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LLANDOVERIAN GRAPTOLITE ZONATION IN THE NORTHERN CANADIAN CORDILLERA

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A number of well exposed and structurally simple, graptolite sections, ranging in age from latest Ordovician through Wenlockian strata are present in the northern Canadian Cordillera. Recent more detailed sampling permits much finer zonation, than previously possible. The following lower and middle Llandoverian zones (following the zonal scheme of Hutt 1975) are recognized or tentatively recognized: *acuminatus* Zone, *atavus* Zone, *acinaces* Zone, *gregarius* Zone, *triangulatus* Zone, *magnus* Zone?, *argenteus* Zone, *convolutus* Zone, *sedgwicki* Zone, and *turriculatus* Zone. The *crispus, griestoniensis* and *crenulata* Zones are only tentatively and indirectly recognizable; instead, expanded and stratigraphically thick *spiralis* and *Cyrtograptus sakmaricus* — *C. laqueus* Zones appear to represent biofacies equivalents. The latter zone is correlated with the *grandis* and *lapworthi* Zone of some writers. The earliest Wenlockian *centrifugus* Zone may be present in a single section.

The lowest Llandoverian *persculptus* Zone is only tentatively recognized, but there appears to be no evidence for a stratigraphic break between the Ordovician and Silurian.

Lower and middle Llandoverian zones are thin, whereas those of the upper Llandoverian are considerably thicker, a fact probably related to the temporal duration of the zones.

K e y w o r d s: Graptolites, stratigraphy, Silurian, Llandovery, Canada.

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INTRODUCTION

The recognition of graptolite-bearing rocks in the northern Canadian Cordilerra stems chiefly from the work of Decker, Warren and Stelck (1947) in northern Yukon, and Ruedemann, in Cameron and Warren (1938) in a brief note on the South Nahanni region (localities 19, 20 in fig. 2 of this paper). It was however, not until the study of Jackson and Lenz (1962), that the full stratigraphic and geographic extent of graptolites found in structurally simple and superbly exposed sequences in northern Yukon became recognized. In that paper, the Llandoverian zones of *Diplograptus modestus, Monograptus cyphus, M. millepeda, M. convolu-*

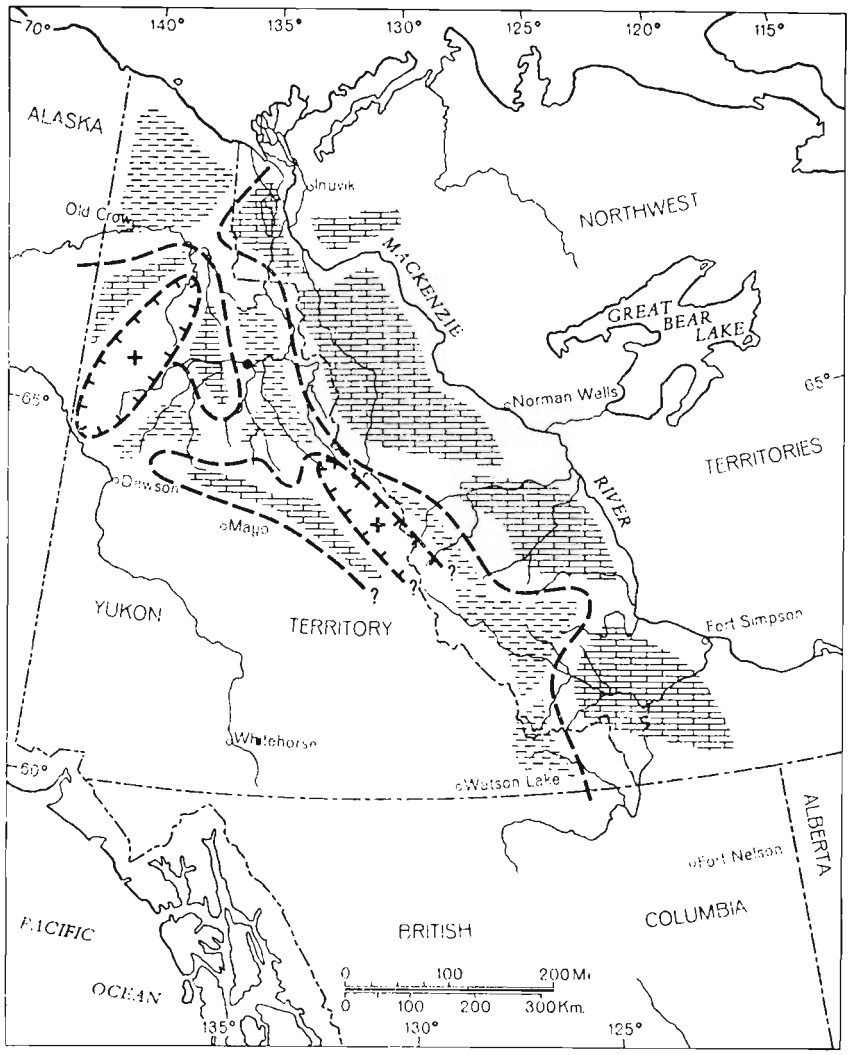

Fig. 1. Late Ordovician — Early Silurian paleogeography and lithofacies. Positive areas indicated by +, carbonates and shales indicated by conventional symbols. Entire shale facies assigned to the Road River Formation. Black dot on river in northern Yukon is location of important Peel River upper canyon section.

