Agglutinated foraminiferal assemblages in Albian shales overlying kimberlite deposits in the Smeaton core from central Saskatchewan, Canada

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ABSTRACT

The Smeaton core from the Fort à la Corne area of central Saskatchewan contains diamond-bearing kimberlite in crater facies interbedded between sediments of the Aptian/Albian Mannville Group and the late Albian Westgate Formation. Minor numbers of thecamoebians occur in Middle Albian terrestrial sediments of the Mannville Group underlying the main kimberlite zone. Immediately above the kimberlite section, agglutinated foraminifera occur in abundance and three assemblages from the late Albian *Verneuilina canadensis* Subzone of the *Miliammina manitobensis* Zone have been recognized in shale of the Westgate Formation. Regional correlations of foraminiferal zones matched with ammonite zones and radiometric dates indicate an age of approximately 100 Ma for the assemblages which, in ascending order, are named the *Ammobaculites*, the *Paratrochammina*, and the *Haplophragmoides* assemblages. The estimated age of these assemblages is compatible with a Pb/U radiometric date of 101 Ma derived from the mineral perovskite within the kimberlite complex.

Species distributions, generic composition, and morphotypic groupings of the agglutinated assemblages indicate that a nearly complete transgressive-regressive sequence is preserved in the Westgate Formation. The *Ammobaculites* assemblage represents the early stages of transgression and marginal marine sedimentation. The *Paratrochammina* assemblage represents deeper water marine sedimentation up to approximately mid-shelf depths with maximum marine conditions attained coincident with peak abundances of *Paratrochammina* and the total foraminiferal abundance. Regression is indicated in the upper part of the Westgate shale by decreased numbers of *Paratrochammina* and decreased total foraminiferal abundance. Continued regression in the upper part of the Westgate shale is indicated by the *Haplophragmoides* assemblage. The Westgate Formation is erosionally truncated in the Smeaton core and is overlain by Quaternary sediment.

Thermal maturity indicators (FCI, Tmax, %VRo, and Lmax) all indicate that low levels of thermal maturity, similar to low maturity regional trends, characterize the Albian sediments in the Smeaton core.

INTRODUCTION

After periodic reports of diamonds in Saskatchewan dating back to 1961, exploration for kimberlites hosted by Cretaceous sediments began in earnest in 1988 in the Fort à la Corne area (Figure 1) of central Saskatchewan (Lehnert-Thiel *et al.*, 1992). Shortly thereafter, diamond-bearing kimberlites were verified by drilling in 1989. By 1994, there were 44 confirmed kimberlite bodies with reports of diamond discoveries and many potential targets to be drilled (Scott-Smith *et al.*, 1994). In 1992, the Geological Survey of Canada drilled a 242 metre core hole in the Fort à la Corne area of central Saskatchewan to obtain detailed scientific information about the genesis of the newly discovered kimberlite deposits. The core, referred to as the Smeaton core, penetrated 100 m of Quaternary till, 15 m of Albian shale, 103 m of kimberlite, and 23 m of Albian siltstones, sandstones, and kimberlite in succession (Figure 2). A multidisciplinary scientific study (Leckie *et al.*, 1997) of the core used sedimentology, volcanology, mineralogy, geochemistry, palynology, micropaleontology, organic petrology, and radiometric dating to document a complex succession of kimberlite crater facies bounded by Middle Albian sediments below and Upper Albian sediments above. Agglutinated foraminifera in particular played a significant role in initially determining the age and stratigraphic position of the kimberlites. In the current study, the distribution, characteristics, and significance of the agglutinated foraminifera recovered from the Albian shales mainly above the kimberlites are examined in more detail.

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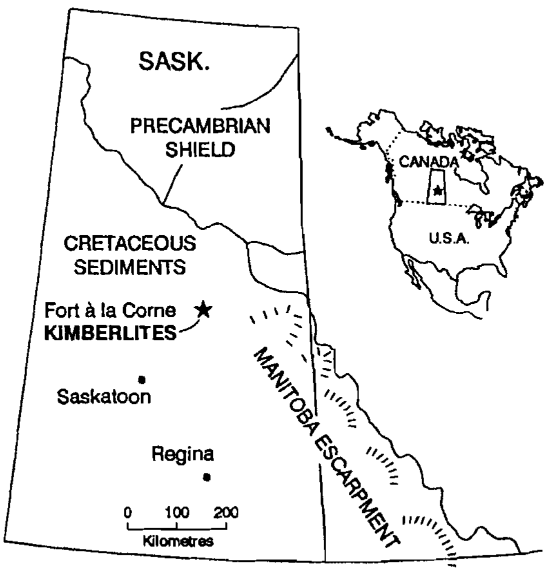

Figure 1. Location of the Smeaton FAC/UK Core 169/8 drilled by the Geological Survey of Canada (GSC Locality C-212501) in the Fort à la Corne area of central Saskatchewan (53°24'36"N; 104°46'W).

