Austrirhizophras Mamet, 1977 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Bordelleta Czár et al., 2007 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| Cabriropora Mamet and Roux, 1975a | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| Cabriroporellopsis Pille and Vachard, 2011 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 |
| Calcifolium Shvetsov and Birina, 1935 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| Calcifolium Vachard and Montenant, 1981 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 1 |
| Coelsputella Wool, 1940 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| Costachioides Vachard and Czár, 2010 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 |
| Crusskamaenca Brenckle, 1985 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cribrokamaenca Brenckle, 1985 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Eostacheoides Petrov and Mamet, 1972 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| Evlania Bykova, 1952 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 |
| Exvortarisella (Elliot, 1970) Mamet and Roux, 1974 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| Falsocalcifolium Vachard and Czár, 2005 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 |
| Fasiella Ivanova, 1973 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 |
| Fasifolium Vachard and Czár, 2010 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 |
| Fourtonella Cummings, 1955a | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Frustulata (Saltovskaya, 1984) Vachard and Czár, 2005 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| Garwoodia Wool, 1941 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| Girvanella Nicholson and Etheridge, 1878 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 |
| Guadielletopora Czár et al., 2007 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| Hedstroemia Rothpletz, 1913 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Hortonella Mamet, 1993 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Issinella Reitlinger, 1954 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| Kamaena Antropov, 1967 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Kamaenella Mamet and Roux, 1974 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Koninckopora Lee, 1912 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Kulikia Golubov, 1961 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Lemosquetella Mamet and Sebbar, 1998 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| Mainiomachetes Czár and Vachard, 2006 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| Mitcheleandia Wethered, 1886 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Moravammina Pokorny, 1951 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| Murviellipora Pille and Vachard, 2011 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| Nanopora Wood, 1964 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Neoprincoidea Czár and Vachard, 2003 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| Neoradiosphaeoporella Vachard and Czár in Vachard et al., 2016 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| Orthrisophras Johnson and Konishi, 1956 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| Ortonella Garwood, 1914 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Ortonellopsis Vachard and Czár in Vachard et al., 2016 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| Palaeoberesella Mamet and Roux, 1974 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Palaeoporellopsis Czár and Vachard, 2004 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| Paraempiporellopsis Pille and Vachard, 1979 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| Pekiskopora Mamet, 1974a | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pseudokulikia Mamet and Roux, 1975b | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| Pseudostacheoides Petrov and Mamet, 1972 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| Renalis (Volgodin, 1932) Mamet and Roux, 1983 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| Richella Mamet and Roux in Mamet et al., 1987 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 |
| Roquesselia Termier, Termier, and Vachard, 1977 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Sacimamminopsis (Sollas, 1921) Vachard and Czár, 2003 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Sinustacheoides Termier, Termier, and Vachard, 1977 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| Speraphrasischia Vachard in Vachard and Beckary, 1991 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| Stachella Mamet and Roux, 1983 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
subrealms. Approximately half of the calcareous algae were considered cosmopolitan (49 genera) or of generalized dispersion (16 genera), but more important for the paleobiogeographic studies, are the endemic taxa to these three realms. The Paleotethys is the most diverse realm containing up to 38 endemic genera.

The geographic distribution of several genera has been updated since Mamet’s (1991, 1992) database, resulting in modification of the distribution of some taxa. Mamet (1968, 1970) and mostly Jansa et al. (1978) identified a total of 31 taxa from different localities in the Maritimes Basin, of which Windsoporella (Mamet and Rudloff, 1972) Vachard, 1980 and Pekiskopora Mamet, 1974c were considered endemic to the North American Realm, with the rest of the assemblages as cosmopolitan or of generalized distribution. Similar taxa were also recorded by Brisebois (1979). The diversity and richness of algae in the Maritimes Basin are difficult to assess because: (1) the possible influence of deep oceans and cold water platforms/currents that did not permit a widespread settlement of the dasycladales (Jansa and Mamet, 1984); (2) limited documentation of these algal assemblages available in only a few publications, even in the absence of illustrations; and (3) variable but often-poor preservation in most of the carbonates in the Windsor Group of Nova Scotia and Codroy Group of Newfoundland, which are often dolomitized or composed of evaporites (Mamet, 1970; Jansa et al., 1978).

Windsoporella was originally considered as an algal genus endemic to the North American Realm, but has been recorded, rarely, in the eastern Paleotethys realm (Vachard, 1980) and subsequently commonly recorded in western European/northern African basins (see revision of the genus Windsoporella by Cózar et al., 2009; Pille and Vachard, 2011).

Jansa et al. (1978) illustrated Pekiskopora sp. (endemic to the North American realm), although it cannot be unquestionably attributed to that genus because of its poor preservation. In those specimens, only the outer morphology is preserved, a feature that does not allow a reliable identification of Pekiskopora, and in general, of any dasycladal algae. Furthermore, the outer morphology is rather like that of other coeval dasycladal algae, e.g., Kulikia Golubsov, 1961. Pekiskopora was also documented (but not illustrated) by Brisebois (1979) in limestones of Brigantian age on the Magdalen Islands in the central Gulf of St. Lawrence (Fig. 1). Although the identification cannot be confirmed at either of these widely separated localities in the Maritimes Basin, its reported presence continues to signal an American connection.

Additional remarks on the algal assemblages need to be highlighted. First, the Maritimes Basin is notable for the occurrence of Kamaenella Mamet and Roux, 1974, a typical Western Paleotethyan genus that does not occur in other regions of North America. Kamaenella thickets are common in many upper Visean platforms from Ireland and England (Gallagher, 1996; Horbury and Adams, 1996; Cózar and Somerville, 2005b). Nevertheless, quantification of the calcareous algae listed by Jansa et al. (1978) was not documented, and thus, it is not possible to precisely establish whether it contributes to similar thickets. Second is the occurrence (although rare) of Saccominopsis (Sollas, 1921) Vachard and Cózar, 2003 in the Maritimes Basin. This problematic alga was attributed to the Udoteaceae algal reproductive organs by Vachard and Cózar (2003), although it was previously attributed to the dasycladal algae (Skompski, 1986), and recorded only in the Paleotethys realm (see distribution of Vachard and Cózar, 2003). In Ireland and northern England, this taxon commonly occurs as ‘floods,’ i.e., rich concentrations in bands in upper Visean limestones (e.g., Hallett, 1971; Gallagher and Somerville, 1997; Cózar and Somerville, 2005b). Its occurrence in the Maritimes Basin has never been documented as flood-like deposits, but its occurrence ‘outside’ of the Paleotethys realm is significant enough by itself. Third is the presence of the problematic alga Anthracoporellopsis Maslov, 1956, a taxon reported by both Jansa et al. (1978) and Brisebois (1979), and restricted to the Paleotethys realm and the Canadian Arctic (Vachard and Cózar, 2010).

As a consequence of the above data, the assemblages of the Maritimes Basin do not contain unquestionable algal or problematic algal genera endemic to the North American Realm in the assemblages of the Maritimes Basin, because the identification of Pekiskopora could not be confirmed and the recrystallized specimens are more similar to the outer morphology of Kulikia (a cosmopolitan taxon). In addition, Pekiskopora is recorded only in the Tournaisian, and thus its occurrence in the late Visean of the Maritimes Basin seems implausible. In contrast, there are at least three typical Paleotethyan genera present: Kamaenella, Saccominopsis, and Anthracoporellopsis.

