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Biochemostratigraphy of the Eramosa Formation in southwestern Ontario, Canada

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Abstract

The lithostratigraphic term 'Eramosa' was introduced in Ontario more than a century ago to include a distinctive package of thin-to-medium bedded, black-to-medium-brown dolostones that make up key cuesta faces and railway road cuts along the Eramosa River in the City of Guelph, southwestern Ontario, Canada. This stratigraphic unit makes up part of a stacked carbonate succession that constitutes one of the most economically significant Paleozoic sedimentary rocks in Ontario. The strata assigned to the Eramosa have a complex history of lithostratigraphic study and the relative age, regional lithostratigraphic relationships, and varied depositional environments of the Eramosa were poorly understood. This research, which combines conodont biostratigraphy and carbonate carbon ($\delta^{13}\text{C}_{\text{carb}}$) isotope stratigraphy to generate a detailed chronostratigraphic framework for the Eramosa Formation in southwestern Ontario, is part of a regional-scale surface and subsurface mapping initiative of the Silurian strata by the Ontario Geological Survey. Dolostone samples from Warton and the City of Guelph, Ontario yielded three biostratigraphically important conodonts: *Ozarkodina sagitta rhenana*, *Kockelella walliseri*, and *Kockelella ortus ortus*. The carbonate carbon ($\delta^{13}\text{C}_{\text{carb}}$) isotope data from the studied intervals record the descending limb of the Sheinwoodian (Ireviken) positive $\delta^{13}\text{C}_{\text{carb}}$ isotope excursion, including a distinctive positive shift in $\delta^{13}\text{C}_{\text{carb}}$ isotope values typical of records of the descending limb of the excursion in Laurentia and Baltica. *Aldridgeodus minimus* was also recovered from these conodont faunas and co-occurs with *Kockelella walliseri*, below the last occurrence of *Ozarkodina sagitta rhenana* (Lower

Kockelella walliseri Zone), suggesting that the range of *Aldridgeodus minimus* should be extended lower into the Sheinwoodian Stage.

Keywords: Silurian, Ontario, Eramosa Formation, conodonts, carbonate carbon isotopes

Introduction

The Niagaran Provincial Series in the Niagara region of western New York has been studied for 150 years (Berry and Boucot 1970; Brett et al. 1995; Cramer et al. 2011a, 2011b) and recent work in this region (Brett et al. 1995; Cramer et al. 2006; McLaughlin et al. 2008; Cramer et al. 2011a) has provided revisions to the relative age assessment of the Niagaran Provincial Series. Chronostratigraphic control for the Silurian strata in Ontario, Canada is less well-constrained due to a history of limited biostratigraphic and chemostratigraphic studies and the complexities of facies changes from the Appalachian Basin across the Algonquin Arch and into the Michigan Basin (see Brunton 2009; Brunton and Brintnell 2011; and Brunton et al. 2012). This is further complicated by lithostratigraphic nomenclatural differences across the Niagara River between the United States Geological Survey (USGS) and the Ontario Geological Survey (OGS) (Brett et al. 1995; Brunton et al. 2005; Cramer et al. 2011a). Study of the strata in southwestern Ontario, Canada is critical for understanding the tectonostratigraphic relationships between the foreland Appalachian Basin and the intracratonic Michigan Basin during the Silurian Period.

Due to refined processing techniques (Jeppsson et al. 1985; Jeppsson 1987; Jeppsson and Anehus 1995, 1999) and an increase in the number of studied sections globally, Silurian conodont taxonomy and biostratigraphy (specifically of the Llandovery Stage and Wenlock Series) have undergone significant revisions in the last two decades (e.g. Jeppsson 1997; Jeppsson et al. 2006; Männik 1998, 2007a, 2007b). As a result, the resolution of Silurian conodont biozonation has increased by an order of magnitude and acted as a catalyst for a revolution in the study of biogeochemical events. A series of extinction events during the Silurian Period (e.g. Jaeger 1959; Jeppsson 1990, 1998; Jeppsson and Aldridge 2000; Jeppsson et al. 1995, 2006; Cramer et al. 2010a, 2010b; Cramer et al. 2012) are correlative with perturbations in the global carbon cycle, which are recorded as major positive carbonate carbon ($\delta^{13}\text{C}_{\text{carb}}$) isotope excursions in marine carbonates. These combined biological and chemical events provide useful chronostratigraphic markers for high-resolution global correlation of Silurian strata, particularly when biostratigraphic information is limited. As a result, integrated conodont biostratigraphy and carbonate carbon ($\delta^{13}\text{C}_{\text{carb}}$) isotope chemostratigraphy for the Silurian System now provide a high-resolution chronostratigraphic framework for Silurian strata globally (Cramer et al. 2011a).

Herein, two outcrops from Wiarton on the central Bruce Peninsula (Highway 6 roadcut and Ledgerock Quarry) and two cores from the City of Guelph (MW 04-06 and MW 07-06) were sampled for conodont biostratigraphy and carbonate carbon ($\delta^{13}\text{C}_{\text{carb}}$) isotope chemostratigraphy. The chronostratigraphic framework constructed from these data not only permits a more accurate age determination and regional correlation for the Eramosa Formation in southwestern Ontario but also permits correlation to the Niagaran Provincial Series in New

York. This research is also a part of the Ontario Geological Survey’s multi-year, regional-scale study to constrain the bedrock aquifers and karst of the Niagara Escarpment.

Stratigraphic Nomenclature

Although the first comprehensive report of the Silurian System of Ontario was published by Logan in 1863, the relative ages, stratigraphic relationships, and depositional environments of these lithostratigraphic units are only now being addressed in a systematic manner (Brunton and DeKeyser 2004; Brunton 2009; Armstrong and Carter 2010; Brunton and Brintnell 2011; Brunton et al. 2012). The term ‘Eramosa’ was first designated by Williams (1915a, 1915b, 1919) for a cuesta-forming dolostone succession in the City of Guelph along the Guelph Line railway cut on the west side of the Eramosa River. Since its designation as a lithostratigraphic unit, the strata encompassing the Eramosa has been given formational rank (Nowlan 1935; Shaw 1937; Rickard 1975; Brett et al. 1995; Brunton 2009; Brunton and Brintnell 2011; Brunton et al. 2012); been referred to as the uppermost member of the Lockport Formation and Amabel Formation (Williams 1919; Caley 1940; Bolton 1953; Liberty and Bolton 1971); and been assigned as the basal member of the Guelph Formation (Sanford 1969; Armstrong and Meadows 1988; Johnson et al. 1992; Armstrong and Dubord 1992; Armstrong 1993a, 1993b; Armstrong and Carter 2006; Armstrong and Dodge 2007). The Ontario Geological Survey (OGS) is in the process of completing a multi-year study mapping the bedrock aquifers and karst of the Niagara Escarpment in southwestern Ontario (Brunton 2009; Brunton and Brintnell 2011; Brunton et al. 2012). This work by the OGS has retained the formational designation of the Eramosa and has

resulted in the recognition of three members of the Eramosa Formation, in ascending order: Vinemount, Reformatory Quarry, and Stone Road (Brunton 2009; Brunton and Brintnell 2011; Brunton et al. 2012). The Reformatory Quarry (less than 0.5 km from Williams' 1919 section, on the east side of the Eramosa River) in the City of Guelph has been described and named as the type section of the Eramosa Formation in southwestern Ontario (Brunton 2009; Brunton and Brintnell 2011; Brunton et al. 2012).