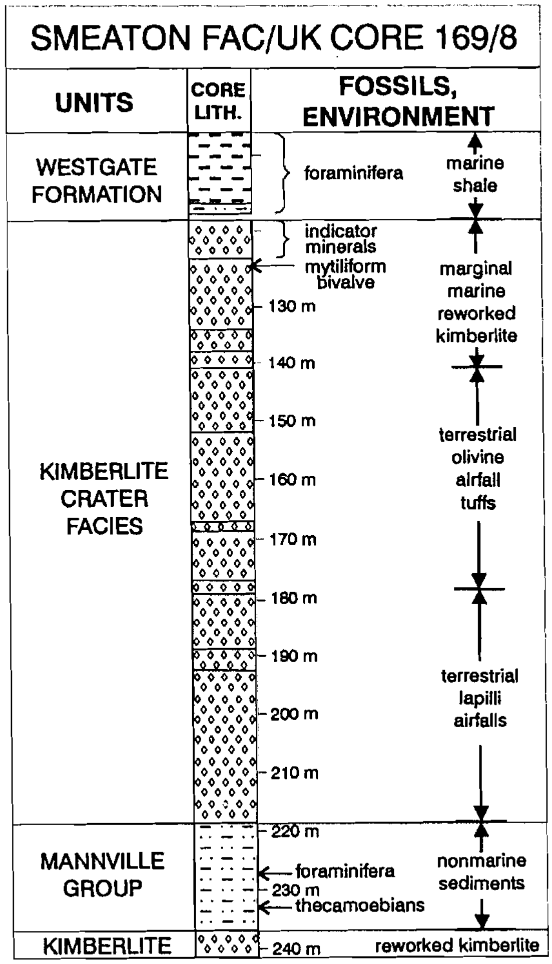

Figure 2. Stratigraphy of Albian rocks and kimberlite succession in the Smeaton FAC/UK Core 169/8 as measured and interpreted by Leckie *et al.* (1997).

GEOLOGICAL AND PALEONTOLOGICAL OVERVIEW

Lithological and paleontological data from the Smeaton core (Figure 2) indicated that the main body of kimberlites (103 m) rested on terrestrial deposits of the Aptian/Albian Mannville Group in a flood plain/deltaic setting (Leckie *et al.*, 1997). At the base of the Mannville sediments, there are 4.5 m of fluvially reworked kimberlitic sediments. The Mannville sediments are mainly composed of fine-grained overbank mudstones apparently deposited in a meandering river or distributary point bar setting. Thecamoebians were recovered at 228.7 and 235.9 m in the core. Pollen and spores examined by D.J. McIntyre (in Leckie *et al.*, 1997) indicated that the Mannville section is middle Albian in age. One poorly preserved dinoflagellate was recovered at 218.4 m.

The main body of kimberlite is characterised by four varieties of kimberlite which include fluvial reworked deposits, lapillistone airfall deposits, olivine crystal tuff airfall deposits, and marine wave reworked deposits (Figure 2). Detailed descriptions and interpretations of the kimberlite succession have previously been provided by Leckie *et al.* (1997). They concluded that only crater facies were present in the Smeaton core and that multiple eruptive phases of violent strombolian to more explosive volcanism were responsible for the kimberlite deposits. The explosions are recorded by airfall deposits on terrestrial sediments of the Mannville Group and erosion of and reworking of positive relief tephra cones (Figure 3). Since the kimberlite lapilli were involved in sedimentary processes and also contained shale clast ejecta, numerous samples were examined from the kimberlitic succession (see Appendix 1). Unfortunately, no foraminifera were recovered from within the kimberlitic units.

The upper part of the kimberlite succession (115.1-140.56 m) consists of subaqueous pyroclastic debris flow deposits overlain by wave influenced reworked kimberlite (Figure 2). This section is highly altered (*e.g.*, complete calcite replacement of olivine) and contains dinoflagellates and one specimen of a bivalve comparable to *Mytilus*, but lacked foraminifera. Crushed residues from samples originally processed for foraminifera from 115.5 to 122.3 m in the core yielded a collection of diamond indicator minerals (garnets, Cr-diopside, Mg-illmenite, Cr-spinel) from mantle peridotite and eclogite. The distribution and abundance of the indicator minerals is indicated in Appendix 1.

A marine transgressive lag beach deposit was identified at the top of the kimberlite at 115.22 to 118.3 m (Figure 2). The kimberlite beach deposits also proved to be barren of foraminifera, but were overlain by 13 m of foraminiferal-bearing,

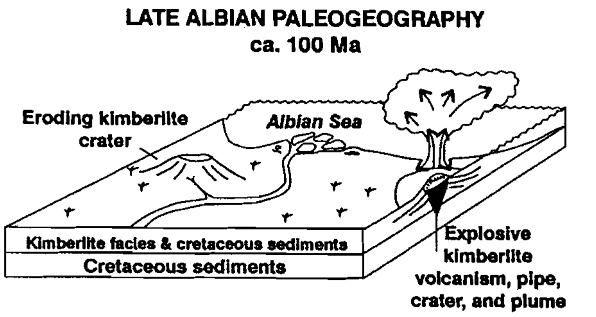

Figure 3. Late Albian palaeogeography of terrestrial kimberlite craters and the adjacent Albian epeiric sea (modified after Leckie *et al.* 1997, fig. 12c).

marginal-marine, silty, sandy mudstone and marine shales of the upper Albian Westgate Formation. Three assemblages of agglutinated foraminifera can be recognized in the core between 100.9 and 113.4 m (Figures 4,5). At the base of the Westgate Formation, a marginal marine assemblage dominated by *Ammobaculites* and *Ammotium* with lesser numbers of *Bathysiphon, Saccammina, Reophax, Miliammina, Psamminopelta, Haplophragmoides, Labrospira, Verneuilina,* and *Caronia* occurs in silty, sandy mudstones. This assemblage is overlain by a section dominated by *Paratrochammina* and *Ammobaculites* with lesser numbers of *Saccammina, Reophax, Miliammina, Psamminopelta, Labrospira, Verneuilinoides, Pseudobolivina, Uvigerinammina, Glomospira,* and *Trochammina*. A final assemblage dominated by *Haplophragmoides* in addition to *Saccammina, Miliammina, Psamminopelta, Labrospira, Verneuilinoides,* and *Pseudobolivina* occurs in the upper part of the formation.