Another significant algal taxon for paleobiogeographic interpretations is Albertaporella Johnson, 1966, described as an early Visean endemic genus in the North American Cordillera (Johnson, 1966; Mamet, 1991) and New Mexico (Armstrong et al., 1992); it has also been recorded in the early Visean of SE Ireland (Cózar and Somerville, 2005a). The most logical explanation is that the taxon migrated via the Rheic corridor (Fig. 2), because there is no record of Albertaporella in the Arctic realm (Mamet and Preat, 2010), and thus, migration by the Franklinian corridor in the Boreal Ocean is discarded (Fig. 2). The apparent absence of Albertaporella in the Maritimes Basin can be explained by the absence of more

### Table 1. Continued.

| Genus                  | North America | Maritimes Basin | Britain/Ireland | Moroccan Meseta | SW Spain | Southern France | NW Spain | Sahara |
|------------------------|---------------|-----------------|-----------------|-----------------|---------|----------------|---------|-------|
| *Stachoeides* Cummings, 1955b | 1  | 1               | 1               | 1               | 1       | 1              | 1       | 1     |
| *Ungdarella* Maslov, 1950    | 1  | 0               | 1               | 1               | 1       | 1              | 1       | 1     |
| *Valenzieria* Termier, Termier, and Vachard, 1977 | 0  | 0               | 0               | 1               | 0       | 0              | 0       | 0     |
| *Wetheredella* Wood, 1948   | 1  | 0               | 1               | 1               | 1       | 1              | 1       | 1     |
| *Windsoporella* (Mamet and Rudloff, 1972) Vachard, 1980 | 1  | 1               | 1               | 1               | 1       | 1              | 1       | 1     |
| *Zadella* Saltovskaya, 1984  | 0  | 0               | 1               | 1               | 1       | 1              | 1       | 1     |
| Total                   | 42 | 23              | 54              | 60              | 59      | 61             | 49      | 49    |
Table 2. Revised late Visean-Serpukhovian foraminifers from the Maritimes Basin, Midcontinent/Appalachian, and western Paleotethys (unilocular genera excluded). 0 = absent; 1 = present.

| GENERA                          | North America | Maritimes Basin | Britain/ Ireland | Moroccan Meseta | SW Spain | Southern France | NW Spain | Sahara |
|--------------------------------|---------------|-----------------|------------------|-----------------|---------|-----------------|---------|-------|
| Ammonarchaediscus Conil and Pirlet and Conil, 1977 |               |                 |                  |                 |         |                 |         |       |
| Ademassa Vachard in Vachard et al., 1993 | 0             | 0               |                  |                 | 1       |                 | 0       | 0     |
| Ammonoverella Cushman, 1928 | 1             | 0               |                  |                 | 1       |                 | 1       | 1     |
| Archaeadiscus Brady, 1873 | 1             | 1               |                  |                 | 1       |                 | 1       | 1     |
| Asterarchaediscus Mkkukho-Maklay in Kiparıssova et al., 1956 | 1             | 1               |                  |                 | 1       |                 | 1       | 1     |
| Bibradya Strank, 1983 | 0             | 0               |                  |                 | 1       |                 | 0       | 0     |
| Biseriella Mamet in Armstrong and Mamet, 1974 | 1             | 0               |                  |                 | 1       |                 | 1       | 1     |
| Bradyina Möller, 1878 | 0             | 0               |                  |                 | 1       |                 | 1       | 1     |
| Brenckleina Zaninetti and Altiner, 1979 | 1             | 0               |                  |                 | 1       |                 | 0       | 1     |
| Browniediscus Brencle, Ramsbottom, and Marchant, 1987 |               |                 |                  |                 |         |                 |         |       |
| Brunis Mikhailov, 1935 | 1             | 0               |                  |                 | 1       |                 | 1       | 1     |
| Calcitornella Cushman and Waters, 1928 | 1             | 0               |                  |                 | 1       |                 | 1       | 1     |
| Calcivertella Cushman and Waters, 1928 | 1             | 0               |                  |                 | 1       |                 | 1       | 1     |
| Cepekia Vašiček & Řžiška, 1957 | 1             | 1               |                  |                 | 1       |                 | 1       | 1     |
| Chomatomediocris Vdovenko in Vdovenko et al., 1973 | 0             | 0               |                  |                 | 1       |                 | 1       | 1     |
| Climacammina Brady in Etheridge, 1873 | 0             | 1               |                  |                 | 1       |                 | 1       | 1     |
| Conilidiscus Vachard, 1988 | 0             | 0               |                  |                 | 1       |                 | 0       | 0     |
| Consobrinellopsis Kainer and Vachard, 2015 | 1             | 1               |                  |                 | 1       |                 | 1       | 1     |
| Cribrina Möller, 1878 | 1             | 1               |                  |                 | 1       |                 | 1       | 1     |
| Cribrinommium Möller, 1879 | 1             | 1               |                  |                 | 1       |                 | 1       | 1     |
| Ecklandia Plummer, 1930 | 1             | 1               |                  |                 | 1       |                 | 1       | 1     |
| Ebhania Conil and Marchant in Conil, 1977 | 0             | 0               |                  |                 | 1       |                 | 0       | 1     |
| Endostracina setata Lipsa, 1970 | 0             | 0               |                  |                 | 1       |                 | 0       | 1     |
| Endostaffella Rozovskaya, 1961 | 1             | 0               |                  |                 | 1       |                 | 1       | 1     |
| Endostaffellopsis Cózar et al., 2016a | 0             | 0               |                  |                 | 1       |                 | 0       | 1     |
| Endotaxis Bogusl and Bražnikova in Azzenberg et al., 1983 | 1             | 0               |                  |                 | 1       |                 | 1       | 1     |
| Eoendothyranopsis Reitlinger and Rostovzeva in Reitlinger, 1966 | 1             | 1               |                  |                 | 1       |                 | 1       | 1     |
| Eoendothyranopsis Reitlinger, 1956 | 0             | 0               |                  |                 | 1       |                 | 0       | 0     |
| Eosigmoilina Ganelina in Kiparisova et al., 1956 | 1             | 1               |                  |                 | 1       |                 | 1       | 1     |
| Eostaffellina Conil and Dîl in Conil et al., 1980 | 0             | 0               |                  |                 | 1       |                 | 1       | 1     |
| Globoendothyra Bogusl and Juferev, 1962 | 1             | 1               |                  |                 | 1       |                 | 1       | 1     |
| Globoophalotis Bogusl, 1987 | 0             | 0               |                  |                 | 1       |                 | 0       | 1     |
| Glomiscus Malakhova, 1973 | 0             | 0               |                  |                 | 1       |                 | 1       | 1     |
| Hoplophragmina Reitlinger, 1950 | 0             | 1               |                  |                 | 1       |                 | 1       | 1     |
| Holkeria Strank, 1982 | 0             | 0               |                  |                 | 1       |                 | 0       | 1     |
| Insolentitheca Vachard in Bensaid et al., 1979 | 0             | 0               |                  |                 | 1       |                 | 0       | 1     |
| Janischewskina Mikhailov, 1939 | 1             | 0               |                  |                 | 1       |                 | 1       | 1     |
| Kasachstanodiscus Marfenkova, 1978 | 1             | 0               |                  |                 | 1       |                 | 0       | 1     |
| Magnitella Malakhova, 1975 | 0             | 0               |                  |                 | 1       |                 | 0       | 1     |
| Mokotovskaya Vachard, 1961 | 1             | 0               |                  |                 | 1       |                 | 1       | 1     |
| Mikhailovella Ganelina, 1956 | 0             | 1               |                  |                 | 1       |                 | 1       | 1     |
| Millerella Thompson, 1942 | 1             | 0               |                  |                 | 1       |                 | 0       | 1     |
| Mironiczka Shlykova, 1969 | 0             | 0               |                  |                 | 1       |                 | 0       | 1     |
| Monotaxinoides Bražnikova and Yartseva, 1956 | 1             | 0               |                  |                 | 1       |                 | 0       | 1     |
| Mstinia Dain in Dain and Grozdilova, 1953 | 1             | 1               |                  |                 | 1       |                 | 1       | 1     |
diverse and richer assemblages due to limited documentation to date, but also because the presence of early Visean strata in the Windsor Group is still debated; if present, these are mostly composed of thick evaporite deposits in cycle 1 (e.g., Jutras et al., 2015; Waldron et al., 2017; Fig. 3) that would themselves have formed an unfavorable environment.

**Foraminifers**

Despite the presence of numerous endemic genera, a clear exclusively worldwide provincialism does not seem to have existed within the Mississippian Fusulinata foraminifers. Mamet and Skipp (1970a) and Mamet (1977) documented continuous interchange between the three main realms—Paleotethys, North American, and Boreal (Fig. 2)—but not exclusive provincialism. Ross (1995) introduced a fourth realm, called Panthalassa or Sonomia, including some terranes in parts of Japan, the southern Russian Far East, British Columbia, and New Zealand. In the Mississippian, geographic and stratigraphic distribution of foraminifers are better known than those of calcareous algae.