tus to *M. sedgwicki*, *M. turriculatus*, and *M. spiralis* were recognized for the first time in northern Yukon. The following year, O'bertos and Jackson (1963), recognized the *spiralis* Zone from the Whittaker and Manetoe Ranges in southwestern Northwest Territories (localities 17, 18 in fig. 2 of this paper). Subsequently, Lenz and Jackson (1964) recognized the *modestus?*, *convolutus-sedgwicki*, *spiralis* and *grandis* Zones in a number of poorly sampled sections in southwestern-most Northwest Territories (including localities 16—21 in fig. 2 of this study). Further south, in northeastern British Columbia, Jackson, Steen and Sykes (1965)

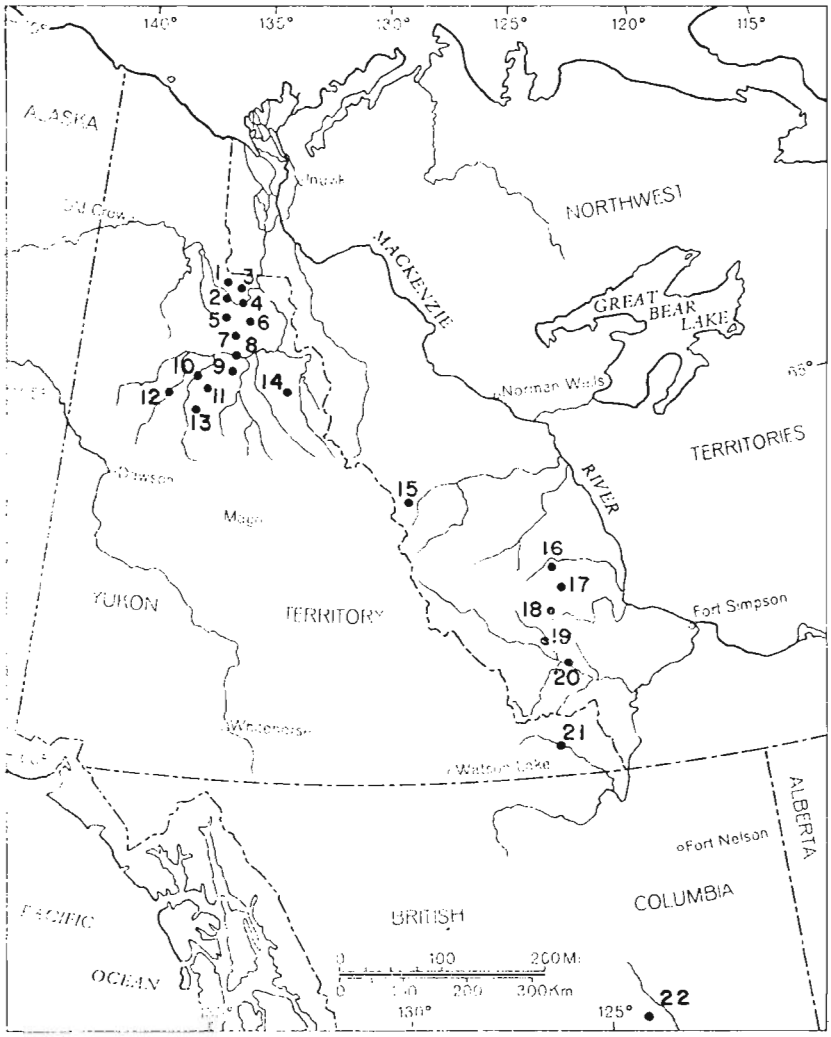

Fig. 2. Index map of graptolite localities. Locality *1* Rock River, north tributary, 66°55′N, 136°14′W; *2* Rock River, south tributary, 66°48′N, 136°16′W; *3* Tetlit Creek, tributary of Road River, and type section of Road River Formation, 66°44′N, 135°47′W; *4* Road River, 66°34 N, 135°43′W; *5* Unnamed creek, west side of Richardson Mountains, 66°30′N, 136°15′W; *6* Trail River, 66°24 N, 135°35′W; *7* Canyon Creek, 66°10′N, 136°10′W; *8* Peel River, upper canyon, 65°53′N, 135°43′W; *9* Deception Range, approx. 65°45′N, 135°35′W; *10* Hart River, 65°37′N, 136°48′W; *11* Between Hart and Blackstone Rivers, approx. 65°20 N, 136°35′W; *12* Blackstone River, 65°24′N, 137°16′W; *13* Pat Lake, 65°07′N, 136°41′W; *14* Snake River, 65°22′N, 133°28′W; *15* Mt. Sekwi, 63°29′N, 128°38′W; *16* Delorme Range, 62°45′N, 125°15′W; *17* Whittaker Range, 62°23′N, 124°48′W; 18 Manetoe Range, 62°10′N, 124°58′W; *19* Clearwater Creek, 61°39′N, 125°35′W; *20* South Nahanni River, 61°34 N, 125°22′W; *21* Beaver River, 60°28′N, 125°50′W; *22* Northeastern British Columbia, 56°50′—57°32′N, 123°45′—124°35′W (after Davies, 1966).

documented the *turriculatus* Zone, and Davies (1966) recognized the *cyphus, gregarius?, turriculatus* and *spiralis* Zones (locality 22 in fig. 2 of this paper).

Some years later, more detailed collecting from the upper canyon area of Peel River (locality 8, fig. 2) permitted the recognition (Lenz and Pedder 1972) of the *vesiculosus, cyphus, gregarius, convolutus, sedgwicki, turriculatus* and *spiralis* Zones. As such, this sequence constituted the most detailed Llandoverian section then recognized in North America.

