Correlation chart for Late Devonian to Permian stratified rocks of the Maritimes Basin, Atlantic Canada.

by John W.F. Waldron[1], Peter S. Giles[2], and Alison K. Thomas[1]

[1]University of Alberta

[2]Geological Survey of Canada

November 2017

Introduction

The correlation chart represents a compilation of many author's work. Correlation in the Maritimes Basin is challenging, both because of a lack of isotopically datable rocks and because biostratigraphically useful fossil groups, such as conodonts, foraminifera, and palynomorphs, tend to lack key species as a result of the unusual environments that existed, especially during the Mississippian.

A second challenge resides in the dispersed nature of the literature. Many larger compilations reference biostratigraphic reports that have not been formally published. In some cases these are unavailable, or are only available in hard-copy at the library of the institution where the work was submitted. Because of this, we have relied on larger-scale compilations rather than recording primary sources in many cases. All citations in the chart should be read as if implicitly followed by the words "and references therein".

A third challenge is representing lithologies that have been described by different authors working for diverse organizations using different terminologies over many decades. Many lithostratigraphic units in the Maritimes basin show great lithological diversity, but with a few exceptions are shown as single shaded blocks in the chart. For example, decisions had to be made whether units are shown as "mainly red" or "mainly grey", or whether mixed units should be shown using shadings representing carbonates or clastics, were based on published descriptions and the authors' experience where available. They necessarily are judgement calls, and others might differ in these assessments.

Timescale

Numerical time scale

In reconciling biostratigraphic data from diverse fossil groups with sparse isotopic data we have primarily used the International Commission on Stratigraphy Geologic Time Scale (GTS 2012) (Becker et al., 2012; Davydov et al., 2012).

In the Devonian Period we use the divisions of Becker et al. (2012). However, we have modified the interpolated correlation between Late Devonian palynomorph zones and the numerical timescale shown by Becker et al. (2012), so as to take into account the precise work of Tucker et al. (1998) in the biostratigraphically well constrained Piskahegan Group of New Brunswick.

In the Carboniferous, our age dates are based on those of Davydov et al. (2010, 2012). However, some isotopic data not available for that compilation (Lyons et al., 2006; Pointon et al., 2012, 2014) suggest that certain ages need revision. A modified time scale has been used here to accommodate these data. Table 1 shows a comparison of ages assigned to principal boundaries within the Carboniferous by several authors, and Table 2 shows the basis for the boundary times chosen here. In addition, it should be noted that Giles (2009) has suggested further revision of the timescale (Table 1) based on a correlation of transgressive-regressive cycles to orbital forcing; further work, not attempted here, would be required to incorporate these suggestions in a revised timescale.

Table 1: Ages assigned to principal boundaries within the Carboniferous by several authors

Stage	**Substage top**	**Davydov et al. (2012)**	**Davydov et al. (2010)**	**P. Giles unpublished compilation (2016)**	**This document**
Moscovian	Asturian	~307.0	308.1	306.2	307.0
	Bolsovian	~309.9?	310.4	308.6	309.9
Bashkirian	Duckmantian	~315.2	315.0	314.6	315.2
	Langsettian	~317.5	316.9	315.8	**316.1**
	Yeadonian	~318.7			**318.6**
	Marsdenian	~320.2			320.2
	Kinderscoutian	~321.3?			321.3
	Alportian	~322.0			322.0
	Chokierian	~322.8			322.8
Serpukhovian	Arnsbergian	~323.6	323.3	322.9	323.6
	Pendleian	~327.7	327.9	326.5	327.7
Visean	Brigantian	~329.1	329.2	328.9	329.1
	Asbian	~332.1	331.6	332.5	332.1
	Holkerian	~336.7	336.0	336.0	**336.2**
	Arundian	~342.8	341.95	342.0	342.8
	Chadian	~344.0	343.9	344.4	344.0
Tournaisian	Ivorian	~346.7	346.3	349.1	346.7
	Hastarian	~351.2	353.4	353.9	351.2

Bolded entries adjusted to fit additional isotopic data

Table 2. Basis for boundary times adopted in the correlation chart

Stage	**Substage top**	**Boundary age adopted (Ma)**	**Method of assigning date**
Artunian		298.8	Davydov et al. (2012)
Stephanian		302.2	Fossil zones do not correlate explicitly so interpolated from Davydov et al. (2012) pg. 605