Previous data on Fusulinata foraminifers from the Maritimes Basin are restricted to a limited number of publications (Mamet, 1968, 1970; Brisebois and Mamet, 1974; Jansa et al., 1978; Brisebois, 1979; Jansa and Mamet, 1984). It is

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**Table 2. Continued.**

| GENERA                      | North America | Maritimes Basin | Britain/Ireland | Moroccan Meseta | SW Spain | Southern France | NW Spain | Sahara |
|-----------------------------|---------------|-----------------|-----------------|-----------------|---------|----------------|---------|-------|
| Neoarchaeodiscus            | 1             | 1               | 1               | 1               | 1       | 1              | 1       | 1     |
| Miklukho-Maklay in Kiparisova et al., 1956 | 1 | 1 | 1 | 1 | 1 | 1 |
| Nodosasperodiscus           | 1             | 0               | 1               | 1               | 1       | 1              | 1       | 1     |
| Conil and Pirlet in Pirlet and Conil, 1977 | 1 | 0 | 1 | 1 | 1 | 1 |
| Nodosarchaeodiscus          | 1             | 0               | 1               | 1               | 1       | 1              | 1       | 1     |
| Conil and Pirlet in Pirlet and Conil, 1977 | 1 | 0 | 1 | 1 | 1 | 1 |
| Omphalotis Shlykova, 1969   | 0             | 1               | 1               | 1               | 1       | 1              | 1       | 1     |
| Palaeotextularia Schubert, 1921 | 1 | 1 | 1 | 1 | 1 | 1 |
| Parabiseriella Cózar and Somerville, 2012 | 0 | 0 | 0 | 1 | 0 | 1 |
| Parabradyina Mamet and Pinard, 1992 | 0 | 0 | 1 | 0 | 0 | 0 |
| Piriteidiscus Vachard, 1988 | 0             | 0               | 0               | 0               | 1       | 0              | 1       | 1     |
| Planochaetodes Miklukho-Maklay in Kiparisova et al., 1956 | 1 | 0 | 1 | 1 | 1 | 1 |
| Planeuthella Reitlinger in Rauer-Chernosova and Fursenko, 1959 | 1 | 0 | 1 | 1 | 1 | 1 |
| Planeuchinia Cózar and Mamet, 2001 | 0 | 0 | 0 | 0 | 1 | 1 |
| Planospirifer Sospatrapova, 1962 | 1 | 0 | 1 | 1 | 1 | 1 |
| Plectogyranopsis Vachard, 1977 | 1 | 1 | 1 | 1 | 1 | 1 |
| Plectogyrina Reitlinger in Rauer-Chernosova and Fursenko, 1959 | 1 | 0 | 0 | 0 | 1 | 0 |
| Plectomediocris Brazhnikova and Vdovenko in Aizenverg et al., 1983 | 0 | 0 | 0 | 0 | 1 | 1 |
| Plectostaffella Reitlinger, 1971 | 1 | 0 | 1 | 1 | 1 | 1 |
| Pojarkovella Simonova and Zab, 1975 | 0 | 0 | 1 | 0 | 1 | 1 |
| Praeostaffella Cózar et al., 2008 | 1 | 0 | 0 | 0 | 0 | 1 |
| Praeplectostaffella Cózar et al., 2008 | 0 | 0 | 1 | 0 | 0 | 1 |
| Protoendothyra Vachard and Cózar, 2004 | 0 | 0 | 0 | 0 | 1 | 1 |
| Pseudoammodiscus Conil and Lys in Conil and Pirlet, 1970 | 1 | 1 | 1 | 1 | 1 | 1 |
| Pseudogongolomopina Bykova, 1955 | 0 | 1 | 1 | 1 | 1 | 1 |
| Pseudolituitubab Vdovenko, 1971 | 1 | 0 | 1 | 1 | 1 | 1 |
| Pseudotaxis Mamet, 1974b | 1 | 1 | 1 | 1 | 1 |
| Quasiarchaeodiscus Miklukho-Maklay, 1960 | 1 | 0 | 1 | 0 | 0 | 0 |
| Rectoconuspira Warthin, 1930 | 1 | 0 | 0 | 0 | 1 | 1 |
| Rectoendothyra Vachard in Aizenverg et al., 1983 | 1 | 0 | 0 | 0 | 1 | 1 |
| Scalebrina Conil and Logerstaey in Conil et al., 1980 | 1 | 0 | 1 | 0 | 0 | 1 |
| Semiendothyra Reitlinger, 1980 | 1 | 0 | 0 | 0 | 1 | 0 |
| Spinobostriniina Conil and Longerstaey in Conil et al., 1980 | 1 | 0 | 0 | 0 | 1 | 1 |
| Spinohyma Mamet, 1976 | 0 | 0 | 1 | 0 | 1 | 1 |
| Spirotrilina Vachard in Vachard and Beckary, 1991 | 0 | 0 | 0 | 0 | 1 | 0 |
| Tetrataxis Ehrenberg, 1854 | 1 | 1 | 1 | 1 | 1 | 1 |
| Tournayella Dain in Dain and Grozdilova, 1953 | 1 | 0 | 0 | 0 | 0 | 0 |
| Travelpolypsis Cushman and Waters, 1928 | 1 | 1 | 1 | 1 | 1 | 0 |
| Tubispinularis Browne and Pohl, 1973 | 1 | 1 | 1 | 1 | 1 | 1 |
| Turrispiroides Reitlinger in Rauzer-Chernosova and Fursenko, 1959 | 1 | 0 | 0 | 0 | 0 | 0 |
| Uralodiscus Malakhova, 1973 | 0 | 0 | 0 | 0 | 1 | 1 |
| Vachardites Cózar et al., 2016a | 0 | 0 | 0 | 0 | 1 | 0 |
| Valvulinella Schubert, 1908 | 0 | 0 | 1 | 0 | 1 | 1 |
| Vicanidae Mamet, 1975 | 1 | 0 | 0 | 0 | 1 | 1 |
| Vissarionovella Cózar and Vachard, 2001 | 0 | 0 | 1 | 0 | 0 | 1 |
| Vissarionatix Mamet, 1970 | 0 | 0 | 1 | 1 | 1 | 1 |
| Volgella Reitlinger in Reitlinger and Melnikova, 1977 | 0 | 0 | 0 | 0 | 0 | 1 |
| Total | 53 | 26 | 76 | 71 | 64 | 68 | 70 | 65 |
noteworthy that taxa recorded by Brisebois (1979) are rather similar to those of Jansa et al. (1978) and Mamet (1970), and they do not contribute to new occurrences of taxa. In total, 50 taxa have been listed by the previous authors. Mamet (1970) based his attribution of the fauna to the North American Realm on the occurrence of Zellerinella Mamet, 1981, and mostly by the absence of some typical Paleotethyan taxa, e.g., Loeblichia Cummings, 1955 (Cummings, 1955a), Valvulinella Schubert, 1908, Omphalotis omphalota (Rauzer-Chernousova and Reitlinger in Rauzer-Chernousova et al., 1936), and Archaeodiscus karreri Brady, 1873. Jansa and Mamet (1984) further extended the comparison, including more detailed paleobiogeographic maps of the geographic distribution of Howchinia Cushman, 1927, Bradyina Möller, 1878, Lituotubella Rauzer-Chernousova, 1948 (Rauzer-Chernousova, 1948b), and Omphalotis Shlykova, 1969 (all absent in the Maritimes Basin), and consideration that the distance between Newfoundland and Ireland was at least 1,000 km separated by a deep ocean, which did not permit faunal interchange, and rejecting contemporaneous paleogeographic reconstructions locating the Maritimes Basin close to Spain or the Moroccan Meseta.

Although most foraminifers recorded in the Visean-early Serpukhovian Windsor Group are cosmopolitan, their distribution is distinct in the different paleobiogeographic domains (Mamet, 1970, fig. 15), but could also be subject to paleoecological constraints (e.g., Mamet and Skipp, 1979). The basal Windsor Group strata comprises a thick interval of evaporites resting on a single marine carbonate unit (Macumber Formation), which defines the base of the group (Fig. 3) and provides the single potential source of foraminiferal data that have proven rare at this stratigraphic level. Thick lower Windsor Group evaporites impede a lack of open marine connections, which would necessarily be reflected in the benthic fauna and result in a limited foraminiferal population. These ‘reduced’ suites are not themselves similar, but they are similarly reduced, as in other apparently better-connected marine basins, e.g., in SW Spain (Cózar, 2003) where the foraminiferal assemblages show many dissimilarities (in diversity, abundance, and first occurrences of taxa) compared with neighboring basins in Morocco, France, and England. In a similar manner, the Maritimes Basin it notable for the rarity of one of the most diagnostic North American taxa, Eoendothyranopsis Reitlinger and Ros-tovzeva in Reitlinger, 1966, which is widespread in Visean North American succesions (e.g., Mamet and Skipp, 1970a, b), but it is also common in Boreal and northwestern Paleotethyan realms (e.g., Loeblich and Tappan, 1987).

