# CARBONACEOUS MEGAFOSSILS FROM THE NEOPROTEROZOIC SHALER SUPERGROUP OF ARCTIC CANADA

*by* H. J. HOFMANN *and* R. H. RAINBIRD

ABSTRACT. A small assemblage of millimetric black carbonaceous compressions from the Wynniatt Formation of the Shaler Supergroup includes *Chuaria circularis*, *Tawuia dalensis* and *Beltina danai*. Also present are string-like remains that may be either pyritized vendotaeniacean filaments or small burrow fills. The occurrence of *Tawuia* is only the second known from North America. The presence of the *Tawuia–Chuaria* assemblage provides important corroborating evidence for correlation of the Wynniatt Formation of the Minto Inlier with the upper part of the Little Dal Group of the Mackenzie Mountains 1000 km to the southwest.

THE tomaculate carbonaceous megafossil *Tawuia* was first described from the Little Dal Group in the Mackenzie Mountains (Hofmann and Aitken 1979). Many more occurrences have since been discovered in Neoproterozoic sequences. All are from localities in the northern hemisphere, including the latest one from Yakutia (Vidal *et al.* 1993), with the most numerous being in China (Hofmann 1992, fig. 7.3.8.). Until now, the locality in the Mackenzie Mountains was the only one in North America. *Tawuia* is invariably associated with specimens of *Chuaria* and, although the converse is not true, this has led to a working hypothesis of a *Tawuia–Chuaria* assemblage zone with potential chronostratigraphical application (Hofmann 1985). Strata of the Shaler Supergroup on northern Victoria Island were targeted for a specific search for carbonaceous megafossils, because this succession commonly has been correlated with the Mackenzie Mountains Supergroup, based on the similarity of the succession of lithological units (e.g. Aitken *et al.* 1978; Young 1979; 1982, fig. 5; Young *et al.* 1979; Jefferson and Young 1989; Rainbird 1991), as well as on geochronometric constraints (Heaman *et al.* 1992; Rainbird *et al.* 1994*b*). The search for carbonaceous megafossils proved successful when the assemblage was located in the Wynniatt Formation in the Kilian Lake area in July 1993. This new material forms the basis of the following discussion. The sequence also contains abundant and well-preserved organic-walled microfossils, which are under separate study by N. J. Butterfield.

## GEOLOGICAL SETTING

The sparse but stratigraphically significant fossil assemblage described herein was obtained from strata of the Shaler Supergroup in the Minto Inlier on Victoria Island, northwestern Canada (Text-figs 1–2). The Minto Inlier is one of several inliers of Shaler Supergroup rocks that collectively comprise the Neoproterozoic Amundsen Basin (Christie *et al.* 1972). The Shaler Supergroup was recently proposed as a consequence of the elevation to formation status of several informal members of the former Shaler Group (Thorsteinsson and Tozer 1962; Rainbird *et al.* 1994*a*). It is generally accepted that sedimentary strata of the Shaler Supergroup belong to Sequence B of Young *et al.* (1979), and are lithostratigraphically equivalent to the Mackenzie Mountains Supergroup in the northern Canadian Cordillera. In the Minto Inlier, the Shaler Supergroup comprises a 4–5 km thick sequence of platform marine carbonate, evaporite, and subordinate siliciclastic rocks and underlying and overlying fluvial and fluvio-deltaic sandstones (Young 1981). It includes, in