Westphalian	Asturian	307.9	Biostratigraphic correlation based on Davydov et al. (2010, 2012)
	Bolsovian	309.9	Biostratigraphic correlation to numerical time scale based on Davydov et al. (2010, 2012)
Namurian	Duckmantian	315.2	Davydov et al. (2012) pg. 605
	Langsettian	**316.1**	Adjusted. from Davydov et al. (2012) pg. 605 then moved to accommodate isotopic data from Lyons et al. (1997)
	Yeadonian	**318.6**	Biostratigraphic correlation based on Davydov et al. (2010, 2012) then moved slightly to accommodate isotopic data from Schmitz and Davydov (2012)
	Marsdenian	320.2	Biostratigraphic correlation to numerical time scale based on Davydov et al. (2010, 2012)
	Kinderscoutian	321.3	Biostratigraphic correlation to numerical time scale based on Davydov et al. (2010, 2012)
	Alportian	322.0	Fossil zones do not correlate well; boundary estimated from Davydov et al. (2012) pg. 605
	Chokierian	322.8	Fossil zones do not correlate well; boundary estimated from Davydov et al. (2012) pg. 605
	Arnsbergian	323.6	Fossil zones do not correlate well; boundary estimated from Davydov et al. (2012) pg. 605
	Pendleian	327.7	Fossil zones do not correlate well; boundary estimated from Davydov et al. (2012) pg. 605
	Brigantian	329.1	Biostratigraphic correlation to numerical time scale based on Davydov et al. (2010, 2012)

	Asbian	332.1	Biostratigraphic correlation to numerical time scale based on Davydov et al. (2010, 2012)
	Holkerian	**336.2**	Biostratigraphic correlation to numerical time scale based on Davydov et al. (2010, 2012), then shifted to accommodate isotopic data from *Pointon et al. (2014)
	Arundian	342.8	Biostratigraphic correlation to numerical time scale based on Davydov et al. (2010, 2012)
	Chadian	344.0	Biostratigraphic correlation to numerical time scale based on Davydov et al. (2010, 2012)
Courceyan	Ivorian	346.7	Davydov et al. (2012)
	Hastarian	351.2	Biostratigraphic correlation to numerical time scale based on Davydov et al. (2010, 2012)

Biostratigraphic time scale

The majority of biostratigraphic ages in the Maritimes basin are based on palynomorphs. However, the palynostratigraphic zonal scheme used is local to the region, and no correspondence to numerical ages has been published. In placing the spore zones in the numerical timescale we first used Utting & Giles (2004) to match the larger zonal subdivisions in Atlantic Canada to stages and European fossil zones. We then mapped the spore zonation of Britain and Ireland (Clayton et al., 1977; Higgs et al., 1988; Riley, 1993) to conodont and foraminferal zones using Davydov et al. (2004, 2010); and finally adjusted again for consistency with the numerical scale adopted here.

In the chart, palynostratigraphic boundaries and zone names are shown in green. Solid lines are tied to a foramiferal or conodont zone boundary that can then be assigned a numerical age using the work of Davydov et al. (2004, 2010, 2012). Dashed lines are interpolated between these relatively constrained boundaries.

Other biostratigraphic schemes, mainly applicable in marine rocks of the Windsor Group, include Bell's (1929) system of macrofossil zones, used by Moore & Ryan (1976) (shown in cyan). However, these zones are difficult to correlate outside the Maritimes Basin, probably because the unusual, highly saline environments hosted a restricted fauna. Foraminifera are found in the same rocks and Mamet's (1970) zonation can be correlated with other regions (Mamet and Skipp, 1970; Von Bitter et al., 2006). However, the correlation with the European and international stages proposed by von Bitter is difficult to reconcile with that of Davydov et al. (2010, 2012), leading to further uncertainty.

As a result of these problems, significant differences of opinion have arisen on the age of the lower part of the Windsor Group, equivalent to Bell's A subzone. In the chart, we show four different possibilities in a sidebar. The youngest age assigned to the basal Windsor Group shown is Early Asbian (~336 Ma in the timescale adopted here), as favoured by Mamet (1970) and St. Peter & Johnston (2009b). An older age of early Holkerian (~344-343 Ma) is favoured in most of the work of Utting and Giles (e.g. 2004), but von Bitter et al. (2006) favour a late Chadian age (~345 - 344 Ma) for the basal Windsor Group. A single isotopic constraint (Barr et al., 1994) implies that the base of the Windsor Group is younger than the St. Peters Gabbro dated at 339 ± 2 Ma. In the chart we place the base of the Windsor Group in a compromise position, above the dated gabbro, but older than the Asbian age favoured by St. Peter & Johnston (2009b), at ~ 338-339 Ma. We reconcile the older foraminiferal age of von Bitter et al (2006) by suggesting (in our column for southern Cape Breton Island) that the Isle Madame limestone from which it was obtained is significantly older than the typical basal Windsor Group rocks elsewhere in the region.