The age of the Eramosa Formation in southwestern Ontario is also an issue of debate. There were no biostratigraphic studies of this lithostratigraphic unit until recently, when Stott et al. (2001) utilized conodonts to assign the Eramosa strata at the Highway 6 roadcut in Wiarton, Ontario to the Sheinwoodian *Ozarkodina sagitta rhenana* Superzone (see Fig. 2). The presence of a morphotype of *Ozarkodina sagitta rhenana* characteristic of the Lower *Kockelella walliseri* Zone (middle Sheinwoodian) further restricted their age diagnosis of the Eramosa strata at this locality (Stott et al. 2001). This study combines conodont biostratigraphy and carbonate carbon ($\delta^{13}\text{C}_{\text{carb}}$) isotope stratigraphy to generate a more detailed chronostratigraphic framework for the Eramosa Formation in southwestern Ontario.

Geological Setting

The province of Ontario, Canada was located on the northeastern margin of the paleocontinent Laurentia, south of the equator in the subtropical climate belt, during the Silurian Period (Cocks and Torsvik 2002). The Algonquin Arch (Fig. 1) acted as a structural barrier (intermittently active forebulge region during the Silurian, Brunton et al. 2012) between

the Michigan Basin and the foreland Appalachian Basin and restricted the influx of siliciclastics to the carbonate-and-evaporite-dominated Michigan Basin (Johnson et al. 1992). Wiarton, Ontario was located to the northwest of the migrating forebulge (Algonquin Arch) and the City of Guelph, Ontario was located to the north of this forebulge (Fig. 1).

Abrupt temporal and spatial changes in depositional environments between the Laurentian cratonic area (Michigan Basin) and the foreland Appalachian Basin are evident in the significant regional variability in fossil content and sedimentary structures of the Eramosa Formation in southwestern Ontario (Brunton 2009; Brunton and Brintnell 2011; Brunton et al. 2012). The Eramosa Formation is interpreted to have been deposited on a broad carbonate ramp that dipped towards the foreland Appalachian Basin. The basal Vinemount Member represents deposition during a short-lived tectonic re-adjustment in the foreland basin that resulted in pulses of terrigenous clay-bearing, dark-brown-to-black dolostones on the Laurentian cratonic ramp. The overlying Reformatory Quarry Member displays sedimentary features and faunas that indicate deposition from more open marine and higher energy settings (small reef mounds and hummocky and swaley cross-stratification) adjacent to the foreland basin to more restricted marine lagoon-to-estuarine environments with sabkha-like cycles in more cratonic areas. The Reformatory Quarry Member also possess seismites that extend from the Bruce Peninsula in Ontario to the Niagara region in western New York (Brunton 2009; Brunton and Brintnell 2011; Brunton et al. 2012).

Sample Localities and Methods

The Eramosa Formation in southwestern Ontario was sampled for both conodont biostratigraphy and for carbonate carbon ($\delta^{13}\text{C}_{\text{carb}}$) isotope stratigraphy at two outcrop localities in Wiarton (Highway 6 roadcut and Ledgerrock Quarry) and two cores (MW 04-06 and MW 07-06) from the City of Guelph. The lithology of the Eramosa Formation in southwestern Ontario is predominantly dolostone. Conodont samples from the two localities in Wiarton were digested using unbuffered acetic acid. Due to low yields from the outcrop samples from Wiarton, the two cores from the City of Guelph were processed utilizing the buffered formic acid technique for conodont extraction (Jeppsson et al. 1985; Jeppsson and Anehus 1995). All conodont samples have been repositated at the School of Earth Sciences Orton Geological Museum at The Ohio State University. The MW 04-06 and MW 07-06 cores were drilled for the City of Guelph Groundwater Resources Assessment Project and are stored at the Ontario Geological Survey, Sudbury, Ontario, Canada.

Carbonate carbon ($\delta^{13}\text{C}_{\text{carb}}$) isotope samples were analyzed at the Texas Tech University Stable Isotope Laboratory (Tables 1, 2, 3, 4). Samples were micro-drilled, and the dolomitic powders were heated for thirty minutes at 480°C under a stream of hot, 99.99% purified helium to remove water and organic material. To dissolve the calcite, samples were reacted with 100% phosphoric acid at 25.2°C for two hours, and the evolved gas was evacuated and discarded. Samples were then placed overnight in an agitated and enclosed water bath maintained at 50°C. Following the method of McCrea (1950), the evolved CO_2 from the dolomitic powder was extracted and purified. These gas samples were analyzed on a VG SIRA-12 isotope ratio mass

spectrometer equipped with a microinlet system. All values were obtained using an internal standard, TTU-2 calcite, calibrated against the international standard, NBS-19. Results are reported using the conventional notation of Craig (1957), relative to VPDB (‰).

Results

Highway 6 Roadcut and Ledgerock Quarry, Wiarton, Ontario

In the present study, only one sample from the Highway 6 roadcut yielded a biostratigraphically useful conodont, *Ozarkodina sagitta rhenana* (Walliser 1964), recovered 14.00-14.10 m above the base of the section within the Goat Island Formation (Figs. 2, 3, 6). No biostratigraphically useful conodonts were recovered from the Eramosa Formation at this locality. Carbonate carbon ($\delta^{13}\text{C}_{\text{carb}}$) isotope data (Fig. 3; Table 1) record a value of +4.26‰ at the base of the roadcut and the highest value of +4.54‰ 5.00 m above the base of the section. Above 5.00 m from the base of the section, $\delta^{13}\text{C}_{\text{carb}}$ values gradually decrease to approximately +3.00‰ at 14.00 m, but increase to +3.30‰ at 15.00 m and remain at about that value throughout the remainder of the section. The presence of *Oz. s. rhenana* within the Goat Island Formation is coincident with gradually declining but elevated carbonate carbon ($\delta^{13}\text{C}_{\text{carb}}$) isotope values (+3.00‰) throughout the entire stratigraphic succession (Goat Island and Eramosa formations) at the Highway 6 roadcut in Wiarton, Ontario.