Another constraint is that the most diverse and richer realms (both in terms of numbers of genera and species, and also number of specimens) are the Paleotethyan and Boreal realms (Mamet and Skipp, 1970a, 1979; Mamet, 1977; Davydov, 2014) as well as realms with more endemic taxa. Thus in the Maritimes Basin, the absence of more numerous Paleotethyan taxa is more likely for North American affinities. A final constraint is the established migration routes for foraminifers. According to Mamet and Skipp (1970a) and Mamet (1977), most foraminifers are Euroasian in origin and migrated westward to western Europe and later to American and Arctic realms. This migration route was established on the basis of: (1) the earliest Late Devonian Endothyridae flourished in Eurasia but are rarely observed in North America; (2) the presence of complete phylogenetic lines in Europe but incomplete ones in North America; (3) impoverished microfauna in North America in regard to Eurasian assemblages, and with few endemic taxa; and (4) heterochronism of the base of the acmes and first occurrences (the oldest forms always occur first in Eurasia, then in the Arctic, and finally in the North American Cordillera). This direction in essence suggests that a communication route had to have existed between western Europe and eastern North America, and those taxa recorded in basins such as the Midcontinent had to have crossed using the Rheic Ocean and then via regions with more similarities with western Europe, i.e., the Maritimes Basin. However, some taxa must have migrated via the northern Boreal Ocean through the Franklinian corridor and Alaska (Harris et al., 1997; Davydov and Cózar, 2019; Fig. 2).

A distinctive feature of the Maritimes Basins, as noted by Mamet (1970) and Jansa and Mamet (1984), is the absence of typical large foraminifers recorded in the Paleotethys realm (e.g., Omphalotis omphalota, large Archaeodiscus Brady, 1873, Bradyina, Janischewskina Mikhailov, 1939). The absence of these taxa in the Maritimes Basin is significant, but even in better-connected marine basins in SW Europe, they can show a similar phenomenon. For instance, in Sierra Morena in SW Spain, which should be paleogeographically relatively close to the Maritimes Basin, a typical late Visean-early Serpukhovian succession occurs (Cózar, 2003). Currently, from this succession, more than 4,000 thin sections have been studied, and only one specimen of Bradyina has been recorded, and no more than five specimens of Janischewskina. In addition, only sparse specimens of the large species of Archaeodiscus have been recorded, and the largest species are absent, compared to successions in Britain and Ireland. Thus, the absence of certain taxa, although at first glance might seem to provide a solid paleogeographic argument, could on the other hand be explained by responses to paleoecological constraints. Hence, the absence of some species is not exclusive to the Maritimes Basin, and needs to be further investigated due to similar patterns in unquestionable Paleotethyan basins. Furthermore, Jansa and Mamet (1984) considered the poor assemblages of the Maritimes Basin as being themselves characteristic and caused by a certain isolation from the main region of marine sedimentation and migration routes.

The second main argument in the comparison of Maritimes Basin foraminifers with those of the North American Realm, is the genus Zellerinella (= Zellerina Mamet in Mamet and Skipp, 1970b, preoccupied), which was formerly considered endemic to this realm (Mamet, 1974c; Armstrong and Mamet, 1977). Equatorial sections might be confused with Eostaffella Rauzer-Chernousova, 1948 (Rauzer-Chernousova, 1948a), Endostaffella Rozovskaya, 1961, or other similar planispiral genera, but the axial sections are more distinctive. Since these earlier studies, the taxonomy of this taxon has progressed notably, and species originally interpreted as a primitive Millerella Thompson, 1942 by Zeller (1953) (e.g., Millerella tortula Zeller, 1953 and Millerella designata Zeller, 1953) were included in the genus Zellerinella/Zellerinella by Mamet in Mamet and Skipp (1970b) and Mamet (1981), and was later reassigned to Paramillerella Thompson, 1951 (Brenchke and Groves, 1981), Plectronillerella Brazhnikova and Vdovenko in Aizenverg et al., 1983 (van Ginkel, 2010), or simply ‘Millerella’. 

Another constraint is that the most diverse and richer realms (both in terms of numbers of genera and species, and also number of specimens) are the Paleotethyan and Boreal realms (Mamet and Skipp, 1970a, 1979; Mamet, 1977; Davydov, 2014) as well as realms with more endemic taxa. Thus in the Maritimes Basin, the absence of more numerous Paleotethyan taxa is more likely for North American affinities. A final constraint is the established migration routes for foraminifers. According to Mamet and Skipp (1970a) and Mamet (1977), most foraminifers are Euroasian in origin and migrated westward to western Europe and later to American and Arctic realms. This migration route was established on the basis of: (1) the earliest Late Devonian Endothyridae flourished in Eurasia but are rarely observed in North America; (2) the presence of complete phylogenetic lines in Europe but incomplete ones in North America; (3) impoverished microfauna in North America in regard to Eurasian assemblages, and with few endemic taxa; and (4) heterochronism of the base of the acmes and first occurrences (the oldest forms always occur first in Eurasia, then in the Arctic, and finally in the North American Cordillera). This direction in essence suggests that a communication route had to have existed between western Europe and eastern North America, and those taxa recorded in basins such as the Midcontinent had to have crossed using the Rheic Ocean and then via regions with more similarities with western Europe, i.e., the Maritimes Basin. However, some taxa must have migrated via the northern Boreal Ocean through the Franklinian corridor and Alaska (Harris et al., 1997; Davydov and Cózar, 2019; Fig. 2).
Chernousova, 1948\[Rauzer-Chernousova, 1948a\]), a typical Paleotethyan taxon, and nella itimes Basin assemblages also contain rather similar to the western), except in the Arctic (Mamet et al., 1993). is only known from the Paleotethys Realm (eastern and hirosei Mikhailov, 1939, and dothyra recorded at Sierra Morena (Cózar, 2001). In addition, the Mar- to be referred to most specimens (if not all) recorded in western Europe need seems to be restricted to the former Soviet Union basins, and that they migrated westward. This process of migration is characterized by a delay of 2 Myr, before their first appearances in North America (see Table 2). Thus, in summary: (1) there is a single foraminiferal taxon (Eoendothyranopsis) in the Maritimes Basin assemblages that is considered more common in the North American Realm, although it has not been illustrated; (2) there are three typical Paleotethyan foraminiferal species: Plectogyranopsis hirosei, Mikhailovella gracilis, and the unilocular polysphaerina bulla, as well as the genera Haplophragmella Reitlinger, 1950, Omphalotis, Pseudeodonthyra Mikhailov, 1939, and Pseudolitituoba Vdovenko, 1971, genera typically represented in the Paleotethyan and Boreal realms.

Koktjubina Marfenkova, 1991 was originally described from Kazakhstan by Marfenkova (1991), and she also included a previously described species from Kazakhstan by Vdovenko (1962), Spiriopectammina exotica Vdovenko, 1962, and a species described from the Windsor Group by Mamet (1970), Biseriammina? windsorensis Mamet, 1970. The genus is predominantly of Paleotethyan affinities, although some rare exceptions are known from the Midcontinent. Rich (1980, pl. 5, fig. 1, non fig. 4) determined Biseriella? exotica (Vdovenko, 1962) in the southern Appalachians, and the specimens identified as Biseriella parva (Chernysheva, 1948) (pl. 5, figs. 2, 3, 6, 7, 10) are also attributable to Koktjubina. Later, Rich (1986, pl. 1, figs. 14–15) identified similar specimens of Biseriella parva as Biseriella exotica. This species, now Koktjubina exotica (Vdovenko, 1962), might be also present in the Peratovich Formation of southern Alaska (Mamet et al., 1993, pl. 13, fig. 7 only).