Further afield, Thorsteinsson (1958) revealed the presence of the now famous, beautifully preserved, uncompressed graptolites in well exposed sections of the Cape Phillips Formation of Cornwallis Island, Canadian Arctic Archipelago. He established the presence of the *cyphus, millepeda, turriculatus, spiralis* and *grandis* Zones.

In southeastern Alaska, an important sequence of graptolites was described by Churkin and Carter (1970). They recognized for the first time in North America, the earliest Silurian *persculptus* Zone. Additionally, they documented the *acuminatus, vesiculosus, cyphus, gregarius, convolutus, sedgwicki,* and *maximus* Zones. This sequence therefore constituted the most complete Lower and Middle Llandoverian succession in North America prior to the present study.

In the most recent studies, Berry and Murphy (1975) recognized only the late Llandoverian *spiralis* and *sakmaricus* Zones from central Nevada; and Carter and Churkin (1977) documented the *turriculatus* Zone from the Phi Kappa Formation of Idaho.

The present study stems from the acquisition for over ten years of graptolites from two major areas in the northern Cordillera (see fig. 2). Until two years ago, however, nearly all the sections had been sampled in a cursorial manner. During the summers of 1976 and 1977, the Peel River upper canyon section (locality 8, fig. 2) and Blackstone River (locality 12) were sampled in detail. These detailed collections in conjunction with earlier sampled sections from other areas, permit a biostratigraphic subdivision of the Llandoverian heretofore unobtainable in North America. Additionally, the lack of structural complexities, and the virtual 100% exposure of some sequences, notably Peel River, qualifies it as one of the finest Llandoverian sequences in the world.

STRATIGRAPHY

The sequence of graptolite-bearing bedded cherts and shales in the Richardson Mountains, northern Yukon, was assigned to the Road River Formation by Jackson and Lenz (1962). The Road River Formation is

now known to extend from almost northernmost Yukon (Lenz and Perry 1972), to almost as far south as latitutde 65° in northeastern British Columbia (Jackson, Steen and Sykes 1965; Davies 1996) (see fig. 1). Lithic characteristics of the Road River vary greatly, ranging from almost entirety chert with a few shale interbeds, to almost totally dark shale, with minor chert. In still other areas, the unit consists of interbedded shales and thin bands of evenly bedded limestones. Coarse clastics are rare to uncommon in the formation, and the presence of volcanic debris is not as yet confirmed (see however, Lenz and Perry 1972). Most complete exposure of the Road River Formation occur in the Richardson Mountains (localities 1—9, 14, fig. 2), where the unit ranges in age from latest Cambrian or earliest Ordovician to late Early Devonian. Sections to the southwest (localities 10—13) although less well exposed provide good supplementary data. Additionally, although poorly sampled to date, the Clearwater Creek section (locality 19) offers excellent potential.

In the Richardson Mountains, the Road River strata, which are thought to be the product of deep water sedimentation (Lenz 1972), appear to grade abruptly to the east and west into shallow water carbonates. Shelly faunas are rare to absent in the Road River Formation of the Richardson Mountains, and uncommon in associated carbonate-shale sequences elsewhere, but may be abundant near or at the carbonate-shale facies transition.

In the central portion of the region, the Road River Formation grades abruptly eastward into, and/or overlies, the Whitttaker Formation.

The western limit of the unit is however, unknown, and whether its recognized westernmost occurrence (or its metamorphic equivalents) represents the western edge of the Silurian continent is at present, unknown.

ZONAL THICKNESS

In a recent provocative paper, Churkin, Carter and Johnson (1977) propose that the thickness of graptolite zone in bedded chert and shale sequences in the Cordillera is related to the time duration of that zone. Accordingly, the small thickness in the earliest Llandoverian *persculptus* Zone is attributed to a short time period, whereas, the thicker *turriculatus* Zone is considered to be the result of a longer period of sedimentation.

In this study an attempt is made to estimate the thicknesses of a number of the Llandoverian graptolite zones. For the purpose of expediency a number of zones are lumped together, and the thicknesses of the following zones or clumps of zones, in order of oldest to youngest, are listed: *persculptus-acuminatus* Zones, *atavus-acinaces-gregarius* Zones, *triangulatus-magnus-argenteus* Zones, *convolutus-sedgwicki* Zones, *tur-*

riculatus Zone, *spiralis* Zone, *sakmaricus-laqueus* Zone. It must however, be emphasized that given zonal thicknesses are approximate, and might be in error by a factor of 1.5 to 2. In spite of the inaccuracies however, a trend is clearly visible, and late Llandoverian zones are generally considerably thicker than early and middle Llandoverian zones. Additionally these figures reinforce the conclusions reached by Churkin, Carter and Johnson (1977). The fact that such zones as *spiralis* or *turriculatus* are more often encountered is thus readily explainable by the greater thickness of these zones as compared with earlier ones.

Zonal thickness in meters (for locality numbers, see fig. 2).