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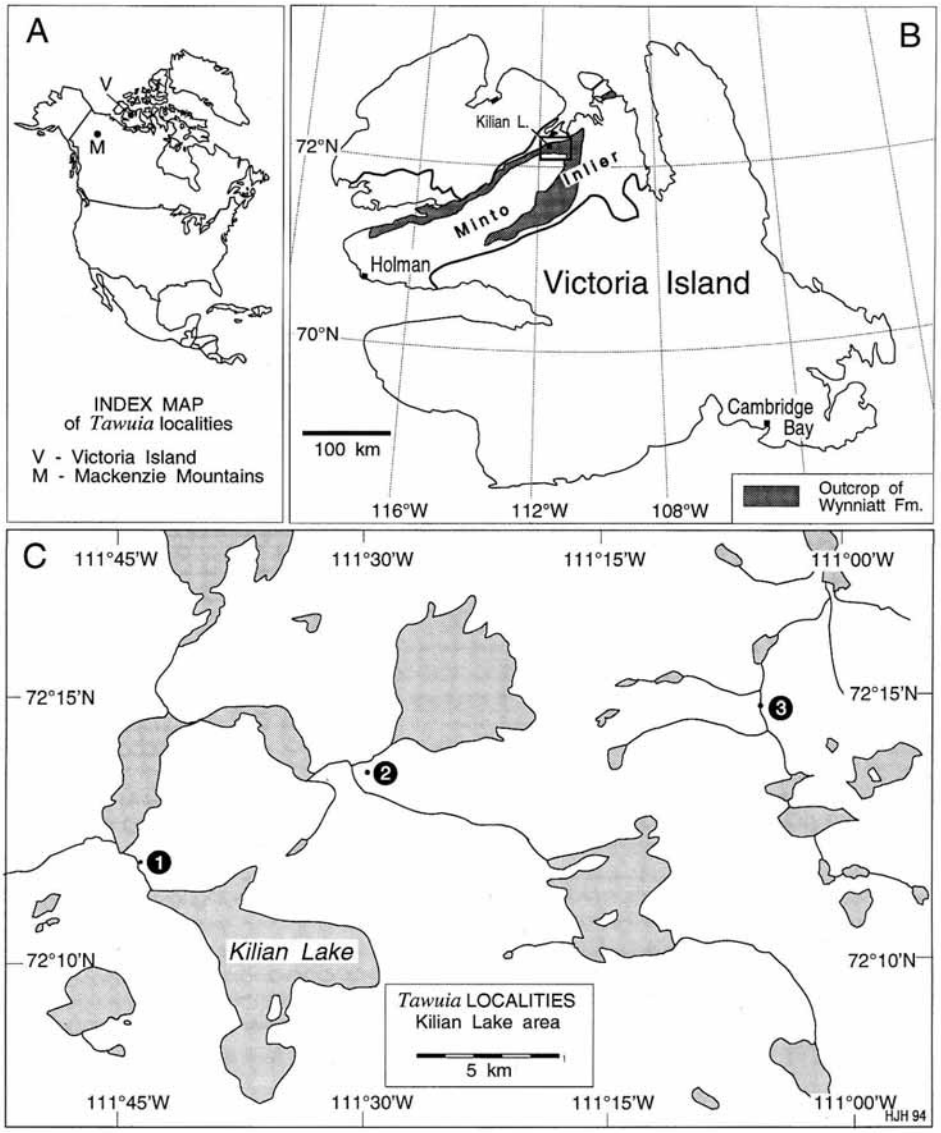
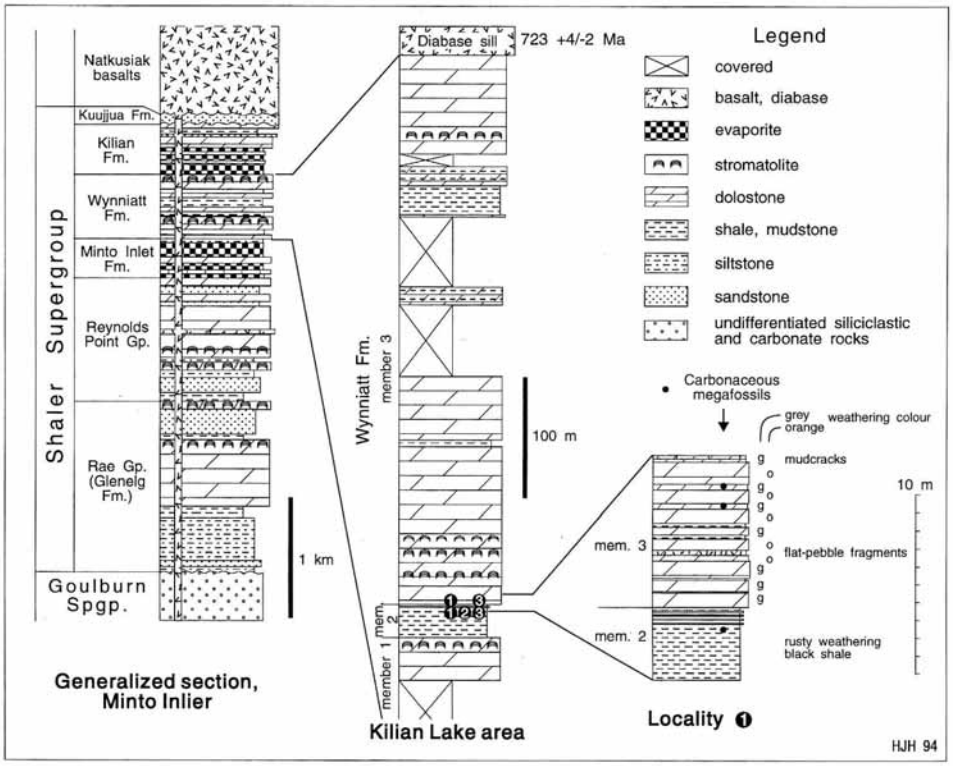



