Current Research (1992) Newfoundland Department of Mines and Energy,
Geological Survey Branch, Report 92-1, pages 203-209

DUNNAGE ZONE GRAPTOLITES: AN EXTENSION OF THE AGE RANGE AND DISTRIBUTION OF CERTAIN ORDOVICIAN FORMATIONS OF THE EXPLOITS SUBZONE

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ABSTRACT

An analysis of Ordovician graptolites from localities in the Dunnage Zone, central Newfoundland, has resulted in refinement of previous correlation and dating of certain strata, of previously unknown age, in the Exploits Subzone. Graptolites recovered from several new fossiliferous localities in the type area of the Upper Ordovician Point Leamington Formation are indicative of the Dicellograptus complanatus *and* Dicellograptus anceps *zones of the Ashgill. The fauna from the latter zone includes* Paraorthograptus pacificus *(Ruedemann) at one locality, demonstrating that the strata belong to the* P. pacificus *Subzone of the late* D. anceps *Zone. Conodonts from detrital clasts in sediments of the Point Leamington Formation and the Goldson Conglomerate indicate the* Amorphognathus superbus *and* Amorphognathus ordovicicus *zones, suggesting that the units are restricted entirely to the Ordovician.*

A sparse Llanvirn fauna, including members of Holmograptus, Xiphograptus *and an unidentifiable diplograptid, occurs in the Strong Island chert of the Exploits and Wild Bight groups, providing the first date for the upper parts of these units. Graptolitic black shale of the Caradoc Lawrence Harbour Formation, which occurs above these medial Ordovician elements of the Exploits Subzone, is also recognizable in the Baie d'Espoir Group on the south coast of Newfoundland.*

INTRODUCTION

In the Exploits Subzone (Figure 1), fossil-bearing units of marine stratified rocks are known to range in age from Tremadoc to Wenlock. Graptolites from black shale facies, present in units as old as Arenig and as young as Llandovery, are particularly useful for biostratigraphic correlation of these Ordovician and Early Silurian rocks. They are also important in establishing the presence or absence of regional variations in the temporal and spatial relationships of laterally discontinuous, diachronous or condensed lithostratigraphical units, especially where such units recur across major structural features. The data presented in this paper exemplify how graptolite faunas can be utilized to document such phenomena, and ultimately aid in our understanding of the tectonic development of the Dunnage Zone.

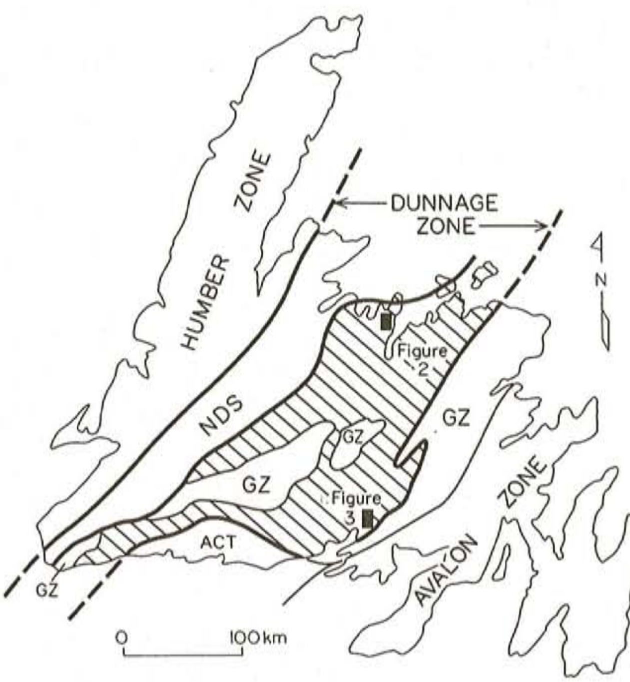

Figure 1. *Locations of the study areas in the Exploits Subzone depicted in Figures 2 and 3. Principal tectonic divisions of the Newfoundland Appalachians are also indicated; Exploits Subzone is patterned, while NDS, GZ and ACT indicate the Notre Dame Subzone, Gander Zone and Avalon Composite Terrane, respectively.*

This project is partially funded by the Canada–Newfoundland Cooperation Agreement on Mineral Development (1990-1994); project carried by Geological Survey Branch, Department of Mines and Energy, Government of Newfoundland and Labrador.