Sources for individual areas

The southern New Brunswick columns shown on the chart are heavily based on the work of St. Peter & Johnston (2009a, 2009b and references therein) together with that of Park (e.g. Park and St. Peter, 2009). In addition, the stratigraphy shown for the Piskahegan Group depends on the work of Bevier (1988) and McGregor and McCutcheon (e.g., Richardson and McGregor, 1986; McGregor and McCutcheon, 1988; Tucker et al., 1998). In the Sackville Sub-basin adjacent to the Nova Scotia border additional information was drawn from Craggs et al.(2015) and personal communication with Andrew MacRae and Matthew Stimson (St. Mary's University).

In Northern Nova Scotia the Cumberland Sub-basin stratigraphy is largely that established by Ryan et al. (1991; Ryan and Boehner, 1994) with additional biostratigraphic revision by Utting et al.(2010) and Opdyke et al. (2014). A previous summary of the lithostratigraphy appeared in Waldron et al. (2013) These references also apply to the northern Cobequid Higlands, where additional information was obtained on the eastern Cobequids from Chandler et al. (1995) and on the ages of igneous rocks from Dunning et al. (2002). The stratigraphy of the central and southern Cobequids is based on summaries by Naylor and Kennedy (1998) Pe-Piper and Piper (2002) and Naylor et al. (2006). For the Stellarton area to the east, we used the work of Yeo & Gao (1987), Chandler et al. (1995) and Waldron et al. (Waldron et al., 1999; Waldron, 2004).

Early work on the Antigonish Sub-basin (Mamet, 1970; Neves and Belt, 1970) is summarized by Boehner & Giles (1993). For western Cape Breton Island we have drawn upon stratigraphic data from Allen et al. (2013) and summarized reports of earlier work by Utting (1987), Hamblin (1989) and Giles et al. (1997). Farther south, data for the Guysborough and Southern Cape Breton Island (Port Hawkesbury) areas are provided by Barr et al (1994) Hamblin (1989), Tenière et al. (2005) von Bitter et al. (2006) and Giles et al. (2010).

The column representing Prince Edward Island and adjacent areas of the Gulf of St. Lawrence is dependent on surface mapping by van de Poll (1989) and subsurface information compiled by Giles & Utting (1999) and Giles (2004), with additional regional

correlations from Allen et al. (2013). The distinctive Cap Rouge well is summarized from Giles & Utting (2001).

Comprehensive summaries of the Lomond-Glengarry and Sydney sub-basins are provided by Boehner & Prime(1993) and Boehner & Giles (2008).

On the Meguma Terrane, the stratigraphy of the Windsor-Kennetcook, Shubenacadie and Musquodoboit basins is addressed by Utting , Giles and Boehner (1979), Giles and Boehner (1982), Boehner (1986), Martel et al. (1993) and Moore et al. (2000).

The stratigraphy of the Bay St. George Sub-basin in SW Newfoundland is founded upon the work of Knight (1983), updated by new palynology documented by Utting & Giles (2004, 2008). In the Deer Lake basin, the stratigraphy described by Belt (1969) was further investigated in a series of publications by Hyde (1979, 1984; Hyde et al., 1988); further comment by Utting and Giles (2004, 2008) is incorporated in the column shown here.

Lithostratigraphy

We have tried to encompass most of the formal, and some informal lithostratigraphic divisions that have been defined in the Maritimes Basin, but inevitably some are omitted. In organizing formations into groups, we have followed what we perceive to be a majority usage, giving priority to geological surveys who use lithostratigraphic subdivisions as a basis for mapping. There are notable differences between different organizations and authors, particularly in the use of the terms "Morien Group" and "Percé Group". Future versions of the chart may be constructed as interactive documents which will be able to show competing versions of lithostratigraphic organization.

