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THE WEASEL GROUP, GOOSE ARM AREA, WESTERN NEWFOUNDLAND: LITHOSTRATIGRAPHY, BIOSTRATIGRAPHY, CORRELATION AND IMPLICATIONS

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ABSTRACT

The Weasel group is a predominantly upright but allochthonous 300-m-thick sequence of suspension-deposited and resedimented carbonates and slates, which occurs immediately below the base of the Humber Arm Allochthon. Rocks are dominated by thick carbonate conglomerates and by fine-grained slightly calcareous siliciclastics (argillites and shales) that are now slates. Also present are lesser nodular and ribbon-bedded dolomitic and shaly limestone and oolitic grainstone. The succession is divided into four parts: a basal, poorly exposed interval of ribbon limestone and slate associated with minor conglomerate and a few possible slump beds; a lower carbonate conglomerate unit of Dresbachian age; a middle slate unit associated with minor fine-grained and rare conglomeratic and grainy carbonate of Franconian age; and an upper carbonate conglomerate unit of Late Cambrian to Ordovician age. The Late Cambrian conglomerates are dolomitized and rich in quartz sand.

The slates, ribbon limestones and conglomerates in the lower part of the formation are lithologically very like the older and also allochthonous Reluctant Head Formation of the Old Mans Pond area. However, they bear no true resemblance to deep-water coeval deposits of the Cow Head Group and the Cooks Brook formation of the Humber Arm Allochthon.

Approximately forty fossiliferous samples from the lower 100 m of the Weasel group have yielded three distinct and previously unrecorded trilobite and inarticulate brachiopod faunas. These redeposited and in-situ *faunas are indicative of the Late Cambrian* Crepicephalus, Dunderbergia *and* Elvinia *zones and show that the base of the formation is younger (early Late Cambrian,* Crepicephalus *Zone) than the top of the Reluctant Head Formation, which is of late Middle Cambrian* Bolaspidella *Zone age.*

The carbonate deposits of the Weasel group are interpreted as resedimented gravity-flow and storm-generated suspension deposits laid down on a distally steepened ramp and toe of slope setting during the Late Cambrian and Ordovician. Most of the clasts in the conglomerates are slope-derived carbonate muds. However, some skeletal and intraclastic grainstone–packstone clasts that compare to rock types logged at the top of the Reluctant Head Formation immediately below true shelf carbonates indicate a shallow water, carbonate sand shoal complex higher on the ramp.

The Weasel group and Reluctant Head Formation probably formed part of a common margin that is believed to have evolved from a prograding ramp during the Middle to early Late Cambrian to a distally steepened ramp and perhaps a true accretionary rimmed shelf during the latest Cambrian and throughout the Ordovician. The shale-dominated interval with Elvinia *fauna suggests that there was a marked sea-level rise during the Franconian Stage, followed by renewed shelf progradation in the Trempealeauan Stage. The pervasive dolomitization and quartz-sand content of the conglomerates at this time fits with geological characteristics of coeval rocks in the Cow Head Group and shelf carbonates preserved in western Newfoundland and is possibly linked to this renewed accretion.*

INTRODUCTION

At the southern edge of the Lomond (NTS 12H/5) map area (Figure 1), Nyman *et al.* (1984, pages 158-159, Figure 23.1) and later, Williams and Cawood (1989) documented a previously unrecognized sequence of thin-bedded grey limestone and buff shale, dark-grey shale and limestone (with local limestone breccia), and limestone conglomerate having a sandy limestone matrix. This sequence, informally named the Weasel group, was interpreted to occupy a separate structural slice -- the 'Weasel slice' -- at the base of the Humber Arm Allochthon (Figure 2) (Nyman *et al.*, 1984, page 161). The group is best exposed along a number of

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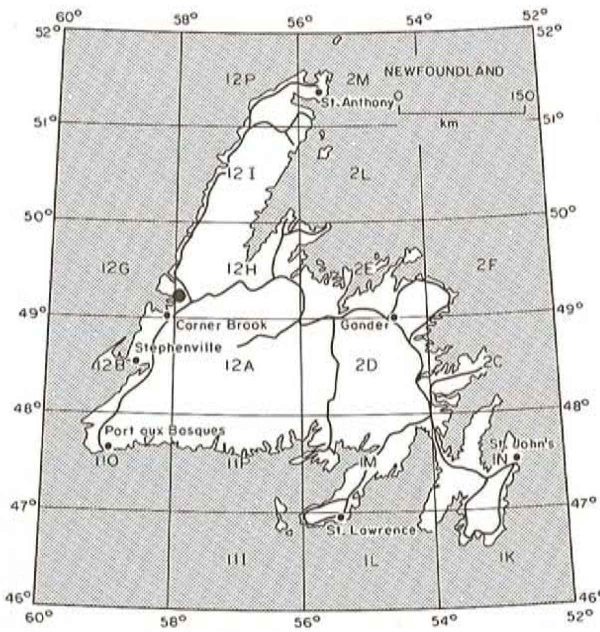


Figure 1. *Location of study area in Newfoundland.*

logging roads that occur just north of Goose Arm Brook North. Beds for the most part strike west and dip moderately to the north, but in the southern part of the slice, the group is folded and faulted. The 'Weasel slice' structurally overlies Ordovician flysch of the Goose Tickle group including limestone conglomerate of the Daniel's Harbour member (Stenzel *et al.*, 1990). These rocks form part of a thrust slice of lower Paleozoic shelf carbonates. The 'Weasel slice' is overlain structurally by dark grey, shaly melange at the base of the Humber Arm Allochthon. Based upon the sedimentary rock characteristics of the Weasel group described below and on the structural position of the 'Weasel slice', the latter is here considered to be part of the structurally disrupted and foreshortened autochthon rather than the Humber Arm Allochthon.

Botsford (1988, page 90) was the first to collect macrofossils from the Weasel group; he reported brachiopods of possible Ordovician age. During 1991, the authors discovered additional macrofossils in the unit. Boyce and Ash obtained forty-one collections from the section; the stratigraphic locations of each were subsequently determined by Knight, who measured a detailed lithostratigraphic section (Figure 3). Conodonts of Middle Ordovician age have been recovered from the conglomerates at the top of the formation (P. Cawood and F. O'Brien, personal communications, 1991).