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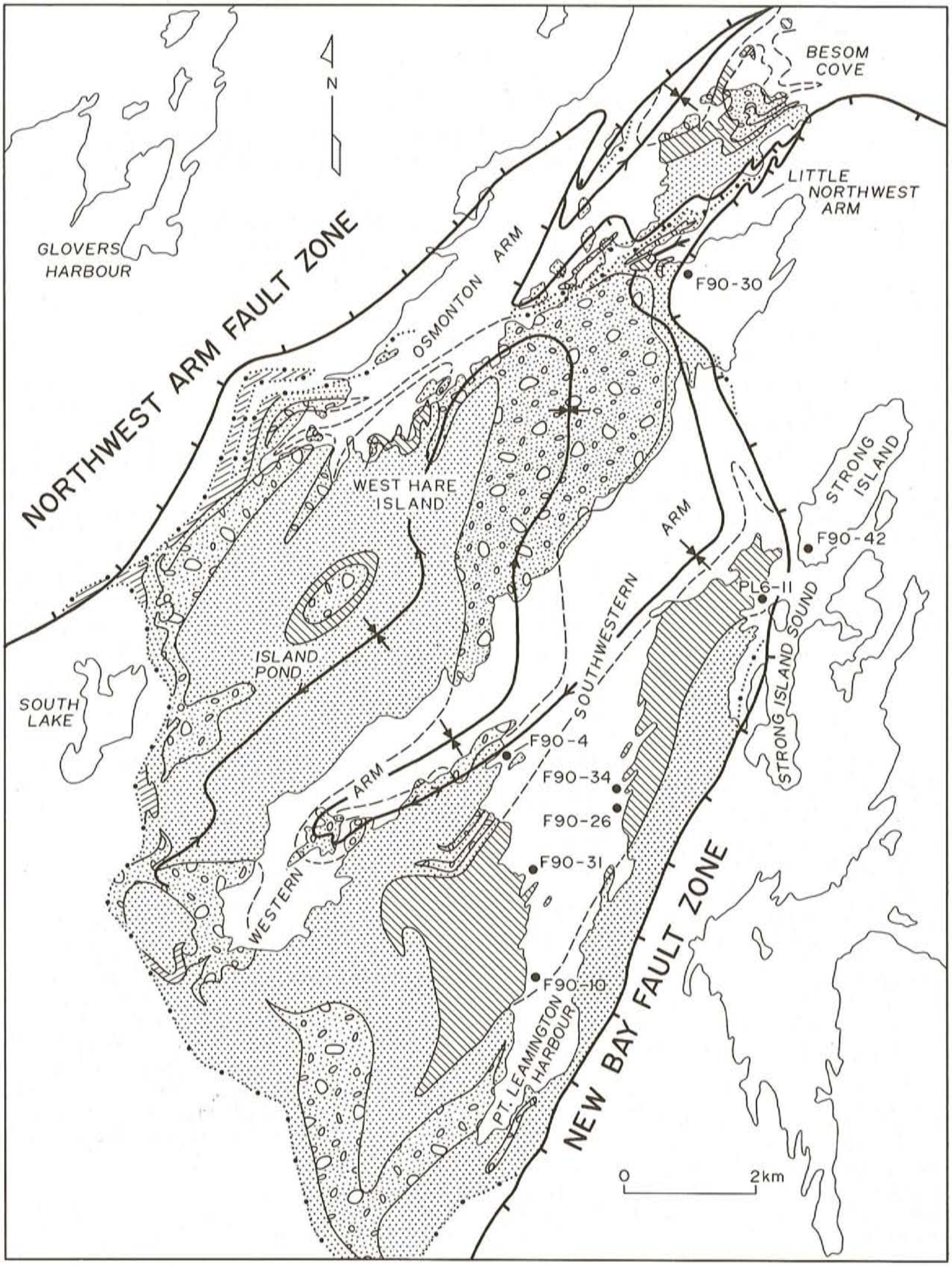

