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PRELIMINARY TRILOBITE BIOSTRATIGRAPHY OF THE COOKS BROOK FORMATION (NORTHERN HEAD GROUP), HUMBER ARM ALLOCHTHON, BAY OF ISLANDS, WESTERN NEWFOUNDLAND

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ABSTRACT

More than one hundred and ten fossiliferous samples from the Cooks Brook formation of Humber Arm, Middle Arm and Penguin Arm have yielded previously unrecorded trilobite faunas. The collections were obtained from the 'lower Cooks Brook (Shaly) interval', Halfway Point member, Brakes Cove member, 'upper conglomerate' and 'Lower Ordovician conglomerate'. The Cooks Brook formation is a sequence dominated by deep-water carbonate gravity deposits that forms part of the Humber Arm Allochthon. It comprises approximately 350 metres of grey-black shale and lime mudstone with interstratified carbonate conglomerate.

The 'lower Cooks Brook (Shaly) Interval' contains an in situ *fauna indicative of the late Middle Cambrian* Ehmaniella *Zone. The Halfway Point member contains* in situ *and redeposited trilobite faunas indicative of the late Middle Cambrian* Ptychagnostus gibbus *and* Bolaspidella *zones (=*Ehmaniella *Zone of restricted biofacies). The Brakes Cove member contains redeposited faunas indicative of the* Cedaria *and* Crepicephalus *zones of the early Late Cambrian Dresbachian Stage. The 'upper conglomerate' contains a redeposited fauna indicative of the* Taenicephalus *Zone of the medial Late Cambrian Franconian Stage. The Bear Cove conglomerate contains redeposited faunas, which range from the* Dunderbergia *Zone of the early Late Cambrian Dresbachian Stage to the* Taenicephalus *Zone of the medial Late Cambrian Franconian Stage. Based on the youngest contained fauna, the probable age of this conglomerate is* Taenicephalus *Zone, identical to that of the 'upper conglomerate'. The Serpentine River strata contain an* in situ *fauna correlative with the* Keithia schucherti *fauna of the allochthonous Cow Head Group, and the* Saukiella junia *or* Saukiella serotina *subzone of the latest Cambrian* Saukia *Zone (Trempealeauan Stage). The 2-m-thick 'Lower Ordovician conglomerate' contains redeposited faunas that range in age from the* Rasettia magna *Subzone of the* Saukia *Zone (Trempealeauan Stage) to the* Symphysurina brevispicata *Subzone of the earliest Ordovician* Symphysurina *Zone (Canadian Series, Gasconadian Stage). Based on the youngest contained fauna, this conglomerate is of probable* Symphysurina *Zone (*Symphysurina brevispicata *Subzone) age.*

The Cooks Brook formation is probably no older than Ehmaniella *Zone (late Middle Cambrian), and the underlying Irishtown formation is no younger than* Glossopleura *Zone (medial Middle Cambrian).*

INTRODUCTION

The Cooks Brook formation is a sequence dominated by deep-water carbonate gravity deposits that forms part of the Humber Arm Allochthon of the Bay of Islands (Figures 1 and 2). It comprises approximately 350 metres of grey-black shale and lime mudstone interstratified with carbonate conglomerate (Figure 3). Originally investigated by Stevens (1965, 1970), the Cooks Brook formation was subsequently restudied by Botsford (1988a, b), where it was assigned to the base of his newly proposed Northern Head group. During the course of his fieldwork, previously unreported late Middle Cambrian to Early Ordovician trilobite faunas were collected from this deep-water carbonate slope deposit (Botsford *et al.*, 1986).

LITHOSTRATIGRAPHY

The Cooks Brook formation conformably overlies the Irishtown formation, which is the uppermost unit of the revised Curling Group of Stevens (1970). The Irishtown formation comprises grey to black shale having thick white quartzitic sandstone and conglomerate (Williams and Cawood, 1989). The Cooks Brook formation in turn is

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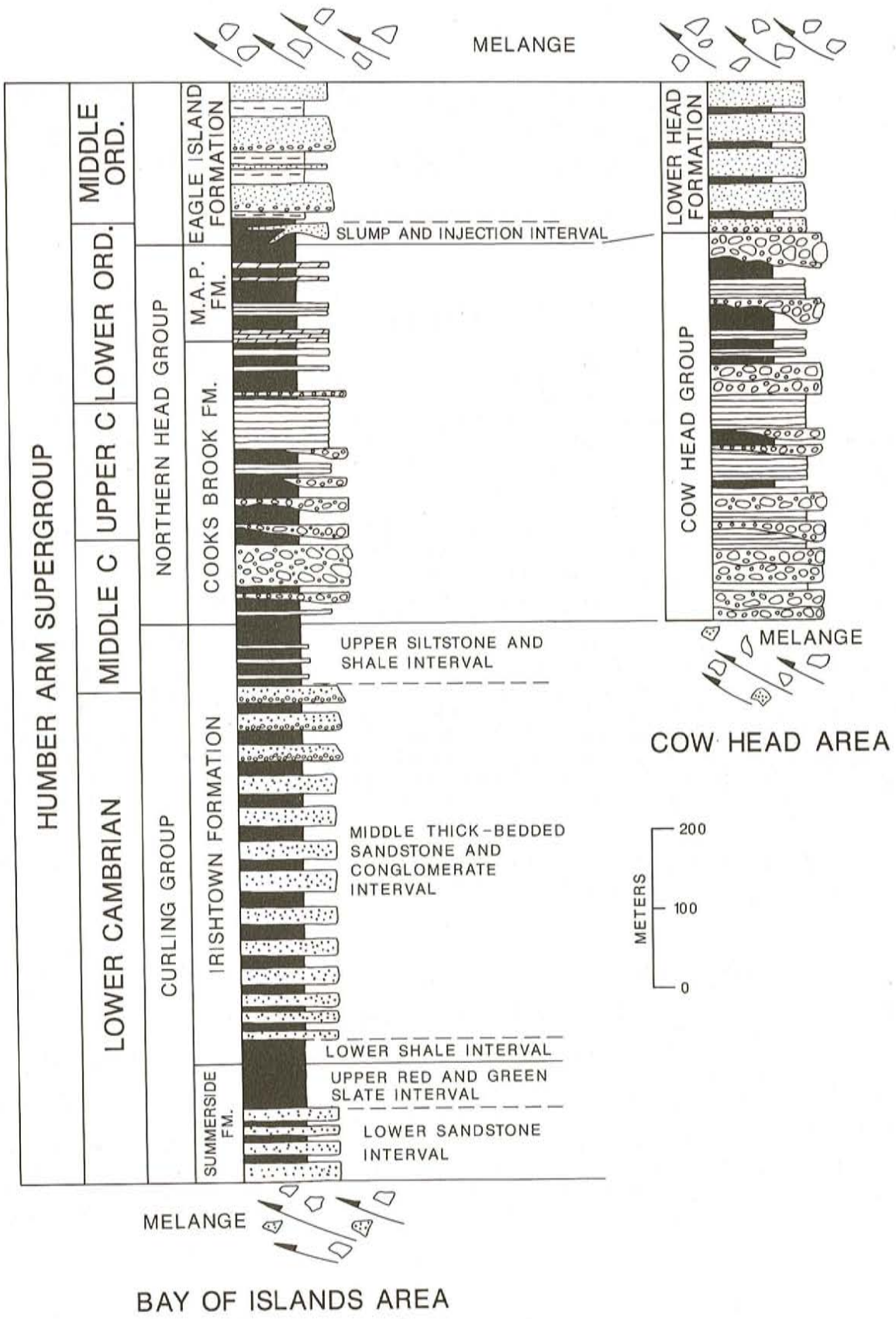