LITHOSTRATIGRAPHY

The stratigraphy of the Weasel group is incompletely understood because of covered intervals and structural complications affecting the road section. The western end of the section in particular is folded, and it is difficult to be sure of the younging direction of beds. It is likely, however, that at least some of this part of the section lies stratigraphically below the section illustrated in Figure 3. Fossils from some conglomerates in this interval indicate that they correlate with the conglomerates at the base of the measured section.

The poorly exposed and deformed basal unit of dominantly ribbon limestone and phyllite is interbedded with some slump beds and a few limestone conglomerates, 0.05 to 1.0 m thick. The ribbon limestones (Plate 1) are planar thin-bedded and laminated, dark blue-grey with yellow- to orange-weathering, dolomitic, thin beds and phyllitic interbeds and partings. These rock types also make up the slump beds. The conglomerate consists of platy- and chip-shaped clasts set in a phyllitic carbonate matrix. However, one conglomerate contained well-rounded, medium- to coarse-grained quartz sand. The ribbon limestone and associated rock types of this interval compare well with the rocks of the Reluctant Head Formation (Knight and Boyce, 1991).

Overlying this interval of unknown thickness, the succession (Figure 3) consists of a 44 m section dominated by thick limestone conglomerate and interbeds of slate, nodular dolomitic argillite and rare ribbon limestone upward (lower conglomerate unit). Clasts (Plate 2) in these conglomerates are dominantly cm-scale plates of lime mudstone, but there are also some larger, rounded clasts up to 40 by 10 cm in size of skeletal–intraclastic grainstone, intraclastic grainstone, oolitic grainstone and intraclastic dolostone. Trilobites are present in many of these clasts. The conglomerates are dominantly clast-supported within a minor matrix comprising dolomitic fine-grained limestone. Conglomerates dominate sections up to 18 m in thickness, but the presence of 1 to 8 cm interbeds of laminated lime mudstone, locally cut out by erosion, indicates that the conglomerates are amalgamated, with beds ranging from 1 to 5 m in thickness. Fine-grained interbeds are generally poorly exposed but comprise 1 to 11 m of dark-grey slates, dolomitic argillite with calcareous nodules, and thin-bedded calcareous and dolomitic phyllite.

Olive-brown-weathering, dark-grey calcareous argillite and grey slate dominate the next 50 m (middle slate unit). These rocks may also underlie a 50-m covered interval that separates the fine-grained siliciclastics from the next overlying conglomerate unit. The slates and argillites are characterized by thin bedding and some calcareous and dolomitic laminae, and locally have a slurry-like appearance associated with small folds, suggesting slumping. The thin beds in the argillite are arranged in limestone–shale and siltstone–shale couplets suggesting, at least in the latter, that they are graded beds. Locally, the argillites are interbedded with centimetre- to decametre-scale intervals of limestone nodules and dolomitic ribbon limestone (Plate 3). Micro-load casts occur at the base of some of the ribbon limestone beds. Rare lenses of small pebble, limestone conglomerate, 3 cm thick and 10 cm wide, also occur.

At the top of this interval, there are two couplets, 1.2 and 3.3 m thick respectively, of oolitic grainstone, which are