Total Llandovery — Locality 1: 150; loc. 3: 100; loc. 8: 190; loc. 12: > 75; loc. 15: 245; loc. 16: 245; loc. 17: 240; loc. 19: > 90; loc. 22: > 130.

persculptus-acuminatus Zones — Locality 2: < 10; loc. 8: 4; loc. 12: 10; loc. 13: 10; loc. 15: > 30; loc. 19: 60; loc. 22: 60?

atavus-acinaces-gregarius Zones — Locality 2: 8; loc. 8: 12; loc. 4: present; loc. 12: > 2; loc. 13: > 6; loc. 5: present.

triangulatus-magnus-argenteus Zones — Locality 2: present; loc. 8: 10; loc. 12: > 2; loc. 15: probably present; loc. 19: present; loc. 22: 15.

convolutus-sedgwicki Zones — Locality 2: probably present; loc. 8: 20; loc. 12: 11; loc. 16: 6; loc. 19: > 3; loc. 6: present; loc. 18: present?

turriculatus Zone — Locality 2: 15; loc. 8: 45; loc. 12: 18; loc. 15: 20; loc. 16: 35; loc. 19: 10; loc. 22: 40; localities 5, 9, 20: present.

spiralis Zone — Locality 2: 90; loc. 3: 40; loc. 8: 35; loc. 12: > 15; loc. 15: 90; loc. 16: 90; loc. 17: 45; loc. 18: 90; loc. 19: >10; localities 1, 4, 5, 7, 10, 11: present.

NORTHERN CANADIAN CORDILLERA GRAPTOLITE ZONATION

Recent studies in the British Isles have considerably refined and expanded the classical Llandovery zonal scheme of Elles and Wood (1901—1918). Two studies, one by Hutt (1975), the other by Rickards (1976) are, with the exception of one zone (the *argenteus* Zone of Hutt vs. the *leptotheca* Zone of Rickards) identical, at least to the top of the *turriculatus* Zone. The zonal scheme of Hutt is fairly closely adhered to as a model for the northern Canadian graptolite zonation. On the other hand, the British late Llandovery *crispus*, *griestoniensis* and *crenulata* Zones are not readily recognizable in Arctic Canada. Northern Canadian zonal equivalents are instead assigned to the well established *spiralis* Zone, and to the overlying (new) *sakmaricus-laqueus* Zone.

Glyptograptus persculptus Zone. — At the present time the zone has not been positively identified in the northern Canadian Cordillera, and in fact the only documented occurrence of it is in southeastern Alaska (Churkin and Carter 1970; Churkin, Carter and Eberlein 1971). In the Peel River section (loc. 8), highest Ordovician (Ashgillian) graptolites are separated from graptolites of the overlying *acuminatus* Zone by only a 30 cm chert interval. Two other localities, Blackstone River (loc. 12) and Clearwater

Creek (loc. 19) show better potential. In the former locality, pre-*acuminatus* Zone, *Orthograptus truncatus* cf. *pauperatus*, a narrow form of *Climacograptus normalis* (or a wide form of *C. miserabilis*), abundant *Diplograptus modestus* (*s.l.*), ?*Glyptograptus* sp., and *Climacograptus* sp. (with a long, proximal spine), are probably assignable to the *persculptus* Zone. The lowest Silurian beds of Clearwater Creek are anomalously thick. There, some 25 m of strata, probably assignable to the *persculptus* Zone, contain only *C. miserabilis*, *Glyptograptus* sp., and rare *Climacograptus* cf. *innotatus*. The appearance of *C. trifilis* and abundant *C. innotatus obesus* in the overlying strata suggests the *acuminatus* Zone.

Orthograptus acuminatus Zone. — This zone has been recognized in a number of localities, and in general is readily recognizable by the appearance of the zonal index species. Additionally it is also marked by the appearance of *Climacograptus trifilis*. In northern Yukon (localities 2, 8, 12, 13) the zone is characterized by an abundance of *C. normalis*, *C. innotatus*, *C. innotatus obesus*, *C.* aff. *pacificus pilosus*, as well as the first appearance of *Glyptograptus lanpheri*, *G.* cf. *gnomus*, *C. rectangularis*, *Diplograptus modestus diminutus*, and *Orthograptus eberleini*. Uncommon species include ?*Cystograptus vesiculosus*, *G. tamariscus magnus*, and ?*Akidograptus ascensus*. On Clearwater Creek (loc. 19) the zone is represented through a thick interval by a low diversity fauna consisting of *C. normalis*, *C. innotatus obesus*, *C. trifilis*, *Glyptograptus* sp. (similar to *G. sinuatus*), and *G.* cf. *enodis latus*. A similar assemblage from northeastern British Columbia (loc. 22) assigned to the "?*modestus* Zone" by Davies (1966), is almost certainly the *acuminatus* Zone. Monograptids have not as yet been found in this zone in the Cordilleran region.

Atavograptus atavus Zone. — This Zone is known from only three localities at the present time (loc. 2, 8, 12), and where present, is thin (eg. 2 m at locality 8; $\leqslant$ 1 m at loc. 12). The zonal assemblage consists of *C. rectangularis* and *C. normalis* in abundance, as well as *G. laciniosus*, *G. tamariscus magnus*, *Cystograptus vesiculosus*, ?*C. vesiculosus*, *Dimorphograptus confertus swanstoni*, *D.* cf. *longissimus* (or new sp. ?), and the first appearance of *Pseudoclimacograptus* (*Metacl.*) *hughesi*, suggesting the *atavus* Zone. Additionally the zone marks the earliest appearance of monograptids in the Cordilleran region. Sicular ends of the rhabdosomes of *Lagarograptus* cf. *acinaces* are found at Rock River (loc. 2) and Blackstone River (loc. 12), ?*Atavograptus* cf. *atavus* is found on Blackstone River, and a few indeterminate monograptids occur on the Peel River (loc. 8).