Figure 1. *Schematic summary of the Humber Arm Supergroup, in the Humber Arm Allochthon, illustrating the relationship of the Bay of Islands and Cow Head areas. M.A.P. is Middle Arm Point formation (from Botsford, 1988a, page 35).*

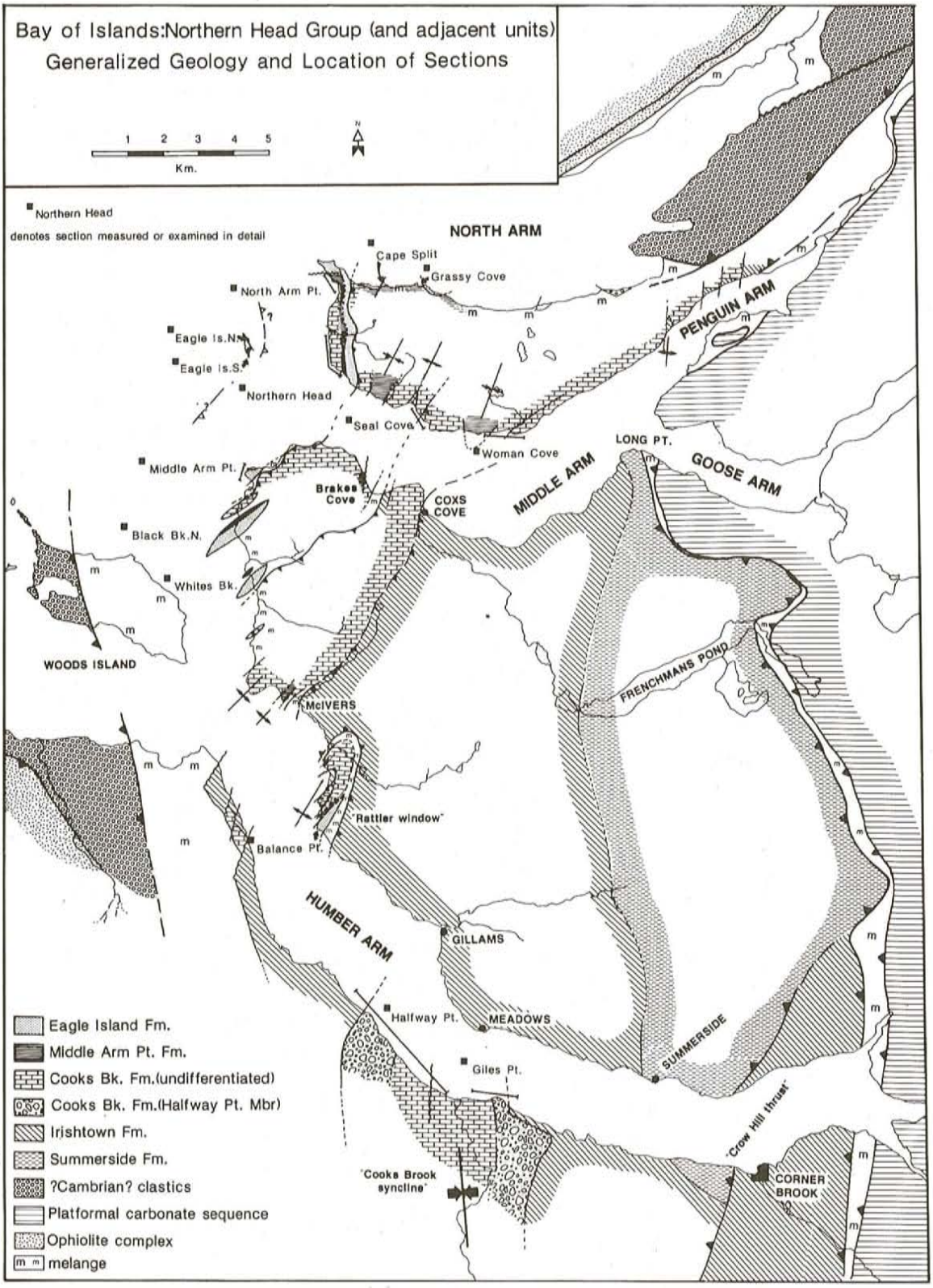

Figure 2. *Simplified geology map of the Bay of Islands area, showing the distribution of the Cooks Brook formation, and the locations of sampled stratigraphic sections (from Botsford, 1988a, page 42).*