AGE OF THE FORAMINIFERAL ASSEMBLAGES AND KIMBERLITES

Collectively, the foraminiferal assemblages from the Smeaton core between 100.9 and 113.4 m are diagnostic of the late Albian *Verneuilina canadensis* Subzone of the *Miliammina manitobensis* Zone which is widespread in the Western Interior of Canada in the Westgate Formation and equivalents (Caldwell *et al.*, 1978). Although there is no direct link to the standard ammonite zonation for the Western Interior Cretaceous, regional correlations indicate that the *V. canadensis* Subzone is predominantly pre-*Neogastroplites* in age (Caldwell *et al.*, 1978). Obradovich (1993, p. 383) reported that the *Neogastroplites haasi* Zone (lowest of the *Neogastroplites* zones) had been radiometrically dated at 98.54 and 98.74 Ma. Comparison of the foraminiferal assemblages from the Smeaton core with subsurface data in south-central Saskatchewan (North & Caldwell, 1975; unpublished data courtesy B.R. North, 1995) indicates a correlation with the mid to lower part of the Westgate Formation or *Miliammina manitobensis* Zone. Therefore, an absolute age *ca.* 100 Ma is assigned.

The kimberlite in the Smeaton core has been dated radiometrically at 101.1 ±2.2 Ma based on Pb/U in the mineral perovskite at 199 m (Leckie *et al.*, 1997). The radiometric determination was considered to be an accurate determination of the timing of the kimberlitic volcanism. This date also places some constraints on the probable maximum age for the *Miliammina manitobensis* Zone and is an important addition to the sparsely controlled chronostratigraphic framework for the Albian in the Western Interior of North America. Obradovich (1993), for example, reports only one radiometric age for a macrofossil zone (*Inoceramus comancheanus - I. bellvuensis* Zone) in the Albian of the Western Interior of North America.

A middle Albian age was determined from palynological assemblages in the Mannville Group below the main kimberlite section (Leckie *et al.*, 1997). There is no evidence of the early late Albian *Haplophragmoides gigas* Zone or *Inoceramus comancheanus* Zone, radiometrically dated at about 104 Ma by Obradovich (1993). Either an unconformity exists at the base of the kimberlite section, or kimberlitic volcanism and subsequent processes of terrestrial reworking dominated the area for a lengthy period.

MICROPALEONTOLOGICAL METHODS

Micropaleontological data for the Westgate Formation and the Mannville Group in the Smeaton core were derived from 100 g samples processed using the technique outlined by Then and Dougherty (1983). The samples were crushed with a mortar and pestle and soaked in beakers on an oscillating hot plate (70°C) using Quaternary O, hydrogen peroxide (35%), and bleach (sodium hypochlorite, 6%) in succession until the sample was disintegrated. Samples were washed on a No. 200 U.S. Series screen and the 75 micron fraction was retained, air dried, and picked manually for microfossils. Preservation of agglutinated foraminifera appeared to be excellent (see Plate 1). There was no evidence of calcareous foraminifera, but this is regionally consistent in foraminiferal assemblages from the upper Albian of the Western Interior Sedimentary Basin of North America.

Five additional samples were analysed using the Foraminiferal Colouration Index (FCI) of McNeil *et al.* (1996) to assess thermal affects below and above the kimberlite deposits. The concept of FCI is explained thoroughly in McNeil *et al.* (1996). To avoid loss of colouration in the laboratory, hydrogen peroxide and bleach were omitted from processing. The actual assessment of colour was carried out on a cardboard microfossil slide with miniature colour chips from the standard Munsell Colour Chart attached. The colour chips were arranged in sequence on a neutral background. A clear plastic overlay allowed for specimens to be laid directly