Lagarograptus acinaces Zone. — The *acinaces* Zone like the underlying *atavus* Zone, is thin and not widely recognized, but is marked by a profusion of a few species of monograptids, chiefly *L. acinaces*, and a marked increase in the overall diversity of species compared with the underlying zones. Other monograptids present in the zone include *Pribylograptus* cf.

incommodus, and *Atavograptus strachani*. Biserials which attain their acme in this zone, or are restricted to it, include *Cystograptus vesiculosus*, *Pseudoclimacograptus (Metaclim.) hughesi*, *Dimorphograptus confertus swanstoni*, *D. physophora alaskensis*, *Orthograptus eberleini*, *Glyptograptus* cf. *lanpheri* and *G. tamariscus magnus*. The fauna of this zone is particularly rich at Pat Lake (loc. 13) where in addition to the above species, it contains *Coronograptus* cf. *gregarius*, *C. gregarius arcuatus*, *Rhaphidiograptus* sp. and *Glyptograptus elongatus*. Long ranging species include *Climacograptus normalis*, *C. rectangularis*, *C. innotatus* and *C. medius*.

Coronograptus gregarius Zone. — This zone is the equivalent of Hutt's (1975) and Rickard's (1976) *C. cyphus* Zone. However, in the total absence of *C. cyphus* in the study region, and in view of the abundance of *C. gregarius*, the latter species is chosen as the zonal name-bearer. The zone is not widely recognized throughout the study area. It is present at Peel River (loc. 8), and may be present on an unnamed tributary of Rock River (loc. 5). It may also be present within a 3 m covered interval on Blackstone River (loc. 12). The zone is marked by an abundance of *C. gregarius*, as well as *Atavograptus strachani*, *C. gregarius arcuatus*, *C. hipposideros*, "*Monograptus*" cf. *angustus*, *M. revolutus*, *M.* cf. *austerus* or *revolutus*, and *Pristiograptus* sp. 2 (of Hutt, 1975). Additional species include "*Orthograptus*" *obuti*, *Dimorphograptus* cf. *confertus swanstoni*, *Glyptograptus endis latus*, *G.* cf. *tamariscus tamariscus*, and *G. laciniosus*. A small collection from locality 5, containing ?*Cystograptus vesiculosus penna*, *Dimorphograptus* cf. *physophora alakensis* and a monograptid may also be assignable to this zone.

Monograptus triangulatus Zone. — At present, the zone is known from only one locality, that of Peel River (loc. 8). Apart from the zonal species — in this instance *M. triangulatus separatus* — the zone is characterized by the first appearance of *Monograptus* cf. *elongatus*, *Rastrites* cf. *longispinus*, *R. approximatus*, and *Lagarograptus inexpeditus*. Additionally *C. normalis* and *C. rectangularis* attain their highest stratigraphic level in this zone.

Diplograptus magnus Zone? — The *magnus* Zone is poorly documented and has been tentatively identified as a separate zone only on Peel River (loc. 8). There the interval is characterized by the incoming of *Monograptus involutus*, in association with *Rhaphidiograptus* cf. *toernquisti*, *M. revolutus*, *C. gregarius*, *M. triangulatus fimbriatus*, *Rastrites* cf. *peregrinus* and *Glyptograptus* cf. *laciniosus*.

Monograptus argenteus Zone. — This zone, although thin, and found at only two localities (Peel River, locality 8, and Blackstone River, locality

Table 1

Suggested ranges of species against zonal scheme used in this study. Generic abbreviation at the end of the table

Species \ Zones	*persculptus*	*acuminatus*	*atavus*	*acinaces*	*gregarius*	*triangulatus*	*magnus?*	*argenteus*	*convolutus*
O. truncatus pauperatus E. & W.	cf								
C. miserabilis E. & W.									
D. modestus (Lapworth) (s.l.)									
C. normalis Lapworth									
O. acuminatus Nicholson									
C. trifilis Manck									
D. modestus diminutus (E. & W.)									
C. rectangularis McCoy		cf					cf		
D. aff. *mucroterminatus* Churkin & Carter									
C. aff. *pacificus pilosus* Riva									
G. tamariscus magnus Churkin & Carter				cf					
G. gnomus Churkin & Carter			cf						cf
O. oberleini Churkin & Carter									
?Ak. ascensus Davies									
G. lanpheri Churkin & Carter		cf		cf					
C. innotatus Nicholson									
Pc. hughesi (Nicholson)									
C. innotatus obesus Churkin & Carter									
Cy. vesiculosus (Nicholson)		cf			cf				
G. laciniosus Churkin & Carter							cf	cf	
C. medius Törnquist									
A. atavus (Jones)			cf						
G. tamariscus Nicholson			?			cf			
D. elongatus Churkin & Carter					cf			cf	
Dm. confertus swanstoni (Lpwth.)					cf				
Dm. cf *longissmus* Kurck									
Pr. aff. *incommodus* (Törnquist)				cf					
Dm. enodis Packham				cf					
Dm. aff. *decussatus* E. & W.									
Dm. physophora alaskensis Churkin & Carter									

Generic abbreviations see p. 149.