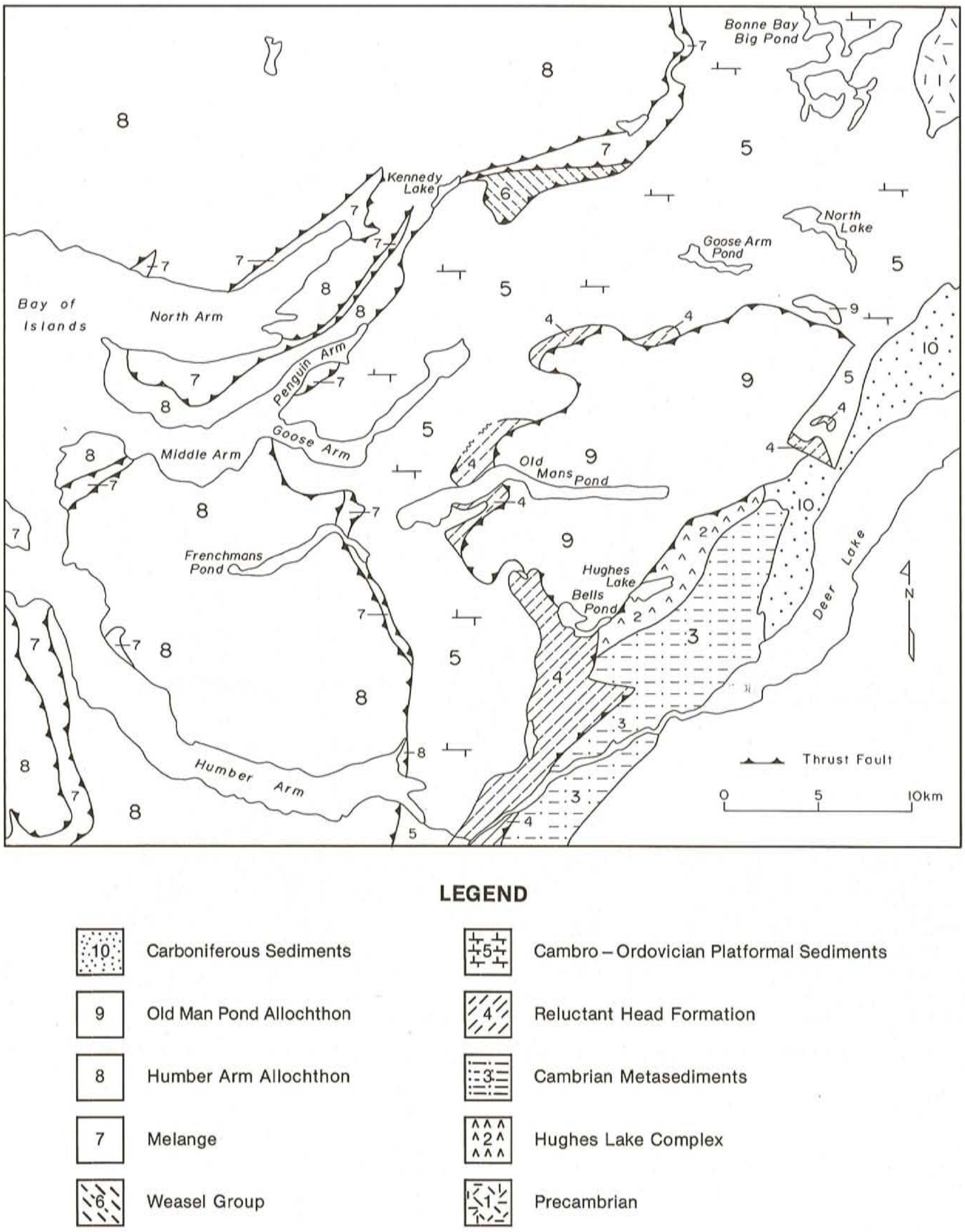
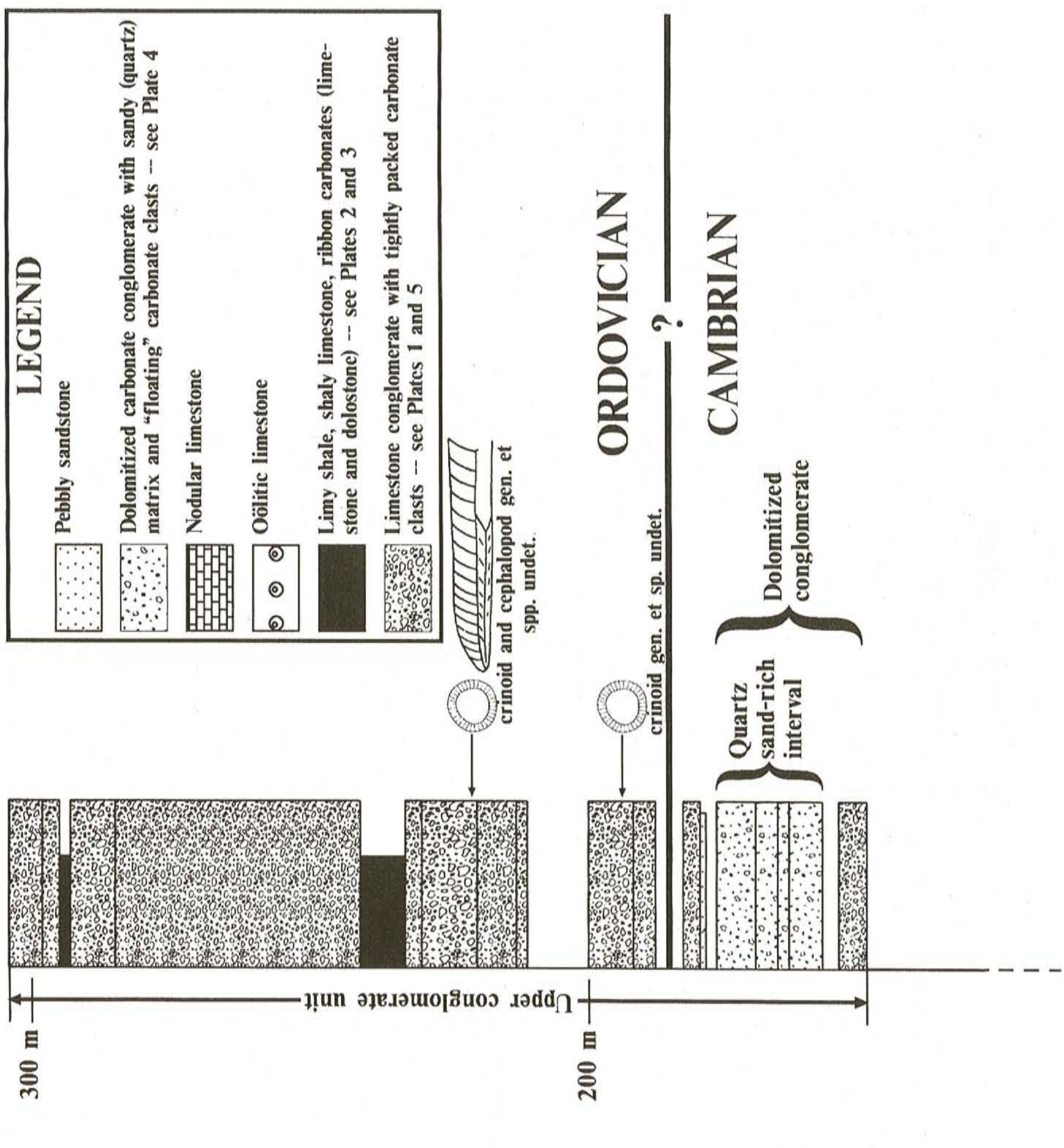


Figure 2. *Simplified geology of the Goose Arm–Humber Arm area showing the location of the study area (after Williams and Cawood, 1989).*


LEGEND
Pebbly sandstone
Dolomitized carbonate conglomerate with sandy (quartz) matrix and "floating" carbonate clasts -- see Plate 4
Nodular limestone
Oölitic limestone
Limy shale, shaly limestone, ribbon carbonates (limestone and dolostone) -- see Plates 2 and 3
Limestone conglomerate with tightly packed carbonate clasts -- see Plates 1 and 5
crinoid and cephalopod gen. et spp. undet.
crinoid gen. et sp. undet.
ORDOVICIAN
?
CAMBRIAN
Quartz sand-rich interval
Dolomitized conglomerate
Upper conglomerate unit
300 m
200 m