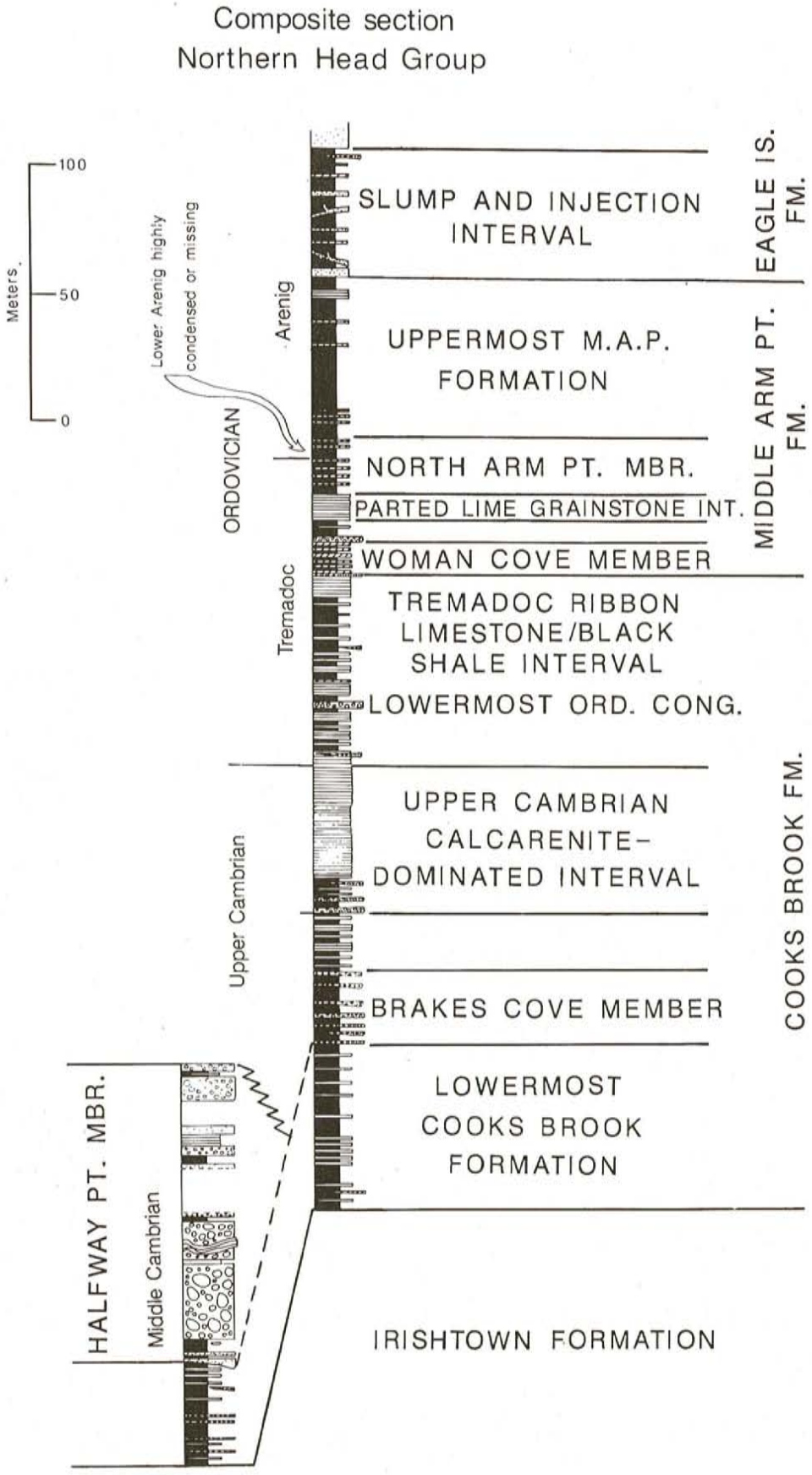

Figure 3. *Composite stratigraphic section through the Northern Head group, showing the subdivisions of the Cooks Brook formation, (from Botsford, 1988a, page 56).*

conformably overlain by the Middle Arm Point formation, a sequence of thin-bedded black and green shale having associated dolomitic siltstone and minor limestone (Williams and Cawood, 1989).

PREVIOUS WORK

Schuchert and Dunbar (1934, page 90) were the first to collect trilobites from the Cooks Brook formation. They identified specimens of *Agnostus* and *Triarthrus* from limestone conglomerates exposed south of the mouth of Serpentine River.

Kindle and Whittington (1965) subsequently restudied Schuchert and Dunbar's material. Their *Triarthrus* was reidentified as *Bienvillia* sp. cf. *B. corax* (Billings, 1865). They also collected additional trilobite material from dark-coloured limestones about half a mile south of the mouth of Serpentine River. They identified the following trilobites:

Apatokephaloides? sp.
Bienvillia sp. cf. *B. corax* (Billings, 1865)
Geragnostus sp.
Leiobienvillia sp.
Loganopeltoides sp.
Richardsonella? sp.
Theodenisia sp.
Zacompsus sp.

The generic assemblage is indicative of a latest Cambrian *Saukia* Zone (Trempealeauan Stage) age. The above taxa further suggest a correlation with the *Keithia schucherti* fauna of the allochthonous Cow Head Group. Ludvigsen *et al.* (1989, page 10) report *Bienvillia corax* (Billings, 1865), as well as species of *Apatokephaloides, Theodenisia* and *Zacompsus* from the fauna, which they correlate with the *Saukiella junia* and *Saukiella serotina* subzones (Ludvigsen *et al.*, 1989, page 10, text-figure 12).

In Bear Cove, 10 km north of Serpentine River, Kindle and Whittington (1965) obtained more trilobites from the Cooks Brook formation, exposed on the White Rocks. From a granular limestone boulder, they reported the following trilobites:

Bathyholcus sp.
Buttsia sp.
Cheilocephalus? sp.
Dunderbergia sp.
Oligometopus sp.
Pseudagnostus sp. cf. *P. prolongus* (Hall and Whitfield, 1877)
Pterocephalia? sp.

The above trilobites are indicative of a *Dunderbergia* Zone age (late Dresbachian Stage).

From an oolitic limestone boulder at Bear Cove, Kindle and Whittington also collected *Parabolinoides*. This genus is indicative of a *Taenicephalus* Zone age (medial Franconian Stage).

At Halfway Point, Dr. R. K. Stevens (Memorial University of Newfoundland) later obtained trilobites from the Halfway Point member of the Cooks Brook formation (Botsford, 1988a, page 465; Botsford *in* Cawood *et al.*, 1988, page 56). From one boulder he collected the following trilobites:

Bathyuriscus sp.
Kootenia sp.
Peronopsis gaspensis? Rasetti, 1948
ptychopariid gen. et sp. nov?
Semisphaerocephalus sp.

From a second boulder, Dr. Stevens also obtained *?Phoidagnostus* sp. The taxa above are indicative of a late Middle Cambrian *Ptychagnostus gibbus* Zone age (A.R. Palmer, personal communication to R. K. Stevens, 1979).

BIOSTRATIGRAPHY

Between 1984 and 1986, and in 1991, the authors collected more than one hundred and ten fossiliferous samples from redeposited clasts (pebbles, cobbles, boulders), and several *in situ* horizons in the Cooks Brook formation. Three main areas were investigated: Humber Arm, Middle Arm and Penguin Arm (Figure 2). Most of the collections were obtained from the 'lowermost Cooks Brook (Shaly) interval', Halfway Point member, Brakes Cove member, 'upper conglomerate' and 'Lower Ordovician conglomerate'.

LOWERMOST COOKS BROOK (SHALY) INTERVAL

Botsford (1988a, page 61) defined the base of the Cooks Brook formation at the first appearance of bedded limestone above the shale-dominated uppermost Irishtown formation. At the Halfway Point type section, these limestones comprise 20- to 50-cm-thick granule to pebble conglomerates, commonly graded and displaying a platy fabric; laminated dolomitic grainstones locally cap the limestones or form separate beds. In the lowest 10 m of the Cooks Brook formation, the carbonates are interbedded with (commonly) laminated dark-grey to black shales, which pass upward into an interval of black-green dolomitic-banded shale. At Halfway Point, the 'lowermost Cooks Brook (shaly) interval' is about 40 m thick, and is conformably overlain by the Halfway Point member.