TEXT-FIG. 1. The *Tawuia*-bearing localities. A, map of North America showing Mackenzie Mountains and Victoria Island localities. B, the outcrop belt of the Wynniatt Formation in Minto Inlier, Victoria Island (after Young 1981); rectangle outlines area magnified in C. C, the newly discovered localities in the Kilian Lake area. Geographical coordinates of Locality 1, 72·198° N, 111·728° W; Locality 2, 72·227° N, 111·499° W; Locality 3, 72·247° N, 111·087° W.

ascending stratigraphical order, the Rae Group (formerly Glenelg Formation), Reynolds Point Group, Minto Inlet Formation, Wynniatt Formation, Kilian Formation, and Kuujjua Formation (Thorsteinsson and Tozer 1962; Young 1981; Jefferson 1985; Rainbird 1991; Rainbird *et al.* 1994*a*; Text-fig. 2). The Shaler Supergroup is overlain by the Natkusiak Formation, an up to 1·1 km thick




TEXT-FIG. 2. Stratigraphical position of the fossils. Section at left after Jefferson and Young (1989, fig. 1; with revised nomenclature of Rainbird *et al.* 1994*a*); section in middle after Young (1981, section K, p. 211), showing positions of Localities 1–3; section at right showing detail of fossil occurrences at Locality 1 at lower end of gorge 1·2 km north-northwest of the outlet of Kilian Lake. Radiometric age from Heaman *et al.* (1992).

sequence of flood basalt flows and minor volcaniclastic rocks that have been dated at 723 Ma (U–Pb baddeleyite from intrusive equivalents: Heaman *et al.* 1992). A maximum age for the Shaler Supergroup of 1077 Ma has been determined from U–Pb analysis of detrital zircon from the Nelson Head Formation of the Rae Group (Rainbird *et al.* 1994*b*).

The stratigraphical location of the fossil assemblage is just below and above the contact zone between a distinctive rusty black shale member and the overlying grey dolostone member of the Wynniatt Formation (members 2 and 3, respectively, of Rainbird and Young 1989; Text-fig. 2). A

relatively rapid shallowing-upward trend is indicated by an abrupt change from primarily flat-laminated carbonaceous mudstone of member 2, indicating deposition below storm wave-base, to the wavy-bedded dolosiltite/dololutite and stromatolitic dolostone of member 3. Episodic subaerial exposure and deposition in the intertidal zone is indicated by desiccation cracks in dolostone interlayers just above the upper fossil-yielding horizon (Text-fig. 2). The depositional environment was influenced by storms in shallow water as indicated by flat-based, wavy-topped quartzarenite beds within the mudstone at the top of member 2, by common intraformational carbonate-pebble conglomerate layers in the lower part of member 3, and by the generally high degree of fragmentation of fossil specimens.