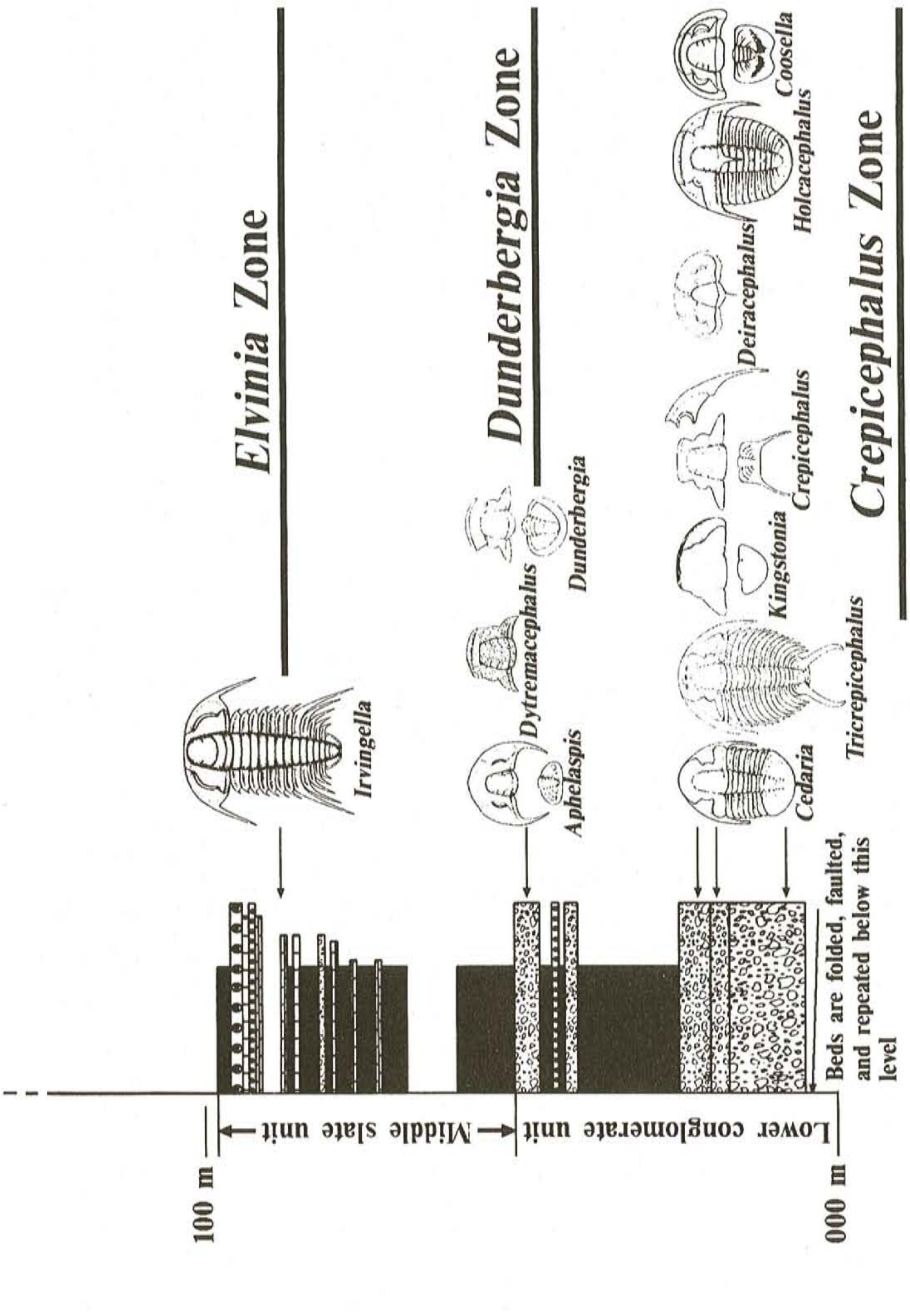


Figure 3. *Stratigraphy section through the Weasel group showing locations of fossil collections, and characteristic taxa. Trilobite reconstructions are after Moore (1959), except for* Irvingella, *which is after Rushton (1967); cephalopod and crinoid cartoons are after Flower (1976) and Sprinkle in Sprinkle and Kier (1987).*

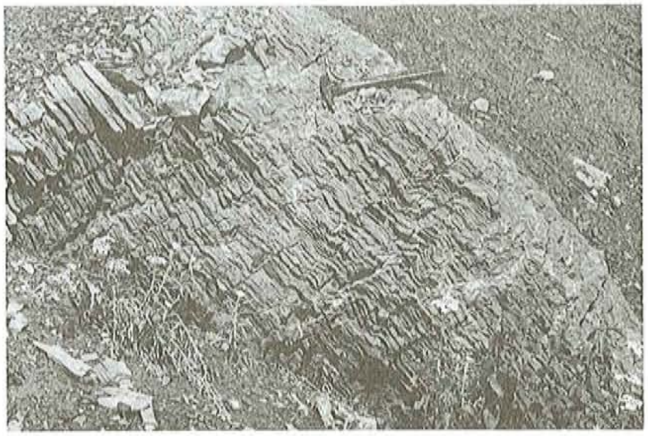


Plate 1. *Dolomitic ribbon limestones of the Weasel group; these are comparable to similar lithofacies in the Reluctant Head Formation.*

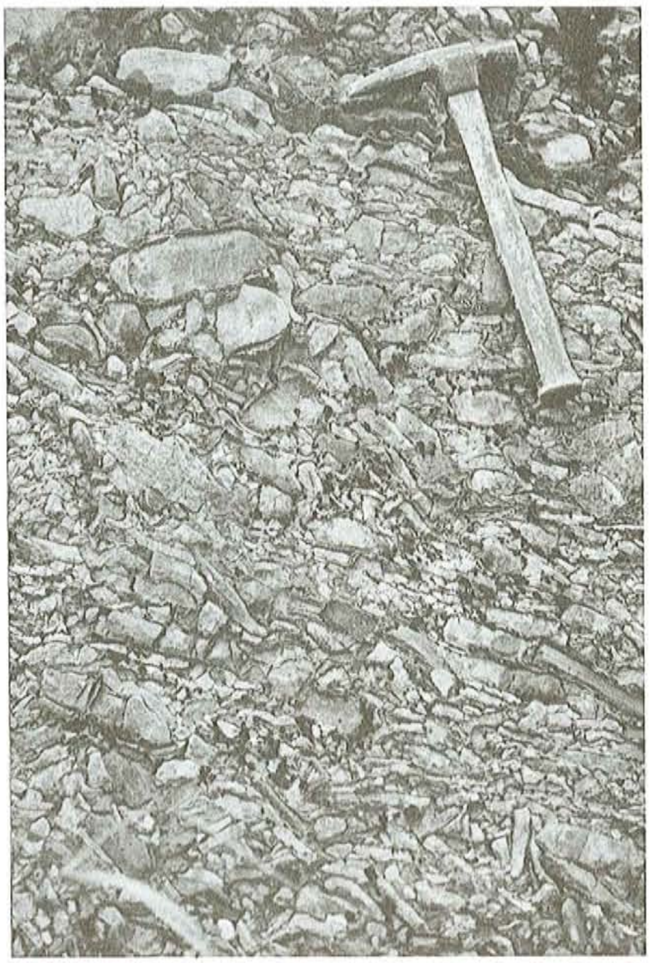


Plate 2. *Limestone conglomerate near the base of the Weasel group, showing tightly packed, platy clasts of lime mudstone; lamination is visible locally in the clasts.*

overlain by intraclastic, limestone conglomerates that are separated by a 40 cm bed of argillite. The oolitic grainstone beds are 60 cm thick and consist of fine- to medium-grained