Three species of Koktjubina are recorded in Ireland, i.e., Koktjubina? atlantica Cózar and Somerville, 2012, Koktjubina windsorensis (Mamet, 1970), and Koktjubina exotica. The most evolved species, described as Koktjubina? atlantica by Cózar and Somerville (2012), is widespread in Ireland and recorded in the Brigantian of SE Ireland. This species occurs in the Windsor Group (Mamet, 1970, pl. 1, fig. 5, as undetermined Biseriamminidae) and in the Canadian Cordillera (Mamet, 1976, pl. 81, figs. 12, 13, as Biseriella sp.). Koktjubina windsorensis is recorded only in the Benburb area of Northern Ireland (see location, Mitchell and Mitchell, 1983), where it occurs in the latest Asbian and Brigantian (Cózar and Somerville, 2012). As mentioned above, Koktjubina windsorensis is known throughout the Windsor Group in the Maritimes Basin, where it was identified as a species of Biseriammina Chernysheva, 1941 by Mamet (1970). Its first appearance in the Maritimes Basin in lower Windsor Group strata differs from its most commonly reported occurrences in the late Visean and Serpukhovian (e.g., von Bitter et al., 2007). The third species recorded in Ireland is Koktjubina exotica, which occurs in the Benburb area and in NW Ireland, but as mentioned above, also in the Midcontinent. These three species clearly suggest a faunal interchange between the Maritimes Basin and Ireland, and Koktjubina windsorensis seems to be endemic to the Maritimes Basin and Northern Ireland.

Jansa et al. (1978) and Brisebois (1979) documented, in widely separated portions of the Maritimes Basin, the occurrence of Polysphaerina bulla Mamet, 1973. Described from Belgium and France (Conil and Lys, 1964; Mamet, 1973), this taxon is a unilocular tabulinitid with secondary spheres (see Vachard, 2016). It is otherwise known only from basins in the western Paleotethys, including Ireland and Britain (e.g., Vachard and Tahir, 1991; Cózar and Rodríguez, 2000; Pille, 2008).

On the other hand, revision of foraminifer assemblages previously published by other authors in von Bitter et al. (2007) are typically Paleotethyan in origin. Moreover, it can be concluded from the above-discussed data, that the foraminifer genera from the Maritimes Basin are typically European and north African (see Table 2). Thus, in summary: (1) there is a single foraminiferal taxon (Eoendothyranopsis) in the Maritimes Basin assemblages that is considered more common in the North American Realm, although it has not been illustrated; (2) there are three typical Paleotethyan foraminiferal species: Plectogyranopsis hirosei, Mikhailovella gracilis, and the unilocular Polysphaerina bulla, as well as the genera Haplophragmella Reitlinger, 1950, Omphalotis, Pseudeodonthyra, and Pseudolitituoba; (3) there is one virtually endemic Paleotethyan genus, Koktjubina, of which one species (Koktjubina windsorensis) is known only from the Maritimes Basin and Northern Ireland; and (4) one other species (Mikhailovella fresnedensis) is only recorded in the Maritimes Basin and SW Spain.

Another interesting feature of the foraminifer assemblages of the Maritimes Basin is that they occur at similar stratigraphic levels as in western Europe (von Bitter et al., 2007). It is well-known that the majority of North American taxa originated in the Paleotethys realm, and that they migrated westward. This process of migration is characterized by a delay of 2–3 Myr, and even up to 5 Myr, before their first appearances in North America, compared to the Paleotethys realm (Mamet, 1977; Davydov, 2014). The apparent absence of these lags in the Maritimes Basin also suggests Paleotethyan affinities for the fauna of the Maritimes Basin.

Other fossil groups

Conodonts.—The main studies of conodont faunas from the Maritimes Basin are those of Globensky (1947), von Bitter (1976), and von Bitter and Plint-Geberls (1982, 1987), subsequently summarized by von Bitter et al. (2007). Only
Globensky (1967) suggested that the conodont assemblages were representative of the North American realm, although following the reinterpretation of some of Globensky’s specimens by von Bitter (1976), the assemblage has more recently been considered as Eurasian. This has been corroborated in the biogeographic provinces defined by Higgins (1981), and more recently, it has been recognized that common taxa are shared between the Maritimes Basin and Britain, e.g., *Mestognathus* Bischoff, 1957, *Taphrognathus transatlanticus* von Bitter and Austin, 1984, *Clydagnostus* woodsorensis (Globensky, 1967), *Vogelgnathus* pesaquadi (Purnell and von Bitter, 1992), *Vogelgnathus* campbelli (Austin and Husri, 1974) (von Bitter and Austin, 1984; von Bitter et al., 1986; Purnell and von Bitter, 1992).

**Rugose corals.**—Since the pioneering work of Lewis (1935), rugose corals from the Maritimes Basin have been traditionally considered paleobiogeographically closer to western European assemblages than to American rugose-coral assemblages (Hill, 1973, 1981). Although taxonomic determinations were not conclusively documented, Poty (2002) recently revised those rugose corals and confirmed that most are typically represented in western Europe, notably in basins from northern England, Ireland, and southern France (*Actinocyathus* d’Orbigny, 1849, *Amplexizaphrentis* Vaughan, 1906, *Axophyllum* Milne-Edwards and Haime, 1850, *Konincophyllum* Thomson and Nicholson, 1876, *Lonsdaleia* McCoy, 1849, *Nemistium* Smith, 1928, *Palastraea* McCoy, 1851, and *Siphonodendron* McCoy, 1849).

**Miospores.**—Following the study by Clayton (1985), palynologists have widely accepted that Atlantic Canada belongs to the same paleobiogeographic province as Europe. Biostratigraphic zones defined in the Windsor Group and coeval strata (e.g., Utting, 1987; Utting and Giles, 2004) are comparable to those used in western Europe (e.g., Neves et al., 1972, 1973; Clayton et al., 1977). A close comparison of both spore zonal schemes was documented by Utting and Giles (2004), and the European miospore zonal scheme, as well as European regional substages, are now used in biostratigraphic analyses of the region (e.g., Jutras et al., 2001, 2015; von Bitter et al., 2007; Utting and Giles, 2008).

**Trilobites.**—Trilobites have not yet been studied in detail in the region, but Brezinski (2003) recorded *Paladin eichwaldi* (Fischer von Waldheim, 1825) in the Windsor Group, which he interpreted to be a typical European taxon.

### Paleobiogeographic results

The dendrograms resulting from hierarchical cluster analyses of algae/problematic algae and foraminifers using the Jaccard coefficient show a low similarity index for the Maritimes Basin (Fig. 4.1, 4.3). The highest similarity indices obtained with algae (0.44) and foraminifers (0.34), although still low values, suggest a closer position for the Maritimes Basin with the North American craton. However, in the case of foraminifers, the similarity index with SW Spain is also 0.34. This is interpreted as the result of ‘missing’ or under-represented data in the Maritimes Basin, which gives an artificial coincidence with the poorest North American Realm, or is composed of numerous endemic forms. The dendrograms using the Raup-Crick coefficient provide more diverse results. The algal cluster also shows a close position of the Maritimes Basin with North America (Fig. 4.2). In contrast, the foraminiferal cluster shows...
higher similarities with terranes in Spain and Gondwana (Fig. 4.4). It might be possible to explain the apparent ‘anomaly’ of the algal data in both the Jaccard and Raup-Crick coefficient methods, in which they show closer affinity to North America, as a result of the fewer number of genera (one-third less) in the database compared to the foraminifers.

The ordination methods (NMDS) using the Jaccard coefficient always suggest widely distant positions between the Maritimes Basin and North American and Paleotethyan realms, slightly closer to the Paleotethys realm, specifically, the Gondwana craton (Sahara) (Fig. 5.1). The foraminifers show closer affinities with the northern Variscan Front (Moroccan Meseta and Sierra Morena, SW Spain) (Fig. 5.3).

These affinities are emphasized using the Raup-Crick coefficient, in which the Maritimes Basin is mostly in an intermediate position between North America and western Europe/northern Africa, which is the most logical presumption. The closer distances, depending on the fossil group, are with the southeastern terranes (NW Spain) and Gondwana (Sahara) (Fig. 5.2, 5.4), but not with Britain/Ireland, as previously authors have proposed.

To minimize this plausible ‘absence of data’ effect in the Maritimes Basin, both groups were analyzed together, and the biota results show a closer proximity to Gondwana or the southern terranes (Fig. 6), at similar distances than with North America. Secondarily, it is observed that there is a close relationship between the Maritimes Basin and terranes in the northern Variscan Front, e.g., SW Spain. However, a close relationship with Laurussia was not observed, as some particular taxa of foraminifers, conodonts, brachiopods, and miospores have suggested. It must be noted that the analysis for algae has been run also considering only Kulikia and not Pekiskopora, and the results were similar. This confirms that the occurrence of a particular taxon did not exert excessive weight in paleobiogeographic comparisons.