## FOSSIL LOCALITIES

The carbonaceous fossils were collected at three localities from near the contact between members 2 and 3 of the Wynniatt Formation, in the northeastern part of the Minto Inlier (Text-figs 1–2). The contact between these two members is relatively sharp and can be readily identified from the air. Locality 1 is situated at the small north-facing cliff, where the contact is exposed on the east side of the lower end of the gorge issuing from Kilian Lake (general area of section H of Young 1981, p. 211). Locality 2 is on the crest of a rusty orange-weathering outcrop with black shale, 8·5 km ENE of Locality 1. Locality 3 exposes the contact zone on both sides of the small stream at the lower end of a gorge 22·5 km ENE of Locality 1.

## SYSTEMATIC PALAEONTOLOGY

The specimens here illustrated are deposited in the National Type Fossil Collection of Canada, at the Geological Survey of Canada in Ottawa, and are catalogued under the GSC numbers (109907–109924) cited in the individual figure captions.

Class CHUARIAPHYCEAE Gnilovskaya and Ishchenko *in* Gnilovskaya *et al.*, 1988
Family CHUARIACEAE Wenz, 1938 emend. Duan, 1982
Genus CHUARIA (Walcott) Vidal and Ford, 1985

*Type species*. *Chuaria circularis* (Walcott) Vidal and Ford, 1985.

*Chuaria circularis* (Walcott, 1899) Vidal and Ford, 1985

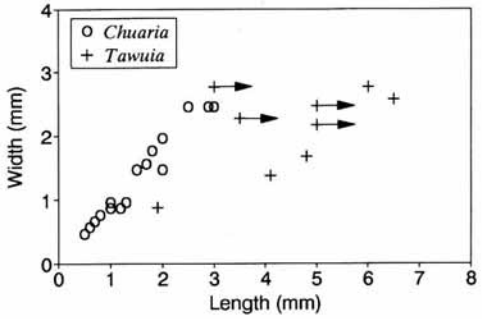
Plate 1, figures 1–6

(For synonymy, see Hofmann 1992, table 23.1.)

*Description*. Shiny black carbonaceous disks with concentric wrinkling, some with short radial clefts at margin; diameter 0·5–3·0 mm (mean 1·45 mm, $N = 18$) specimens from the black shale member somewhat smaller (mean 1·31, $N = 12$) than those from dolostone member (mean 1·73, $N = 6$); for scatter plot, see Text-figure 3. Some disks slightly elliptical, with aspect ratios of up to 1·3. One specimen with lobate protrusion of shiny black material without wrinkling (Pl. 1, fig. 4).

*Occurrence*. Localities 1–3.

*Remarks*. The population density is very low, and only a few specimens are visible even on bedding surfaces of layers on which abundance is greatest. The assemblage is thus relatively poor in




TEXT-FIG. 3. Scatter plot of width versus length of carbonaceous films assigned to *Chuaria* and *Tawuia* from the Wynniatt Formation. Arrows indicate that the original length of the *Tawuia* specimen is greater than the preserved fragment.

macrofossils compared to most other occurrences of the taxon, but it compares with one found in the 'Rusty shale' unit of the Little Dal Group of the Mackenzie Mountains described by Hofmann (1985).

Some specimens are unusual for *Chuaria circularis* in that they show short radial clefts, like those in the much smaller but thick-walled acritarch taxon *Turuchanica* (now considered a species of *Leiosphaeridia*), indicating rupture when the stress during compaction exceeded the tensile strength of the envelope. In one specimen (Pl. 1, fig. 4), rupture apparently has allowed the contents to spill and spread laterally; taphonomic conditions were appropriate for preserving the evidence for this leakage. This feature is uncommon in *Chuaria*, and is thus a noteworthy one for the Wynniatt Formation occurrence.

Family TAWUIACEAE Ishchenko *in* Gnilovskaya *et al.*, 1988
Genus TAWUIA Hofmann *in* Hofmann and Aitken, 1979

*Type species*. *Tawuia dalensis* Hofmann *in* Hofmann and Aitken, 1979.