Two samples from the Ledgerock Quarry yielded two biostratigraphically useful conodonts, *Ozarkodina sagitta rhenana* (Walliser 1964) and *Kockelella walliseri* (Helfrich 1975) were both recovered from a sample taken at 4.65-4.80 m above the base of the section. *Oz. s.*

rhenana was also recovered from a sample higher in the section (5.90-6.00 m above the base of the section), 0.10 m above the base of the seismite bed which is 5.60-5.90 m from the base of the section. The recovery of *K. walliseri* is below the topmost occurrence of *Oz. s. rhenana* (Figs. 2, 3, 6). The highest carbonate carbon ($\delta^{13}\text{C}_{\text{carb}}$) isotope value recorded at the quarry is +3.29‰, which occurs at the base of the section. The values begin a steady decline to approximately +1.00‰ throughout the remaining 6.40 m of the section, however, the lowest value recorded, +0.61‰ was from the top of the quarry (Fig. 3; Table 2). The presence of both *Oz. s. rhenana* and *K. walliseri* is coincident with steadily decreasing carbonate carbon ($\delta^{13}\text{C}_{\text{carb}}$) isotope values within the Eramosa Formation at the Ledgerrock Quarry in Warton, Ontario.

MW 04-06 and MW 07-06 Cores, City of Guelph, Ontario

Two biostratigraphically useful conodonts, *Ozarkodina sagitta rhenana* (Walliser 1964) and *Kockelella walliseri* (Helfrich 1975), were recovered from samples within the MW 04-06 core. The first occurrence of *Oz. s. rhenana* is from a sample 65.67-63.00 feet down core. *K. walliseri* was recovered from a sample 38.83-37.75 feet down core and is below the highest occurrence of *Oz. s. rhenana* (30.33-29.42 feet down core). *Aldridgeodus minimus* Jeppsson (in Calner et al. 2008) was also recovered from this core, from a sample taken 38.83-37.75 feet down core, and it co-occurs with *K. walliseri*, below the last occurrence of *Oz. s. rhenana* (Figs. 2, 4, 6). Carbonate carbon ($\delta^{13}\text{C}_{\text{carb}}$) isotope values throughout the MW 04-06 core (Fig. 4; Table 3) are consistently elevated, typically greater than +2.50‰. There is a small decrease in $\delta^{13}\text{C}_{\text{carb}}$ values recorded from 69.25-61.85 feet down core where values fall from +2.81‰ in the upper part of the Goat Island Formation to a low of +1.51‰ near the base of the Eramosa Formation.

219 Within the Eramosa Formation $\delta^{13}\text{C}_{\text{carb}}$ values record a fairly significant positive shift
 220 (approximately 1.00‰ to 1.50‰) and reach a high of +3.51‰ (26.42 feet down core) near the
 221 middle of the seismite (29.83-24.00 feet down core). The ranges of *Oz. s. rhenana* and *K.*
 222 *walliseri* overlap at a level in the core (38.83-37.75 feet down core) that is within the positive
 223 shift in $\delta^{13}\text{C}_{\text{carb}}$ values, below the seismite, within the Eramosa Formation.

224 Three biostratigraphically useful conodonts, *Ozarkodina sagitta rhenana* (Walliser
 225 1964), *Kockelella walliseri* (Helfrich 1975), and *Kockelella ortus ortus* (Walliser 1964), were
 226 recovered from samples within the MW 07-06 core. *K. walliseri* was recovered from four
 227 samples that ranged from 169.17-151.92 feet down core, and *Oz. s. rhenana* was recovered
 228 above the highest sample yielding *K. walliseri* (148.50-147.58 feet down core). *Aldridgeodus*
 229 *minimus* Jeppsson (in Calner et al. 2008) was also recovered from this core (from samples that
 230 spanned an interval from 172.58-151.92 feet down core) and it co-occurs with *K. walliseri*,
 231 below the last occurrence of *Oz. s. rhenana* (Figs. 2, 5, 6). *Kockelella ortus ortus* was recovered
 232 from two samples 136.58-136.00 feet and 135.08-133.42 feet, respectively (both of these
 233 samples are above the Eramosa seismite, which is located 140.00-137.00 feet down core).

234 Carbonate carbon ($\delta^{13}\text{C}_{\text{carb}}$) isotope values in the MW 07-06 core (Fig. 5; Table 4) are low in the
 235 Goat Island Formation at the base of the core (+1.24‰, decreasing to +0.88‰). At the base of
 236 the Eramosa Formation $\delta^{13}\text{C}_{\text{carb}}$ values fluctuate, but increase, recording a fairly significant
 237 positive shift (approximately 1.50‰) that reaches a high of +3.02‰ (155.92 feet down core).
 238 After this positive shift, $\delta^{13}\text{C}_{\text{carb}}$ values begin to gradually decrease to the top of the core,
 239 through the remainder of the Eramosa and the overlying Guelph formations. The ranges of *Oz.*
 240 *s. rhenana* and *K. walliseri* do not overlap in the core, however the range of *K. walliseri* is

coincident with the positive shift in $\delta^{13}\text{C}_{\text{carb}}$ values, whereas the only occurrence of *Oz. s. rhenana* is above the level of the positive shift in $\delta^{13}\text{C}_{\text{carb}}$ values. The range of *K. o. ortus* is within the gradual decline in $\delta^{13}\text{C}_{\text{carb}}$ values above the seismite in the core.

Discussion

Highway 6 Roadcut and Ledgerock Quarry, Wiarton, Ontario

The presence of *Ozarkodina sagitta rhenana* within the Goat Island Formation at the Highway 6 roadcut is coincident with gradually declining, but elevated, carbonate carbon ($\delta^{13}\text{C}_{\text{carb}}$) isotope values throughout the entire section (Goat Island and Eramosa formations) indicating that these stratigraphic units are within the *Ozarkodina sagitta rhenana* Superzone and record either the end of the peak or the onset of the descending limb of the Sheinwoodian (Ireviken) positive carbon ($\delta^{13}\text{C}_{\text{carb}}$) isotope excursion (Fig. 3; Table 1). The recovery of *Kockelella walliseri* below the highest occurrence of *Ozarkodina sagitta rhenana* at Ledgerock Quarry is coincident with steadily decreasing carbonate carbon ($\delta^{13}\text{C}_{\text{carb}}$) isotope values indicating that this interval of Eramosa strata at this locality is within the Lower *Kockelella walliseri* Zone of the *Ozarkodina sagitta rhenana* Superzone and records the descending limb of the Sheinwoodian (Ireviken) positive carbon ($\delta^{13}\text{C}_{\text{carb}}$) isotope excursion (Fig. 3; Table 2). The conodont biostratigraphy and carbonate carbon ($\delta^{13}\text{C}_{\text{carb}}$) isotope stratigraphy permit one of two conclusions regarding the chronostratigraphic position of the Eramosa at the two localities studied in Wiarton, Ontario. The Eramosa strata exposed at the top of the Highway 6 roadcut correlate to a position either just below or equivalent to the Eramosa strata exposed at the

base of the Ledgerrock Quarry (Fig. 3). Both sections are within the *Ozarkodina sagitta rhenana* Superzone and contain elevated $\delta^{13}\text{C}_{\text{carb}}$ values (Fig. 3; Tables 1, 2). However, due to the presence of *Kockelella walliseri*, carbonate carbon ($\delta^{13}\text{C}_{\text{carb}}$) isotope values below +3.00‰, and the seismite, it appears that the Eramosa strata above the base at the Ledgerrock Quarry sit stratigraphically above the highest strata exposed at the Highway 6 roadcut.