Plate 3. *Planar thin-bedded, finely laminated, dark-grey calcareous argillite and shaly, dolomitic limestone below* Irvingella *locality.*

ooids, mixed in the upper bed with intraclastic lime sand-grains. The overlying conglomerates, which are 0.6 and 2.7 m thick respectively, are matrix-supported grading up into clast-supported in the higher bed. Oolitic and intraclastic sand occurs in the matrix. Clasts are dominantly platy lime mudstone having some oolitic and intraclastic grainstone clasts.

The top 150 m of the group is dominated by a clast-supported carbonate conglomerate (upper conglomerate unit). This unit is subdivided into three parts. In the first 33 m, the conglomerates are all dolomitized and include a middle interval, 18 m thick, rich in quartz sand. These dolomitized conglomerates pass upward into a succession of limestone conglomerates. At 83 m from the base of the unit, 8 m of shaly argillite and calcareous argillite interrupts the succession of limestone conglomerate.

The dolomitized conglomerate comprises buff-weathering, pale grey to grey, fine-grained dolomite and is arranged in unsorted and normally graded beds, 1 to 3 m thick. Clasts in the conglomerate are generally flat plates of buff-weathering, fine-grained dolomite to dark grey to black, grainy dolomite. Many clasts display lamination. In the middle of the section, the conglomerate matrix consists of abundant quartz sand (Plate 4), which also forms beds up to 20 cm thick of massive and crossbedded quartz arenite that gradationally cap some conglomerate beds. The quartz sand is well rounded, either fine grained or medium to coarse grained in different beds and diminishes in quantity upward in the section.

Conglomerates in the remaining part of the upper section are all limestone. They consist of metre-thick, welded beds that are poorly sorted, clast-supported, ungraded to normally graded (Plate 5). Pebbles are dominantly of centimetre-size plates of lime mudstone and fewer but larger (10 to 40 cm) rounded clasts of grainstone and packstone. The grainy clasts are commonly intraclastic and skeletal and include trilobite, cephalopod, gastropod, crinoid and possibly some sponge fragments. Rare dolostone clasts also occur.

Plate 4. *Closeup of dolomitized carbonate conglomerate showing sandy matrix of rounded quartz grains, with 'floating' carbonate clasts.*

Plate 5. *Welded, Ordovician limestone conglomerate from the upper conglomerate unit. Large rounded grainstone clasts overlie a layer of small chips and plates of laminated lime mudstone and rare dolostone.*

BIOSTRATIGRAPHY

Trilobites were collected from several rounded, skeletal–intraclastic grainstone clasts in a number of limestone conglomerate beds in the lower conglomerate unit of the measured section and loose blocks along the measured section (Figure 3), as well as from the structurally underlying deformed section. Four clasts in the limestone conglomerates of the basal 20 metres of the section yielded a *Crepicephalus* Zone fauna comparable to a fauna collected from conglomerate clasts in the structurally underlying deformed section and from some loose blocks along the measured section. A younger fauna, suggestive of the *Dunderburgia* Zone, was collected from a conglomerate at the top of the lower conglomerate unit. One trilobite horizon having an *Elvinia* Zone fauna was located in the overlying middle slate unit. Identifiable fossils were not recovered from the upper conglomerate unit, although cross-sections of trilobites and other organisms are visible in weathered, glacially scoured outcrops.

LOWER CONGLOMERATE UNIT

The lower conglomerate unit consists of a basal subunit comprised of three beds and an upper subunit of interbedded argillite and conglomerate. Two clasts from the basal limestone conglomerate bed (12 m thick) yielded the following composite fauna:

Brachiopoda-Inarticulata

Gen. et sp. undet.

Trilobita

?*Cheilocephalus* sp. undet.
Crepicephalus sp. undet.
Grandagnostus/Hypagnostus sp. undet.
Kingstonia sp. undet.

One clast from a large dislodged block of the overlying 3-m-limestone conglomerate bed provided the following taxa:

Brachiopoda-Inarticulata

Gen. et sp. undet.

Trilobita

Crepicephalus sp. undet.
Deiracephalus sp. cf. *D. unicornis* Palmer, 1962
Holcacephalus sp. undet.
Kingstonia sp. undet.

One clast in the upper (5 m) limestone conglomerate bed yielded the trilobite *Tricrepicephalus* sp. undet.

In Alabama, *Deiracephalus unicornis* Palmer, 1962 occurs with the *Crepicephalus* Zone-correlative species *Glyptagnostus stolidotus* Öpik, 1961 in the Conasauga Formation (Palmer, 1962, page F-4, Figure 4). *Deiracephalus unicornis* Palmer, 1962 also occurs in the Cow Head Group of western Newfoundland (Palmer, 1962, page F-31; Kindle, 1982; Plate 1.3, Figure 11), in boulders collected from Zone 5 of Kindle (1982), i.e., *Cedaria* to *Crepicephalus* Zone (Table 1).

The above taxa indicate a correlation with Zone 5 of Kindle (1982), i.e., *Cedaria* to *Crepicephalus* Zone. However, based on the youngest fauna collected from these beds, the basal 20 m of the lower limestone conglomerate unit is of probable early Late Cambrian *Crepicephalus* Zone age (early Dresbachian Stage).