Approximately 30 m above the base of the Cooks Brook formation, two pygidia of *Ehmaniella cloudensis* (Howell, 1943) were collected from a limestone conglomerate lens (in matrix at the base of a small channel/scour). Previously, the only fossils from the 'lowermost Cooks Brook (Shaly) interval', were indeterminate agnostids from thin limestone beds in Middle Trout River Brook (Botsford, 1988a, page 62). *Ehmaniella cloudensis* (Howell, 1943) is the characteristic species of the late Middle Cambrian *Ehmaniella cloudensis* Zone (Knight and Boyce, 1987); it is widespread throughout

western Newfoundland in the lower part of the (autochthonous) March Point Formation (Howell, 1943; Boyce, 1977; Stouge and Boyce, 1983; Knight and Boyce, 1987). The specimens are, therefore, firmly indicative of a late Middle Cambrian *Ehmaniella* Zone age (Knight and Boyce, 1987). This suggests that the Cooks Brook formation is probably no older than *Ehmaniella* Zone (late Middle Cambrian), and the underlying Irishtown formation is no younger than *Glossopleura* Zone (medial Middle Cambrian).

HALFWAY POINT MEMBER

The Halfway Point member is approximately 120 m thick; it consists predominantly of lime conglomerates separated by interbedded, parted lime grainstones and nodular to ribbon limestones and is best exposed at Halfway Point, on the south shore of Humber Arm (Botsford, 1988a, page 58).

In 1991, the Halfway Point member was again sampled for trilobites. Fifty-three collections were obtained, mainly from the basal conglomerates (*Bathyuriscus–Elrathina* Zone trilobite fauna, of Figure 4). Preliminary analysis suggests that the basal conglomerates include clasts of *Bolaspidella* Zone age, as well as *Ehmaniella* Zone and *Ptychagnostus gibbus* Zone (*Bathyuriscus–Elrathina* Zone of earlier workers). Consequently, the basal conglomerates are probably younger (*Bolaspidella* Zone) than earlier believed.

The basal conglomerates of the Halfway Point member are interrupted by several metres of shale. Below the shale, at least two distinct conglomerate layers occur; from these, seventeen fossiliferous samples were collected. Most of the collections have yet to be studied in detail. However, *?Onymagnostus/Ptychagnostus* sp. undet. occurs in a light-grey platy limestone clast (sample number (SN) 91F018C) collected from a fallen block derived from the lower conglomerate; it indicates a Middle Cambrian age. From the upper conglomerate, the following trilobite taxa were retrieved from possible matrix (SN 91F019A):

agnostid gen. et sp. undet.
Bathyuriscus sp. undet.
Modocia sp. undet.

In the Great Basin, the genus *Modocia* appears just below the base of the *Bolaspidella* Zone (Robison, 1976, page 98, text-figure 4).

Above the shale, at least three distinct conglomerate layers occur; from these, twenty-two fossil collections were obtained. From the lowest layer, the trilobites of five collections have been examined in (relative) detail. A lime

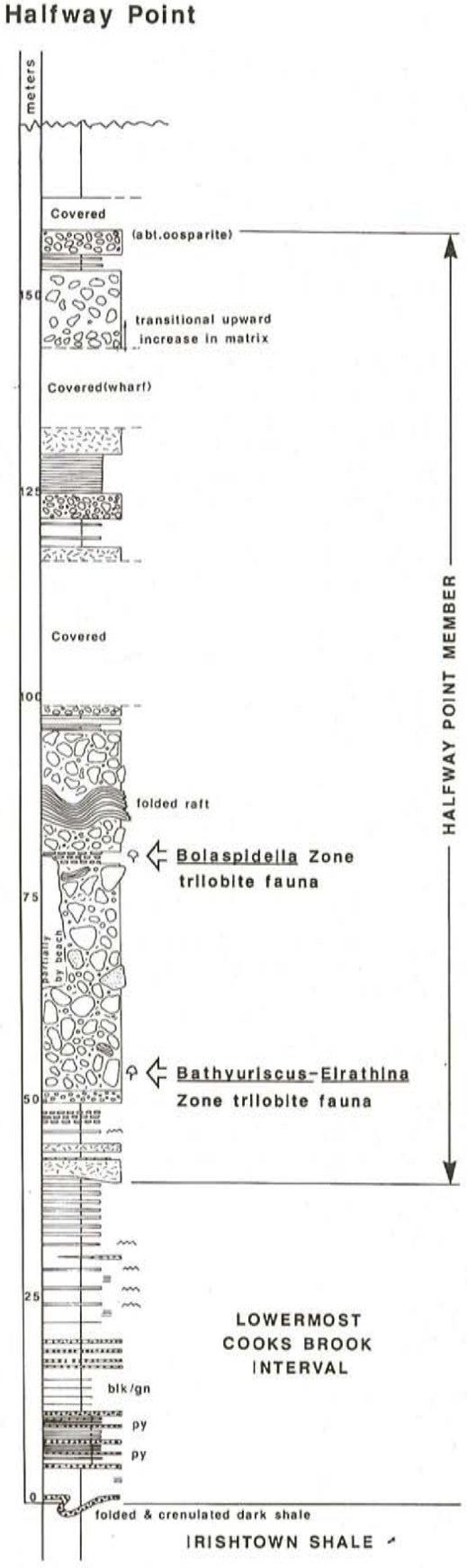

Figure 4. *Stratigraphic section through the "lower Cooks Brook (Shaly) interval' and the Halfway Point member of the Cooks Brook formation (from Botsford, 1988a, page 60).*

mudstone clast (SN 91F020A) in a fallen block yielded the following:

Ehmaniella cloudensis (Howell, 1943)
Hypagnostus sp. undet.
Olenoides foveolatus Rasetti, 1948

The fortuitous occurrence of *Ehmaniella cloudensis* (Howell, 1943) and *Olenoides foveolatus* Rasetti, 1948 in the same sample allows some interesting correlations to be made. As stated above, *Ehmaniella cloudensis* (Howell, 1943) is the characteristic species of the late Middle Cambrian *Ehmaniella cloudensis* Zone in the autochthonous sequence of western Newfoundland. *Olenoides foveolatus* Rasetti, 1948 was originally described by Rasetti (1948) from Middle Cambrian boulders in the Lévis Formation of Québec; it also occurs in the *Ptychagnostus gibbus* Zone-correlative *Zacanthoides gilberti* Fauna of the allochthonous Cow Head Group in western Newfoundland (Young and Ludvigsen, 1989). There it is associated with the agnostid *Peronopsis interstricta* (White, 1874), which, according to Young and Ludvigsen (1989, page 11) is similar to *Peronopsis gaspensis* Rasetti, 1948 (previously reported from the Halfway Point member—see above). The *Ehmaniella cludensis* Zone of the autochthon and the *Zacanthoides gilberti* Fauna of the allocthon both correlate, therefore, with the *Ptychagnostus gibbus* Zone. In addition, Knight and Boyce (1987, page 361, Figure 4) report *Zacanthoides* sp. undet. from the *Olenoides longispinus* Zone in the March Point Formation of Canada Bay. Boyce *(op. cit.)* believes that this species is probably conspecific with *Zacanthoides gilberti* Young and Ludvigsen, 1989; if so, the *Olenoides longispinus* Zone probably also correlates, at least in part, with the *Zacanthoides gilberti* Fauna and the *Ptychagnostus gibbus* Zone (Table 1).