12) is fairly readily recognized by the presence of *M.* cf. *argenteus argenteus* and *M.* aff. *cygneus* (*sensu* Obut, Sobolevskaya and Nikolaev 1967), and by the appearance of lobate monograptids such as *M. millipeda*, *M.* cf. *lobiferus* and *M. communis*. Associated new taxa include *Petalograptus*

Table 1a

	acinaces	*gregarius*	*triangulatus*	*magnus?*	*argenteus*	*convolutus*	*sedgwicki*	*turriculatus*
L. acinaces Törnquist		cf			?			
A. strachani Hutt & Rickards		cf						
Cr. gregarius Lapworth								
„*O*". *obuti* Rickards & Koren								
G. enodis latus Packham								
„*M*". *angustus* Rickards		cf						
M. revolutus Kurck								
Cr. gregarius arcuatus Obut & Sobolevskaya								
Cr. hipposideros Toghill								
M. elongatus Törnquist			cf					
Ra. longispinus Perner			cf		cf			
Ra. approximatus Perner								
M. triangulatus separatus Sudbury								
L. inexpeditus Obut & Sob.								
Rh. cf. *toernquisti* E. & W.								
Ra. peregrinus Barrande				cf	cf			
M. triangulatus fimbriatus Nicholson				?				
M. involutus Lapworth								
M. cygneus Törnquist (*sensu* Obut and Sob., 1967)								
M. millepeda McCoy								
M. argenteus Nicholson					cf	cf		
Pet. minor Elles					cf	cf		
M. lobiferus McCoy								
Pet. ovatoelongatus Kurck								
Ra. orbitus Churkin & Carter								
M. communis (Lapworth)								
Pet. folium Törnquist								
D. thuringiacus Eisenack								
M. sidjachenkoi (Obut & Sob.)								

cf. *minor*, *P. ovatoelongatus*, *Rastrites orbitus*, *R.* sp. (similar to *R. phleoides*), and ?*Pseudoplegmatograptus* sp. Additionally, the zone marks the highest range of *M. revolutus*, *C. gregarius* (upper limit same as on Bornholm: Bjerreskov 1975), *C.* cf.*rectangularis* and *G.* cf. *laciniosus*. A single specimen of *L.* cf. *acinaces* has also been recovered from the same strata.

Monograptus convolutus Zone. — The widespread distribution of the zone (localities 6, 8, 12, 16, 18, 19) suggests that it is present throughout the entire geographic range of the Road River facies. The zone is probably present in east-central Alaska (Churkin and Brabb 1965) and in south-

Table 1b

	convolutus	*sedgwicki*	*turriculatus*
O. inopinatus Bouček	——		
Ra. fugax Barrande	——		
M. convolutus Hisinger	——		
M. cf. *limatulus* Törnquist	——	——	
Ceph. tubulariformis (Nicholson)	—		
Pc. undulatus (Kurck)	——	——	
Pet. intermedius Bouček & Přibyl	——	——	
Ps. obesus obesus (Lapworth)	cf	cf	——
Ra. phleoides Törnquist	——		
Ceph. cometa cometa (Geinitz)	—		
Pr. regularis (Törnquist)	——	——	——
Pet. praecursor Bouček & Přibyl	——		
M. proteus (Barrande)	cf		——
M. pseudobecki (Bouček & Přibyl)	——	——	cf
M. mirus (Barrande)	——		
M. sedgwicki (Portlock)	cf	——	cf
M. tenuissmus (Obut & Sob.)	——		
M. clingani Carruthers	——		
Pr. nudus (Lapworth)	——	——	cf
M. marri (Perner)	cf		——
O. cyperoides (Törnquist)		cf	
M. spiralis contortus (Perner)		cf	cf
Pet. ovatus (Barrande)		cf	
M. planus (Barrande)		——	
Ra. maximus Carruthers		——	
Pet. tenuis (Barrande)		——	
Ra. linnaei Barrande		——	
Ceph. cometa extrema Bouček & Přibyl		——	
Pet. altissimus E. & W.		——	——
Pet. palmeus clavatus Bouček & Přibyl		——	——

eastern Alaska (Churkin and Carter 1970), and is documented in Idaho (Carter and Churkin 1977).

Characteristic of, and apparently restricted to, the zone are *M. convolutus, Petalograptus folium, M. sidjachenkoi, Diplograptus thuringiacus, Pseudoclimacograptus (Metaclim.) undulatus, Orthograptus insectiformis*? (or *O. inopinatus*?), and possibly *M. limatulus. Cephalograptus tubulariformis* occurs in the middle, while *C. cometa cometa* appears in the upper part of the zone, a positioning exactly as shown by Bjerreskov (1975), and Rickards, Hutt and Berry (1977). Additional important components of the zone include *Rastrites peregrinus, R. orbitus, R. phleoides, M. communis, M. clingani, Pristiograptus regularis, Petalograptus praecursor,*

Table 1c

	sedgwicki	*turriculatus*	*spiralis*	*sakmaricus-laqueus*
Pet. wilsoni Hutt		cf		
M. decipiens Törnquist				
M. decipiens valens Přibyl & Münch				
Div. ramosus Manck			cf	
Pet. elongatus Bouček & Přibyl				
Pret. perlatus (Nicholson)	cf			
M. turriculatus (Barrande)				
Pet. conicus Bouček		cf		
M. flagellaris Törnquist		cf		
M. exiguus exiguus (Nicholson)				
Div. capillaris (Carruthers)				
M. spiralis Geinitz				
M. halli (Barrande)				
Pr. variabilis (Perner)				
M. planus obtusus Schauer				
Ps. obesus reticulatus Bouček & Přibyl		cf		
M. delicatulus E. & W.		cf		
M. falx (Suess)				
M. cf. *knockensis* E. & W.				
Pr. initialis (Eisenack)				
M. runcinatus Lapworth				
M. sartorius Törnquist		cf	cf	
Ret. g. geinitzianus Barrande				
M. priodon Bronn		cf		