Figure 2. *Simplified geological map of the Point Leamington Formation in the Point Leamington basin. Modified, in part, from Geological Survey Branch, Open File maps 90-124 and 91-171 (O'Brien, 1990, 1991b). Graptolite localities F90-26 and F90-34; together with PL6-11 (Williams, 1991b), belong to the* D. complanatus *Zone, and F90-4, F90-10 and F90-31 are indicative of the* D. anceps *Zone of the Point Leamington Formation. Localities F90-30 and F90-42 are from within the Strong Island chert.*

LEGEND

UPPER ORDOVICIAN

POINT LEAMINGTON FORMATION

Pebbly wacke – polymictic conglomerate lenticles (*P. linearis* Zone to *D. anceps* Zone ?)

Grey shale-dominant lenticles (*D. complanatus* Zone to *D. anceps* Zone ?)

Grey shale-dominant lenticles (*D. clingani* Zone ?)

Unseparated turbidite sandstone units

KEY

Lithostratigraphic boundary (defined, assumed)..........

Regional fault zone (ticks indicate general dip direction)..........

Major syncline (plunge direction indicated)..........

Stratigraphic base/external structural boundary of Point Leamington Formation..........

Fossil locality.......... F90-30

BIOSTRATIGRAPHY

Ashgill graptolites from the Point Leamington Formation

The definition and graptolite biostratigraphy of the Upper Ordovician Point Leamington Formation of north-central Newfoundland was revised recently by Williams (1991b). The base of this lithostratigraphic unit of siliciclastic flysch was defined on the incoming of the first thick sandstone beds overlying the black shale of the upper part of the Lawrence Harbour Formation (the latter formation being an expansion of the Lawrence Harbour Shale of Helwig, 1969). Where the Lawrence Harbour Formation underlies the Point Leamington Formation, the transition occurs at a level within the *Dicranograptus clingani* or *Pleurograptus linearis* zones, depending upon locality. It was further demonstrated that stratigraphically higher intervals of interbedded shale and sandstone within the formation belong to distinctly different graptolite biozones, and that assemblages indicating the *Dicellograptus complanatus* and *Dicellograptus anceps* zones of Scotland, were present.

More recently, during a Geological Survey Branch multidisciplinary project that included remapping the Point Leamington Formation in its type area, *D. anceps* Zone assemblages have been recovered from eight additional localities and *D. complanatus* Zone faunas from a further two. Most of these sites have yielded graptolites that are also present in the locations reported on by Williams (1991b) and they simply serve to confirm most of his biostratigraphic conclusions. However, such new data, integrated with other unpublished biozonal information, are useful in identifying and mapping certain stratigraphic intervals in the Point Leamington Formation in which fossiliferous dark-grey shale predominates over quartz-wacke in an otherwise monotonous turbidite sandstone succession.

D. complanatus Zone

Faunal assemblages indicative of the *D. complanatus* Zone occur near the base of the largest mappable lenticle of shaly flysch in the Point Leamington Formation. Extending from Strong Island Sound to the vicinity of Southwest Arm (Figure 2), this thinly stratified lenticle of interbedded dark-grey shale and light-grey concretionary sandstone is host to most of the olistostromal deposits in the Point Leamington Formation. Although much smaller than the largest body and to date unyielding of graptolites, possibly contemporaneous lenticles of dark-grey shaly flysch are located in Osmonton Arm near West Hare Island and again near Besom Cove, as well as on the peninsula separating Osmonton and Southwest arms near Island Pond (Figure 2).