A lime grainstone cobble (SN 91F020B) from another fallen block yielded:

agnostid gen. et sp. undet.
Asaphiscus sp. cf. *A. laeviceps* (Walcott, 1884)

Asaphiscus sp. cf. *A. laeviceps* (Walcott, 1884) also occurs in the upper part of the March Point Formation in western Newfoundland (Stouge and Boyce, 1983). *Asaphiscus laeviceps* (Walcott, 1884) is a younger Middle Cambrian species than *Asaphiscus wheeleri* Meek, 1873 (Palmer, 1954). This implies a *Bolaspidella contracta* Subzone age (see below).

Another lime grainstone clast (SN 91F020D) contained the following:

Bathyuriscus sp. undet.
?Bolaspidella sp. undet.
ptychopariid? gen. et sp. undet.

?Bolaspidella sp. undet. suggests a *Bolaspidella* Zone age for this clast.

The following were obtained from a lime mudstone clast (SN 91F020F):

Pagetia sp. undet.
ptychopariid gen. et spp. undet.

Rasetti (1966, page 504) and Robison (1976, page 98, text-figure 4), state that the genus *Pagetia* ranges from the (late Early Cambrian) *Bonnia—Olenellus* Zone to the top of the (Middle Cambrian) *Oryctocephalus* Zone (*Ptychagnostus gibbus* Zone-correlative), and is entirely a pre-*Bolaspidella* Zone taxon.

Another lime mudstone clast (SN 91F020G) yielded:

Trilobita

Bathyuriscus sp. undet.
Ehmania borealis Howell, 1943

Ehmania borealis Howell, 1943 ranges through the *Glossopleura walcotti, Polypleuraspis, Olenoides longispinus* and *Ehmaniella cloudensis* zones in the autochthonous sequence of the Canada Bay area (Knight and Boyce, 1987). This widespread species most often occurs in the lower part of the March Point Formation in association with *Ehmaniella cloudensis* (Howell, 1943) (Howell, 1943; Boyce, 1977; Stouge and Boyce, 1983; Knight and Boyce, 1987); therefore, it is also probably indicative of a late Middle Cambrian *Ehmaniella* Zone age.

From the middle conglomerate layer, notable for its shaly matrix, a platy clast of buff-weathering, dark-grey dolomite mudstone—wackestone (SN 91F021C) yielded:

Asaphiscus sp. cf. *A. wheeleri* Meek, 1873
Bathyuriscus sp. undet.

Asaphiscus wheeleri Meek, 1873 occurs in the *Bathyuriscus fimbriatus* Subzone of the *Bolaspidella* Zone in Utah (Robison, 1964, page 512, text-figure 2).

Finally, from the upper conglomerate layer, three collections have merited special attention. The trilobite *Olenoides foveolatus* Rasetti, 1948 was obtained from a large, platy lime mudstone clast (SN 91F022A) near the base of the layer and below a large Irishtown Formation block. As stated above, *Olenoides foveolatus* Rasetti, 1948 also occurs in the *Ptychagnostus gibbus* Zone-correlative *Zacanthoides gilberti* Fauna of Cow Head Group.

Another rectangular (30 by 15 cm) boulder of light blue-grey weathering, dark blue-grey lime mudstone—wackestone (SN 91F022H) yielded the following:

Brachiopoda-Inarticulata

Gen. et sp. undet.

Trilobita

Bathyuriscus fimbriatus Robison, 1964. (=*Orria* sp. of Kindle, 1982, Plate 1.2, figure 8)
ptychopariid gen. et sp. undet.

Table 1. Correlation of rock units in the Bay of Islands area. Restricted shelf trilobite zones after Lochman-Balk and Wilson (1958), Palmer (1965), Robison (1976) and Stitt (1971, 1977, 1983). Open shelf agnostoid and polymeroid zones after Öpik (1967), Palmer (1962), Robison (1976, 1988). West Newfoundland platform trilobite zonation is provisional and subject to change: Albertan portion is based on sequence in Canada Bay (Boyce *in* Knight and Boyce, 1987); Dresbachian and Franconian parts based on faunas of the Port au Port Peninsula (Boyce, 1977, unpublished); Trempealeauan and Gasconadian intervals are based on Goose Arm sequence (Boyce *in* Knight and Boyce, 1991). Cow Head trilobite zonation after Fortey *et al.* (1982), Kindle (1982), Ludvigsen *et al.* (1989) and Young and Ludvigsen (1989). The Reluctant Head Formation and the Weasel group have been placed in the same column only to save space. Dashed lines indicate uncertainty

SYSTEM	SERIES	STAGE	TRILOBITE ZONATIONS: RESTRICTED SHELF POLYMEROID ZONES	RESTRICTED SHELF POLYMEROID SUBZONES	OPEN SHELF POLYMEROID ZONES	OPEN SHELF AGNOSTOID ZONES	WEST PLATFORM (COMPOSITE)	NFLD SLOPE (COW HEAD)	ROCK UNITS: WEST NEWFOUNDLAND "AUTOCHTHON"	"PARAUTOCHTHON"	ALLOCHTHON
EARLY ORDOVICIAN	CANADIAN	GASCONADIAN	*SYMPHYSURINA*	*SYMPHYSURINA WOOSTERI*			*HYSTRICURUS MILLARDENSIS*	*SYMPHYSURINA*	WATTS BIGHT FORMATION		LOWER ORDOVICIAN CONGLOMERATE
				SYMPHYSURINA BULBOSA							
				SYMPHYSURINA BREVISPICATA							
			MISSISSQUOIA	*MISSISSQUOIA TYPICALIS*			*MISSISSQUOIA TYPICALIS*	*MISSISSQUOIA TYPICALIS*			
				MISSISSQUOIA DEPRESSA							
LATE CAMBRIAN	CROIXIAN	TREMPEALEAUAN	*SAUKIA*	*EUREKIA APOPSIS*			*PLETHOPELTIS*	*PHYLACTERUS SAYLESI*	BERRY HEAD FORMATION: UPPER MEMBER	WEASEL GROUP	
				SAUKIELLA SEROTINA				*KEITHIA SCHUCHERTI*			
				SAUKIELLA JUNIA							
				RASETTIA MAGNA				*KEITHIA SUBCLAVATA*			
		FRANCONIAN	*SARATOGIA*	*DRUMASPIS TEXANA*			*TAENICEPHALUS*	*ONCHONOTUS RICHARDSONI*	BERRY HEAD FORMATION: MIDDLE MEMBER		
				SARATOGIA LIRAE				*BEOTHUCKIA DUOMENTA*			
			TAENICEPHALUS					*ROKSASPIS TURBINELLA*		UPPER CONGLOMERATE UNIT	
				PARABOLINOIDES							
			ELVINIA	*IRVINGELLA MAJOR*			*CAMARASPIS CONVEXUS*	ZONE 7	BERRY HEAD FORMATION: LOWER MEMBER	MIDDLE SLATE UNIT	
		DRESBACHIAN	*DUNDERBERGIA*				*DUNDERBERGIA*	ZONE 6	PETIT JARDIN FORMATION: UPPER DOLOSTONE MEMBER	LOWER CONGLOMERATE UNIT	COOKS BROOK FORMATION
			PREHOUSIA				*DYTREMACEPHALUS STRICTUS*				
			DICANTHOPYGE								
			APHELASPIS			*GLYPTAGNOSTUS RETICULATUS*					
			CREPICEPHALUS			*GLYPTAGNOSTUS STOLIDOTUS*	*CREPICEPHALUS RIVUS*	ZONE 5			
			CEDARIA			*LEJOPYGE LAEVIGATA*	*WELLERASPIS NEWFOUNDLANDENSIS*		PETIT JARDIN FORMATION: MIDDLE LIMESTONE MEMBER		BRAKES COVE MEMBER
MIDDLE CAMBRIAN	ALBERTAN		*ELDORADIA*		*BOLASPIDELLA*		*ELDORADIA DUNBARI*			RELUCTANT HEAD FORMATION	
			EIHMANIELLA			*PTYCHAGNOSTUS PUNCTUOSUS*	*EIHMANIELLA CLOUDENSIS*	ZONE 4	PETIT JARDIN FORMATION: LOWER DOLOSTONE MEMBER		HALFWAY POINT MEMBER
								ZONE 3			
						PTYCHAGNOSTUS ATAVUS			MARCH POINT FORMATION		
						PTYCHAGNOSTUS GIBBUS					LOWER COOKS BROOK
						PTYCHAGNOSTUS PRAECURRENS	*OLENOIDES LONGISPINUS*				
			GLOSSOPLEURA		*ORYCTOCEPHALUS*	*PERONOPSIS BONNERENSIS*	*POLYPLEURASPIS*	ZONE 2 + *ZACANTHOIDES GILBERTI*	PENUNSULA COVE FORMATION		IRISHTOWN FORMATION
							GLOSSOPLEURA WALCOTTI				
			ALBERTELLA				*PROLIOSTRACUS*				
			PLAGIURA				*ALOKISTOCARE (AMECEPHALUS) CLEORA*				