A major concern about the lack of diversity of the Maritimes Basin is seen in the dichotomic results using the Jaccard or Raup-Crick coefficients for individual fossil groups (Figs. 4, 5). The Jaccard coefficient is one of the more widely used coefficients for biogeographic models, but owing to missing data, the Raup-Crick coefficient has become more commonly used in paleobiogeographical models, to highlight

Figure 5. Non-metric Multidimensional Scaling (NMDS) ordination method using the Jaccard coefficient (1, 3) and Raup-Crick coefficient (2, 4) of algal/problematic algae and foraminifers. Abbreviations as in Fig. 4.
unusual taxa and not the more widely expanded taxa. This difference between the indices is minimized when the database is larger (Fig. 6), showing similar results.

The lack of diversity is a marked handicap in analysis of the fauna and flora of the Maritimes Basin, because the total number of recorded foraminiferal and algal genera are only one-quarter or one-third as large as those in the Paleotethys Realm (26 vs 107 and 23 vs 70, respectively), and one-half of those in North America (26 vs 53, and 23 vs 42, respectively) (already considered as containing impoverished assemblages; see Tables 1, 2). Thus, although low diversity was considered a characteristic feature of the Maritimes Basin by Jansa and Mamet (1984), it is apparent that further research is necessary to increase its recorded diversity, which currently looks insufficient; owing to this apparent low diversity, the statistical results have to be taken with some caution.

**Paleobiogeographic implications**

Because the oldest Visean rocks of the Windsor Group succession are dominated by thick evaporites (Fig. 3), Mamet (1970) and Jansa and Mamet (1984) postulated that the Maritimes Basin was a semiclosed platform. This was invoked for the precipitation of evaporites, because most paleogeographic reconstructions show Ireland/Britain and the Maritimes Basin at approximately the same low latitude, between 10° and 20°S (e.g., Roy, 1973; Smith et al., 1973; but not Ziegler, 1978). Jansa and Mamet (1984) considered that the distance between Ireland and the Maritimes Basin was at least 1,000 km, and separated partly by a graben/rift structure (Rockall-Hatton Bank of Le Pichon, 1977 and Ziegler, 1978) and involved a wide Rheic Ocean. Recent reconstructions suggest that this distance was ~800 km during the Devonian (Waldron et al., 2018). Thus, it can be assumed that the distance during the Mississippian was even less, due to the closing related to the progressing Variscan orogeny.

Despite the faunal, floral, and stratigraphical similarities between the Maritimes Basin and western European/northern African basins, it is certainly apparent that there are also dissimilarities, which prevent a perfect interconnectedness. On the other hand, the tectonic style in the Maritimes Basin is more typically Appalachian, following the assumed attachment of the terranes of the North American region since the Devonian.

The presence of a land barrier between western Europe and Newfindland was discussed and dismissed by previous authors (e.g., Jansa and Mamet, 1984). We agree with that conclusion, because the existence of a land barrier would have prevented the marine faunal and floral interchange that is now well known. The occurrence of an ocean that acted as a potential paleobiological barrier, controlled by currents, water depth, and ocean width (Jansa and Mamet, 1984), is the most likely hypothesis. However, the presence of this ocean disagrees with the hypothesis that considered that the closure of the Rheic Ocean occurred during the Devonian or in the earliest Mississippian (e.g., Nance et al., 2012) and only a Rheonohercy-nian Ocean could have been open from the Middle to Late Mississippian (see Fig. 7). The close similarities and clear influence of Paleotethyan late Visean assemblages suggest a narrower ocean than previously supposed, and also, not very deep, to allow migration of most benthic biota. It is difficult to estimate ocean width, but it was likely to have been <1,000 km, as recent reconstructions have suggested. Whatever the separation, fluid and constant faunal/floral interchange must have been permitted. However, the low diversity of the Maritimes Basin assemblages is a conditioning factor because it might be the result of the few studies in the region, or it might be actual low diversity. In the first case, if the diversity of assemblages (number of genera) could be increased as a result of more studies in the region, that would imply a more constant interchange of fauna, and thus, a narrower oceanic width. In contrast, if, after more studies in the region, the diversity is not significantly increased, this would imply a certain isolation of the Maritimes Basin, either by a wider ocean or by stronger oceanic currents, allowing only sporadic interchange of fauna/flora with the Paleotethys realm (as during major transgressive events). It is also noteworthy that during sedimentation of the basal Windsor
not connected. Tectonic and sedimentological models promote comparison of the Maritimes Basin with those in Ireland and Britain (e.g., Waldron et al., 2018), and it is automatically assumed that the biological influence of those northern regions is inherited. However, alternative scenarios might need to be considered in which the benthic biota arrived in the Maritimes Basin by crossing the Paleohtethys Ocean from more southerly positions near the Gondwana coast, or from the northwestern terranes across a still-open Rheic Ocean (Fig. 7). This would suggest narrower oceans in this region for the late Visean-early Serpukhovian period. Indirectly, for this communication with the Paleohtethys Ocean to occur, it is envisaged that the Moroccan Meseta was not attached to Gondwana during the Visean (Fig. 6), a fact described only for the early to mid-Visean (Cózar et al., 2020), whereas for the late Visean-early Serpukhovian interval, it is not yet clearly defined. However, if the Meseta was attached to Gondwana, this would imply higher similarity indices between the Meseta and the Maritimes Basin than with Gondwana, which is not the case. The occurrence of Saharan assemblages in the Maritimes Basin suggests that the annexation of the Moroccan Meseta to Gondwana had not happened during the late Visean and early Serpukhovian.

Paleobiogeographic models are, in general, in disagreement with the paleogeographic models based on tectonics, magmatism, or paleomagnetism. For the last, there is a predominance of models that suggest that the closure of the Rheic Ocean occurred during the Devonian, with no connection between the Rheic and Paleohtethys oceans (e.g., Kroner and von Romer, 2013; Stampfl i et al., 2013; Scotese, 2015), whereas another group of authors considered that the gateway between the two oceans existed until the Permian (Vai, 2003; Walsh et al., 2007; Domeier et al., 2012). Rarely, some authors have highlighted the importance of fossil groups for these paleogeographic reconstructions for the Carboniferous (e.g., Cocks and Prots, 2011). Related to this aspect, ammonoids, rugose corals, brachiopods, and foraminifers do not show synchronicity in the timing of the closure of the Rheic-Paleothethys gateway, ranging from the mid-Visean, late Visean, early Serpukhovian, and late Serpukhovian, respectively, but clearly, all are later than the Devonian (Korn et al., 2012; Arez et al., 2013; Quiao and Shen, 2014, 2015; Davyrov and Cózar, 2019). The fauna and flora of the upper cycles of the Maritimes Basin (cycles 2–5), with strong similarities with the Paleothethys realm, confirm good communication at least until the early Serpukhovian (or a younger age for the Windsor-Codroy groups; von Bitter et al., 2007). Anomalous impoverished Visean assemblages in the Maritimes Basin suggest at least intermittent communication with the North America Realm during the same period. Species in common between the Paleothethys and the North American realms during the Visean/Serpukhovian confirm communication through the Maritimes Basin. Marine communication of the Paleothethys and North American realms through the Maritimes Basin ceased very near the beginning of the Serpukhovian with the termination of any open marine deposition that might have supported even impoverished marine faunas. This stratigraphic break is marked by the top of the Windsor and Codroy groups, assigned a latest Visean to earliest Serpukhovian age by von Bitter et al. (2007). In the Maritimes Basin, miospores recorded a major paleoenvironmental crisis in the Amsbergian

Figure 7. Paleobiogeographical sketch of the Maritimes Basin and basins in western Europe and North Africa during the late Visean-early Serpukhovian. Black arrows are plausible migration routes to the Maritimes Basin. Terranes based on Stampfli et al. (2013). Br = New Brunswick; BRK = Betics-Rif-Kabebilies; Cb = Coastal Block; Ch = Channel; CI = Central Iberian Zone; CZ = Cantabrian and Asturian-Leonese Zone; eM = eastern Moroccan Meseta; MC = Central Massif of France; Mg = Meguma; MN = Montagne Noire; MR = Mid-Germany rise; OM = Ossa-Morena Zone; Py = Pyrenees and Catalonia; SP = South Portuguese Zone; wM = western Moroccan Meseta.
sources with intermittent linkages to all of our studied regions. When marine communication ceased, the biota of the Maritimes Basin relictified marine transgression. Until marine communication, and well before the onset of severe and extensive glaciations of the Pennsylvanian during the coldest times of the Paleozoic (Giles, 2012), marine connections through the Maritimes Basin were at best intermittent and short-lived (Giles, 2009) and limited to short episodes of glacioeustatic marine transgression. Until marine communication ceased, the biota of the Maritimes Basin reflects multiple sources with intermittent linkages to all of our studied regions.