Strata of the *D. complanatus* Zone interval provide a younger age limit for several lithological subunits in the lowest 100 to 1000 m of the Point Leamington Formation. Immediately underlying *D. complanatus* Zone strata is a regionally developed sequence marked by distinctive, pyritic, bedding-parallel, worm burrows and other possible trace fossils. The monotonous turbidite sandstone succession below the trace-fossil horizon, but well above the Lawrence Harbour Formation, contains several of the stratigraphically lower lenticles of pebbly and conglomeratic (Goldson) flysch in the Point Leamington basin. Thus, the generalized stratigraphy of the pre-*D. complanatus* portion of the Point Leamington Formation is, in ascending order, thin- to medium-bedded turbidite sandstone, massive pebbly sandstone and polymictic conglomerate, and siltstone–sandstone rhythmites that have conspicuous trace fossils. This succession is capped by the previously discussed olistostrome-bearing shaly flysch lenticles and floored by either the Lawrence Harbour Formation or the oldest (*D. clingani* Zone) grey shale lenticles in the Point Leamington Formation. Characteristic of the marginal regions of the entire Point Leamington basin, and probably in part of *P. linearis* Zone age (Williams, 1991b), it varies considerably in total thickness, although a predictable sequential order of individual subunits is commonly present.

D. anceps Zone

Several taxa in addition to those described by Williams (1991b) have been identified from graptolite collections made in new localities within the *D. anceps* Zone of the Point Leamington Formation. Of these findings, the most important are, from taxonomic and biostratigraphic perspectives, the recovery of mature specimens of *D. anceps* (Nicholson), recognized tentatively by Williams (1991b) only on the presence of one small proximal fragment, and of *Paraorthograptus pacificus* (Ruedemann) from one locality. The latter species is characteristic of the later part of the *D. anceps* Zone (*P. pacificus* Subzone) in southern Scotland (Williams, 1982), and is an invaluable taxon for correlation of Upper Ordovician graptolitic sequences throughout the world.

The lenticle of shaly flysch in the Point Leamington Formation that contains *D. complanatus* Zone assemblages near its base extends stratigraphically upward through the *D. complexus* Subzone and into the *P. pacificus* Subzone of the *D. anceps* Zone. North of the town of Point Leamington, where it displays its maximum thickness (O'Brien, 1990), this lenticle is host to five, stratigraphically unique olistostrome horizons; each of these debris flows is separated by unbroken Point Leamington Formation carrying *in situ D. anceps* Zone assemblages. The youngest dated block of transported material in these olistostromes is Ashgill in age, although Caradoc olistoliths are also present (Williams, 1991b). Slump-folded shale blocks have yielded graptolites belonging to the *P. linearis* Zone, while rip-up clasts of nodular limestone contain conodonts indicative of the *Amorphognathus superbus–Amorphognathus ordovicicus* biozones. Both are consistent with the age of the enclosing or autochthonous strata in this part of the Point Leamington Formation.

In the vicinity of Western Arm, Point Leamington strata that overlie the largest shaly lenticle in the formation contain graptolite assemblages that also place these beds within the *D. anceps* Zone. Faunas characteristic of this biozone were recovered from minor grey-shale intervals in a turbidite sandstone sequence that is interstratified with several small lenticles of polymictic conglomerate and that directly underlie the main body of Goldson Conglomerate in the Point Leamington basin (Figure 2; O'Brien, 1990). Detrital limestone clasts systematically sampled from the uppermost exposed parts of the Goldson Conglomerate have failed to yield conodonts that are any younger than the upper Ashgill, possibly implying that a preserved record of Silurian deposition is not to be found in this region (see also Arnott *et al.*, 1985). The biostratigraphic information discerned from the expanded paleontological database is of fundamental importance in interpreting the lithostratigraphically isolated lenticles of pebbly and conglomeratic flysch within the Point Leamington basin. It successfully demonstrates that these are not contemporaneous tongues emanating from a single, alternately regressive and transgressive, sheet deposit of Goldson Conglomerate but, instead, that such lenticles generally become thicker and more laterally continuous with time. Conglomeratic infilling of the basin, which occurred throughout much of Ashgill time, overlapped most of the period of accumulation of the host greywacke succession.