Bathyuriscus fimbriatus Robison, 1964 ranges from the *Bathyuriscus fimbriatus* Subzone to the *Bolaspidella contracta* Subzone of the *Bolaspidella* Zone in Utah (Robison, 1964, page 512, text-figure 2). Kindle (1982; Plate 1.2, figure 8) illustrated *Orria* sp. (from Zone 3 of the Cow Head Group), which Boyce and Ash consider conspecific with *Bathyuriscus fimbriatus* Robison, 1964.

Bathyuriscus sp. cf. *B. fimbriatus* Robison, 1964 was also collected from a rounded (15 cm) cobble of light blue-grey weathering, dark blue-grey lime mudstone–wackestone (SN 91F022I). Here it should be noted that samples 91F022H and 91F022I were collected from loose blocks of Cooks Brook formation resting on the middle conglomerate layer. However, because these blocks do not have a shaly matrix, they are probably not from that layer. Consequently, their source is either the lower or upper layers. Boyce thinks they fell from the upper layer; Knight (personal communication, 1991) believes they were pushed from the lower layer by ice.

The basal conglomerates of the Halfway Point member contain faunas correlative with the restricted shelf *Ehmaniella* Zone, as well as the open shelf *Ptychagnostus gibbus* (agnostid) Zone and *Bolaspidella* (polymeroid) Zone. Based on their youngest contained faunas, they are of probable *Bolaspidella* Zone (*Bathyuriscus fimbriatus* Subzone) age. Consequently, they are slightly younger than earlier believed.

Trilobites were also collected from three *in situ* horizons near the top of the lower half Halfway Point member ('*Bolaspidella* Zone trilobite fauna' of Figure 4). The thin-bedded, nodular dolomitic lime mudstone yielded the following composite fauna:

Bathyuriscus elegans (Walcott, 1916)
Hemirhodon sp. cf. *H. amplipyge* Robison, 1964
Modocia nuchaspina Robison, 1964

In Utah, *Bathyuriscus elegans* (Walcott, 1916) and *Hemirhodon amplipyge* Robison, 1964 occur in the upper half of the *Bolaspidella contracta* Subzone of the *Bolaspidella* Zone; *Modocia nuchaspina* Robison, 1964 is restricted to the base of the *Bolaspidella contracta* Subzone (Robison, 1964, text-figure 2). The *in situ* fauna of the Halfway Point member, therefore, correlates with that of the *Bolaspidella contracta* Subzone of the *Bolaspidella* Zone, as well as that of Zone 4 of the Cow Head Group (Kindle, 1982); it probably also correlates with that of the upper part of the parautochthonous Reluctant Head Formation (Knight and Boyce, 1991; Boyce *et al., this volume*).

The above fauna was the highest obtained from the Halfway Point member. Consequently, the uppermost strata of the unit may be as young as *Cedaria* Zone.

BRAKES COVE MEMBER

The Brakes Cove member is 12 to 15 m thick; it consists of 0.5- to 2.0-m-thick units of pebble to cobble conglomerate interbedded on a 3 m scale with nodular to ribbon limestone (Botsford, 1988a, page 62).

Fossiliferous boulders were collected from the Brakes Cove member at Brakes Cove, Northern Head and Woman Cove Head in Middle Arm, and at Allans Brook in Penguin Arm.

Cedaria Zone Faunas

For the purposes of this preliminary report, fossil collections characterized by specimens of *Cedaria* **only** are correlated with the *Cedaria* Zone of the early Late Cambrian Dresbachian Stage.

At Northern Head, the following composite fauna was obtained from seven boulders (SN 85F092, 85F094, 85F095, 85F099, 85F101-103):

Brachiopoda–Inarticulata

Gen. et sp. undet.

Trilobita

Balderia sp. cf. *B. aspera* Robison, 1988
?Bonneterrina sp. undet.
Cedaria sp. undet.
Holcacephalus tenerus (Walcott, 1916)
Hypagnostus sp. undet.
Kingstonia sp. undet.
Kormagnostus seclusus (Walcott, 1884)
Tricrepicephalus sp. undet.

At Woman Cove Head, the following composite fauna was obtained from eight boulders (SN 85F106, 85F107, 85F109-85F111, 85F113-85F115):

Trilobita

?Bolaspidella sp. of Kindle (1982)
Cedaria sp. undet.
?Cedaria sp. undet.
Exigua quebecensis (Rasetti, 1946)
Hemirhodon sp. cf. *H.* sp. 1 of Robison (1988)
Hypagnostus sp. undet.
Kormagnostus seclusus (Walcott, 1884)
Onchonotopsis pergibba Rasetti, 1946
Peronopsis tenuis (Illing, 1916)
Syspacheilus sp. undet.
Tricrepicephalus sp. undet.
Welleraspis newfoundlandensis Lochman, 1938
Welleraspis sp. cf. *W.* sp. of Palmer *in* Palmer and Peel, 1981, Plate 6, figures 5-7)

Balderia aspera Robison, 1988, *Cedaria prolifica* Walcott, 1924, *Exigua quebecensis* (Rasetti, 1946), *Hemirhodon* sp. 1 of Robison (1988), *Kormagnostus seclusus* (Walcott, 1884), *Onchonotopsis pergibba* Rasetti, 1946, *Peronopsis tenuis*

(Illing, 1916) and *Welleraspis newfoundlandensis* Lochman, 1938 all occur in *Cedaria* Zone-correlative strata of the Holm Dal Formation in north Greenland (Robison, 1988, pages 26-29).