P. cf. *intermedius*, *Pseudoretiolites perlatus*, and the first occurrence of *Diversograptus*.

Monograptus sedgwicki Zone. — This zone has been documented at only two localities, Peel River (loc. 8), and Blackstone River (loc. 12). In the former locality it may be as thin as 2 m, whereas in the latter it may be as much as 10 m thick. On Peel River, the zone appears to be represented by an association of *Rastrites longispinus*, *Pristiograptus regularis*, *M.* cf. *proteus*, *M.* cf. *denticulatus*, *M. pseudobecki*, *M. mirus*, *M. tenuissmus*, and *M.* cf. *marri*; the zonal index species is not present. On Blackstone River, however, the zone is well documented by the presence of *Petalograptus intermedius*, *P. wilsoni*, *P. altissimus*, *P. palmeus clavatus*, *Rastrites* cf. *perfectus*, *M. sedgwicki*, *M. planus*, *M. pseudobecki*, *M. decipiens*, *Pristiograptus nudus*, and *Orthograptus* cf. *cyperoides*. Specimens of *M.* cf. *spiralis contortus* and a *Rastrites* somewhat similar to *R. maximus* also occur in the zone. Equally distinctive of the zone, is the presence of

Table 1d

	spiralis	*sakmaricus-laqueus*
M. parapriodon	cf	
Ret. g. angustidens E. & W.		
Mon. griestoniensis (Nicol)	cf	
St. grandis (Suess)		
St. g. imperfectus Bouček & Münch		
St. g. maior Bouček		
M. curvus Manck		
Ret. g. densireticulatus Bouček		
M. tullbergi spiraloides Přibyl		
M. spinulosus Tullberg		
Ps. giganteus Bouček & Münch		
Ct. lapworthi Tullberg		
Ct. aff. *lapworthi* Tullberg		
Ct. sakmaricus Koren		
Ct. laqueus Jackson & Etherington		
Mon. linnarssoni (Tullberg)		
M. praecedens Bouček		cf
?Holoret. balticus Eisenack		

Generic abbreviations:

A — *Atavograptus*
Ak. — *Akidograptus*
C. — *Climacograptus*
Ceph. — *Cephalograptus*
Cr. — *Coronograptus*
Cy. — *Cystograptus*
Ct. — *Cyrtograptus*
D. — *Diplograptus*
Dm. — *Dimorphograptus*
Div. — *Diversograptus*
G. — *Glyptograptus*
Holoret. — *Holoretiolites*
L. — *Lagarograptus*
M. — *Monograptus*
Mon. — *Monoclimacis*
O. — *Orthograptus*
Pc. — *Pseudoclimacograptus*
Pet. — *Petalograptus*
Pr. — *Pristiograptus*
Ps. — *Pseudoplegmatograptus*
Pret. — *Pseudoretiolites*
Ra. — *Rastrites*
Ret. — *Retiolites*
Rh. — *Rhaphidiograptus*
St. — *Stomatograptus*

Cephalograptus cometa extrema. Additionally, a single occurrence of a form similar to *Barrandeograptus pulchellus* occurs in the lower part of the zone on Blackstone River (loc. 12).

Monograptus turriculatus Zone. — As suggested by the thickness of the zone, it is widespread. The zone is readily recognizable by the typical association of the zonal species and *M. exiguus exiguus*, which range throughout the entire zonal interval.

The zone, or its equivalents, has been variously defined by different workers. Hutt (1975) and Bjerreskov (1975) for example, recognize only a single *turriculatus* Zone above the *sedgwicki* Zone; whereas Rickards (1976) recognizes a separate *maximus* Zone above the *sedgwicki* Zone and below a more restricted *turriculatus* Zone. On the other hand, Münch (1952), Obut, Sobolevskaya and Nikolaev (1967), Schauer (1971) and Bjerreskov (1975) term the *maximus* Zone equivalent the *linnaei* Zone. In this study, a single *turriculatus* Zone, equivalent to the combined *maximus* (= *linnaei* Zone) and restricted *turriculatus* Zone, is used, since the vast majority of species range throughout the zone.

The zone is well represented and well developed on Rock River (loc. 2), Road River (loc. 4), Peel River (locs. 8, 9), Blackstone River (loc. 12), Mt. Sekwi (loc. 15), Whittaker and Delorme Ranges (locs. 16, 18), Clearwater Creek (locs. 19, 20), and northeastern British Columbia (loc. 22).

Monograptus turriculatus occurs throughout the Canadian Cordillera. The zone is characterized by *Pseudoplegmatograptus obesus obesus* and *P.* cf. *obesus reticulatus*, *Rastrites maximus* (in the lower part of the zone), *Petalograptus* cf. *wilsoni*, *P.* cf. *palmeus clavatus*, *P. altissimus* *M.* cf. *halli*, *M. runcinatus* and *M. marri*. It also marks the first positive appearance of *M. proteus*, *M. tullbergi*, *M. decipiens valens*, and *Diversograptus ramosus*. Rare specimens of *M. spiralis spiralis*, *M.* cf. *priodon*, and *Retiolites geinitzianus angustidens* occur in the upper part of the zone, and in Clearwater Creek (loc. 19) only, *M. flagellaris* occurs.