Arenig–Llanvirn Graptolites from the Strong Island Chert

The Strong Island chert is a regionally widespread unit without formal rank that occurs in both the Exploits and Wild Bight groups (O'Brien, 1990). It overlies, with primary depositional contact, volcanic or sedimentary formations that comprise, in some though not all locations, the upper parts of these undated rock groups (O'Brien, 1991a; Dec *et al.*, *this volume*). The Strong Island chert conformably underlies the basal division of grey-mottled chert in the Lawrence Harbour Formation (Caradoc) and, together, these two units represent the most laterally extensive yet anomalously thin sedimentary packet in the Exploits Subzone. However, in some rare localities, the Lawrence Harbour Formation rests directly on Exploits or Wild Bight formations, which elsewhere form the local substrate of the Strong Island chert.

Recently discovered graptolite occurrences in the Strong Island chert, approximately five kilometres distant from each other along strike, were revisited and recollected in 1991. Fossiliferous intervals located in Little Northwest Arm and in the type area on Strong Island itself are thin, dark-grey, silty laminae occurring within a thin-bedded sequence of grey siltstone and sandstone, most of which are too pale and coarse for graptolite preservation. Within these laminae, most of the carbonaceous material is of uncertain origin; some is, however, composed demonstrably of graptolite fragments, and a few of these are sufficiently well preserved to permit tentative identification.

The majority of fragments represent dendroids (benthic graptolites) of little, if any, biostratigraphic use. Both localities yield a variety of forms, including specimens probably assignable to the genera *Acanthograptus, Dendrograptus* and *Dictyonema*. The extremely fragmentary nature of the material does not allow more positive identification; the first two genera range from Cambrian to at least Silurian, while *Dictyonema* is also known from the Carboniferous (Bulman, 1970). The only significance of these forms is paleoenvironmental, as benthic graptolites are apparently restricted to relatively shallow, near-shore conditions. The preservation of their fragile, organic skeletons in a hemipelagic chert and epiclastic turbidite sequence thus indicates relatively limited post-mortem transport of the rhabdosomes from their original setting and rapid burial in a deep oceanic, reducing environment, possibly located on the flanks of an emergent volcanic ridge.

The graptoloid fauna of the Strong Island locality is dominated by fragments of a slender, two-stiped sinograptid, apparently belonging to the species *Holmograptus lentus* (Törnquist). This species is a senior synonym of *H. callotheca* (Bulman) (Jaanusson, 1960; Skevington, 1965); the systematics of this and related species were discussed in full by Archer and Skevington (1973). The original description (Törnquist, 1911) was based on pyritized moulds from the upper Didymograptus Shale of Scania, Sweden. Bulman's (1932, 1936) description of this species was based on three-dimensional, isolated material from the Holen Limestone (variously known as the 'gra Vaginatumkalk', 'Lower Orthoceras Limestone' and 'Asaphus Limestone') of Öland, Sweden, as were most subsequent descriptions (see Skevington, 1965). The Strong Island specimens are, however, very similar in terms of their overall stipe width and form, sicular dimensions and folded dorsal margin. The Holen Limestone is now generally correlated with the top *D. hirundo* or *D. artus* Zone of the United Kingdom (Jaanusson, 1982), suggesting a late Arenig or early Llanvirn age. A detailed stratigraphic discussion of these intervals was given by Skevington (1965), who concluded that the interval yielding *H. lentus* was equivalent to the Llanvirn *D. artus* (ex *'D. bifidus'*) Zone of Wales. *H. callotheca* was also described by Bell (1960) from the D_{a3} interval of the Victorian slatebelts in the Lachlan foldbelt of southeast Australia, where a graptolitic flysch also directly overlies an oceanic substrate of mafic volcanic rocks (Gray and Willman, 1991).