?Bolaspidella sp. of Kindle (1982) occurs in Boulder 468 of Kindle's (Cow Head Group) Zone 4, which he correlated with the uppermost part of the *Bolaspidella* Zone. *Cedaria prolifica* Walcott, 1924 ranges from the uppermost part of the *Lejopyge laevigata* Zone (*Cedaria* Zone-correlative) to the *Glyptagnostus stolidotus* Zone (*Crepicephalus* Zone-correlative) (Robison, 1988, page 59). *Exigua quebecensis* (Rasetti, 1946), *Holcacephalus* sp. cf. *H. tenerus* (Walcott, 1916) and *Onchonotopsis pergibba* Rasetti, 1946 also occur in Upper Cambrian boulders in the Lévis Formation of Québec (Rasetti, 1946b). *Holcacephalus tenerus* (Walcott, 1916) occurs in both the *Cedaria* Zone and the *Crepicephalus* Zone of Montana (Lochman and Duncan, 1944, page 136).

Robison (1988, page 45) stated that *Kormagnostus seclusus* (Walcott, 1884) is an exceptionally variable and widespread species, which ranges from the lower *Lejopyge laevigata* Zone (*Bolaspidella* Zone-correlative) to the *Glyptagnostus stolidotus* Zone (*Crepicephalus* Zone-correlative).

Peronopsis tenuis (Illing, 1916) ranges from the *Ptychagnostus gibbus* Zone to the *Lejopyge laevigata* Zone (Robison, 1988, page 48). However, the pygidium of *P. tenuis* from the Brakes Cove member displays the secondary median node characteristic of *P. tenuis* of the *Lejopyge laevigata* Zone (latest *Bolaspidella* Zone- to *Cedaria* Zone-correlative).

Welleraspis newfoundlandensis Lochman, 1938 is also found in *Cedaria* Zone-correlative beds in the Petit Jardin Formation of the Port au Port Peninsula, western Newfoundland (Lochman, 1938), and in the middle limestone member of the Petit Jardin Formation in Goose Arm, western Newfoundland (Knight and Boyce, 1991). *Welleraspis* sp. of Palmer *in* Palmer and Peel (1981) occurs in *Cedaria* Zone-correlative strata of the Cass Fjord Formation in north Greenland (Palmer and Peel, 1981, page 17).

Cedaria Zone to *Crepicephalus* Zone Faunas

Faunas characterized by specimens of *Deiracephalus, Holcacephalus tenerus* (Walcott, 1916), *Kingstonia, Kormagnostus seclusus* (Walcott, 1884), *Pemphigaspis* and *Tricrepicephalus* (and lacking either *Cedaria* and *Crepicephalus*) are correlated with a late *Cedaria* to *Crepicephalus* zonal age because these taxa range between the two zones.

At the type section in Brakes Cove, Botsford (1988a) obtained the following fauna from 6 boulders (SN 86F088, 86F091, 86F093, 86F094, 86F096, 86F097):

Trilobita

Deiracephalus sp. undet.
Densonella sp. undet.
Gen. et sp. undet.
Holcacephalus tenerus (Walcott, 1916)
Kingstonia sp. undet.
Kormagnostus seclusus (Walcott, 1884)
?Meteoraspis sp. undet.
Tricrepicephalus sp. undet.

Another boulder (SN 86F099) yielded the following:

Trilobita

Catillicephala sp. undet.
Cedaria sp. cf. *C. brevifrons* Palmer, 1962
Cedaria prolifica Walcott, 1924
Modocia sp. cf. *M. nevadensis* Palmer, 1954
Pemphigaspis bullata Hall, 1863

As stated above, *Cedaria prolifica* Walcott, 1924 ranges from the *Cedaria* Zone to the *Crepicephalus* Zone. *Modocia nevadensis* Palmer, 1954 occurs with *Asaphiscus laeviceps* (Walcott, 1884) in *Bolaspidella* Zone-correlative strata in Nevada (Palmer, 1954). *Pemphigaspis bullata* Hall, 1863 was also formerly known as *Hallaspis matutina* (Hall, 1863)—see Palmer (1951). It occurs in the early Dresbachian *Cedaria* and *Crepicephalus* zones of Minnesota and Wisconsin (Raasch and Lochman, 1943, page 231). *Pemphigaspis bullata* Hall, 1863 also occurs in *Crepicephalus* Zone-correlative strata of the Warrior Formation in Pennsylvania (Tasch, 1951) and the Bonneterre Dolomite of Missouri (Lochman, 1968).

At Seal Cove, one boulder (SN 85F230) yielded the following:

Trilobita

?Bynumina sp.
Deiracephalus sp. undet.
Gen. et sp. undet.
Kingstonia sp. undet.
?Sigmocheilus sp.

At Allans Brook, Penguin Arm, the following was collected from two boulders (SN 86F082, 86F084):

Trilobita

Kingstonia sp. undet.

Crepicephalus Zone Faunas

For the purposes of this preliminary report, any fossil collections containing specimens of *Crepicephalus* are correlated with the *Crepicephalus* Zone of the early Late Cambrian Dresbachian Stage.

At the type section in Brakes Cove, the following composite fauna was obtained from three boulders (SN 86F090, 86F092, 86F095):

Trilobita

Crepicephalus sp. undet.
Holcacephalus tenerus (Walcott, 1916)

Hypagnostus sp. undet.
Kormagnostus seclusus (Walcott, 1884)
Meteoraspis sp. undet.
Pseudagnostus sp. cf. *P. prolongus* (Hall and Whitfield, 1877)
Tricrepicephalus sp. undet.

At Northern Head, the following composite fauna was obtained from twelve boulders (SN 85F089, 85F090, 85F093, 85F096-85F098, 85F100, 85F104, 85F226-85F229):

Trilobita

Blainiopsis sp. cf. *B. holtedahli* Poulsen, 1946
Blountia/Coosella sp. undet.
Bynumina sp. undet.
Cedaria sp. undet.
?Cedaria sp. undet.
Crepicephalus sp. undet.
Coosella/Meteoraspis sp. undet.
?Coosella sp. undet.
?Deiracephalus sp. undet.
?Eldoradia sp. undet.
Gen. et sp. undet.
Holcacephalus tenerus (Walcott, 1916)
Hypagnostus sp. undet.
?Hypagnostus sp. undet.
Kingstonia sp. undet.
Kormagnostus seclusus (Walcott, 1884)
?Modocia sp. undet.
Onchonotopsis sp. cf. *O. occidentalis* Palmer, 1968
Ptychagnostus/Trilobagnostus sp. undet.
Tricrepicephalus sp. undet.
?Welleraspis sp. undet.