*Tawuia dalensis* Hofmann *in* Hofmann and Aitken, 1979

Plate 1, figures 7–13

(For synonymy, see Hofmann 1992, table 23.1.)

*Description*. Short, compressed tomaculate objects, preserved as rectilinear smooth, shiny carbonaceous ribbons with round termini, and as smooth impressions where carbonaceous material is absent and only the form remains; some specimens fragmentary and widely dispersed, population density very low. Observed dimensions for specimens from dolostone 1·9–6·5 mm long, 0·9–2·8 mm wide ($N = 8$), with aspect ratios (length/width) between 1·67 and 2·93; single complete specimen from rusty weathering shale member 1·9 × 0·9 mm (for scatter plot, see Text-fig. 3). Longitudinal and diagonal folds in specimens readily attributable to taphonomic factors.

*Occurrence*. Localities 1–3.

*Remarks*. The specimens from the Wynniatt formation are all short, stubby, and straight (no J-, C-, U-, or S-shaped individuals were encountered). In size, shape, and low abundance they most

closely resemble the occurrences in the 'Rusty shale unit' of the upper part of the Little Dal Group in the Mackenzie Mountains (Hofmann 1985, pl. 38, figs 2–3). The Wynniatt and Little Dal specimens are indistinguishable from those referred to *Tawuia sinensis* (Duan 1982), which is here considered to be a synonymous taxon.

Class CHUARIAPHYCEAE?
Family BELTINACEAE Hofmann, 1994
Genus BELTINA Walcott, 1899

*Type species*. *Beltina danai* Walcott, 1899.

*Beltina danai* Walcott, 1899

Plate 1, figures 14–17

(For synonymy, see Hofmann 1992, table 23.1.)

*Description*. Shiny smooth carbonaceous compressions with angulate outlines, as well as smooth impressions where carbonaceous material absent; tendency towards equidimensional polygons, including roughly triangular, quadrate, and more complex polygonal forms. Dimensions ranging from submillimetric, to about 20 $mm^2$ in area ($N = 6$). Some specimens showing parallel, *en echelon*, cracks perpendicular to marginal crease, or polygonal cracks.

*Occurrence*. Locality 1.

*Remarks*. The angulate carbonaceous films are fragments of larger, possibly considerably larger, organisms. The specimen with semicircular outline in Plate 1, figure 16 may be a piece of one of the large taxa known from the Neoproterozoic, such as *Tawuia* or *Longfengshania*, or an as yet undescribed form. The presence of abundant cracks, and the large size, indicate the somewhat brittle nature of the organic material at the time of fossilization, possibly in an advanced stage of dehydration (exposure to air), or material whose physical properties reflect a distinct initial chemical composition. Until larger, more complete specimens become available, the size, nature, and affinities of these remains will stay problematic.