The specimens from Strong Island are distinct from other earlier members of *Holmograptus* described from the Cow Head Group of western Newfoundland by Williams and Stevens (1988). Three specimens of a biserial graptoloid were also recovered, but these are unidentifiable even to generic level. The presence of diplograptids does, however, confirm an age of latest Arenig or later.

The graptoloid fauna recovered from Little Northwest Arm is even sparser, consisting of only five specimens sufficiently complete to permit identification. Of these, three are poorly preserved examples of *Holmograptus*. They are similar to those of Strong Island in terms of overall rhabdosome form and width, but lack the folded dorsal margin. This morphological difference may, however, be merely a reflection of poor preservation, and they are thus here referred to *Holmograptus* sp. cf. *H. lentus* (Törnquist). The remaining two graptoloid specimens are horizontal, two-stiped forms, belonging either to *Didymograptus (Expansograptus)* or *Xiphograptus*. The distinction between these genera relies solely on the presence of a virgella on the sicula of *Xiphograptus*, but unfortunately this is commonly not visible in poorly preserved material. The specimens do not exhibit a virgella, but agree well in all other respects with the revised definition of *Xiphograptus svalbardensis* (Archer and Fortey) published by Williams and Stevens (1988). The material from Little Northwest Arm is therefore here referred questionably to that species. *X. svalbardensis* first occurs in mid-Arenig strata of the Cow Head Group (Williams and Stevens, 1988), but there ranges into at least the late Arenig. The association of *Holmograptus* sp. cf. *H. lentus* and *Xiphograptus svalbardensis?* does not permit an unequivocal age determination, but perhaps suggests a broadly similar late Arenig–early Llanvirn age to that deduced for the Strong Island locality.

The graptolite assemblages discussed above are particularly important in light of the biostratigraphic evolution of Middle and Upper Ordovician rocks near the New Bay Fault Zone (Figure 2), a regionally significant structure affecting the Exploits Group, the Lawrence Harbour Formation and the Point Leamington Formation (Helwig, 1969; O'Brien, 1991a). Within this fault zone, Ashgill strata of the *D. complanatus* Zone are separated from uppermost Arenig–lowermost Llanvirn strata of the *D. hirundo* or *D. artus* zones by a multi-unit sequence of folded and faulted beds whose combined structural–stratigraphic thickness is as little as 500 m. Of note is the fact that some distance from the New Bay Fault Zone the pre-*D. complanatus* portion of the Point Leamington Formation alone exceeds this thickness. Nevertheless, within this tract of attenuated stratigraphy, most regionally developed units are present, such as the trace-fossil horizon and lowest polymictic conglomerate lenticle in the lower Point Leamington Formation, the *P. linearis, D. clingani, D. multidens* (?) and *N. gracilis* intervals from parts of both the upper and lower Lawrence Harbour Formation, the *Holmograptus*-bearing beds of the Strong Island chert and the uppermost volcanic formation of the Exploits Group (see Dec *et al., this volume*). East of the New Bay Fault Zone, recent graptolite discoveries have been made near the base of the uppermost volcanic formation of the Exploits Group, but the fauna has yet to be positively identified and compared with that of the Strong Island chert. Still, it is highly probable that both the Mid and Late Ordovician successions within the fault zone were originally condensed, and that the regional juxtaposition of early Ashgillian and late Arenigian units cannot be solely explained by anomalously large, post-Ashgillian displacements in the New Bay Fault Zone.

St. Josephs Cove Formation, Baie d'Espoir Group

Williams (1991a) previously recorded the presence of Middle Ordovician graptolites from several black shale localities in the Baie d'Espoir Group (Figure 3; Colman-Sadd, 1980). However, he failed to recover any material from Twillick Brook along the river, 50 to 100 m east of the Bay d'Espoir highway (48°4'N, 55°34'W), where black shale occurs near felsic volcanic rocks of the Twillick Brook Member of the Baie d'Espoir Group. He commented that the reason for the absence of graptolites was unclear, as both lithology and lack of intense structural deformation seemed ideal for their preservation. On lithological grounds, he