Conclusions

Analyzing the foraminiferal taxa in the Maritimes Basin, several genera and species typically represented in the Paleotethys realm can be recognized, contrasting with previous studies that the Maritimes Basin lacked typical Paleotethyan genera and species. Typical North American fauna/flora are negligible or absent, and apparent similarities are based on the absence of typical Paleotethyan genera and species. Low diversity has been argued by some as a feature typical of the Maritimes Basin, although it could be simply a result of less-detailed paleontological works or the predominance of hostile facies.

The Maritimes Basin has been compared with basins in Laurussia, in particular Ireland and England. The influence of the Laurussian margin is supported by the occurrence of some species of brachiopods, miospores, and foraminifers, with dispersal via the Rhehenocryanian Ocean. However, multivariate analysis of the marine benthic microfossils confirms that although the assemblages are of Paleotethyan affinity, they are closer to assemblages in the Gondwana platform and terranes of the Variscan Front (Moroccan Meseta/SW Spain). Owing to the relative position of the terranes between the Laurussia and Gondwana continents, we suggest that migration of the biota occurred not only via the incipient Paleotethys Ocean, but also by a still-open Rheic Ocean, with additional influence of the Rheohenocryanian Ocean. Our assessment indicates multiple sources for the biota of the Maritimes Basin. Paleogeographic models that located the Maritimes Basin opposite the North African coast would fit better in the observed paleobiogeographic relationships.

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References

Aizenberg, D.E., Astakhova, T.V., Berchenko, O.I., Brazhnikova, N.E., Vdovenko, M.V., Dunueva, N.N., Zernetskaya, N.V., Poletaev, V.I., and Sergeeva, M.T., 1983. [Late Serpukhovian Substage in the Donets Basin: Kiev, Akademiya Nauk Ukrainskoi SSR, Institut Geologicheskikh Nauk, 164 p. [in Russian]

Antropov, I.A., 1967. [Algae from the Devonian and early Carboniferous (Touraisian) of the center of the eastern part of the Russian Platform]: Akademiya Nauk SSSR, Akademiya Nauk SSSR, Sibirskoe Otdelenie, Trudy Instituta Geologi i Geofiziki, p. 118–125. [in Russian]

Antczak, B., Dora, G., Lefebvre, Y., Godderis, Y., Macouin, M., and Nardin, E., 2013. The spatial and temporal distribution of Mississippian rugose corals: Contribution of modelled oceanic currents and temperature data to this problem, in Nardin, E., and Aretz, M., eds., Pre-Cenozoic Climates International Workshop: When Data and Modelling Meet: Strata, 1, v. 14, p. 8, 9.

Armstrong, A.K., and Mamet, B.L., 1974, Carboniferous biostратigraphy, Prudhoe Bay State 1 to Northeastern Brooks Range, Arctic Alaska: Bulletin of the American Association of Petroleum Geologists, v. 58, p. 640–660.

Armstrong, A.K., and Mamet, B.L., 1977, Carboniferous microfacies, microfossils, and corals, Lisburne Group, Arctic Alaska: U.S. Geological Survey Professional Paper, v. 849, 144 p.

Armstrong, A.K., Mamet, B.L., and Repetski, J.E., 1992, Stratigraphy of the Mississippian System, south-central Colorado and north-central New Mexico: U.S. Geological Survey Bulletin, v. 1787-E, 23 p.

Austin, R.L., and Husri, S., 1974. Dinantian conodont faunas of County Clare, County Limerick and County Leitrim: An appendix, in Bouckaert, J., and Streel, M., eds., International Symposium on Belgian Micropalaeontological Limits from Emnian to Viséan, Namur 1974, Volume 3: Brussels, Geological Survey of Belgium, p. 18–69.

Barham, M., Murray, J., Joachimski, M.M., and Williams, D.M., 2012, The onset of the Permo-Carboniferous glaciation: Reconciling global stratigraphic evidence with biogenic apatite δ¹⁸O records in the late Viséan: Journal of the Geological Society of London, v. 169, p. 119–122, https://doi.org/10.1144/jgs2011-125.

Belt, E.S., 1929, Horton-Windsor District, Nova Scotia: Geological Survey Canada, Memoir 155, 268 p.

Belt, E.S., 1944, Carboniferous rocks and fossil flora of northern Nova Scotia: Geological Survey Canada Memoir 238, 277 p.

Belt, E.S., 1969, Newfoundland Carboniferous stratigraphy and its relation to the Maritimes and Ireland: American Association of Petroleum Geologists Memoir, v. 12, p. 734–753.

Bensaid, M., Ternier, H., Ternier, G., and Vachard, D., 1979, Le Carbonifère (Viséen supérieur-Bachkirien) entre Bou Chber et Ich ou Mellal (Maroc central): Annales de la Société Géologique du Nord, v. 98 (for 1978), p. 180–204.

Bichoff, G., 1957, Die Conodontenstratigraphie des rheinohemizyischen Unterkarbons mit Berücksichtigung der Wochlumeriastufe und der Devon/Karbon-Grenze: Abhandlungen des Hessischen Landesandes für Bodenfor- schung, v. 19, p. 1–64.

Blakey, R.C., 2008, Gondwana paleogeography from assembly to breakup—A 500 m.y. odyssey, in Fielding, C.R., Frank, T.D., and Isbell, J.L., eds., Resolving the Late Paleozoic Ice Age in Time and Space: The Geological Society of America Special Paper 441, p. 1–28, https://doi.org/10.1130/2008.2441(01).

Blakey, R.C., 2013, Using paleogeographic maps to portray Phanerozoic geologic and paleotectonic history of western North America [abs.]: AAPG Bulletin, v. 97, p. 146.

Bogush, O.I., 1987, [Systematic features and scope of the genus Globoen- dothyra Reitlinger, 1959 (Foraminifera)]: Institut Geologi i Geofiziki, Akademiya Nauk SSSR, Sibirskoe Otdelenie, v. 651, p. 71–95. [in Russian]

Bogush, O.I., and Juferev, O.V., 1962. [Foraminifera and Stratigraphy of Karatu and Talas Alatau Carboniferous Deposits]: Moscow, Akademiya Nauk SSSR, Sibirskoe Otdelenie, Trudy Instituta Geologi i Geofiziki, 234 p. [in Russian]

Bourque, P.-A., Madi, A., and Mamet, B.L., 1995, Waulsortian-type bioherm development and response to sea-level fluctuations: Upper Viséen of Béchir Basin, western Algeria: Journal of Sedimentary Research, v. B65, p. 80–95.

Brady, H.B., 1873, On Archaeodiscus karreri, a new type of Carboniferous Foraminifera: Annals and Magazine of Natural History, v. 12, p. 286–290.

Brazhnikova, N.E., and Yartseva, M.V., 1956, [To the question of evolution of the genus Monotaxis]: Academy of Sciences USSR Questions of Micropaleontology, v. 1, p. 62–68. [in Russian]

Brenchke, P.L., 1985, Cribrrokamaena and Crassikamaena, new genera of late Paleozoic algae from the United States: Micropaleontology, v. 31, p. 55–67.

Brenchke, P.L., 2004, Late Viséan (Mississippian) calcareous microfossils from the Tarim Basin of western China: Journal of Foraminiferal Research, v. 34, p. 144–164, https://doi.org/10.2113/0340144.
foraminifera? Rivista Italiana di Paleontologia e Stratigrafia, v. 110, p. 591–603, https://doi.org/10.13130/2039-4942/5827.

Vachard, D., and Cósar, P., 2005, Falsocalcifolium nov. gen., and revision of the tribe Calciforiniaceae (Mississippian, incertae sedis algae): Geobios, v. 38, p. 803–822, https://doi.org/10.1016/j.geobios.2004.05.004.

Vachard, D., and Cósar, P., 2010, An attempt of classification of the Paleozoic incertae sedis Algospongia: Revista Española de Micropaleontología, v. 42, p. 129–241.