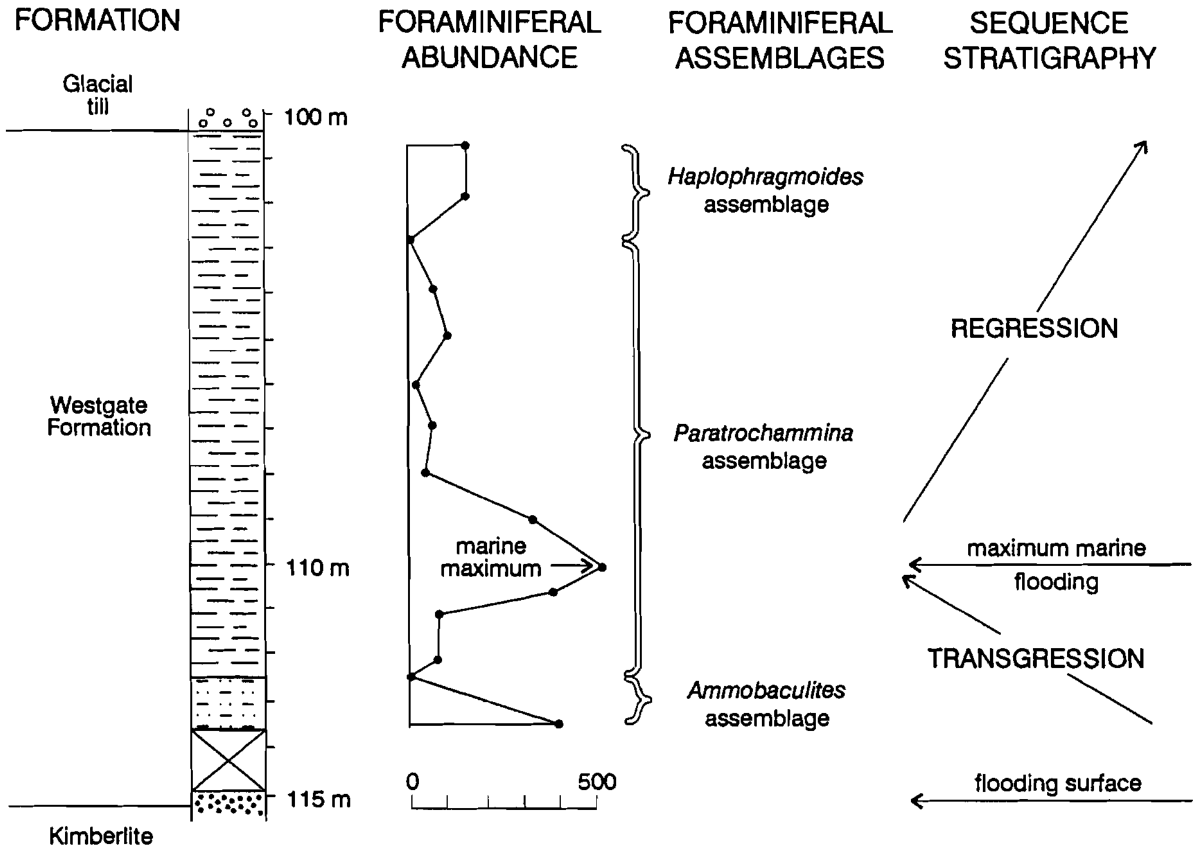

Figure 4. Foraminiferal abundance (per 100 g sediment), assemblages, and sequence stratigraphy of the upper Albian Westgate Formation in the Smeaton FAC/UK Core 169/8, central Saskatchewan.

over the colour chips to determine colour. The colour assessment is based on dry specimens and represents the generalized colour of a specimen. The colour, or FCI value, is assessed simply by determining which colour chip best accommodates the specimen. The determination can be done accurately and consistently within the increments of the Munsell colour chart. Individual FCI measurements were tabulated to give average FCI data (Table 1).

FORAMINIFERAL ASSEMBLAGES AND BIOSTRATIGRAPHY

1. *Ammobaculites* Assemblage

Marine transgressive facies in the Smeaton core are first recognized in the upper part of the kimberlite (Figure 2) as indicated by dinoflagellates, a mytiliform bivalve, and sedimentary structures suggesting wave reworking of kimberlitic subaqueous airfalls (Leckie *et al.*, 1997). A coarsening upward unit at 115.22 to 118.3 m is capped by an erosional surface and a pebble conglomerate interpreted as a transgressive lag deposit. Unfortunately, a 1.5 m gap in the core overlies this pebble conglomerate, but sandy mudstones immediately above this gap yield abundant specimens of agglutinated foraminifera collectively grouped as the *Ammobaculites* assemblage. Several lines of evidence indicate that this assemblage represents a marginal marine, periodically high-energy environment. These include the sandy mudstone sediments, the coarsely grained texture of the agglutinated foraminifera (e.g., *Ammotium* sp., Pl. 1, Fig. 9), the generic composition (*Lagenammina, Ammobaculites, Ammotium, Verneuilina,* and *Caronia*), and the predominance of endobenthic morphotypes ("infaunal" morphogroup 3b in the classification of Jones & Charnock, 1985, and Nagy, 1992). The two species, *A. tyrrelli* Nauss and *Ammotium* sp., comprise 75 % of the assemblage in sample 113.4 m. Such high dominances of *Ammobaculites* and *Ammotium* are typical of shallow water, marginal marine environments such as lagoon, marsh, and estuary (Ellison, 1972; Murray, 1991; Radley, 1993; Wightman, 1990). Note: endobenthic is used rather than infaunal following the recommendations of Walker & Miller (1992) who noted that infaunal suggests organisms living on/within other host organisms rather than organisms living mostly below the substrate.

The close proximity of the *Ammobaculites* assemblage to reworked kimberlitic deposits containing abundant diamond indicator minerals raised the possibility that microdiamonds could be incorporated into the tests of agglutinated foraminifera. Unfortunately, this has not been observed in the material at hand, but future observations may prove to be fruitful.