Bibliography

Allen, J.P., Fielding, C.R., Rygel, M.C., and Gibling, M.R., 2013, Deconvolving signals of tectonic and climatic controls from continental basins: An example from the late Paleozoic Cumberland Basin, Atlantic Canada: Journal of Sedimentary Research, v. 83, p. 847–872.

Barr, S.M., Grammatikopoulos, A.L., and Dunning, G.R., 1994, Early Carboniferous gabbro and basalt in the St. Peters area, southern Cape Breton Island, Nova Scotia: Atlantic Geology, v. 30, p. 247–258.

Becker, R.T., Gradstein, F.M., and Hammer, O., 2012, The Devonian Period, *in* Gradstein, F.M., Ogg, J.G., Schmitz, M., and Ogg, G. eds., The Geological Timescale 2012, Elsevier, p. 559–601.

Bell, W.A., 1929, Horton–Windsor District, Nova Scotia: Geological Survey of Canada Memoir, v. 155.

Belt, E.S., 1969, Newfoundland Carboniferous stratigraphy and its relation to the Maritimes and Ireland, *in* Kay, M. ed., North Atlantic Geology and Continental Drift, American Association of Petroleum Geologists Memoir, v. 12, p. 734–753.

Bevier, M.L., 1988, U-Pb geochronologic studies of igneous rocks in New Brunswick, *in* Abbott, S.A. ed., Thirteenth Annual Review of Activities, New Brunswick Department of Natural Resources and Energy, Minerals and Energy Division, Information Circular, p. 134–140.

Boehner, R.C., 1986, Salt and Potash Resources in Nova Scotia: Nova Scotia Department of Mines and Energy Bulletin, v. ME 005, 346 p.

Boehner, R.C., and Giles, P.S., 1993, Geology of the Antigonish Basin, Antigonish County, Nova Scotia: Nova Scotia Department of Natural Resources, Mines and Energy Branches, Memoir, v. 8, 109 p.

Boehner, R.C., and Giles, P.S., 2008, Geology of the Sydney Basin, Cape Breton and Victoria Counties, Cape Breton Island, Nova Scotia: Nova Scotia Department of Natural Resources, Mineral Resources Branch Memoir, v. ME II, 90 p.

Boehner, R.C., and Prime, G., 1993, Geology of the Loch Lomond Basin and Glengarry Half Graben, Richmond and Cape Breton Counties, Cape Breton Island, Nova Scotia: Nova Scotia Department of Natural Resources Memoir, v. ME 009, 71 p.

Chandler, F.W., Waldron, J.W.F., Palmer, S., Giles, P.S., Gall, Q., Howells, K., and Durling, P., 1995, Geological Map of the Stellarton Gap (NTS 11E/07, 09, 10 and 15): Nova Scotia Department of Natural Resources, Minerals and Energy Branch, Report, v. 95–2, p. 41.

Clayton, G., Coquel, R., Doubinger, J., Gueinn, K.J., Loboziak, S., Owens, B., and Streel, M., 1977, Carboniferous miospores of western Europe: illustration and zonation: Rijks Geologische Dienst, v. 29, p. 1–71.

Craggs, S., Keighley, D., Waldron, J.W.F., and Park, A., 2015, Salt tectonics in an intracontinental transform setting: Cumberland and Sackville basins, southern New Brunswick, Canada: Basin Research, p. n/a-n/a, doi: 10.1111/bre.12152.

Davydov, V.I., Crowley, J.L., Schmitz, M.D., and Poletaev, V.I., 2010, High-precision U-Pb zircon age calibration of the global Carboniferous time scale and Milankovitch band cyclicity in the Donets Basin, eastern Ukraine: U-Pb AGE OF THE CARBONIFEROUS AND CYCLICITY: Geochemistry, Geophysics, Geosystems, v. 11, p. n/a-n/a, doi: 10.1029/2009GC002736.

Davydov, V.I., Korn, D., Schmitz, M.D., Gradstein, F.M., and Hammer, O., 2012, The Carboniferous Period, *in* Gradstein, F.M., Ogg, J.G., Schmidtz, M., and Ogg, G. eds., The Geologic Time Scale 2012, Elsevier, p. 603–651.

Davydov, V., Wardlaw, B.R., and Gradstein, F.M., 2004, The Carboniferous Period, *in* Gradstein, F.M., Ogg, G., and Smith, A.G. eds., A Geologic Time Scale 2004, Cambridge University Press, p. 222–248.