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EXPLANATION OF PLATE 1

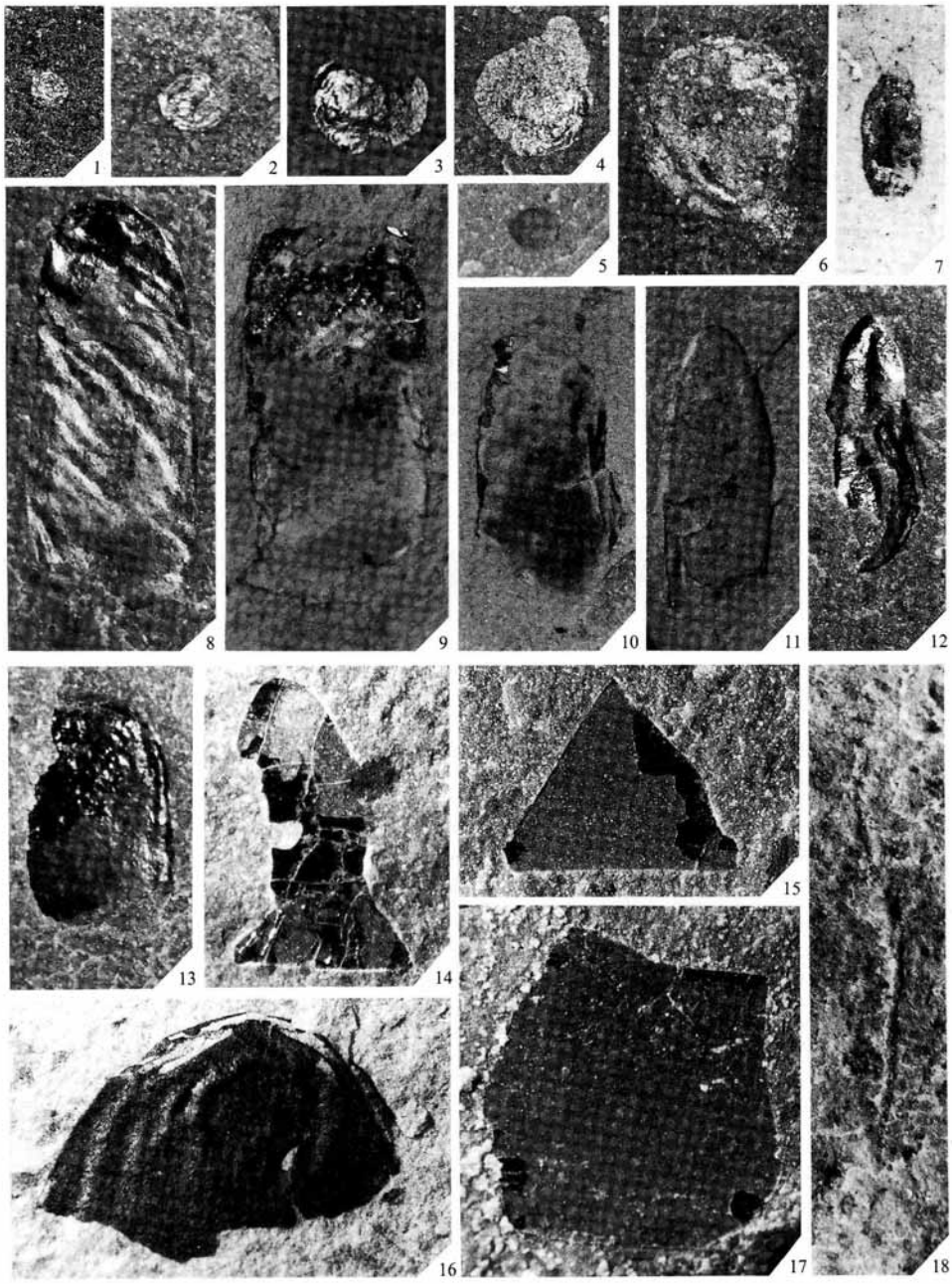
Figs 1–6. *Chuaria circularis* (Walcott) Vidal and Ford; Wynniatt Formation, Neoproterozoic; Victoria Island, Canada. 1, GSC 109907; member 2; Locality 3. 2, GSC 109908; member 2; Locality 1. 3, GSC 109909; member 3; Locality 1. 4, GSC 109910; member 3; Locality 1. 5, GSC 109911; member 2; Locality 2. 6, GSC 109912; member 2; Locality 3.

Figs 7–13. *Tawuia dalensis* Hofmann; Wynniatt Formation, Neoproterozoic; Victoria Island, Canada. 7, GSC 109913; member 2; Locality 2. 8, GSC 109914; member 3; Locality 1. 9, GSC 109915; member 3, Locality 1. 10, GSC 109916; member 3; Locality 1. 11, GSC 109917; member 3; Locality 3. 12, GSC 109918; member 3; Locality 1. 13, GSC 109919; member 3; Locality 3.

Figs 14–17. *Beltina danai* Walcott; Wynniatt Formation, Neoproterozoic; Victoria Island, Canada. 14, GSC 109920; member 3; Locality 1. 15, GSC 109921; member 3; Locality 1. 16, GSC 109922; member 3; Locality 3. 17, GSC 109923; member 3; Locality 1.