MW 04-06 and MW 07-06 Cores, City of Guelph, Ontario

The interval of the MW 04-06 core from the single occurrence of *Kockelella walliseri* to the topmost occurrence of *Ozarkodina sagitta rhenana* (38.83-29.42 feet) can be placed within the Lower *Kockelella walliseri* Zone of the *Ozarkodina sagitta rhenana* Superzone, and the remainder of the core sampled below this interval is within the *Ozarkodina sagitta rhenana* Superzone (Figs. 2, 4). The interval of core that contains *Ozarkodina sagitta rhenana* below the sole recovery of *Kockelella walliseri* could potentially be placed within the *Ozarkodina sagitta rhenana* Zone, however due to the rarity of *Kockelella walliseri* in this core (only one $\text{P}_1(\text{Pa})$ element recovered), a placement within the *Ozarkodina sagitta rhenana* Superzone is more appropriate (Figs. 2, 4). The presence of both *Oz. s. rhenana* and *K. walliseri*, combined with the carbonate carbon ($\delta^{13}\text{C}_{\text{carb}}$) isotope values within the core indicate that the Eramosa strata within the MW 04-06 core records the descending limb of the Sheinwoodian (Ireviken) positive carbon ($\delta^{13}\text{C}_{\text{carb}}$) isotope excursion (Fig. 4; Table 3). However, the $\delta^{13}\text{C}_{\text{carb}}$ values in the MW 04-06 core record a fairly significant positive shift (approximately 1.00‰ to 1.50‰) within the Eramosa before beginning to decline near the top of the Eramosa.

In the MW 07-06 core, *Ozarkodina sagitta rhenana* was recovered from a sample above the highest sample that yielded *Kockelella walliseri*, indicating that this interval of the Eramosa (169.17-147.58 feet) is within the Lower *Kockelella walliseri* Zone of the *Ozarkodina sagitta rhenana* Superzone (Figs. 2, 5). The recovery of *Kockelella ortus ortus* above the seismite in the core indicates that this interval of the Eramosa (136.58-133.42 feet) in the core is within the *Kockelella ortus ortus* Superzone. *Ozarkodina sagitta sagitta* (Walliser 1964) was not recovered from the core, suggesting that this interval of the Eramosa within the core could potentially be further constrained to the *Kockelella ortus ortus* Zone (Figs. 2, 5). The Lower *Kockelella walliseri* Zone combined with the carbonate carbon ($\delta^{13}\text{C}_{\text{carb}}$) isotope values in the Eramosa of the MW 07-06 core indicate that the Eramosa strata (below the seismite) record the descending limb of the Sheinwoodian (Ireviken) positive carbon ($\delta^{13}\text{C}_{\text{carb}}$) isotope excursion (Fig. 5; Table 4). However, the $\delta^{13}\text{C}_{\text{carb}}$ values in the MW 07-06 core record a fairly significant positive shift (approximately 1.50‰) within the Eramosa before beginning to decrease throughout the remainder of the Eramosa Formation and the overlying Guelph Formation. The strata above the Eramosa seismite and within the *Kockelella ortus ortus* Superzone in the core represent a younger package of deposition of the Eramosa Formation than was sampled at any of the other localities included in this study.

The end (descending limb) of the Sheinwoodian (Ireviken) positive carbon ($\delta^{13}\text{C}_{\text{carb}}$) isotope excursion is restricted to the Lower *Kockelella walliseri* Zone of the *Ozarkodina sagitta rhenana* Superzone (Cramer et al. 2010b). In many sections globally there is a distinct positive shift in $\delta^{13}\text{C}_{\text{carb}}$ values recorded in the descending limb of the Sheinwoodian (Ireviken) positive carbon ($\delta^{13}\text{C}_{\text{carb}}$) isotope excursion (e.g. the Ohessare and Ruhnu cores from Baltica, Figs. 7, 8 in

Cramer et al. 2010b; Route 421 roadcut in Madison, Indiana, Fig. 18 in Brett et al. 2012). The MW 04-06 and MW 07-06 cores from the City of Guelph also record a distinct positive shift in $\delta^{13}\text{C}_{\text{carb}}$ values within the descending limb of the Sheinwoodian (Ireviken) $\delta^{13}\text{C}_{\text{carb}}$ excursion.

Regional Correlations of the Eramosa

The strata of the Eramosa Formation of the combined Highway 6 roadcut and Ledgerrock Quarry stratigraphic sections of the Wiarton region (Fig. 3) and the Eramosa Formation of the MW 04-06 and MW 07-06 cores of the City of Guelph region (Figs. 4, 5) all record the descending limb of the Sheinwoodian (Ireviken) positive carbon ($\delta^{13}\text{C}_{\text{carb}}$) isotope excursion within the *Ozarkodina sagitta rhenana* Superzone, but these sections in southwestern Ontario are not completely correlative.

The occurrence of *Kockelella ortus ortus* so close to the highest occurrence of *Ozarkodina sagitta rhenana* is problematic. The highest occurrence of *Ozarkodina sagitta rhenana* from all sections sampled occurs within the first 10 cm above the top of the seismite at Ledgerrock Quarry in Wiarton (Fig. 3). The lowest sample that contained *Kockelella ortus ortus* comes from a sample that was between 12.70-17.78 cm above the top of the seismite in the MW 07-06 core in the City of Guelph (Fig. 5). In the MW 07-06 core, the presence of *Kockelella ortus ortus* so close to the last occurrence of *Ozarkodina sagitta rhenana* (136.58-136.00 feet and 148.50-147.58 feet, respectively) in relation to the seismite (these occurrences should be separated by the Upper *Kockelella walliseri* Superzone – Middle *Kockelella walliseri* Zone, *Kockelella patula* Zone, uppermost *Kockelella walliseri* range – and post *Kockelella walliseri* interregnum, but are only separated here by a few centimetres, see Fig. 2) suggests one of

several possibilities: 1) there is more than one seismite; 2) the Upper *Kockelella walliseri* Superzone and post *Kockelella walliseri* interregnum are represented by a severely condensed interval (a few centimetres at most); 3) there is a disconformity that has removed the strata that would represent the Upper *Kockelella walliseri* Superzone and post *Kockelella walliseri* interregnum; or 4) the range of *Kockelella ortus ortus* should be extended down into the middle Sheinwoodian or the range of *Ozarkodina sagitta rhenana* should be extended up into the latest Sheinwoodian. Using the data from this study, there is insufficient evidence to fully evaluate these hypotheses, however some important observations should be highlighted. The two sections in question (Ledgerrock Quarry in Wiarton and the MW 07-06 core in the City of Guelph) are separated by 120 km, and although the Ontario Geological Survey has found no evidence suggesting that there is more than one seismite within the Eramosa lithofacies, the possibility cannot be excluded. No mineralized hardgrounds, phosphatic lags, or other lithologic evidence was observed in the first 20 cm above the seismite at any of the localities studied herein, therefore it is unlikely that the Upper *Kockelella walliseri* Superzone and post *Kockelella walliseri* interregnum are represented by a condensed interval. It is likely that the presence of *Kockelella ortus ortus* so close to *Ozarkodina sagitta rhenana* is the result of a disconformity (Brunton 2009; Brunton and Brintnell 2011; Brunton et al. 2012), however at this time there is insufficient evidence to confirm this possibility. In this study, there is no evidence of a co-occurrence of *Kockelella ortus ortus* with either *Kockelella walliseri* or *Ozarkodina sagitta rhenana*, therefore a range extension of either species, based on data herein, is unwarranted (Fig. 2). However, it should be noted that *Kockelella patula* (Walliser 1964) and *Kockelella ortus ortus* have been found to co-occur in one sample from Haragan Creek,