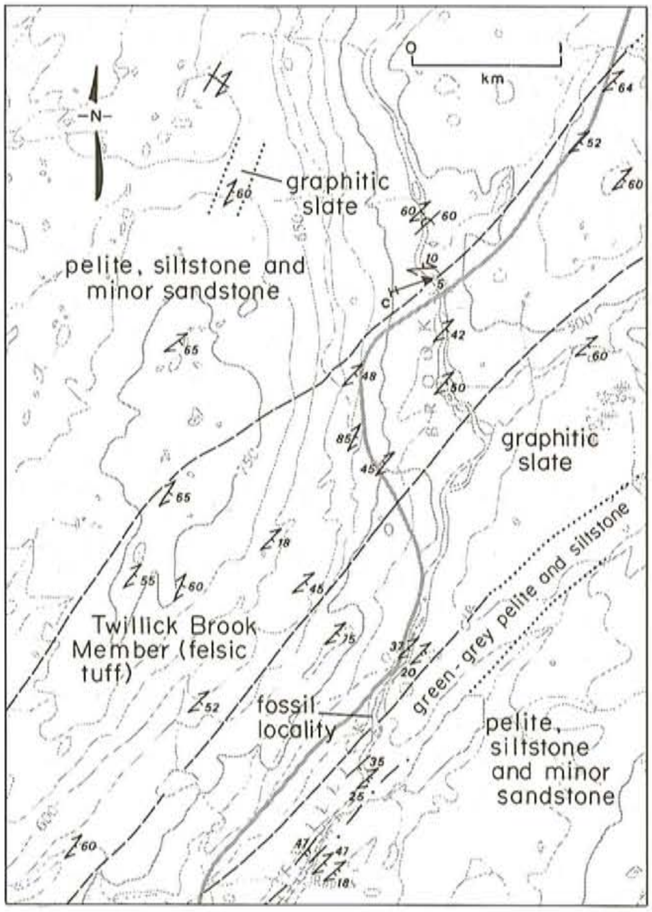

Figure 3. *Location of graptolitic black shale in the St. Josephs Cove Formation of the Baie d'Espoir Group at Twillick Brook, Bay d'Espoir.*

considered that the black shale was identical to the graptolitic unit exposed in neighbouring localities, and similar to the lower part of the Lawrence Harbour Formation, exposed some 100 km distant across the structural width of most of the Exploits Subzone (Figure 1).

During 1991, a few graptolites were found in black shales at the southernmost end of the river section, just below a small waterfall and below a newly built Department of Fisheries cabin. The graptolites are too poorly preserved for identification of any kind, but do appear to be similar to those Caradoc examples found elsewhere in the Baie d'Espoir Group. This would imply a significantly younger age for the black shale than the Llanvirn age determined radiometrically from adjacent volcanic rocks of the Twillick Brook Member (Colman-Sadd *et al.*, *in press*).

CONCLUSIONS

In its type area, the Upper Ordovician Point Leamington Formation contains several graptolite-bearing lenticles of shaly flysch that extend the age range of the Formation from the *D. clingani* Zone of the Caradoc to the *P. pacificus* Subzone (*D. anceps* Zone) of the Ashgill. A paleoenvironmentally unique graptolite assemblage, most probably belonging to the *D. artus* Zone of the Llanvirn, has been recovered from hemipelagic strata presently included in the upper part of the Middle Ordovician (and older ?) Exploits and Wild Bight groups. Black carbonaceous shale of Caradoc age occurs throughout much of northeastern and southern Newfoundland and is present within several major rock groups of the Exploits Subzone.

ACKNOWLEDGMENTS

The authors thank Erwin Wheaton for his assistance in the field and acknowledge, in particular, his keen sense of smell for fossils. This work on graptolites (SHW) and on conodonts (FHCOB) was undertaken under separate paleontological research contracts with the Geological Survey Branch, Newfoundland Department of Mines and Energy. Fieldwork carried out by BHOB was funded by the Canada–Newfoundland Cooperation Agreement on Mineral Development (1990-94).

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