In Alaska, *Onchonotopsis occidentalis* Palmer, 1968 occurs with *Lejopyge calva* Robison, 1964 (Palmer, 1968, page B92), a species indicative of a *Lejopyge laevigata* Zone age (latest *Bolaspidella* Zone–to *Cedaria* Zone-correlative–see Table 1).

At Allans Brook, Penguin Arm, Botsford obtained the following from one boulder (SN 86F083):

Trilobita

Bienella sp. cf. *B. problematica* Lochman *in* Lochman and Duncan (1944)

Bienella problematica Lochman *in* Lochman and Duncan, 1944 occurs in the *Crepicephalus* Zone of Montana (Lochman and Duncan, 1944, page 65).

To summarize, the Brakes Cove member contains faunas indicative of the *Cedaria* and *Crepicephalus* zones (early Dresbachian Stage), which are comparable to those of Zone 5 in the allochthonous Cow Head Group (Kindle, 1982). They also correlate with the faunas of the middle limestone and upper dolostone members of the autochthonous Petit Jardin Formation of Goose Arm (Knight and Boyce, 1991) and those of the lower conglomerate unit of the parautochthonous Weasel group (Boyce *et al.*, *this volume*).

UPPER CONGLOMERATE

The 'upper conglomerate' is best exposed at Seal Cove. It is a 30-m-thick-interval dominated by 0.2- to 0.8 m-thick lensoid pebble conglomerate units; these are interbedded with abundant green shale and 1 to 2 m packages of nodular to ribbon limestone (Botsford, 1988a, page 67).

One fossiliferous boulder collected by Botsford (1988a) yielded the following (SN 85F231):

Trilobita

?Dellea sp. undet.
Orygmaspis (Parabolinoides) hebe (Frederickson, 1949)

The above trilobites are indicative of a *Taenicephalus* Zone age (medial Franconian Stage).

LOWER ORDOVICIAN CONGLOMERATE

The 'Lower Ordovician conglomerate' is best exposed immediately east of the tip of Northern Head proper. It is a 2-m-thick unit of ungraded pebble to boulder conglomerate with planar boundaries. The conglomerate occurs within a sequence of parted to ribbon lime grainstones (Botsford, 1988a, page 72).

From one boulder (SN 85F120) at Northern Head, Dr. P.A. Cawood (Memorial University of Newfoundland) obtained for us a pygidium of *Platydiamesus inornatus* (Raymond, 1924). This species is indicative of a *Saukia* Zone age; it is known from the Gorge Formation of Vermont, the Lévis Formation of Québec, and the Shallow Bay Formation (Cow Head Group) of western Newfoundland (Ludvigsen *et al.*, 1989, page 38). In Québec and Vermont (Raymond, 1924, 1937; Rasetti, 1944, 1945, 1946a, 1963; Clark and Shaw, 1968), it is associated with species that also occur in the *Rasettia magna, Saukiella junia, Saukiella serotina* and *Eurekia apopsis* subzones of the *Saukia* Zone in Oklahoma (Stitt, 1977). In western Newfoundland, *Platydiamesus inornatus* (Raymond, 1924) occurs in the *Keithia subclavata* and the *Keithia schucherti* faunas of Ludvigsen *et al.* (1989, pages 9-10).

Four other boulders at Northern Head (SN 85F118, 85F119, 85F121, 85F122) yielded the following composite fauna:

Brachiopoda–Articulata

Apheorthis sp. undet.
?Nanorthis sp. undet.

Trilobita

Ptychopleurites brevifrons (Kobayashi, 1936)
Symphysurina bubops Winston and Nicholls, 1967

Ptychopleurites brevifrons (Kobayashi, 1936) occurs in the *Mississquoia depressa* Subzone of the *Mississquoia* Zone in Oklahoma (Stitt, 1977; Miller *et al.*, 1982, text-figure 4). It also occurs in the *Mississquoia depressa* Subzone of the *Parabolinella* Zone in the District of Mackenzie (Ludvigsen, 1982a, b).

In Oklahoma, central Texas and Utah, *Symphysurina bubops* Winston and Nicholls, 1967 is restricted to the *Symphysurina brevispicata* Subzone of the *Symphysurina Zone* (Stitt, 1977; Miller *et al.*, 1982, text-figures 4, 7, 8).

Based on the youngest contained fauna, the age of the 'Lower Ordovician conglomerate' is most likely *Symphysurina* Zone (*Symphysurina brevispicata* Subzone)–Canadian Series, Gasconadian Stage. Consequently, it correlates with the uppermost part of the autochthonous Berry Head Formation (Port au Port Group), and at least the basal portion of the Watts Bight Formation (St. George Group) exposed along Goose Arm (Knight and Boyce, 1991, page 146, Figure 3). This fauna probably also correlates with those of the *Symphysurina* conglomerates of the Cow Head Group, exposed at Broom Point (Fortey *et al.*, 1982).

SUMMARY

Trilobite species indicate that the Cooks Brook formation ranges in age from the late Middle Cambrian *Ptychagnostus gibbus* Zone to the Early Ordovician *Symphysurina* Zone. The Cooks Brook formation, therefore, correlates with Beds 0 to 8 of the allochthonous Cow Head Group (James and Stevens, 1986). It also broadly correlates with the autochthonous March Point, Petit Jardin and Berry Head formations (Port Au Port Group) and the Watts Bight Formation (St. George Group). The Halfway Point member contains *in situ* and redeposited trilobite faunas indicative of the late Middle Cambrian *Ptychagnostus gibbus* and *Bolaspidella* zones (=*Ehmaniella* Zone of restricted biofacies). The Brakes Cove member contains redeposited faunas indicative of the early Late Cambrian *Cedaria* and *Crepicephalus* zones. The 'Upper Conglomerate' contains a redeposited fauna indicative of the medial Late Cambrian *Taenicephalus* Zone. The Bear Cove conglomerate of Kindle and Whittington (1965) contains redeposited faunas that range from the early Late Cambrian *Dunderbergia* Zone to the medial Late Cambrian *Taenicephalus* Zone. Based on the youngest contained fauna, the probable age of this conglomerate is *Taenicephalus* Zone, identical to that of the 'upper conglomerate'. The Serpentine River strata of Kindle and Whittington (1965) contain an *in situ* fauna indicative of the *Saukiella junia* or *Saukiella serotina* Subzone of the latest Cambrian *Saukia* Zone. The 2-m-thick 'Lower Ordovician' conglomerate contains redeposited faunas that range in age from the *Rasettia magna* Subzone of the latest Cambrian *Saukia* Zone to the *Symphysurina brevispicata* Subzone of the earliest Ordovician *Symphysurina* Zone. Based on the youngest contained fauna, this conglomerate is probably *Symphysurina* Zone (*Symphysurina brevispicata* Subzone) in age.

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