Oklahoma (Barrick and Klapper 1976, Table 3, Sample 5) and *Kockelella ortus ortus* has been recovered below the highest occurrence of *Kockelella patula* in the Avalanche Lake Sections in the Northwest Territories (Over and Chatterton 1987, Table 4). In two sections in the Carnic Alps, *Ozarkodina sagitta rhenana* and *Ozarkodina sagitta sagitta* have been found to co-occur (Corradini and Corrigan personal communication 2015). Based on the current known ranges of both subspecies (*Kockelella ortus ortus* and *Ozarkodina sagitta rhenana*) it is possible that both species may require range extensions, however more data is required globally before this can be properly demonstrated.

Conclusions

The Ontario Geological Survey (Sudbury) has re-evaluated the Silurian stratigraphic succession in southwestern Ontario and the Eramosa Formation within the regional nomenclatural hierarchy (Brunton 2009; Brunton and Brintnell 2011; Brunton et al. 2012). The presence of *Ozarkodina sagitta rhenana*, *Kockelella walliseri*, and *Kockelella ortus ortus*, combined with the carbonate carbon ($\delta^{13}\text{C}_{\text{carb}}$) isotope data (that record the descending limb of the Sheinwoodian (Ireviken) $\delta^{13}\text{C}_{\text{carb}}$ excursion), clearly demonstrates that the Eramosa Formation studied herein is limited to an interval from the middle to upper Sheinwoodian Stage (*Ozarkodina sagitta rhenana* Superzone to *Kockelella ortus ortus* Zone). The Lower *Kockelella walliseri* Zone of the *Ozarkodina sagitta rhenana* Superzone should contain the end of the Sheinwoodian (Ireviken) positive carbon ($\delta^{13}\text{C}_{\text{carb}}$) isotope excursion (see Fig. 2; Calner et al.

2004; Cramer et al. 2006; Cramer et al. 2010a, 2010b), and the data herein are consistent with this (Figs. 3, 4, 5).

In the Niagara region of western New York the term 'Eramosa' is a designated lithostratigraphic unit given formational rank (Rickard 1975, see discussion in Brett et al. 1995), and the Eramosa in the Niagara region overlies the Goat Island Formation and is, in turn, overlain by the Guelph Formation. The Gasport and Goat Island formations in the Niagara region, are within the *Ozarkodina sagitta rhenana* Superzone (the Lower *Kockelella walliseri* Zone of the *Ozarkodina sagitta rhenana* Superzone occurs within the Goat Island Formation, Cramer et al. 2006, 2010a, 2010b) and the Goat Island Formation records the descending limb of the Sheinwoodian (Ireviken) $\delta^{13}\text{C}_{\text{carb}}$ excursion (Cramer et al. 2006; Cramer et al. 2010a, 2010b). In the Niagara region the Eramosa Formation is therefore younger than the Lower *Kockelella walliseri* Zone (possibly either the Upper *Kockelella walliseri* Superzone or *Kockelella ortus ortus* Superzone, Cramer et al. 2006, 2010a, 2010b) and above the end of the Sheinwoodian (Ireviken) $\delta^{13}\text{C}_{\text{carb}}$ excursion (Cramer et al. 2006, 2010a, 2010b; McLaughlin et al. 2008).

In southwestern Ontario, the lower portion of the Eramosa studied herein, is within the *Ozarkodina sagitta rhenana* Superzone (parts of the Eramosa in the studied sections definitively lie within the Lower *Kockelella walliseri* Zone, see Figs. 3, 4, 5), and records the descending limb of the Sheinwoodian (Ireviken) $\delta^{13}\text{C}_{\text{carb}}$ excursion. Therefore, the Eramosa Formation in southwestern Ontario correlates to at least some part of the Goat Island Formation (i.e. below the Eramosa Formation) in the Niagara region. The Eramosa Formation in the City of Guelph region correlates with the Vinemount Member of the Goat Island Formation in the Niagara

region (the Ontario Geological Survey considers the Vinemount Member to be the basal member of the Eramosa Formation and not the upper member of the Goat Island Formation; Brunton 2009; Brunton and Brintnell 2011; Brunton et al. 2012). Only the upper portion of the Eramosa Formation (upper Reformatory Quarry Member in the MW 07-6 core from the City of Guelph; Brunton 2009; Brunton and Brintnell 2011; Brunton et al. 2012), above the seismite, studied in southwestern Ontario is possibly correlative with the lower portion of the Eramosa of the Niagara region (Cramer et al. 2006, 2010a, 2010b). Additional work will further clarify interregional chronostratigraphic correlation of the Eramosa Formation and help resolve the lithostratigraphic nomenclatural differences between the United States Geological Survey (USGS) and the Ontario Geological Survey (OGS).

Taxonomic Note

Aldridge (1985) first reported *Ozarkodina?* sp. nov. from the Much Wenlock Limestone Formation in Britain, and the species was later named *Aldridgeodus minimus* by Jeppsson in Calner et al. (2008). The first North American recovery of *A. minimus* was documented by von Bitter and Purnell (2005) from the Eramosa Formation at Hepworth, Ontario. Compared to other Silurian conodont elements, *Aldridgeodus minimus* is diminutive and, as a result, suffers a higher rate of taphonomic loss, complicating its recovery using standard processing techniques (Calner et al. 2008). *Aldridgeodus minimus* has been reported to range from the *Kockelella ortus ortus* Zone through the main part of the *Polygnathoides siluricus* Zone, late Sheinwoodian through early Ludfordian (Calner et al. 2008; see Fig. 2). In both cores from the City of Guelph,

Ontario, *Aldridgeodus minimus* (Fig. 6) co-occurs with *Kockelella walliseri* below the last occurrence of *Ozarkodina sagitta rhenana*, indicating that the range of *Aldridgeodus minimus* must be extended down to at least the middle Sheinwoodian Lower *Kockelella walliseri* Zone (von Bitter et al. 2012; see Fig. 2).