Structurally below the measured section, six clasts from folded and faulted conglomerates yielded well-preserved fossils of which five gave the following composite fauna:

Brachiopoda-Inarticulata

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

Trilobita

agnostid gen. et sp. undet.
Cedaria sp. undet.
Coosella sp. undet.
Crepicephalus sp. undet.
Deiracephalus sp. undet.
Gen. et sp. undet.
Kingstonia sp. undet.
Tricrepicephalus murphyi Kindle, 1948
Tricrepicephalus sp. undet.

Tricrepicephalus murphyi Kindle, 1948 is also known from the Murphy Creek Formation of the Gaspé Peninsula, Québec (Kindle, 1948).

The above taxa are strongly indicative of a *Crepicephalus* Zone age. Consequently, the deformed limestone conglomerate beds are probably equivalent to the basal conglomerate unit of the measured section.

The structurally lowest limestone conglomerate in the deformed section yielded one collection containing as yet unidentified inarticulate brachiopods and agnostid and ptychopariid trilobites with possible Middle Cambrian affinity.

Clasts from a 4-m-thick conglomerate bed at the top of the lower conglomerate unit yielded a younger trilobite fauna including the following composite fauna:

Brachiopoda-Inarticulata

Gen. et sp. undet.

Trilobita

Aphelaspis spp. undet.
Dunderbergia spp. undet.
Dytremacephalus sp. undet.
Gen. et sp. undet.
?Glyptagnostus sp. undet.
Hardyoides sp. undet.
Parahousia sp. cf. *P. subequalis* Palmer, 1965
Pseudagnostus communis (Hall and Whitfield, 1877)
ptychopariid gen. et sp. undet.
?Simulolenus sp. undet.

Parahousia subequalis Palmer, 1965 occurs in the *Dunderbergia* Zone of Nevada (Palmer, 1965, page 67). According to Shergold (1977, page 83), *Pseudagnostus communis* (Hall and Whitfield, 1877) ranges from the *Aphelaspis* Zone (late Dresbachian Stage) to the *Saukia* Zone (Trempealeauan Stage).

The above taxa indicate a correlation with Zone 6 of Kindle (1982), i.e., *Aphelaspis* to *Dunderbergia* Zone. Of the above taxa, the most common are *Aphelaspis, Dunderbergia* and *Dytremacephalus.* Based on the youngest contained fauna, this conglomerate is of probable Late Cambrian *Dunderbergia* Zone age (late Dresbachian Stage).

One grainstone cobble, probably from bedrock yielded the following:

Trilobita

agnostid gen. et sp. undet.
Blountia sp. undet.
Carinamala sp. undet.
Coosella sp. undet.
Coosia sp. undet.
Kingstonia sp. undet.
Komaspidella–Maryvillia sp. undet.

Another yielded the following:

Brachiopoda-Inarticulata

Gen. et sp. undet.

Trilobita

Blountia sp. undet.
?Meteoraspis sp. undet.
?Terranovella sp. undet.

The above two collections correlate with the older *Cedaria* to *Crepicephalus* Zone faunas of the lower 20-m-thick conglomeratic interval.

The trilobite fauna recovered from the lower conglomerate unit is predominantly an open-shelf type.

MIDDLE SLATE UNIT

Approximately 38 m above the base of the unit, loose weathered slabs of cleaved, dark-grey calcareous argillite and shaly limestone (derived from the immediately underlying outcrop) yielded the following:

Trilobita

Irvingella sp. cf. *I. major* Ulrich and Resser *in* Walcott, 1925—including cranidia, librigenae, thoraxes, pygidia, nearly complete specimen
pterocephaliid? sp. undet. -- complete specimen

Although trilobites are extremely rare at this locality, several complete and nearly complete specimens were found. The *Irvingella* material is particularly significant because, despite the fact that it is a cosmopolitan genus, the only other species of *Irvingella* known from complete material is *Irvingella nuneatonensis* (Sharman, 1886)—see Rushton (1967, Plate 52). The presence of *Irvingella* sp. cf. *I. major* Ulrich and Resser *in* Walcott, 1925 indicates a correlation with the uppermost part of the *Elvinia* Zone and Zone 7 of Kindle (1982).

UPPER CONGLOMERATE UNIT

Conglomerates of probably Cambrian age in the upper unit are dolomitic and unfossiliferous. Overlying limestone conglomerates yielded few fossils although at 194 m above the base of the section, two clasts contained crinoid remains, and slightly higher clasts contained an unidentified porifera. The highest collection was obtained 221 m above the base of the section. Here, large boulders in dolomitic limestone conglomerate yielded cross-sections of a large, straight cephalopod and crinoid debris.

The porifera and the large cephalopod suggest that the upper limestone conglomerate unit is of Ordovician rather than Cambrian age. This is confirmed by a conodont fauna identified from a sample obtained by Dr. P.A. Cawood from the upper part of the Weasel group and identified by F. O'Brien (personal communication, 1991). It included the following conodont species:

Ansella jemtlandica (Löfgren, 1978)
Periodon aculeatus (Hadding, 1913)
Scolopodus oldstockensis Stouge, 1984

This assemblage is a Middle Ordovician late Whiterock type, which is also present in the upper part of the autochthonous Table Head Group of western Newfoundland (F. O'Brien, personal communication, 1991; see also Stouge, 1984, page 19, Figure 18).

COMPARISON WITH THE RELUCTANT HEAD FORMATION

The Reluctant Head Formation is an enigmatic unit comprising thin interbedded ribbon limestone and dolostone as well as limestone breccia/conglomerate. It may be as thick as 250 m and is distributed extensively in the eastern part of the Pasadena (NTS 12H/4) and Lomond (NTS 12H/5) map sheets, and extends down to the Humber River gorge (Gillespie, 1983; Williams *et al.*, 1982; Knight and Boyce, 1991; Knight, unpublished data; Waldron and Milne, 1991). In 1991, four new fossiliferous horizons were discovered within the unit. In addition, five of the sixteen 1990 localities (Knight and Boyce, 1991) were re-investigated. The following species have been identified:

Trilobita

Asaphiscus sp. cf. *A. wheeleri* Meek, 1873
Hemirhodon convexifrons Rasetti, 1948
Kormagnostus seclusus (Walcott, 1884)

The above fauna is dominated by pygidia of *Hemirhodon convexifrons* Rasetti, 1948, ranging in size from a couple of millimetres to at least 5 cm.