Vachard, D., and Montenat, C. 1981, Biostatigraphie, micropaleontologie et paleogeographie du Permien de la region de Tezak (Montagnes Centrales d’Afghanistan): Paleontographica B, v. 178, p. 1–88.

Vachard, D., Tahiri, A., 1991, Foraminifères, algues et pseudoalgues du Viséen de la région d’Oulmes (Maroc): Géologie Méditerranéenne, v. 18, p. 119–242.

Vachard, D., Massa, D., and Strank, A., 1993, The Carboniferous of Al-37 borehole, Cyrenaica, Libya: Biostatigraphical analysis and paleogeographic implications: Revue de Micropaleontologie, v. 36, p. 165–186.

Vachard, D., Pille, L., and Gaillot, J., 2010, Palaeozoic Foraminifera: Systematics, paleoecology and responses to global changes: Revue de Micropaleontologie, v. 53, p. 209–254, https://doi.org/10.1016/j.revmic.2010.10.001.

Vachard, D., Cósar, P., Arez, M., and Izart, A., 2016, Late Viséan–early Serpukhovian cyanobacteria and algae from the Montagne Noire (France): Taxonomy and biostatigraphy: Bulletin of Geosciences, v. 91, p. 433–466, https://doi.org/10.3140/bull.geosci.1613.

Vai, G.B., 2003, Development of the palaeogeography of Pangaea from late Carboniferous to early Permian: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 196, p. 125–155, https://doi.org/10.1016/S0031-0182(03)00136-X.

van Ginkel, A.C., 2010, Systematics of the Eastafellidae (late Palaeozoic Foraminifera): Cushman Foundation for Foraminiferal Research, Special Publication 42, 130 p.

van Staal, C.R., Dewey, F.J., MacNiocaill, C., and McKerrow, W.S., 1998, The Cambrian–Silurian tectonic evolution of the northern Appalachians and British Caledonides: History of a complex, west and southwest Pacific-type segment of Iapetus, in: Blundell, D., and Scott, A.C., eds., Lyell: The Past is the Key to the Present: Geological Society of London Special Publication 143, p. 199–242.

Váňický, M., and Růžička, B., 1957, Namurian Foraminifera from the Ostrava–Karviná Coal District: Acta Musei Nationalis Pragae, Series B, Historia Naturalis/Fossil Imprint, v. 13, p. 341–362.

Vaughan, A., 1906, Faunal lists and account of the faunal succession: Quarterly Journal of the Geological Society of London, v. 62, p. 205–322.

VDovenko, M.V., 1954, [Some new types of Foraminifera from the lower Visean strata of the Donets basin]: Bulletin of the University of Kyiv, Geology and Geography Series, v. 5, p. 63–76, [in Russian]

VDovenko, M.V., 1962, [Some new foraminiferal species from upper Visean and lower Namurian deposits of southwestern central Kazakhstan]: Paleontologicheski Zhurnal, v. 1962, p. 41–46, [in Russian]

VDovenko, M.V., 1971, [A new genus of Foraminifera from the Viséan deposits of the Great Donbas]: Reports of the Academy of Sciences of the Ukrainian SSR, v. 10, p. 877–879, [in Russian]

Volodin, A.G., 1932, [Archaeocyathiids of Siberia, Volume 2, Fauna from the Cambrian limestones of Altai]: Moscow-Leningrad, Gosudarstvennoe Naukno-Tekhichesko Geologo-Razvedchye Izdatelstvo, 106 p. [in Russian]

von Bitter, P.H., 1976, Paleocology and distribution of Windsor Group (Viséan–early Namurian) conodonts, Port Hood Island, Nova Scotia, Canada: Geological Association Canada, Special Paper 15, p. 225–241.

von Bitter, P.H., and Austin, R.L., 1984, The Dinantian Taphrognavus transatlanticus conodont Range Zone of Great Britain and Atlantic Canada: Palaeontology, v. 27, p. 95–111.

von Bitter, P.H., and Legrand-Blain, M., 2007, Gigantoproductid brachiopods from the Musquodoboit Limestone of Nova Scotia (upper Windsor Group, Mississippian): Late Asian-Britannian palaeobiogeographic connections between eastern Canada and central England, in: Wong, T.E., ed., Proceedings, International Congress on Carboniferous and Permain Stratigraphy, 25th, Utrecht, The Netherlands, 10–16 August 2003: Amsterdam, Royal Netherlands Academy of Arts and Sciences, p. 191–203.

von Bitter, P.H., and Plint-Geberls, H.A., 1982, Conodont biostratigraphy of the Codroy Group (lower Carboniferous), southwestern Newfoundland, Canada: Canadian Journal of Earth Sciences, v. 19, p. 193–221.

von Bitter, P.H., Sandberg, C.A., and Orchard, M.J., 1986, Phylogeny, speciation, and palaeoecology of the early Carboniferous (Mississippian) conodont genus Mestognathus: Royal Ontario Museum, Life Sciences Contributions, v. 143, 115 p.

von Bitter, P.H., Giles, P.S., and Utting, J., 2007, Biostatigraphic correlation of major cycles in the Windsor and Codroy groups of Atlantic Canada with the Mississippian Stages of Britain and Ireland, in: Wong, T.E., ed., Proceedings, International Congress on Carboniferous and Permian Stratigraphy, 25th, Utrecht, The Netherlands, 10–16 August 2003: Amsterdam, Royal Netherlands Academy of Arts and Sciences, p. 513–534.

Waldron, J.W.F., Barr, S.M., Park, A.F., and White, C.E., 2015, Late Palaeozoic strike-slip faults in Maritime Canada and their role in the reconfiguration of the northern Appalachian orogen: Tectonics, v. 34, p. 1661–1684, https://doi.org/10.1002/2015TC003882.

Waldron, J.W.F., Giles, P.S., and Thomas, A.K., 2017, Correlation chart for Late Devonian to Permian stratified rocks of the Maritimes Basin, Atlantic Canada: Nova Scotia Department of Energy Open File Report 2017-02, 12 p.

Waldron, J.W.F., Schofield, D.L., and Murphy, J.B., 2018, Diachronous Palaeozoic accretion of peri-Gondwanan terranes at the Laurentian margin, in: Wilson, R.W., Houseman, G., McCaffrey, K., Doré, A.G., and Royden, W., eds., Tectonic Evolution: 50 Years of the Wilson Cycle Concept: Geological Society London, Special Publication 470, p. 289–310.

Walsh, G.J., Aleinikoff, J.N., and Wiitsch, R.P., 2007, Timing of Alleghanian orogenesis and dome formation in southern Connecticut: American Journal of Science, v. 307, p. 168–215.

Warthin, A.S., Jr., 1930, Micropaleontologie of the Wetsumka, Wewoka and Holdenville formations: Oklahoma Geological Survey Bulletin 53, p. 1–95.

West, L.M., Brandon, A., and Smith, M.A., 1968, A tidal flat evaporite facies in the Viséan of Ireland: Journal of Sedimentary Petrology, v. 38, p. 1079–1093.

Wethered, E., 1886, On the structure and organs of the Lower Limestone Shales, Carboniferous Limestone and upper limestones of the Forest of Dean: Geologcal Magazine, v. 3, p. 529–533.

Wood, A., 1940, Two new calcareous algae of the family Dasyacidaeae from the Carboniferous Limestone of: Proceedings of the Liverpool Geological Society, v. 18, p. 14–18.

Wood, A., 1941, The lower Carboniferous calcareous algae Mitichleemia Wethered and Garwoodia gen. nov.: Proceedings of the Geological Association, v. 52, p. 216–226.

Wood, A., 1948, Sphaeroocidium, a misinterpreted fossil from the Wenlock Limestone: Geological Association Proceedings, v. 59, p. 9–22.

Wood, A., 1964, A new dasyacidean alga, Nanopora, from the lower Carboniferous of England and Kazakhstan: Palaeontology, v. 7, p. 181–185.

Zaninetti, L., and Altiner, D., 1979, La famille des Archaediscidae (Foraminifera): Analyse taxonomique et propositions pour une nouvelle subdivision: Archives des Sciences, Genève, v. 32, p. 163–175.

Zeller, D.E.N., 1953, Endothyroid Foraminifera and ancestral fusulinids from the Mississippian of England and Kazakhstan: Palaeontology, v. 7, p. 155–157.

Ziegler, P.A., 1978, Northwestern Europe: Tectonics and basin development: Geologie en Mijnbouw, v. 57, p. 586–526.

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