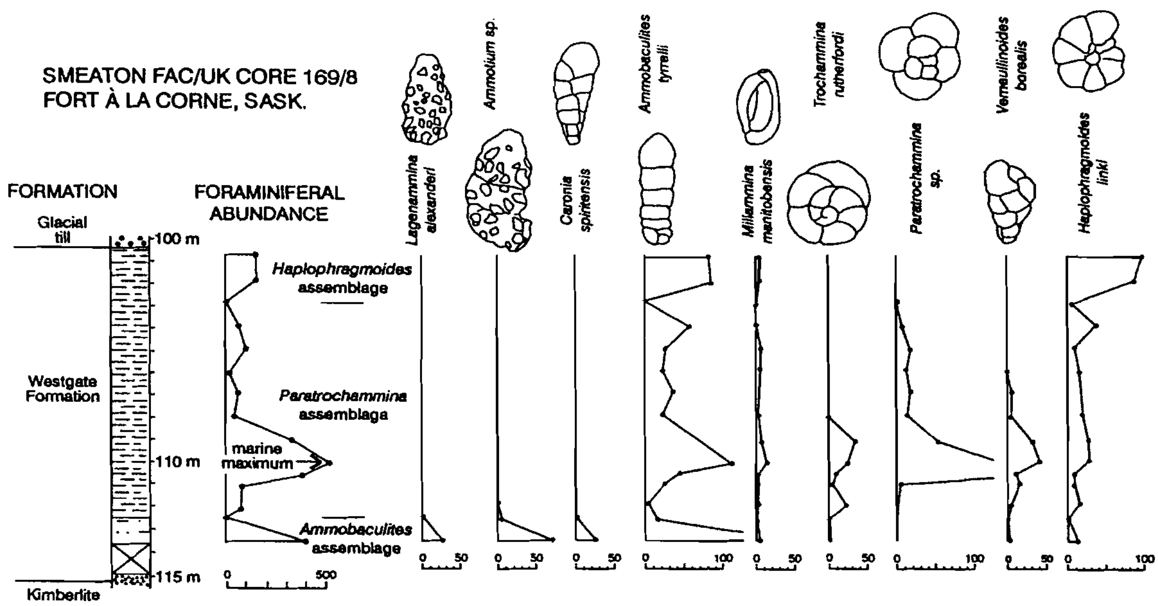

Figure 5. Abundance distributions (per 100 g sediment) of selected agglutinated foraminifera in the Westgate Formation, Smeaton FAC/UK 169/8 core.

2. *Paratrochammina* Assemblage

The *Ammobaculites* assemblage diminishes rapidly upsection in the Smeaton core. Several new species appear at 112 m, and the dominance shifts from *Ammobaculites,* although still abundantly represented by *A. tyrrelli,* to *Paratrochammina* sp. which peaks at 110.5 m. The section from 112 to 104 m is referred to as the *Paratrochammina* assemblage, characterized by *Saccammina placenta* (Grzybowski), *Miliammina manitobensis* Wickenden, rare *Psamminopelta bowsheri* Tappan, *Haplophragmoides linki* Nauss, *Labrospira* sp., *Ammobaculites tyrrelli* Nauss, *Verneuilinoides borealis* Tappan, rare *Pseudobolivina variana* (Eicher), rare *Hippocrepina* sp., *Paratrochammina* sp., *Reophax* sp., *Uvigerinammina manitobensis* (Wickenden), *Glomospira glomerosa* Eicher, and *Trochammina rutherfordi* Stelck & Wall.

The *Paratrochammina* assemblage provides several lines of evidence to indicate that marine conditions, and probably water depth, peaked during its time of development. The absolute foraminiferal abundance reaches a peak of 499 specimens/100 g of shale at 110 m and just below this, *Paratrochammina* reaches a peak abundance at 110.5 m. Brönnimann & Whitaker (1988) reported that modern species of *Paratrochammina* sp. were distributed at water depths from 58 to 3264 m based on data from the Discovery expedition. The peaks of foraminiferal abundance at 110 and 110.5 m are interpreted as representing the "surface", or zone, of maximum flooding for the Westgate Formation in the Smeaton core. It is impossible to determine a precise water depth, but given the geological setting of an epeiric sea, a maximum water depth of mid-shelf is considered likely. Other genera of the *Paratrochammina* assemblage provide additional evidence of a deeper marine environment relative to the *Ammobaculites* assemblage. Species from foraminiferal morphogroup 2 (Jones & Charnock, 1985) are abundant in the *Paratrochammina* assemblage. Species include *S. placenta, Paratrochammina* sp., *G. glomerosa,* and *T. rutherfordi,* all characterized by globular to plano-convex test shapes which suggest a surface dwelling habit with individuals feeding on flocculent detritus typical of deeper quieter marine environments.

Recognition of the maximum flooding surface (mfs) is of particular significance for sequence stratigraphic interpretation (Figure 4), as the mfs is a widespread potentially correlatable event and hypothetically equivalent to a time line. The section below the mfs represents the transgressive portion of the sequence and the section above records the regressive part of the sequence. The mfs potentially provides a datum for regional correlations and sequence analysis in the Westgate Formation and will be a focal point in future research.