Fig. 18. Pyritized vendotaeniacean or burrow; member 3; Wynniatt Formation, Neoproterozoic; Locality 3, Victoria Island, Canada.

All figures are × 10.




HOFMANN and RAINBIRD, *Neoproterozoic megafossils*

### Other remains
### Vendotaeniacean or trace fossil

Plate 1, figure 18

*Description.* Smooth three-dimensional strings of uniform width, compositionally different from matrix; cross section elliptical, 0·15 mm wide, 0·1 mm high; best preserved fragment, 6·5 mm long, partially pyritized, slightly bent, both part and counterpart preserved; two smaller specimens 1·5 and 1·0 mm long, respectively, both altered to limonite.

*Occurrence.* Locality 3.

*Remarks.* The available material is insufficient to do more complete studies without destroying the best preserved specimen. Strings of similar size, but preserved as microcrystalline calcite in dolosiltite, were reported as *Tyrasotaenia*? sp. from the Little Dal Group in the Mackenzie Mountains. As with the Little Dal material, the Wynniatt remains may represent partially pyritized filament casts of vendotaeniaceans such as *Tyrasotaenia*, or tiny, filled, *Planolites*-like burrows. The conservative interpretation, that they represent vendotaeniaceans, is difficult to reconcile with the fact that all the other associated fossils are preserved as carbonaceous compressions rather than three-dimensional objects. An alternative interpretation, previously considered for the strings from the Little Dal Group, is that these fossils may represent fills of tiny burrows of vagile endobionts of unknown affinities, possibly protistan heterotrophs or primitive metazoans (Hofmann 1985, p. 350). However, while the new material could be taken as further circumstantial evidence for the existence of organisms capable of producing trace fossils as far back as the mid-Neoproterozoic, the true nature of the present material remains unresolved.

## DISCUSSION

The assemblage of carbonaceous fossils in the Wynniatt Formation is characterized by low abundance; specimens are small, dispersed, and commonly fragmentary. The angular and isolated nature of films assigned to *Beltina* demonstrate that probably they were reworked in a high energy environment. Moreover, the presence of desiccation cracks in dolosiltite within a few decimeters of the *Tawuia*-bearing layers at Locality 1 indicates episodic emergence and, at most, intertidal water depths during the accumulation of this material.

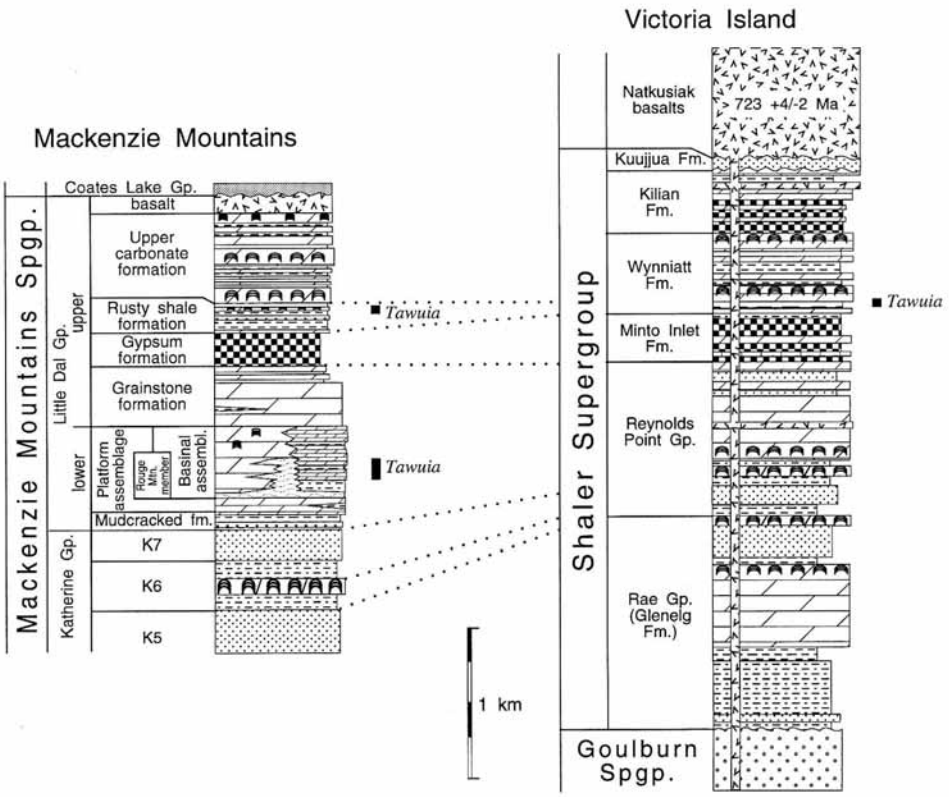
Early-formed taphonomic features such as concentric folds in *Chuaria*, and diagonal, *en echelon*, folds in *Tawuia*, and marginal creases in *Beltina* specimens show the pliable nature of the fossil materials at the time of deposition. Parallel and triradiate shrinkage cracks in the thicker angulate films demonstrate increasing brittleness of the films with maturation of the organic matter during diagenesis. Similar cracking of carbonaceous residue was observed in *Tawuia* specimens in the Little Dal Group (Hofmann 1985, pl. 37, fig. 5). The presence of radial clefts in some *Chuaria* specimens and lobate pattern of spilled cell contents of one specimen are significant features of this assemblage.