Dunning, G.R., Barr, S.M., Giles, P.S., McGregor, D.C., Pe-Piper, G., and Piper, D.J.W., 2002, Chronology of Devonian to Early Carboniferous rifting and igneous activity in southern Magdalen Basin based on U-Pb (zircon) dating: Canadian Journal of Earth Sciences, v. 39, p. 1219–1237.

Giles, P.S., 2009, Orbital forcing and Mississippian sea level change: time series analysis of marine flooding events in the Viséan Windsor Group of eastern Canada and implications for Gondwana glaciation: Bulletin of Canadian Petroleum Geology, v. 57, p. 449–470.

Giles, P.S., 2004, Stratigraphic and structural interpretation of HB Fina Northumberland Strait F-25 well, western Maritimes Basin, eastern Canada: Geological Survey of Canada, Open File, v. 1840.

Giles, P.S., and Boehner, R.C., 1982, Geological Map of the Shubenacadie and Musquodoboit Basins, central Nova Scotia: Nova Scotia Department of Mines and Energy, Map.

Giles, P.S., and Boehner, R.C., 1979, The Windsor Group stratigraphy in the Shubenacadie and Musquodoboit basins of central Nova Scotia, *in* Nova Scotia Department of Natural Resources, Mines and Energy Branch, Open File Report, v. 410.

Giles, P.S., Hein, F.J., and Allen, T.L., 1997, Bedrock geology of Port Hood – Lake Ainslie (11K04, 11K03, 11F13), Cape Breton Island, Nova Scotia: Geological Survey of Canada Open File, scale 3253.

Giles, P.S., Naylor, R.D., Téniere, P.J., White, C.E., Demont, G., and Force, E.R., 2010, Bedrock Geology Map of the Port Hawkesbury Area, Part of NTS Sheet 11F/06, 11F/07. 11F/11 and 11F/16, Inverness, Richmond, Guysborough and Antigonish Counties, Nova Scotia: Nova Scotia Department of Natural Resources Open File Map, scale 2010-6.

Giles, P.S., and Utting, J., 1999, Maritimes Basin stratigraphy – Prince Edward Island and adjacent Gulf of St. Lawrence.: v. 3732.

Giles, P.S., and Utting, J., 2001, SHELL – AMOCO Cap Rouge F-52 Gulf of St. Lawrence, eastern Camada: Geological Survey of Canada Open File, v. 3204.

Hamblin, A.P., 1989, Sedimentology, Tectonic Control, and Resource Potential of the Upper Devonian – Lower Carboniferous Horton Group, Cape Breton Island, Nova Scotia [Ph. D. thesis]: University of Ottawa, 300 p.

Higgs, K.T., McPhilemy, B., Keegan, J.B., and Clayton, G., 1988, New data on palynological boundaries within the Irish Dinantian: Review of Palaeobotany and Palynology, v. 56, p. 61–68.

Hyde, R.S., 1984, Geologic history of the Carboniferous Deer Lake Basin, west-central Newfoundland, Canada: International Congress on Carboniferous Stratigraphy and

Geology (9th: 1979: Washington D.C and University of Illinois at Urbana-Champaign) Compte Rendu, v. 3, p. 85–104.

Hyde, R.S., 1979, Geology of Carboniferous Strata in Portions of the Deer Lake Basin, Western Newfoundland: Mineral Development Division, Department of Mines and Energy, Newfoundland and Labrador, Report, v. 79–6, 43 p.

Hyde, R.S., Miller, H.G., Hiscott, R.N., and Wright, J.A., 1988, Basin architecture and thermal maturation in the strike-slip Deer Lake Basin, Carboniferous of Newfoundland: Basin Research, v. 1, p. 85–105.

Knight, I., 1983, Geology of the Carboniferous Bay St. George Subbasin, western Newfoundland: Newfoundland Department of Mines and Energy, Mineral Development Division, Memoir, v. 1, 358 p.

Lyons, P.C., Krogh, T.E., Kwok, Y.Y., Davis, D.W., Outerbridge, W.F., and Evans Jr, H.T., 2006, Radiometric ages of the Fire Clay tonstein [Pennsylvanian (upper Carboniferous), Westphalian, Duckmantian]: A comparison of U-Pb zircon single-crystal ages and 40Ar/39Ar sandine single-crystal plateau ages: International Journal of Coal Geology, v. 67, p. 259–266.