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Figure 1. Present-day map of the Great Lakes Region illustrating the location of Paleozoic structural basins and arches in the region. The localities of Warton, Ontario (Highway 6 roadcut and Ledgerock Quarry) and the City of Guelph, Ontario (MW 04-06 core and MW 07-06 core), and Niagara, New York are shown with shaded circles.

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Figure 2. Chronostratigraphy for the upper Telychian Stage of the Llandovery Series and the Sheinwoodian and Homerian stages of the Wenlock Series of the Silurian System. Chronostratigraphy, carbonate carbon ($\delta^{13}\text{C}_{\text{carb}}$) isotope excursions, and global conodont zonation from Cramer et al. (2011a); Sardinian conodont zonation from Corradini and Serpagli (1999); Baltic conodont zonation from Männik (2007a, 2007b); selected conodont ranges from Jeppsson (1997), Männik (2007a, 2007b), Corradini (2008), and Corrigan et al. (2009). Horizontal bars at the bottom or top of a species range indicate the first appearance datum (FAD) and the last appearance datum (LAD) of that species, respectively. Dashed lines in the range of a species indicate the scattered presence of that species. Ranges of species that extend beyond what is represented in the figure are indicated with an arrow. Numbers between the 'Zone' and 'Subzone' columns under the 'Baltic Conodont Zonation' represent datums of the Ireviken Event and Mulde Event (Jeppsson et al. 2006). Species abbreviations: *Pt.* – *Pterospathodus*; *Pt. am.* – *Pterospathodus amorphognathoides*; *Pt. p.* – *Pterospathodus pennatus*; *Oz. p.* – *Ozarkodina polinclinata*; *Ps.* – *Pseudooneotodus*; *Oz. s.* – *Ozarkodina sagitta*; *K.* *Kockelella*; *K. o.* – *Kockelella ortus*; *A.* – *Aldridgeodus*; *Oz. b.* – *Ozarkodina bohémica*; *Ct.* – *Ctenognathodus*. Conodont data collected by this study suggests a range extension for *Aldridgeodus minimus* down to at least the middle Sheinwoodian Lower *Kockelella walliseri* Zone (please refer to results and discussion sections and Figs. 5 and 6 for conodont occurrence data).

Figure 3. Lithostratigraphy, conodont biostratigraphy, and carbonate carbon ($\delta^{13}\text{C}_{\text{carb}}$) isotope chemostratigraphy from the Highway 6 roadcut and the Ledgerrock Quarry, in Wiarton, Ontario. Potential correlation of the Eramosa strata at the Wiarton localities (uppermost strata exposed at Highway 6 roadcut correlate to a position either just below or equivalent to the strata exposed at the base of the Ledgerrock Quarry). All conodont occurrences are noted to the right of the stratigraphic column for the Highway 6 roadcut and to the left of the stratigraphic column for the Ledgerrock Quarry. Abbreviations: VPBD – Vienna Pee Dee belemnite; *Oz. s.* – *Ozarkodina sagitta*; *K.* – *Kockelella*; *Oz.* – *Ozarkodina*; *W.* – *Wurmiella*; *Ps.* – *Pseudooneotodus*.

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Figure 4. Lithostratigraphy, conodont biostratigraphy, and carbonate carbon ($\delta^{13}\text{C}_{\text{carb}}$) isotope chemostratigraphy from the MW 04-06 core, in the City of Guelph, Ontario. All conodont occurrences are noted to the right of the stratigraphic column. Abbreviations: VPBD – Vienna Pee Dee belemnite; *Oz. s.* – *Ozarkodina sagitta*; *K.* – *Kockelella*; *W.* – *Wurmiella*; *Oz.* – *Ozarkodina*; *A.* – *Aldridgeodus*. Note the occurrence of *Aldridgeodus minimus* below the last occurrence of *Ozarkodina sagitta rhenana* within the core.

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Figure 5. Lithostratigraphy, conodont biostratigraphy, and carbonate carbon ($\delta^{13}\text{C}_{\text{carb}}$) isotope chemostratigraphy from the MW 07-06 core, in the City of Guelph, Ontario. All conodont occurrences are noted to the right of the stratigraphic column. Abbreviations: VPBD – Vienna Pee Dee belemnite; *Oz. s.* – *Ozarkodina sagitta*; *K.* – *Kockelella*; *K. o.* – *Kockelella ortus*; *W.* – *Wurmiella*; *A.* – *Aldridgeodus*; *Ps.* -- *Pseudooneotodus*. Note the occurrence of *Aldridgeodus minimus* below the last occurrence of *Ozarkodina sagitta rhenana* within the core.

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763 **Figure 6.** Scanning electron microscope (SEM) photomicrographs of conodonts recovered from
 764 the Eramosa lithofacies in Wiarton and the City of Guelph, Ontario. **1-3: *Ozarkodina sagitta***
 765 ***rhénana* (Walliser 1964).** 1. oral view of P_1 (Pa) element, Ledgerrock Quarry, 4.65-4.80 m, 280x;
 766 2. oral view of P_1 (Pa) element, Ledgerrock Quarry, 5.90-6.00 m, 220x; 3. lateral view of P_1 (Pa)
 767 element, MW 07-06 core, 148.67-147.58 feet, 130x. **4-5: *Kockelella walliseri* (Helfrich 1975).**
 768 4. oral view of P_1 (Pa) element, MW 07-06 core, 169.17-168.17 feet, 71x; 5. oral view of P_1 (Pa)
 769 element, MW 07-06 core, 169.17-168.17 feet, 111x. **6-7: *Kockelella ortus ortus* (Walliser**
 770 **1964).** 6. lateral view of P_1 (Pa) element, MW 07-06 core, 135.08-133.42 feet, 100x; 7. lateral
 771 view of P_1 (Pa) element, MW 07-06 core, 136.58-136.00 feet, 297x. **8-13: *Aldridgeodus***
 772 ***minimus* Jeppsson (2003).** 8. lateral view of P_1 (Pa) element, MW 07-06 core, 162.42-161.58
 773 feet, 500x; 9. lateral view of P_2 (Pb) element, MW 07-06 core, 166.33-165.50 feet, 240x; 10.
 774 lateral view of S_0 (Sa) element, MW 07-06 core, 169.17-168.17 feet, 430x; 11. lateral view of
 775 S_1 (Sb) element, MW 07-06 core, 159.58-158.58, 327x; 12. lateral view of M element, MW 07-06
 776 core, 159.58-158.58 feet, 500x; 13. lateral view of M element, MW 07-06 core, 152.66-151.92
 777 feet, 500x. **14-17: *Wurmiella excavata* (Branson and Mehl 1933).** 14. lateral view of P_1 (Pa)
 778 element, MW 07-06 core, 179.92 feet, 120 x; 15. lateral view of P_1 (Pa) element, MW 07-06
 779 core, 162.42-161.58 feet, 250x; 16. lateral view of P_1 (Pa) element, MW 07-06 core, 159.58-
 780 158.58 feet, 138x; 17. lateral view of P_2 (Pb) element, MW 07-06 core, 179.92 feet, 147x. **18:**
 781 ***Kockelella* sp.** 18. lateral view of P_2 (Pb)? element, MW 07-06 core, 162.42-161.58 feet, 300x.
 782 **19-20: *Wurmiella excavata* (Branson and Mehl 1933).** 19. lateral view of P_2 (Pb) element, MW
 783 07-06 core, 159.58-158.58, 120x; 20. lateral view of S_2 (Sc) element, Ledgerrock Quarry, 5.90-
 784 6.00 meters, 67x. **21-22: *Ozarkodina ex gr. confluens* (Branson and Mehl 1933).** 21. lateral