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

Hemirhodon convexifrons Rasetti, 1948 was originally described from latest Middle Cambrian boulders in the Lévis Formation conglomerates of Québec (Rasetti, 1948, page 318, Table 2). A possibly related species, *Hemirhodon amplipyge* Robison, 1964, occurs in the *Bolaspidella contracta* Subzone of the *Bolaspidella* Zone (Robison, 1964, page 512, Text-figure 2) in Utah. Other species of *Hemirhodon* include the following:

Hemirhodon emarginatus Rasetti, 1946
Hemirhodon schucherti Raymond, 1937
Hemirhodon simplex Rasetti, 1946
Hemirhodon sp. of Kindle (1982; Plate 1.2, figure 18)
Hemirhodon spp. of Palmer (1968, page B45; Plate 6, figures 5-7)
Hemirhodon sp. 1 of Robison (1988, page 95; Figure 16, 1-7)
Hemirhodon vermontensis (Howell, 1937)

Of the above species, *Hemirhodon* sp. of Kindle (1982) and *Hemirhodon* spp. of Palmer (1968) occur in *Bolaspidella* Zone-correlative rocks. The remainder occur in (early Dresbachian) *Cedaria* Zone-correlative strata.

Kormagnostus seclusus (Walcott, 1884) ranges from the lower *Lejopyge laevigata* Zone (*Bolaspidella* Zone-correlative) to the *Glyptagnostus stolidotus* Zone (*Crepicephalus* Zone-correlative) (Robison, 1988, page 45).

The above taxa suggest that the top of the Reluctant Head Formation was deposited entirely within the late Middle Cambrian *Bolaspidella Zone.* Consequently, it is probably a lateral equivalent of the lower dolostone member of the Petit Jardin Formation exposed in Goose Arm. The top of the Reluctant Head Formation is thus older than the base of the Weasel group.

INTERPRETATION OF THE WEASEL GROUP

The lithofacies in the Weasel group consist of resedimented and suspension-deposited carbonates and siliciclastic mudstones. Phyllites and ribbon limestones associated with some slump beds and rare, thin lenticular limestone conglomerate, form the lowest beds in the section. The very fine grain-size and planar lamination and thin bedding suggest quiet, dominantly suspension-deposition below wave base with only minor gravity-induced instability and resedimentation. The carbonate mud was probably placed in suspension by storms stirring the bottom in the shallower parts of the ramp and shelf (see Markello and Read, 1981). This suggests that these rocks were laid down on the distal ramp slope as interpreted for similar lithofacies of the Reluctant Head Formation at Old Mans Pond to the south (Knight and Boyce, 1991).

The succeeding massive conglomerates of the lower and upper conglomerate units were probably deposited by debris flows generated at the top of the slope. This is suggested by the dominance of platy fine-grained limestones derived from the slope itself and by the presence of lesser amounts of intraclastic and skeletal grainstone clasts. The latter are similar to lithofacies in the uppermost beds of the Reluctant Head Formation that are interpreted as deposits of higher energy, shallow-water settings including a carbonate sand shoal (Knight and Boyce, 1991). The association of the debris flows with siliciclastic muds and rare calcareous beds suggests that they bypassed the lower slope and came to rest at a toe of slope–basinal setting. This, and the types of the clasts, suggest a distally steepened ramp (Tucker and Wright, 1990); this interpretation is further strengthened by the absence of clasts of true shallow-water shelf origin or clasts derived from a rim barrier, as is seen in coeval deposits of the Cow Head Group and Cooks Brook formation (James, 1981; James and Stevens, 1986; Botsford, 1988). The fossils in the lowest conglomerates indicate that they were deposited during the early and late Dresbachian *Crepicephalus* and *Dunderburgia* zones.

Predominance of siliciclastic muds with very scarce fine-grained carbonate nodules and laminae suggest that the middle slate unit was deposited in a deepwater basinal setting. Thin-bedded couplets of siltstone–shale and carbonate–shale suggest that dilute turbidites and storms may have transported fine terrigenous sediment to the basin. The calcareous laminae probably record storms that stirred up carbonate shelf mud. The trilobites at the top of the unit date the deposition of the slates as *Elvinia* Zone. A few resedimented oolitic grainstone and limestone conglomerate beds suggest renewed progradation of the shelf post-*Elvinia* Zone.

The quartz sand-rich, dolomitized conglomerates at the base of the upper conglomerate section are also probably Late Cambrian in age. Rounded quartz sand occurs in dolostones of the upper dolostone member of the Petit Jardin Formation throughout western Newfoundland (Chow, 1986; Knight, 1991; Knight and Boyce, 1991; Knight and Cawood, 1991) and is also abundant in the middle of the Tuckers Cove member of the Shallow Bay formation, Cow Head Group (James and Stevens, 1986) and the Cooks Brook formation (Botsford, 1988). James and Stevens (1986) indicate that the quartz sand reached the slope in the late Franconian to Trempealeauan. The well-rounded grains are believed to be eolian in origin and reached the deepwater by largely bypassing the shelf during sea level low-stand (Coniglio, 1985; Chow, 1986; James and Stevens, 1986).

Limestone conglomerates of the upper unit of the Weasel group revert to amalgamated, massive debris flows with insignificant fines but interbedded with dark siliciclastic shales. Dominantly lime mudstone clasts and lesser grainstone clasts rich in crinoid debris suggest the flows were generated at the upper slope and deposited at the toe of slope. Conodonts indicate that this steepened margin persisted into the Middle Ordovician.

The Reluctant Head Formation and Weasel group are preserved in two separate thrust slices but contain lithofacies of similar aspect, although different ages. This suggests that the parts of the Cambrian shelf margin from which they were structurally transported was a prograding ramp through the late Middle Cambrian (*Bolaspidella* Zone) and the early Late Cambrian (Dresbachian Stage). However, whereas the Reluctant Head Formation grades upward into peritidal shelf dolostones through a sequence of crossbedded carbonate sands (Knight and Boyce, 1991), the Weasel group is completely deepwater in origin. The predominance of conglomerates in the Weasel group suggests that the ramp at least evolved into a distally steepened type by the early Late Cambrian and continued as such throughout the Early and Middle Ordovician. The domination, through the Late Cambrian and Ordovician, of thick limestone conglomerates of very similar character to those in the Dresbachian indicates that the margin did not change significantly during the Lower and Middle Ordovician. If this is true, the Ordovician part of the Weasel group was also deposited upon a distally steepened ramp. In addition, since the Weasel group is all deepwater, the Weasel thrust slice must have originated farther basinward than the Old Mans Pond slice (Knight and Boyce, 1991) and associated thrust slices (e.g., 'Pye's ridge', see Knight, *this volume*) that carried Reluctant Head Formation and overlying shelf carbonates to their present position in the Humber tectonostratigraphic zone.