Mamet, B.L., 1970, Carbonate microfacies of the Windsor Group (Carboniferous), Nova Scotia and New Brunswick: Geological Survey of Canada, Paper, v. 70–21, 121 p.

Mamet, B., and Skipp, B., 1970, Lower Carboniferous foraminifera: Preliminary zonation and stratigraphic implications for the Mississippian of North America, *in* Sixth International Congress of Carboniferous Stratigraphy and Geology, v. 3, p. 1129–1146.

Martel, A.T., McGregor, D.C., and Utting, J., 1993, Stratigraphic significance of Upper Devonian and Lower Carboniferous miospores from the type area of Horton Group, Nova Scotia: Canadian Journal of Earth Sciences, v. 30, p. 1091–1098.

McGregor, D.C., and McCutcheon, S.R., 1988, Implications of spore evidence for Late Devonian age of the Piskahegan Group, southwestern New Brunswick: Canadian Journal of Earth Sciences, v. 25, p. 1349–1364.

Moore, R.G., Ferguson, S.A., Boehner, R.C., and Kennedy, C.M., 2000, Preliminary Geological Map of the Wolfville/Windsor Area, Hants and Kings Counties, Nova Scotia [21H/01 and parts of 21A/16C and D]: Nova Scotia Department of Natural Resources, Open File Map, v. ME 2000-3.

Moore, R.G., and Ryan, R.J., 1976, Guide to the Invertebrate Fauna of the Windsor Group In Atlantic Canada: Nova Scotia Department of Natural Resources Paper ME 1976-005, 57 p.

Naylor, R.D., Brisco, D.C., and Fitzgerald, L.C., 2006, A Summary of the Stratigraphy of the Late Carboniferous (Pennsylvanian) Cumberland Group, NTS Areas 11E/06 and 11E/07, *in* Mineral Resources Branch, Report of Activities 2005, Nova Scotia Department of Natural Resources, Report, v. ME 2006-1, p. 127–134.

Naylor, R.D., and Kennedy, C.M., 1998, Stratigraphy and sedimentology of the late Carboniferous Parrsboro Formation, *in* MacDonald, D.R. ed., Report of Activities 1997, Nova Scotia Department of Natural Resources Report, v. ME1998-01.

Neves, R., and Belt, E.S., 1970, Some observations on Namurian and Visean spores from Nova Scotia, Britain and northern Spain, *in* Complete Rendu - Sixieme Congres International de Stratigraphie et de Geologie du Carbonifere, Sheffield, v. 3, p. 1233–1242.

Opdyke, N.D., Giles, P.S., and Utting, J., 2014, Magnetic polarity stratigraphy and palynostratigraphy of the Mississippian-Pennsylvanian boundary interval in eastern North America and the age of the beginning of the Kiaman: Geological Society of America Bulletin, v. 126, p. 1068–1083, doi: 10.1130/b30953.1.

Park, A.F., and St. Peter, C.J., 2009, Stratigraphy and structure of the Indian Mountain Deformed Zone, Maritimes Basin, Westmorland County, Southeastern New Brunswick: New Brunswick Department of Natural Resources; Minerals, Policy and Planning Division, Mineral Resources Report, v. 2009–1, 114 p.

Pe-Piper, G., and Piper, D.J.W., 2002, A synopsis of the geology of the Cobequid Highlands, Nova Scotia: Atlantic Geology, v. 38, p. 145–160.

Pointon, M.A., Chew, D.M., Ovtcharova, M., Sevastopulo, G.D., and Crowley, Q.G., 2012, New high-precision U-Pb dates from western European Carboniferous tuffs; implications for time scale calibration, the periodicity of late Carboniferous cycles and stratigraphic correlation: Journal of the Geological Society, London, v. 162, p. 713–721.

Pointon, M.A., Chew, D.M., Ovtcharova, M., Sevastopulo, G.D., and Delcambre, B., 2014, High-precision U-Pb zircon CA-ID-TIMS dates from western European late Visean bentonites: Journal of the Geological Society of London, v. Pre-Issue publication.

Richardson, J.B., and McGregor, D.C., 1986, Silurian and Devonian Spore Zones of the Old Red Sandstone Continent and Adjacent Regions: Geological Survey of Canada Bulletin, v. 134.

Riley, N.J., 1993, Dinantian (lower Carboniferous) biostratigraphy and chronostratigraphy in the British ISles: Journal of the Geological Society, London, v. 150, p. 427–446.