3. *Haplophragmoides* Assemblage

After reaching peak abundance at about mid-point in the *Paratrochammina* assemblage zone (Figure 5), foraminiferal abundance declines upsection until the assemblage is no longer recognizable at the 103 m mark in the core. The *Haplophragmoides* assemblage is thus recognized from 103 to 100.6 m. The assemblage change results not from any new occurrences of species, but rather from the disappearance of taxa and changes in the abundances of taxa. The *Haplophragmoides* assemblage contains *S.*

Table 1. Foraminiferal Colouration Index (FCI) data for five samples from the Smeaton FAC/UK 169/8 core. FCI data for samples 102, 110, and 113.4 m were derived from representative splits of the total agglutinated foraminiferal assemblage. Samples 228.7 and 235.9 m consisted of thecamoebians rather than foraminifera.

Smeaton Core Samples			FCI Data						
Lithology	**Colour**	**Metres**	**1**	**2**	**3**	**4**	**5**	**6**	**Average**
Shale	medium dark grey	102	0	0	10	29	0	0	3.7
Shale	olive grey	110	0	8	57	11	0	0	3
Mudstone	light olive grey to olive grey, glauconitic	113.4	0	5	28	22	5	2	3.5
Claystone	light brown grey to brown grey	228.7	5	1	0	0	0	0	1.2
Claystone	dark yellowish brown	235.9	12	15	0	0	0	0	1.6

placenta, *M. manitobensis*, *P.* bowsheri, *H. linki*, *Labrospira* sp., *A. tyrrelli*, *V. borealis*, and *P. variana*. *Haplophragmoides linki* makes up about 50% of the assemblage. The *Haplophragmoides* assemblage is dominated by endobenthic detritivores. The globular and plano-convex morphotypes typical of the underlying *Paratrochammina* assemblage disappear almost entirely. The changes in foraminiferal abundance, generic composition, and morphotypes suggest that regressive conditions continued, possibly to the point that water depth was decreasing. Apparently, sediment influx increased and substrates became less suitable for benthic foraminifera than previously.

The Westgate Formation in the Smeaton core is erosionally truncated at 100.9 m and overlain by Quaternary till which precludes examination of the upper part of the formation.

THERMAL MATURITY OF FORAMINIFERA IN THE SMEATON CORE

Using the thermal maturity techniques established by McNeil *et al.* (1996) and explained further in the Methods section of this paper, Foraminiferal Colouration Index (FCI) was determined for thecamoebian samples in the Mannville Group below the kimberlites and for foraminiferal samples in the Westgate Formation above the kimberlites (Table 1). Unfortunately, no foraminifera were recovered from within the kimberlitic section despite evidence of marine sedimentation in the upper part of the kimberlite and the presence of black shale clasts that were presumed to be crater ejecta from the kimberlite explosions.

Specimens of thecamoebians from 228.7 and 235.9 m were calculated to have "FCI" values of 1.2 and 1.6. Three samples from the Westgate Formation, above the kimberlite section, yielded FCI values ranging from 3.0 to 3.7 (Table 1). All FCI values from the Smeaton core indicate low levels of thermal maturation, and the measurements from the Westgate Formation are reasonably consistent. The values from the Mannville Group are slightly lower than those from the Westgate Formation, which is the opposite of normal burial trends. It is not known if the difference in FCI from above and below the kimberlite is a real thermal effect or whether it is simply within the range of variation to be expected from different sedimentary environments and different taxa.

Previous assessments of the thermal conditions surrounding the emplacement of the kimberlites in the Smeaton core indicated no evidence of a thermal aureole from kimberlitic material, even though the kimberlitic material must have originated from hot (1200°C) magma (Leckie *et al.*, 1997). Agglutinated foraminifera are sensitive indicators of thermal change at these low levels of maturity (McNeil *et al.*, 1996), so that even moderate elevations in temperature would probably have been reflected in the FCI values. RockEval measurements through the entire Smeaton core ranged from Tmax values of 418 to 434 °C, which is consistent with the regional, low-maturity trends in the Westgate Formation (Bloch *et al.*, 1999). Dispersed huminite and low-reflecting bitumen also provided low maturity values of 0.35 and 0.20 %VRo respectively.

Fluorescence measurements on a specimen of *Ammotium* sp. from 113.4 m near the base of the Westgate Formation produced a fluorescence of intermediate intensity, orange yellow in colour (Lmax 520-550 nm), indicative of relatively low thermal maturity, compatible with the FCI determination. The details of the preliminary examination of the fluorescent properties of agglutinated foraminifera are presented in the paper by Stasiuk and McNeil (this volume).

CONCLUDING REMARKS

Agglutinated foraminifera recovered from shales in the Smeaton core contribute significantly to the stratigraphic, palaeogeographic, and thermal context surrounding the emplacement of kimberlites in the Fort à la Corne area of central Saskatchewan. In detail, they provide information on the palaeoenvironmental and palaeogeographic setting surrounding emplacement of the kimberlite facies. They place a minimum age of approximately 100 Ma on the kimberlite explosions. Distributions of foraminifera within the Westgate Formation overlying the kimberlites provide fairly precise information about the transgressive-regressive sequence stratigraphic nature of marine shale that transgressed and buried the kimberlite crater facies. Agglutinated foraminifera provide a framework for potential future correlations of other kimberlitic complexes within Albian shales of the Fort à la Corne area of central Saskatchewan. FCI values (3.0-3.7) indicate low levels of thermal maturation. This is consistent with other maturity indicators in the Smeaton core. Measurement of the fluorescence properties of the fossilized organic cement of *Ammotium* sp. also indicates low levels of thermal alteration. The lack of any significant thermal alteration below or above the kimberlites indicates that the kimberlite ejecta cooled rapidly and that exposure of organic matter to high temperatures was negligible or of very short duration.