Monograptus spiralis Zone. — It has long been recognized (Thorsteinsson 1958; Jackson and Lenz 1962) that the *spiralis* Zone, as employed in Cordilleran and Arctic Canada represents a considerably greater period of time, than the range of the zonal species in the British Isles (see Rickards 1976), or in continental Europe (Münch 1952; Bjerreskov 1975). Thus the Cordilleran and Arctic Canadian *spiralis* Zone appears to equate with *crispus*, *griestoniensis*, and probably the *crenulata* Zones of Great Britain (Rickards 1976), and the *crispus*, *griestoniensis* and *spiralis* Zones of Bornholm (Bjerreskov 1975).

The *spiralis* Zone is the most widespread and generally the thickest zone in the Llandoverian of Cordilleran and Arctic Canada. It is readily recognized in the Cape Phillips Formation of Arctic Canada (Thorsteinsson 1958; pers. observation) and ranges from northern Yukon to northeastern British Columbia in the Cordilleran region. It is present in the Roberts Mountain Formation of Nevada (Berry and Murphy 1975).

The zonal species while occurring sparingly in the underlying *turriculatus* Zone, is characteristically very abundant in the *spiralis* Zone. Additionally, the association of *M. spiralis*, *M. priodon* and monoclimacids is a clear indicator of the zone. Other common and ubiquitous species

include *Retiolites geinitzianus geinitzianus* and its subspecies *angustidens*. Less widespread and less common species include *M. tullbergi spiraloides*, *M.* cf. *griestoniensis*, *M. marri*, *M.* cf. *sartorius*, *M. curvus*, *Diversograptus* spp., *Stomatograptus grandis*, *S. grandis imperfectus*, *S. grandis maior*, and possibly *Pseudoplegmatograptus giganteus*. The three subspecies of *Stomatograptus* also range into the overlying zone.

Cyrtograptus sakmaricus — *C. laqueus* Zone. — In 1969, Jackson and Etherington described the occurrence of early forms of cyrtograptids from the *spiralis* and post-*spiralis* strata (described by Jackson and Etherington 1969, as earliest Wenlockian) from the Rock River (loc. 2), Road River (loc. 4) and Clearwater Creek (loc. 19). These forms were described as *Cyrtograptus canadensis* and *C. laqueus*. Additional collecting reveals that these two species are also present on Peel River (loc. 8), and that the zone is almost certainly recognizable in the Delorme Range (loc. 16), and possibly the Whittaker Range (loc. 17).

Species common to the zone include those species continuing upwards from the *spiralis* Zone including *Retiolites geinitzianus* and its subspecies *angustidens*, *Stomatograptus grandis* and at least two of its subspecies, and members of the *Monoclimacis vomerinus* group. *M. spiralis* is only rarely found in the lower part of the zone. Additional important constituents of the zone comprise *Cyrtograptus lapworthi* and *C.* aff. *lapworthi*.

Jackson and Etherington (1969) implied that *C. canadensis* and *C. laqueus* are typically associated. However, the present study on the basis of as-yet insufficient evidence, suggests that *C. canadensis* and *C. lapworthi* and/or *C.* aff. *lapworthi* appear about simultaneously above the *spiralis* Zone, whereas *C. laqueus* appears somewhat higher in section.

There are nomenclatural problems involving both *C. canadensis* and *C. laqueus*. It now seems relatively clear that *C. canadensis* is the junior synonym of Koren's (1968) *C. sakmaricus*, and the presence of secondary cladia on *C. laqueus* would suggest assignment of the species to the genus *Averianowagraptus* Obut. However, the fact that secondary cladia are not present in all rhabdosomes suggests that a more conservative taxonomic approach is justified in this instance. Accordingly *laqueus* is retained within the genus *Cyrtograptus*.

In the Canadian Arctic Archipelago, *C. sakmaricus* and *C.* aff. *lapworthi*, in association with *Retiolites* and *Stomatograptus* are common in post-*spiralis* Zone (beds (pers. observation). Elsewhere, *C. laqueus*, in association with *C. kirki* has recently been reported from Idaho (Carter and Churkin 1977), and *C.* cf. *sakmaricus*, *C. lapworthi* and *C.* aff. *lapworthi* are present in central Nevada (Berry and Murphy 1975).

Age assignment of the zone is difficult, but in view of the presence of typical *spiralis* Zone species, the appearance of *M.* cf. *praecedens*, *M.* cf. *parapriodon*, *Monoclimacis linnarssoni*; and the association with

C. lapworthi and *C.* aff. *lapworthi*, a correlation with the combined *proboscifórmis* and *grandis* Zones of Bouček (1933) and Münch (1952), the *grandis* Zone of Jackson (1966), and the *lapworthi* Zone as employed by Bjerreskov (1975) seems reasonable. Consequently, the zone is considered to be latest Llandoverian in age.

?Cyrtograptus centrifugus Zone. — On and one-half meters above the highest occurrence of *C. laqueus* on Peel River, there appears a fauna of rather different composition. The fauna is composed of *M.* cf. *riccaronensis*, *M.* cf. *priodon*, *M. flexilis belophorus*, *M.* cf. *minimus cautleyensis*, *C.* cf. *centrifugus*, and a *Cyrtograptus* sp. somewhat similar to *C. lundgreni*, but with a much more protracted proximal end. An assignment to the *centrifugus* Zone of Bouček (1933), Münch (1952), Schauer (1971), and Bjerreskov (1975), and a correlation to the earliest Wenlockian, seems reasonable.

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