Ryan, R.J., and Boehner, R.C., 1994, Geology of the Cumberland Basin, Cumberland, Colchester and Pictou Counties, Nova Scotia: Halifax, Nova Scotia Department of Natural Resources Memoir 10, v. 10, 222 p.

Ryan, R.J., Boehner, R.C., and Calder, J.H., 1991, Lithostratigraphic revision of the Upper Carboniferous to Lower Permian strata in the Cumberland Basin, Nova Scotia and the regional implications for the Maritimes Basin in Atlantic Canada: Bulletin of Canadian Petroleum Geology, v. 39, p. 289–314.

St. Peter, C.J., and Johnson, S.C., 2009a, Palynological Data for Late Devonian–Carboniferous Strata of the Maritimes Basin of Southeastern New Brunswick (NTS 21 H/9, 10, 14, 15, 16 and 21 I/01, 02): New Brunswick Department of Natural Resources; Minerals, Policy and Planning Division, Open File (Online), p. 275.

St. Peter, C.J., and Johnson, S.C., 2009b, Stratigraphy and structural history of the late Paleozoic Maritimes Basin in southeastern New Brunswick, Canada: New Brunswick Department of Natural Resources, Memoir, v. 3, 348 p.

Teniere, P.J., Barr, S.M., and White, C.E., 2005, Stratigraphy and structure of the Horton Group, Lochaber-Mulgrave area, northern mainland Nova Scotia: Atlantic Geology, v. 41, p. 41–52.

Tucker, R.D., Bradley, D.C., Ver Straten, C.A., Harris, A.G., Ebert, J.R., and McCutcheon, S.R., 1998, New U–Pb zircon ages and the duration and division of Devonian time: Earth and Planetary Science Letters, v. 158, p. 175–186.

Utting, J., 1987, Palynology of the lower Carboniferous Windsor Group and Windsor-Canso boundary beds of Nova Scotia, and their equivalents in Quebec, New Brunswick and Newfoundland: Geological Survey of Canada, Bulletin, v. 374, 93 p.

Utting, J., and Giles, P.S., 2004, Biostratigraphical implications of new palynological data from the Mississippian of Newfoundland and Nova Scotia, Canada, *in* Memoirs of the Association of Australasian Palaeontologists, v. 29, p. 115–160.

Utting, J., and Giles, P.S., 2008, Palynostratigraphy and lithostratigraphy of Carboniferous Upper Codroy Group and Barachois Group, southwestern Newfoundland: Canadian Journal of Earth Sciences, v. 45, p. 45–67.

Utting, J., Giles, P.S., and Dolby, G., 2010, Palynostratigraphy of Mississippian and Pennsylvanian rocks, Joggins area, Nova Scotia and New Brunswick, Canada: Palynology, v. 34, p. 43–89, doi: 10.1080/01916121003620569.

Van de Poll, H.W., 1989, Lithostratigraphy of the Prince Edward Island redbeds:

Von Bitter, P.H., Giles, P.S., and Utting, J., 2006, Biostratigraphic correlation of major cycles in the Windsor and Codroy groups of Nova Scotia & Newfoundland, Atlantic Canada, with the Mississippian substages of Britain and Ireland, *in* Wong, T.. ed., Proceedings of the XVth International Congress on Carboniferous and Permian Stratigraphy, Utrecht, Royal Netherlands Academy of Arts and Sciences, p. 513–534.

Waldron, J.W.F., 2004, Anatomy and evolution of a pull-apart basin, Stellarton, Nova Scotia: Geological Society of America Bulletin, v. 114, 1/2, p. 109–127.

Waldron, J.W.F., Chandler, F.W., Durling, P., Gillis, K.S., and Naylor, R.D., 1999, Geological Compilation Map of the Stellarton Basin: Geological Survey of Canada Open File, v. 3757.

Waldron, J.W.F., Rygel, M.C., Gibling, M.R., and Calder, J.H., 2013, Evaporite tectonics and the late Paleozoic stratigraphic development of the Cumberland basin, Appalachians of Atlantic Canada: Geological Society of America Bulletin, v. 125, p. 945–960.

Yeo, G.M., and Gao, R.-. X., 1987, Stellarton graben: an upper Carboniferous pull-apart basin in northern Nova Scotia, *in* Beaumont, C. and Tankard, A.J. eds., Sedimentary basins and basin-forming mechanisms, Canadian Society of Petroleum Geologists Memoir 12, p. 299–309.