ACKNOWLEDGEMENTS

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Appendix 1. Distribution of foraminifera, bone fragments, pyritized diatoms, and diamond indicator minerals in core samples from the Smeaton FAC/UK core 169/8 (Geological Survey of Canada, locality no. C-212501). All specimens stored at the Geological Survey of Canada, Calgary. Modified after Leckie *et al.* (1997, Table 1).

FORAMINIFERA

Metres	*Bathysiphon* sp.	*Lagenammina alexanderi*	*Miliammina manitobensis*	*Psamminopelta bowsheri*	*Reophax* sp.	*Haplophragmoides linki*	*Labrospira* sp.	*Ammotium* sp.	*Ammobaculites tyrrelli*	*Trochammina rutherfordi*	*Verneuilinoides borealis*	*Caronia spiritensis*	*Verneuilina canadensis*
100.9			1	1		96	12		92		22		
102			1			85	3		81		10		
103													
104						33			55		5		
105			4		1	5	7		25				
106			4	1		12	6		21	1			
107			1			17	6		33		2		
108			1			20	5		22		3		
109			6		4	20	11		72	39	32		
110			13		9	29	9		111	28	40		
110.5			2	1		9	8		44	11	11		
111			2			9	9		26	9	17		
112			1			15	18		3	28	4		
112.4			1				7	7	16				1
113.4	1	28	5	2	3	12	3	81	220	6	1	28	8
115.5													
115.7													
119.3													
120.9													
121.1													
122.3													
228.7	1												
235.9													
236.2	Barren												
223.4	Barren												

Metres	*Saccammina placenta*	indeterminant fragments	*Paratrochammina* sp.	*Glomospira glomerosa*	*Pseudobolivina variana*	*Hippocrepina* sp.	*Uvigerinammina manitobensis*	Total Abundance	MISC. thecamoebians	bone debris (fish?)	diatoms (pyritized)	indicator minerals
100.9	3	49			1			277				
102	8	4						192				
103								0				
104		18	2			1		114		6		
105	1	73	13				1	130		2	1	
106	3	10	12	1			1	72		1		
107		27	17	1				104		7		
108	2	25	13				2	93		4	15	
109	3	79	56	3	2	1	1	329		9	71	
110	4	118	137	1				499		16	32	
110.5	9	81	201	1				378		3	6	
111	1	37	3	2				115		11	6	
112		34	3					106		26	3	
112.4	1	8						41		8		
113.4								398		11		
115.5												17
115.7												2
119.3												100
120.9												43
121.1												20
122.3												19
228.7									5			
235.9									30			
236.2	Barren											
223.4	Barren											

Barren: 23 samples of shale clasts and kimberlite with shaly sediment were processed from 122.9 to 220.8 m.

Appendix 2. Foraminifera in the Upper Albian Westgate Formation, Smeaton FAC/UK core 169/8 listed according to morphogroup assignment. Morphogroups, life positions, and probable feeding strategies after Jones & Charnock (1985) and Nagy (1992).

Foraminiferal Morphogroups in the Smeaton Core

Group	Shape	Life Position	Feeding Strategy?	Species
1	tubular	elevated	suspension	Bathysiphon sp.
2a	globular	surficial	passive deeposit feeder	Saccammina placenta Saccammina sp.
2b	plano-convex	surficial		Trochammina rutherfordi Paratrochammina sp. "31"
3a	rounded planular	endobenthic to surficial	active detritivore, bacterivore, hervibore	Haplophragmoides linki Labrospira sp.
3b	subcylindrical	endobenthic	detritivore, bacterial scavenger	Lagenammina alexanderi Miliammina manitobensis Reophax sp. Ammobaculites tyrrelli Ammotium sp. Verneuilinoides borealis Caronia spiritensis Verneuilina canadensis Pseudobolivina variana Hippocrepina sp. Uvigerinammina manitobensis
4a	flat planispiral, irregular	epibenthic	active to passive herbivore, detritivore	Psamminopelta bowsheri Glomospira glomerosa
4b	irregular attached	epibenthic	Passive herbivore	not present

Plate 1.

All illustrated specimens are from the Smeaton FAC/UK Core 169/8 (GSC Locality C-212501). Type specimens (identified by prefix GSC and type number) are curated in the type collections of the Geological Survey of Canada and are stored at GSC Calgary. Sample numbers are indicated by metres below kelly bushing.

1. *Saccammina placenta* (Grzybowski), GSC 89637, (x108), 110 m.

2. *Lagenammina alexanderi* (Loeblich and Tappan), GSC 89638, (x49), 113.4 m.

3a,b. *Glomospira glomerosa* Eicher, GSC 89639, (x160), 111 m.

4a,b. *Miliammina manitobensis* Wickenden, GSC 89640, (x78), 110.5 m.

5a,b. *Psamminopelta bowsheri* Tappan, GSC 89641, (x81), 106 m.

6. *Reophax sikanniensis* Stelck, GSC 89642, (x49), 113.4 m.