The carbonaceous fossils in the Wynniatt Formation are comparable to those in the Little Dal Group of the Mackenzie Mountains, but the assemblage is much more depauperate. In particular, in their small size and sparse population density the remains more closely resemble those in the 'Rusty shale' unit in the upper Little Dal Group than those in the 'Basinal' and 'Platformal' assemblages in the lower Little Dal Group, which have abundant and very large specimens (Hofmann 1985, p. 333). The balloon-shaped *Longfengshania*, the coiled filament *Grypania*, and the questionably branched filamentous *Daltaenia* were not encountered in the Wynniatt Formation. However, these latter taxa are very rare in the Little Dal group, and their apparent absence in the Wynniatt biota may simply reflect the much lower fossil abundance there, or may be due to differing palaeoenvironmental settings.

The presence of a new occurrence of three-dimensionally preserved strings of sub-millimetric diameter in the Wynniatt Formation contributes more circumstantial, though inconclusive,

evidence for burrowing activity of microscopic organisms in sediments predating late Neoproterozoic glaciations.

The correlation of the Victoria Island and Mackenzie Mountains sections, incorporating the new biota from the lower part of the Wynniatt Formation, is shown in Text-figure 4. The carbonaceous




TEXT-FIG. 4. Correlation of *Tawuia–Chuaria* assemblages in the Mackenzie Mountains (stratigraphy after Aitken 1981) and in Victoria Island (stratigraphy after Rainbird *et al.* 1994*a*).

megafossils support the scheme proposed by Young (1979, table 1, but not fig. 1, which is different because in that figure the 'Rusty shale' unit is correlated with the Minto Inlet Formation); his later paper (Young 1982, fig. 5) also shows the correlation now preferred.

## CONCLUSIONS

The new carbonaceous macrobiota demonstrates the presence of *Tawuia*, *Chuaria*, and *Beltina* in the Wynniatt Formation on Victoria Island, only the second area in North America from which *Tawuia* is now known. The occurrence is consistent with the concept of a broad Neoproterozoic *Tawuia–Chuaria* biozone, and it reinforces long-distance correlation of the Shaler Supergroup with

the Mackenzie Mountains Supergroup. The data indicate that representatives of the *Tawuia–Chuaria* assemblage of the lower part of the Little Dal Group should be looked for in the Reynolds Point Group.

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H. J. HOFMANN
Department of Geology
University of Montreal
P.O. Box 6128, Station A
Montreal H3C 3J7, Canada

R. H. RAINBIRD
Geological Survey of Canada
601 Booth Street
Ottawa K1A 0E8, Canada

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