785 view of P₁(Pa) element, MW 04-06 core, 43.50-42.50 feet, 170x; 22. lateral view of S₁(Sb)
786 element, MW 04-06 core, 23.33-22.67 feet, 127x. **23: “Ozarkodina” sp.** 23. lateral view of
787 P₁(Pa) element, MW 04-06 core, 43.50-42.40 feet, 229x. **24-25: Kockelella? sp.** 24. lateral
788 view of S₁(Sb)? element, Ledgerock Quarry, 5.90-6.00 meters, 120x; 25. lateral view of P₂(Pb)
789 element, Ledgerock Quarry, 5.90-6.00 meters, 240x.

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807 **Table 1.** Carbonate carbon ($\delta^{13}\text{C}_{\text{carb}}$) isotope data with conodont zonation based on recovered
808 conodont biostratigraphic data for the Highway 6 roadcut in Wiarton, Ontario.

809

810 **Table 2.** Carbonate carbon ($\delta^{13}\text{C}_{\text{carb}}$) isotope data with conodont zonation based on recovered
811 conodont biostratigraphic data for the Ledgerrock Quarry in Wiarton, Ontario.

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813 **Table 3.** Carbonate carbon ($\delta^{13}\text{C}_{\text{carb}}$) isotope data with conodont zonation based on recovered
814 conodont biostratigraphic data for the MW 04-06 core in the City of Guelph, Ontario.

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816 **Table 4.** Carbonate carbon ($\delta^{13}\text{C}_{\text{carb}}$) isotope data with conodont zonation based on recovered
817 conodont biostratigraphic data for the MW 07-06 core in the City of Guelph, Ontario.

101x76mm (300 x 300 DPI)

122x66mm (300 x 300 DPI)

391x667mm (300 x 300 DPI)

268x371mm (300 x 300 DPI)

250x321mm (300 x 300 DPI)

219x317mm (300 x 300 DPI)

Highway 6 Roadcut Wiarton, Ontairo				
Metre	Conodont Zone	$\delta^{13}\text{C}_{\text{carb}}$	$\delta^{18}\text{O}$	Formation
20.80	<i>Ozarkodina sagitta rhenana</i> Superzone	3.33	-6.18	Eramosa
20.30	<i>Ozarkodina sagitta rhenana</i> Superzone	3.42	-6.36	Eramosa
20.00	<i>Ozarkodina sagitta rhenana</i> Superzone	3.30	-6.36	Eramosa
19.50	<i>Ozarkodina sagitta rhenana</i> Superzone	3.28	-6.68	Eramosa
19.00	<i>Ozarkodina sagitta rhenana</i> Superzone	3.42	-6.38	Eramosa
18.50	<i>Ozarkodina sagitta rhenana</i> Superzone	3.35	-6.48	Eramosa
16.50	<i>Ozarkodina sagitta rhenana</i> Superzone	3.34	-6.73	Goat Island
15.00	<i>Ozarkodina sagitta rhenana</i> Superzone	3.34	-6.80	Goat Island
14.00	<i>Ozarkodina sagitta rhenana</i> Superzone	2.99	-6.73	Goat Island
13.00	???	3.23	-6.64	Goat Island
12.00	???	3.57	-6.32	Goat Island
11.00	???	3.61	-6.32	Goat Island
10.00	???	3.64	-6.99	Goat Island
9.00	???	3.94	-6.56	Goat Island
8.00	???	4.10	-6.46	Goat Island
7.00	???	3.92	-6.81	Goat Island
6.00	???	3.97	-7.15	Goat Island
5.00	???	4.54	-6.47	Goat Island
4.00	???	4.37	-6.12	Goat Island
3.00	???	4.53	-6.40	Goat Island
2.00	???	4.18	-6.65	Goat Island
1.00	???	3.99	-6.92	Goat Island
0.00	???	4.26	-6.89	Goat Island

Ledgerrock Quarry Wiarton, Ontario				
Metre	Conodont Zone	$\delta^{13}\text{C}_{\text{carb}}$	$\delta^{18}\text{O}$	Formation
6.40	???	0.61	-4.07	Eramosa
6.00	Lower <i>Kockelella walliseri</i> Zone	1.78	-5.95	Eramosa
5.50	Lower <i>Kockelella walliseri</i> Zone	1.38	-6.60	Eramosa
5.00	Lower <i>Kockelella walliseri</i> Zone	1.61	-6.76	Eramosa
4.65	Lower <i>Kockelella walliseri</i> Zone	1.86	-6.45	Eramosa
4.53	<i>Ozarkodina sagitta rhenana</i> Superzone	1.79	-6.58	Eramosa
4.50	<i>Ozarkodina sagitta rhenana</i> Superzone	1.57	-6.62	Eramosa
4.00	<i>Ozarkodina sagitta rhenana</i> Superzone	1.97	-6.51	Eramosa
3.50	<i>Ozarkodina sagitta rhenana</i> Superzone	2.31	-7.18	Eramosa
3.00	<i>Ozarkodina sagitta rhenana</i> Superzone	2.04	-6.34	Eramosa
2.50	<i>Ozarkodina sagitta rhenana</i> Superzone	2.07	-6.17	Eramosa
2.00	<i>Ozarkodina sagitta rhenana</i> Superzone	2.20	-6.41	Eramosa
1.50	<i>Ozarkodina sagitta rhenana</i> Superzone	2.68	-6.54	Eramosa
1.00	<i>Ozarkodina sagitta rhenana</i> Superzone	3.13	-6.58	Eramosa
0.50	<i>Ozarkodina sagitta rhenana</i> Superzone	3.28	-6.88	Eramosa
0.00	<i>Ozarkodina sagitta rhenana</i> Superzone	3.29	-6.20	Eramosa