The deposition of basinal siliciclastic muds above the lower conglomerate unit suggests sea level rise drowned the margin during the early Franconian *Elvinia* Zone. The return of thick debris flows, rich in quartz sand, points to renewed shelf progradation by the end of the Franconian. The pervasive dolomitization and quartz-sand content of the conglomerates at this time seems to fit chronostratigraphically with coeval rocks of the periplatformal Cow Head Group and Cooks Brook formation. Quartz sand is abundant in the middle of the Tuckers Cove member, Shallow Bay formation, Cow Head Group and in a calcarenite interval in the Cooks Brook formation at Northern Head (James and Stevens, 1986; Botsford, 1988; personal communication, 1991). The sand reached the slope setting during the late Franconian to early Trempealeauan.

Quartz sand is also widespread but not especially abundant in peritidal shelf carbonates of the upper part of the Petit Jardin Formation, which is also pervasively dolomitized. The very fine-grained dolostones retain original sedimentary structures indicative of essentially synsedimentary dolomitization (Haywick, 1985). Since coeval dolostones also occur in the Old Mans Pond and associated thrust slices of the Pasadena and adjoining map areas, this suggests that dolomitization extended out to the shelf edge during this period. This begs the question, was the sandy carbonate conglomerate of the Weasel group dolomitized at this same time? If it was, progradation of the margin must be linked to relative sea level fall.

The conclusion that the Weasel group and Reluctant Head Formation were laid down on a Cambrian to Ordovician ramp shelf appears to differ markedly from the interpretation of the Newfoundland shelf margin deduced from the geological character of the Cow Head Group as outlined by James and Stevens (1986) and James *et al.* (1989). They showed essentially that the shelf edge adjacent to the site of the Cow Head Group was marked by carbonate sand shoals and metazoan-microbial buildups and was for the most part a rimmed to, at times, a bypass margin.

In addition, the conclusions drawn from the stratigraphy of the Weasel group and Reluctant Head Formation also appear to contrast with a recent hypothesis that a northwest-trending, cross-strike discontinuity, located at the southern end of the Long Range Precambrian inlier at Bonne Bay affected the style of sedimentation of lower Paleozoic rocks (Cawood and Botsford, 1991). Cawood and Botsford (1991) argue that there are significant differences in sedimentary facies across the proposed discontinuity. This occurs not only between the periplatform sediments of the Cooks Brook and Middle Arm Point formations of the Humber Arm Allochthon and those of the Cow Head Group, but also in the basement cover sequence, particularly the rift facies. This difference, they infer, reflects paleogeographic variations along the margin at the Newfoundland Promontory controlled by synsedimentary activity across the discontinuity. In their scheme, the Weasel group and Reluctant Head Formation should lie south of the discontinuity together with the Cooks Brook formation and Northern Arm formation.

Comparison of the Cooks Brook and the Middle Arm Point formations with the Weasel group and the Reluctant Head Formation indicates, however, that there are significant lithological and chronostratigraphic differences between the two, suggesting that no commonality existed. Studies of the Canada Bay area and the Goose Arm area show significant similarity between the Cambrian–Ordovician successions of the two areas (Knight and Boyce, 1987, 1991; Knight and Saltman, 1980; Knight, 1987). For example, as in the Goose Arm area, it is possible to trace coeval Cambrian ramp and shelf lithofacies from proximal to distal settings in an imbricate thrust stack in the Canada Bay area. This includes the presence of Reluctant Head type rocks overlain by dolomitized carbonate sands and peritidal carbonates in the most easterly thrust slices adjacent to the Hare Bay Allochthon. This implies that the ramp style of margin extended at least from the Humber Arm–Goose Arm areas northward along the eastern side of the Great Northern Peninsula. This appears to contradict the across-strike discontinuity model of Cawood and Botsford (1991). In addition, unpublished studies in 1987 by Knight and Boyce showed that the Lower to Middle Cambrian siliciclastic to carbonate succession at the south end of the Long Range Inlier records a eastward-deepening ramp similar to the eastward-deepening trend present in coeval sedimentary rocks at the northern end of the Long Range Inlier from St. Barbe to Canada Bay (Knight, unpublished data; see also James *et al.*, 1987, 1989; Knight and Cawood, 1991).

The cumulative evidence of a Cow Head margin model (rimmed platform; James and Stevens, 1986), modified rimmed to drowned-faulted margin model for the Cooks Brook–Middle Arm Point formations (Botsford, 1988; Cawood and Botsford, 1991) and the ramp model presented here for the Pasadena area indicate that the margin varied along its length.

To resolve this dilemma, it is proposed that the different style of margin (i.e., rimmed shelf versus ramp shelf) reflects deposition along different parts of a margin whose geomorphology was fundamentally structurally controlled as a result of rifting. A relatively narrow shelf having a steep-rimmed margin flanked by Cow Head type lithofacies might be expected to form along a transform margin. The westward swing of the margin across the Gulf of St. Lawrence to Gaspé, Québec, may reflect such a feature (Stockmal *et al.*, 1987; Knight *et al.*, 1991). Broad platforms having distally steepened ramps may be the margin morphology where the shelf evolves above a broad foundation of Precambrian basement such as was likely for the Newfoundland Promontory, north of the transform fault. This margin configuration requires changing the apex of the promontory as proposed by Williams (1978) and Williams and Cawood (1989) to more realistically reflect the distribution of shelf rocks and the distribution of Laurentian basement in Newfoundland inferred from Lithoprobe transects (Keen *et al.*, 1986; Marillier *et al.*, 1989). In addition, it suggests that the Taconian emplacement of the Humber Arm Allochthon was northward rather than from the east as is currently accepted (Cawood and Botsford, 1991).

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