7a,b. *Haplophragmoides linki* Nauss, GSC 89643, (x72), 111 m.

8a,b. *Labrospira* sp., GSC 89644, (x60), 100.9 m.

9a,b. *Ammotium* sp., GSC 89645, (x50), 113.4 m.

10. *Ammobaculites tyrrelli* Nauss, GSC 89646, (x65), 104 m.

11. *Ammobaculites tyrrelli* Nauss, GSC 89647, (x56), 110 m.

12a-c. *Paratrochammina* sp., GSC 89648, (x86), 110 m.

13a-c. *Paratrochammina* sp., GSC 89649, (x88), 110 m.

14a-c. *Paratrochammina* sp., GSC 89650, (x106), 109 m.

15a-c. *Trochammina rutherfordi* Stelck and Wall, GSC 89651, (x117), 109 m.

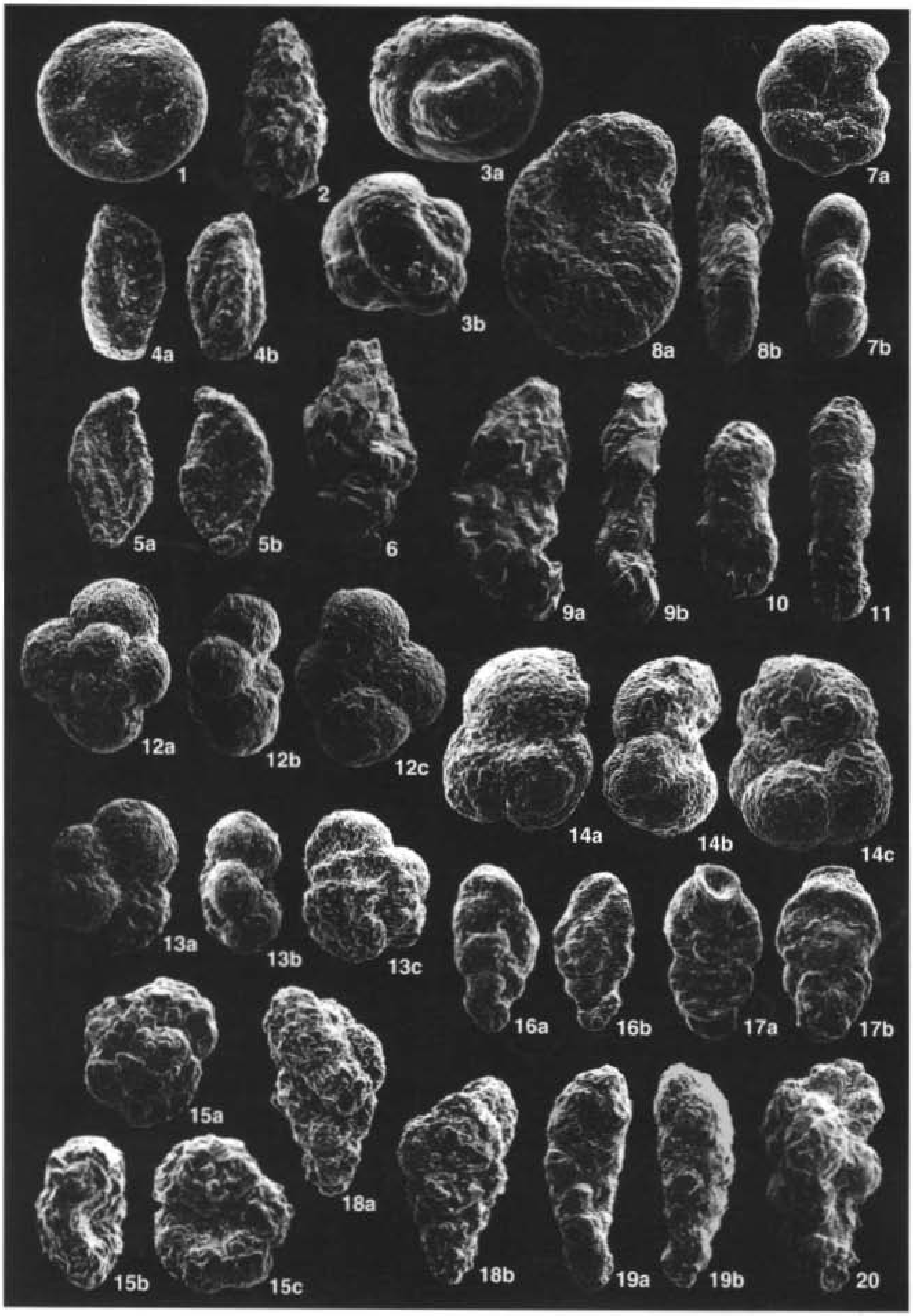
16a,b. *Pseudobolivina variana* (Eicher), GSC 89652, (x111), 109 m.

17a,b. *Uvigerinammina manitobensis* (Wickenden), GSC 89653, (x97), 109 m.

18a,b. *Verneuilinoides borealis* Tappan, GSC 89654, (x90), 111 m.

19a,b. *Caronia spiritensis* (Stelck and Wall), GSC 89655, (x79), 113.4 m.

20. *Verneuilina canadensis* Cushman, GSC 89656, (x56), 113.4 m.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