Feet Down Core	Conodont Zone	$\delta^{13}\text{C}_{\text{carb}}$	$\delta^{18}\text{O}$	Formation
17.00	???	2.58	-7.87	Eramosa
19.00	???	2.64	-7.75	Eramosa
19.25	???	2.61	-7.20	Eramosa
21.42	???	2.73	-7.12	Eramosa
22.25	???	2.66	-7.16	Eramosa
22.42	???	3.06	-7.49	Eramosa
23.00	???	2.96	-8.26	Eramosa
25.25	???	2.77	-7.32	Eramosa
25.42	???	3.01	-7.47	Eramosa
26.42	???	3.51	-7.68	Eramosa
27.42	???	2.81	-7.89	Eramosa
28.25	???	2.88	-7.28	Eramosa
28.75	???	2.88	-7.68	Eramosa
30.00	Lower <i>Kockelella walliseri</i> Zone	2.80	-7.94	Eramosa
31.08	Lower <i>Kockelella walliseri</i> Zone	2.90	-7.34	Eramosa
31.25	Lower <i>Kockelella walliseri</i> Zone	2.85	-7.33	Eramosa
32.08	Lower <i>Kockelella walliseri</i> Zone	3.05	-7.26	Eramosa
33.08	Lower <i>Kockelella walliseri</i> Zone	3.00	-7.40	Eramosa
34.25	Lower <i>Kockelella walliseri</i> Zone	2.96	-7.11	Eramosa
35.83	Lower <i>Kockelella walliseri</i> Zone	2.45	-7.34	Eramosa
36.33	Lower <i>Kockelella walliseri</i> Zone	2.81	-6.95	Eramosa
37.25	Lower <i>Kockelella walliseri</i> Zone	2.65	-7.33	Eramosa
37.75	Lower <i>Kockelella walliseri</i> Zone	2.68	-7.24	Eramosa
39.00	<i>Ozarkodina sagitta rhenana</i> Superzone	2.82	-7.32	Eramosa
40.25	<i>Ozarkodina sagitta rhenana</i> Superzone	2.94	-7.42	Eramosa
41.50	<i>Ozarkodina sagitta rhenana</i> Superzone	2.46	-7.00	Eramosa
42.42	<i>Ozarkodina sagitta rhenana</i> Superzone	2.81	-7.18	Eramosa
43.25	<i>Ozarkodina sagitta rhenana</i> Superzone	2.75	-6.96	Eramosa
44.17	<i>Ozarkodina sagitta rhenana</i> Superzone	2.73	-7.00	Eramosa
46.08	<i>Ozarkodina sagitta rhenana</i> Superzone	2.57	-7.01	Eramosa
46.25	<i>Ozarkodina sagitta rhenana</i> Superzone	2.64	-7.42	Eramosa
48.50	<i>Ozarkodina sagitta rhenana</i> Superzone	2.61	-6.67	Eramosa
49.25	<i>Ozarkodina sagitta rhenana</i> Superzone	2.81	-7.13	Eramosa
49.50	<i>Ozarkodina sagitta rhenana</i> Superzone	2.81	-7.13	Eramosa
50.75	<i>Ozarkodina sagitta rhenana</i> Superzone	2.69	-7.57	Eramosa
52.25	<i>Ozarkodina sagitta rhenana</i> Superzone	2.67	-7.24	Eramosa
55.25	<i>Ozarkodina sagitta rhenana</i> Superzone	2.38	-6.85	Eramosa
56.25	<i>Ozarkodina sagitta rhenana</i> Superzone	2.53	-6.55	Eramosa
58.25	<i>Ozarkodina sagitta rhenana</i> Superzone	1.87	-7.66	Eramosa
61.67	<i>Ozarkodina sagitta rhenana</i> Superzone	1.94	-7.32	Eramosa
61.92	<i>Ozarkodina sagitta rhenana</i> Superzone	1.65	-7.36	Eramosa
62.83	<i>Ozarkodina sagitta rhenana</i> Superzone	1.65	-7.38	Eramosa
64.33	<i>Ozarkodina sagitta rhenana</i> Superzone	2.27	-6.84	Eramosa
64.67	<i>Ozarkodina sagitta rhenana</i> Superzone	1.51	-7.11	Eramosa
66.50	???	2.39	-6.67	Goat Island
67.67	???	2.46	-6.92	Goat Island
67.92	???	2.45	-6.88	Goat Island
69.25	???	2.82	-6.77	Goat Island
70.67	???	2.69	-6.48	Goat Island
72.00	???	2.81	-7.61	Goat Island

MW 07-06 Core City of Guelph, Ontario					
Feet Down Core	Conodont Zone	$\delta^{13}\text{C}_{\text{carb}}$	$\delta^{18}\text{O}$	Formation	
112.92	???	1.55	-7.02	Guelph	
113.42	???	1.61	-7.77	Guelph	
116.92	???	1.57	-7.96	Guelph	
119.92	???	1.83	-7.49	Guelph	
122.92	???	2.03	-7.39	Guelph	
125.92	???	2.17	-7.70	Guelph	
128.92	???	1.99	-7.35	Guelph	
131.92	???	2.11	-8.35	Eramosa	
134.92	<i>Kockelella ortus ortus</i> Superzone	2.12	-7.75	Eramosa	
134.92	<i>Kockelella ortus ortus</i> Superzone	1.93	-7.05	Eramosa	
136.25	<i>Kockelella ortus ortus</i> Superzone	1.94	-7.11	Eramosa	
137.92	???	1.79	-6.61	Eramosa	
140.92	???	1.95	-7.22	Eramosa	
143.92	???	2.06	-6.97	Eramosa	
144.00	???	2.15	-7.27	Eramosa	
146.92	???	2.22	-8.07	Eramosa	
148.00	Lower <i>Kockelella walliseri</i> Zone	2.12	-7.04	Eramosa	
149.92	Lower <i>Kockelella walliseri</i> Zone	2.51	-7.79	Eramosa	
152.25	Lower <i>Kockelella walliseri</i> Zone	2.42	-7.72	Eramosa	
152.92	Lower <i>Kockelella walliseri</i> Zone	2.76	-7.56	Eramosa	
155.92	Lower <i>Kockelella walliseri</i> Zone	3.02	-7.78	Eramosa	
156.25	Lower <i>Kockelella walliseri</i> Zone	2.65	-7.78	Eramosa	
158.92	Lower <i>Kockelella walliseri</i> Zone	2.79	-7.82	Eramosa	
159.08	Lower <i>Kockelella walliseri</i> Zone	2.76	-7.48	Eramosa	
161.92	Lower <i>Kockelella walliseri</i> Zone	1.98	-7.44	Eramosa	
162.00	Lower <i>Kockelella walliseri</i> Zone	2.51	-7.00	Eramosa	
164.58	Lower <i>Kockelella walliseri</i> Zone	2.98	-7.38	Eramosa	
164.92	Lower <i>Kockelella walliseri</i> Zone	2.02	-7.47	Eramosa	
165.92	Lower <i>Kockelella walliseri</i> Zone	2.72	-7.46	Eramosa	
167.92	Lower <i>Kockelella walliseri</i> Zone	1.23	-7.51	Eramosa	
168.67	Lower <i>Kockelella walliseri</i> Zone	2.35	-7.41	Eramosa	
172.50	???	1.42	-7.34	Eramosa	
173.92	???	1.19	-6.61	Eramosa	
176.92	???	1.49	-7.11	Eramosa	
179.25	???	0.88	-6.56	Goat Island	
179.92	???	1.24	-6.99	Goat Island	